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Optimising Household Food Waste Behaviour for Diet Quality and Food Security

by

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Thesis for the Degree of Doctor of Philosophy (PhD)

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<u>Abstract</u>

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The aim of this thesis is to understand how to optimise householders' food waste behaviour using a case study in the UK. The research contributes evidence for effective and targeted food waste behaviour interventions to reduce food waste for improved food security, diet quality and reduced greenhouse gas emissions. The thesis takes a three-paper structure with a final chapter that presents a collation of results into the Motivation, Abilities and Opportunities framework to assist well-rounded intervention planning.

Drawing on international literature on household food waste, food security and diet quality as well as behavioural change theory and motivational theory, gaps were identified and three distinct research questions were posed. Systematic review, photographic food waste diary, sociodemographic survey, and qualitative interviews were selected as methods to address the research questions. Most published research examined sociodemographic variables and food waste using survey methods, or examined food waste in relation to avoidable food waste but not possibly avoidable food waste. There were also limitations in research that explored food waste in relation to diet quality and socio-demographic variables. The majority of research that was theory driven used models of behaviour change such as the Theory of Planned Behaviour, or frameworks such as the Motivation, Opportunities and Abilities framework. However, there was a lack of research exploring drivers for food waste behaviour using a motivational theory i.e., Self-Determination Theory.

The research completed in this project provides evidence of what nudges are effective for household food waste behaviour change. It offers novel insights on statistically significant sociodemographic patterns of food waste by categories of avoidable and possibly avoidable food waste. Further, it demonstrates the utility of photographic data collection to identify categories of food waste in a large sample. The thesis collated primary data on the proportion of healthy (NOVA 1) food waste in total food waste in relation to categories of avoidable, unavoidable and possibly avoidable food waste. Finally, the research highlighted new insights on how to motivate and strengthen motivation for food waste reduction behaviours in households using the Self-Determination Theory. This assembly of new knowledge builds a case for household food waste interventions using a targeted approach based on sociodemographic characteristics. It also supports household food waste interventions using tailored personalised approaches to optimise motivational drivers for food waste behaviour change. Each of the three analytical papers presented contributes to further understanding of food waste in household settings to illuminate how interventions may work most effectively, and better target segments of the population. This collection of research can inform behaviour change interventions to optimise food waste behaviour for diet quality, food security, and by extension reduced greenhouse gas emissions.

Table of Contents

Table of Tables

Table of Figures

Research Thesis: Declaration of Authorship

Name: Hannah Ruth Barker

Thesis Title: Optimising Food Waste Behaviour for Diet Quality and Food Security

I declare that this thesis and the work presented in it are my own and has been generated by me as the result of my own original research.

I confirm that:

1. This work was done wholly or mainly while in candidature for a research degree at this University;
2. Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;
3. Where I have consulted the published work of others, this is always clearly attributed;
4. Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work;
5. I have acknowledged all main sources of help;
6. Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself;
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Signature: Date:

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Abbreviations

GHG ....Green House Gas

FLW.......................................Food Loss and Waste

FAO ....Food Agriculture Organisation

EU ....European Union

WRAP....................................Waste and Resources Action Programme

Defra.....................................Department for Environment, Food and Rural Affairs

NHS ....National Health Service

UN..United Nations

SDG..Sustainable Development Goals

CFS...Committee of World Food Security

HLPE......................................High Level Panel of Experts on Food Security and Nutrition

G20 ....Group of Twenty

COP..Conference of the Parties

LFHW ....Love Food Hate Waste

JSNA.......................................Joint Strategic Needs Assessment

WCA.......................................Waste Composition Analysis

US ....United States

LAFA......................................Loss Adjusted Food Availability

TPB...Theory of Planned Behaviour

MOA ....Motivation Opportunities Abilities

NAM ....Norm Activation Model

TIB..Theory of Interpersonal Behaviour

SDT ....Self-Determination Theory

SHIFT.....................................Social influence, Habit formation, Individual self, Feelings and Cognition
and Tangibility

NDNS ....National Diet and Nutrition Survey

IBM ....International Business Machines

Chapter 1 Introduction

Food waste is a phrase heard frequently in the media, with alarm raised over the amount of food wasted throughout the food supply chain. This is twinned with environmental and societal pressures on our ecosystem affecting greenhouse gas emissions and hunger. There is a tension between food quality, insecurity and waste that offers a series of challenges for people working in policy, sustainability and public health. The work presented here aims to explore connections between food waste and food security at the household level by linking data on food waste with data relating to diet quality using a sociodemographic characteristic perspective. Furthermore, the thesis explores which behavioural insights are effective for food waste behaviour change and how food waste behaviours are motivated in households.

There is a notable range of definitions of Food Loss and Waste (FLW) in the literature (Spang *et al.,* 2019). The majority of definitions similarly identify food in FLW as that which is intended for consumption by humans, rather than animals or biofuel (Parfitt, Barthel and MacNaughton, 2010; FAO, 2013; Buzby, Wells and Hyman, 2014). Typically, definitions of FLW differ regarding edibility/inclusion of inedible parts, stage of the food supply chain and destination (Östergren *et al.,* 2014; Bellemare *et al.,* 2017; Roodhuyzen *et al.,* 2017; Spang *et al.,* 2019).

There are differences between definitions regarding the inclusion or exclusion of inedible parts of food items (Spang *et al.,* 2019). Edibility relates to whether there is expectation of the food part being inedible, e.g., bones or banana peel (Spang *et al.,* 2019). Some food parts are widely considered inedible across cultures and contexts (e.g., egg shells), while others differ considerably (e.g., carrot peel) (Blichfeldt, Mikkelsen and Gram, 2015; WRAP, 2020b). Furthermore, the term "Avoidability" conceptualises edibility further by introducing a third concept "possibly avoidable" (Corrado *et al.,* 2017; WRAP, 2020b). Thus, comparisons are difficult as the definitions of edibility and the inclusion of inedible parts vary (Spang *et al.,* 2019).

Across stages of the food supply chain there are differences in categorising FLW (Spang *et al.,* 2019). Usually, definitions pertain to postharvest activities (Spang *et al.,* 2019). However, other times definitions commence on the farm, and here include losses such as unharvested crops (Buzby, Wells and Hyman, 2014; Roodhuyzen *et al.,* 2017). Thus, baselines for food available for consumption varies (food harvested or food grown) affecting the amount of loss reported. Furthermore, along the supply chain there are differences in definitions of food loss and food waste, here frequently food waste occurs at the retail and consumer level, while food loss occurs earlier during production, transportation and processing (Bellemare *et al.,* 2017; Roodhuyzen *et al.,* 2017). Other literature classifies waste and loss as "voluntary" and "involuntary" (Buzby, Wells and Hyman, 2014). Some

definitions in the literature do not distinguish between food loss and waste at all (Östergren *et al.,* 2014).

Finally, there are FLW definitions according to "destination" (Spang *et al.,* 2019). For example, if food is diverted to animal feed or biomaterial processing it is removed from the human food supply chain and may no longer be considered FLW. Other times FLW is only considered as waste when ending in landfill rather than a perceived more productive use such as composting (Roodhuyzen *et al.,* 2017). Additionally, FLW definitions extend to overnutrition as food waste (Blair and Sobal, 2006), when consumption exceeds human needs; and loss of quality across the food supply chain (FAO, 2013; Committee of World Food Security, 2015; Roodhuyzen *et al.,* 2017).

A variety of definitions for FLW exist, however, for the purpose of this thesis I will adhere to the definitions set out by the Food and Agriculture Organisation (FAO). Lost or wasted food is defined in accordance with food loss, food waste and food wastage (FAO, 2013). Food loss infers a decrease in mass or nutritional value of food intended for human consumption and food waste refers to food appropriate for human consumption that is discarded whether or not it has spoiled (FAO, 2013). Food wastage includes loss and waste of the food itself and all the resources utilised in production, transportation and processing (European Parliament, 2012; Chaboud and Daviron, 2017; FAO, 2019). Every year one third of all food, 1.3 billion tons, worth around $1 trillion, is lost or wasted along the food supply chain (Gustavsson, Cederberg and Sonesson, 2011; FAO, 2014). This quantity of FLW could address undernourishment for one-eighth of the global population (Gustavsson, Cederberg and Sonesson, 2011). Reducing FLW can also help to address the worldwide challenge to respond to increasing food demand, which may exceed current demand by 150-170% by 2050 (FAO, 2009); and/or coincide with decreased capacity for food production due to climate change (Beddington, 2009). The impact on environmental outcomes is also considerable; greenhouse gas emissions from food that is not consumed total 8-10% of global emissions (United Nations Environment Programme, 2021). Food waste and loss have significant implications for sustainability across human and environmental health, contributing to global warming, land degradation, unsustainable resource use, reducing food availability and affordability and impacting viability of global and local food systems (FAO, 2019).

In the European Union (EU), post farm gate, it was estimated that households contributed 53% of total food waste weight, in comparison with 30% from food production and processing and 12% from hospitality and food services (Stenmarck *et al.*, 2016). WRAP (Waste and Resources Action Programme) estimated the annual food waste from UK households, hospitality and food service, manufacture, retail and wholesale in 2015 at approximately 10.2 million tonnes (WRAP, 2021). The financial cost was valued at over £20 billion per annum and the environmental cost was associated

with over 25 million tonnes of greenhouse gas emissions per annum (WRAP, 2021). By weight, 70% of the UK food wasted post-farm gate was from households (WRAP, 2021). This waste coincides with rising food insecurity, a public health obesity epidemic and a cost-of-living crisis (Conolly and Craig, 2019; Harari *et al.*, 2022; Smith and Thompson, 2023). Household food insecurity, where people do not have a sufficient quality diet without the need for external support such as food banks, is a concern for 8% of the UK population (Defra, 2021b; Smith and Thompson, 2023), though more recent (June 2023) surveys from the Food Foundation place this number at 17% (The Food Foundation, 2023a). Additionally, in the UK, the majority of adults are overweight or obese (outcomes associated with food insecurity and poorer diet quality), affecting 67% of men and 60% of women, adding pressure to the National Health Service (NHS) with related diseases through the need for treatment and support (Conolly and Craig, 2019). Meanwhile, rising costs of living could push households with previously sufficient income to have difficulty affording food in comparison with past years (Harari *et al.*, 2022).

This broad acknowledgement of the detrimental impact of FLW to the climate, society and economy has raised the global profile of this issue to present in the global action agenda by the World Resources Institute, which proposed actions to realise the United Nations' (UN) Sustainable Development Goal (SDG) 12.3 of reducing the world's FLW by 50% by 2030 (Flanagan et al., 2019; Willett et al., 2019). Within the UK, action is also being taken to address food waste. The UK food commitments include Courtauld 2025 which constitutes a target to reduce UK food waste (post-farm gate) by 20% per person by 2025, versus a 2015 baseline (WRAP, 2020a). Food waste is also an important objective in UK policy. The UK 25 Year Environment Plan and Resources & Waste Strategy aims to eliminate food waste to landfill by 2030 and, more broadly, to eliminate all avoidable waste (including plastic waste) by 2050 (Defra, 2018; HM Government, 2018). Definitions for what constitutes zero avoidable waste are in the process of being established in each sector, for example, construction (Defra, 2018); in the food sector avoidable waste is consistently defined as food that could be eaten but is discarded uneaten (Lebersorger and Schneider, 2011). Notwithstanding these policies, evidence on what comprises effective interventions at the household level to support the achievement of the Courtauld 2025 target and to eliminate avoidable food waste by 2050 remains limited despite efforts to achieve this goal (Yamakawa *et al.*, 2017).

Food waste behaviours in the home are daily activities with a complex variety of influencing factors. FLW materialises partly from daily behaviours of consumers e.g., overbuying, overpreparing, over-portioning and not re-using leftovers but also from cultural norms, social norms, political structures, education and personal norms (Roodhuyzen *et al.*, 2017; Schanes, Dobernig and Gözet, 2018; Boulet, Hoek and Raven, 2021a). Household food waste behaviours are thus likely to need evaluation using behaviour change theories and psychological motivational theories in combination with socio-

demographical household characteristics to indicate best approaches for local councils to create effective food waste reduction interventions that also address pressing public health and social inequalities. Intervention at the local level is relevant due to differing barriers to FLW across the UK and the national government's commitment to locality-focused policy (HM Government, 2011).

This thesis explores links between household-level food waste and food security by connecting data on food waste with data on diet quality and in the context of household sociodemographic characteristics. The thesis also explores what drives food waste behaviours and what behavioural insights work to change food waste behaviours. These relationships may have important implications for social inequalities, health outcomes and the environment (Reynolds *et al.*, 2020). However, substantive systematic reviews, quantitative and qualitative primary research is needed to understand outcomes. The study of household food waste behaviours in relation to social inequalities and health is of notable importance to local councils, social care, public health professionals and academics, for whom understanding the relationships between these issues is vital (HM Government, 2011; HM Government, 2022; Dimbleby, 2021). These relationships are significant for the development of future food systems where food waste reduction interventions support food security, effective resource provisioning and provide improved public health guidance (Reynolds *et al.*, 2020).

This thesis aims to optimise Hampshire householders' food waste behaviour through contributing evidence to inform targeted and effective food waste behaviour interventions for avoidable and possibly avoidable food waste reduction, improved food security, diet quality, and by extension reduced greenhouse gas emissions. To do this, the thesis will identify patterns of food waste behaviour and how this varies by sociodemographic characteristics. It will also seek to understand what behaviour change insights work to change household food waste behaviour and how motivational drivers affect food waste reduction behaviours in households. Hampshire is applied as a case study as part of a collaboration with Hampshire County Council. The study area is representative of other high-income regions in the UK, as described later in section 1.3; and being European it will also have relevance to other high-income areas in Europe. The research aims to inform the development of three research questions. The three research questions are addressed through three original papers (here, Chapters 3,4 and 5) and work presented in Chapter 6. In Chapter 6, the findings of the three original papers are brought together within a framework to highlight the contribution of the thesis to intervention planning. Furthermore, a tool is proposed for use in Hampshire County Council to inform future food waste interventions or campaigns.

1.1 Development of future food waste interventions

Understanding food waste patterns in relation to sociodemographic variables, i.e., what food is being wasted and by whom is important to tailor interventions to address food waste most effectively. A socio-demographic approach is important because of social inequalities that are linked to food security and poorer diets including low income, unemployment, disability, low educational attainment, younger age and non-white ethnicity (Loopstra, Reeves and Tarasuk, 2019; Pool and Dooris, 2022). If interventions can be developed to reduce food waste and improve food security and diet quality then this improves social inequalities and health outcomes for the most vulnerable in society.

To create effective interventions, we need to (1) identify what is known about the impact of behaviour change techniques for food waste behaviour change interventions, and (2) understand why food is being wasted. Understanding how to motivate individuals is important to support interventions to be most effective. This is especially important for groups most at risk of food insecurity. It is useful for local governments to understand what, by whom and why food is being wasted to sufficiently plan and allocate future funding and services to reduce household food waste and address food insecurity and health outcomes (Government Office for Science, 2017; Local Government Association, 2023).

1.1.1 Resource allocation

Efficient resource use in intervention planning (i.e., deciding what to spend money on to get the best outcome) by local government for food waste reduction requires predictions of what food households waste, by whom and why. It also requires understanding what is already known to be effective to change food waste behaviours. Knowledge of these aspects helps tailor the direction of intervention planning.

Despite the growing issue of food waste, research on what behavioural insights work to support household food waste behaviour change has not been systematically reviewed using a critical appraisal (Barker *et al.,* 2021). Research is lacking that analyses sociodemographic characteristics with measured food waste weight categorised by diet quality and possibly avoidable food waste. Increased fresh vegetable and fruit food waste can be linked to healthy eating (Yu and Jaenicke, 2017; Conrad *et al.*, 2018; Conrad, 2020) as households purchase more fresh produce in an aim to consume the recommended five portions a day. Without schemes to minimise this source of food waste through efficient storage, preparation and cooking there may be less of an improvement in diet quality, and socially deprived areas and populations may experience increased risk of food insecurity over time.

Theories of motivation have not often been applied to explain drive for food waste reduction behaviours, and those that have frequently use the theory of planned behaviour (Ajzen, 1991) or the motivation opportunities abilities framework (Ölander and ThØgersen, 1995). However, these theories do not differentiate between more than two types of motivation (Ajzen, 1991; Ölander and ThØgersen, 1995). Thus, exploring household food waste using a theoretical model of motivation that differentiates between more than two types of motivation presently appears absent from the literature. Understanding how motivation affects food waste behaviour is notable for the development and planning of social and public healthcare services and effective interventions for food waste reduction at the household level. This is because motivation is a key mechanism to support behaviour change (Michaelsen and Esch, 2021).

To address these issues of food waste and food security providers can:

- Improve intervention planning with information on food waste patterns in households by sociodemographic characteristics
- Improve intervention effectiveness with knowledge on what behavioural insights change food waste behaviour, and how to most effectively motivate food waste behaviour change.

Research on household food waste related to the considerations noted above can answer these concerns.

1.1.2   Monitoring and evaluation

Although it is not mandated, local councils could collect and use data at a more granular scale (such as household) on food waste to track what is being wasted to more comprehensively monitor food waste progress towards UN, SDG and Courtauld targets or to evaluate the success of household food waste interventions.

Currently in the UK, food waste from households is routinely measured at a local council level by waste recycling either when it is incorporated with other organic matter or when it is collected separately as food waste, and then only weight is recorded (Defra, 2021a). WRAP regularly synthesises these data to calculate nationwide estimates of food waste (WRAP, 2020b). Household characteristics included in the calculations were limited to a measure of social class (measured by population percentage within the local authority belonging to Social Grade D or E); population density (inhabitants per square km); and whether the local authority was in England, Wales, Scotland or Northern Ireland (WRAP, 2020b).

In the UK the Resources and Waste Strategy suggested that food businesses and companies take responsibility to track their own food waste and a food waste reduction roadmap has been designed to this end (Defra, 2018; IGD & WRAP, 2020). The situation is different for household food waste. There are currently no plans outlined in the Resources and Waste Strategy for progressing methods of routinely measuring household food waste despite this being the largest food waste output post-farm gate in the UK and a part of achieving the Courtauld Commitment 2025 (Defra, 2018; WRAP, 2021). Given that objectives to reduce food waste are important and require tracking, there is opportunity and need to advance feasible methods that local authorities could use to assess their progress on food waste reduction for local households. This is also relevant to the SDG targets. Over time, these may become more closely measured, and if the UK can prepare in advance, it will offer a competitive advantage to achieving these goals.

1.2   Policy perspectives on food waste and food security

Commitments and declarations to eradicate hunger and malnutrition are longstanding such as the Live Aid concert to raise funds for famine relief in Ethiopia in 1985 (Hillmore, 1985) or the launch of Oxfam in 1942 (Oxfam, 2023). In 1996 the Rome Declaration of the World Food Summit pledged to diminish the amount of people with inadequate food by 2015 (FAO, 1996). The Committee of World Food Security (CFS), established in 2008, is a platform for international and intergovernmental stakeholders to work together to safeguard food security and nutrition for everyone (Pinstrup-Andersen, Gitz and Meybeck, 2016). Recommendations set by the High-Level Panel of Experts on Food Security and Nutrition (HLPE) were adopted by the CFS calling for stakeholders to focus food security and nutrition as core objectives for sustainable food systems and to address individually and collaboratively FLW to this end (Committee of World Food Security, 2015). The HLPE suggested it was necessary for FLW reduction strategies to contemplate decreases in nutritional wastage along the supply chain as well as quantification by mass (Östergren *et al.*, 2014; Garcia-Herrero *et al.*, 2019).

The Global Strategic Framework for Food Security and Nutrition was implemented in 2015 by G20 countries (Pinstrup-Andersen, Gitz and Meybeck, 2016). Paragraph 25 of the framework stated that to address food security and nutrition G20 members could consider actions on recovery and redistribution of safe, nutritious food destined for waste to those most in need (Pinstrup-Andersen, Gitz and Meybeck, 2016). This can be critiqued in three ways. First, the redistribution of food waste is not an appropriate response to food insecurity. This is because of the complex dependence of market attachment on food system flows (Midgley, 2014), affecting the type of food available which may or may not be healthy, and the frequency or volume of available food, which may not match with demand or need. Second, it is incongruent with definitions that stipulate food security is reached when dietary needs are met without interventions (Kneafsey et al. 2011). Third, this

statement is not a strong mandate and it has been suggested that FLW 'has been historically the largest overlooked component of achieving the internationally recognized "right to food"' (p. 480; Telesetsky, 2014). To fully use food recovery and redistribution as a resource, important distinctions must be made concerning real food waste for recovery and surplus food for beneficial redistribution in communities, as effective management approaches of both differ (Midgley, 2014). Food surplus is generated when the requirement for supply, availability and nutrition of food exceeds its demand. This can occur along the supply chain from field to household, and means that edible produce accumulates which can result in FLW (Melacini, Rasini and Sert, 2017; Sert *et al.*, 2018). Considering the links of FLW with food surplus, it is counter-productive to rely on redistributing food surplus as a key solution for hunger.

Currently the global focus on food waste in relation to climate change can be identified via the Conference of the Parties (COP) agenda. In 2021 focus was still lacking as food waste was absent from the COP26 agenda (UK Climate Change Conference UK 2021, 2021). However, at COP27 global partners co-hosted the Food Systems Pavilion to debate opportunities for sustainable food systems to combat climate change, and a session on tackling FLW for food security and climate goals was realised (COP27 Egypt, 2022). For COP 28 UAE, transforming food systems is at the heart of where efforts are intended to be prioritised (COP28 UAE, 2023).

Food security is a highly visible development priority in comparison with food waste reduction. Of the UN SDGs, SDG 2 (zero hunger) sets out to end hunger, achieve food security and improve nutrition and promote sustainable agriculture (Pérez-Escamilla, 2017). Plans to reduce global food waste sit under SDG 12 to ensure sustainable consumption and production patterns, the target to halve the global food waste *per capita* by 2030 is one of eleven targets under SDG 12 (Pérez-Escamilla, 2017). Goals of food security, improved nutrition and sustainable agriculture can all be influenced positively with actions to reduce food waste. A vital part of this is to understand the nutritional losses contained in food waste along the food supply chain in order to effectively target crucial problem areas. As food security is a prominent SDG goal it is prudent to explore thoroughly every action that could realise success; focus on food waste is helpful in this regard.

1.2.1 Food waste policy and local actions UK

In response to commitments outlined in the Waste and Resources Strategy, the UK government supports initiatives for food waste reduction (Defra, 2018). In 2020, £1.15 million of government funding was allocated to address household and supply chain food waste (Defra, 2020b). These national initiatives reach households through WRAP's Love Food Hate Waste (LFHW) campaign (WRAP, 2022a), WRAP's Wasting Food: It's Out of Date (WRAP, 2023), and redistribution of surplus

food (Defra, 2018). LFHW is a national brand aimed at reducing household food waste. To this end, LFHW has developed useful toolkits for local authorities (WRAP, 2022a). Local authorities can choose to access and use the LFHW toolkit to support action on food waste interventions in their local communities. Other local actions can include accessing national government funding that supports large organisations, such as FareShare, to redistribute surplus food via charities and community groups in the local area (Defra, 2020a; FareShare, 2023). However, this is an imperfect solution as FareShare state their redistribution represents 1% of good-to-eat surplus food wasted annually in the UK (FareShare, 2023). In local government, actions can also be taken to encourage volunteers to become waste prevention community champions across the region to raise awareness and encourage collaboration (Volunteer First, 2023). Finally, collaboration in national campaigns can form part of the local authority response. For example, WRAP's first Food Waste Action Week took place in 2021, which was aimed at households and businesses, and was supported by 135 businesses and organisations across the UK, such as local authorities (WRAP, 2022b). Otherwise, the initiatives supported by the national UK government operated mainly at the business level for agriculture, retail, food service companies or hospitality (Defra, 2018). These included: the Food Waste Reduction Road Map, statutory guidance with a hierarchy of nine options to address food surplus and waste, and a government food waste champion (Defra, 2018).

As noted above, it is statutory for local authorities in the UK to regularly measure and report food waste weight in their area, either through calculating food waste mixed with other organic matter or via weighing kerbside food waste collections (Defra, 2021a). This process allows high-level monitoring against national targets (WRAP, 2020b). However, local intelligence to identify and target groups of people most effectively for food waste reduction interventions that work would have merit and remains an area that can be developed for local action.

Legislation, mandates and approaches for food waste recycling are a devolved matter and thus vary across the UK in England, Wales, Scotland and Northern Ireland. Wales has universal weekly household food waste collection (Croner-I, 2023). Under new laws, Wales, from the 6th of April 2024 will also have a legal requirement for all businesses that create more than 5kg of food waste to recycle it (Welsh Government 2023). Scotland legislates that for food businesses producing more than 5 kg of food waste that this is separated for food recycling collection (Croner-I, 2023). Furthermore, most Scottish households (80%) have access to food waste collection services (Scottish Government, 2022). Meanwhile, The Food Waste Regulations of Northern Ireland, legally require all Northern Irish Councils to offer households with a food caddy or brown wheelie bin to separate their food waste for recycling (Fermanagh & Omagh District Council, 2023)

In England, in 2022, a Defra consultation was held to establish whether to mandate large food businesses in England to report annually on food waste, however the outcome was to continue with a voluntary approach and review its effectiveness from mid-2025 (Defra, 2023a). The Environment Act 2021 Legislation in England stipulates action on food waste recycling: large businesses will be required to segregate food waste from other waste; and all households will receive weekly food waste collections for recycling (HM Government, 2021; Defra, 2023b). The weekly recycling of food waste has been stated to be introduced for most households across England by 2026 (Defra, 2023b).

1.2.2   Food security policy and local actions UK

On a national level in the UK, actions of food security include regular analysis of data on food security to assess past, current trends and forecast future trends, to present a report to parliament on food security at least once every three years (Defra, 2021b). These data evaluate the UK supply chain, the UK food supply and household level food security. National schemes to address household level food security include: free school meals and the healthy start voucher scheme, school holiday provision or meals on wheels services (Defra, 2022). Local government can support eligible residents who are experiencing or who are at risk of food insecurity by encouraging access to this existing funded support offered nationally (Page and Marshall, 2023). In practice, the dominant response to household food insecurity is through the third sector and food aid, though these resources are also often supported financially in part by local government (Smith and Thompson, 2023). Local government can identify groups or households most at risk of food security using intelligence to target support and take action to prevent food insecurity (Defra, 2021b; Smith and Thompson, 2023). They can connect people with services that address drivers of poverty or low income alongside support for physical and mental health (Page and Marshall, 2023). Local government has a key role in improving food security in their local populations, they might do this by seeking opportunities for a systems approach to food security, availability and access, that also benefit the environment and health (Page and Marshall, 2023). To enable this national government has a requirement to commit to adequate and long-term funding for the successful planning of preventative interventions. To inform this action, evidence of what works in communities, that also supports those affected, is needed (Smith and Thompson, 2023).

1.2.3   Public health policy in relation to diet quality and local actions UK

Levelling up the United Kingdom White Paper states its eighth mission is to improve well-being in every area of the UK, closing the gap between top performing and other areas (HM Government, 2022). Actions to achieve this include moving forward with recommendations from the independent review by Henry Dimbleby for a national food strategy (Dimbleby, 2021). Nationally, the UK government has

committed to piloting the school cooking revolution and the community Eatwell strategy (HM Government, 2022). On a local level, governments can access funding for these pilot schemes, and carry out robust monitoring and evaluation of the programmes to understand their effectiveness. Local governments can use local intelligence to target populations most at risk of poorer diet quality, for example people who live near a higher density of fast-food outlets, or people who have limited local access to healthy and affordable food (Smith and Thompson, 2023). Further evidence on how to motivate individuals to eat well remains a priority, as the national and Hampshire level data show that approximately 30% of Year 6 children and 60% of adults are overweight (Hampshire and Isle of Wight Public Health Intelligence Team, 2023).

1.3   Study region Hampshire, England, UK

Hampshire was selected as the study region as it represents similar demographics to other counties in England (Hampshire and Isle of Wight Public Health Intelligence Team, 2023). Hampshire comprises a population with wide-ranging affluence and deprivation including food security (Hampshire and Isle of Wight Public Health Intelligence Team, 2023). Meanwhile food waste at the household level is high across the nation in all counties (Gillick and Quested, 2018). To describe the study region, we will summarise maps and figures of socio-demographic data of the area. These data were collected as part of the UK, Hampshire's Joint Strategic Needs Assessment (JSNA), aiming to visualise current and future patterns of health, wellbeing and inequality in the Hampshire population. These data were accessed on the 23rd of June 2023 from the Healthy Places Report and the Healthy Lives Report (Hampshire and Isle of Wight Public Health Intelligence Team, 2023).

The proportion of children who lived in low-income households in Hampshire was mapped throughout the region by geographies of population density, showing a range between 8% and 39.9% in 2022 (Hampshire and Isle of Wight Public Health Intelligence Team, 2023). In 2020-2021 the proportion of children living in low-income households in the UK was 18.5%. At this time in the Hampshire districts, three districts had a proportion greater than this: the Isle of Wight (22.1%), Havant (19.3%) and Gosport (19%). The two districts in Hampshire with the lowest proportions of children living in low-income households were Hart (7.3%) and Fareham (10.8%) (Hampshire and Isle of Wight Public Health Intelligence Team, 2023).

The overall risk of food insecurity across Hampshire and the Isle of Wight was also mapped, and shown in Figure 1 below (Hampshire and Isle of Wight Public Health Intelligence Team, 2023). It was clear that throughout the region there were frequently areas at risk of food insecurity at the highest deciles: 1 and 2.8.
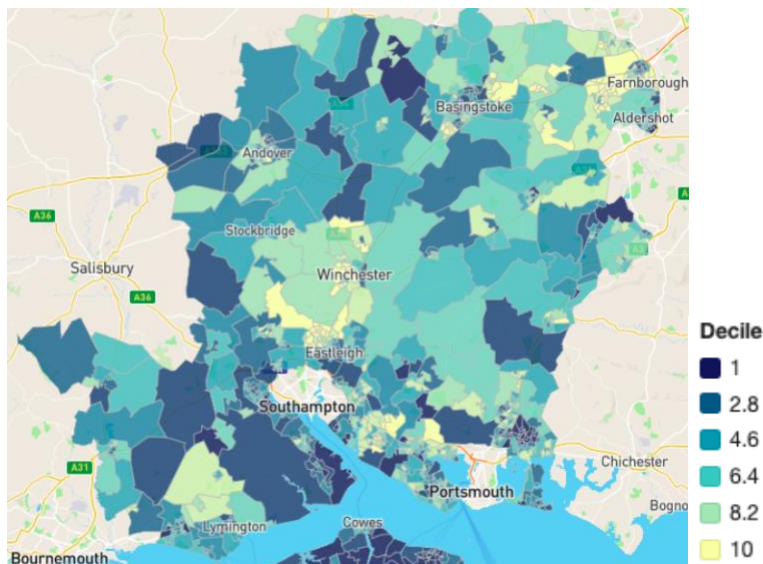
Figure 1 Overall risk of food insecurity across Hampshire (Hampshire and Isle of Wight Public Health Intelligence Team, 2023)

The percentage of adults (aged 18+) classified as overweight or obese in England is similar to the Hampshire percentage over time. Overweight or obesity is an important marker because of research demonstrating the links between high prevalence of obesity and poorer diet quality (Nishtar, Gluckman and Armstrong, 2016; Smethers and Rolls, 2018; Swinburn *et al.*, 2019; Rauber *et al.*, 2021) and health outcomes, such as: hypertension, higher fasting glucose or metabolic syndrome (Poti *et al.*, 2017). In 2020/21 the percentage of obesity or overweight for England and the percentage of obesity or overweight for Hampshire were both between 63% and 64% (Hampshire and Isle of Wight Public Health Intelligence Team, 2023). As part of the National Child Measurement Programme, data showed that in 2019/20 the percentage of overweight or obese children in year 6 (10-11 year olds) for England was similar to, but higher than the Hampshire percentage, between 35-36% and between 30-31% respectively (Hampshire and Isle of Wight Public Health Intelligence Team, 2023). The English percentage was shown to increase to between 37-38% in 2021/22, thus the trajectory for the Hampshire percentage was estimated to increase also. Finally, data were sourced on the proportion of the population eating '5 a day' of fruit and vegetables on a 'usual day'. The data showed that approximately half of the population achieved this target. The proportion of the population eating '5 a day' was greater for Hampshire than for England, between 59-60% and between 55-56% respectively (Hampshire and Isle of Wight Public Health Intelligence Team, 2023).

1.4   Statement of covid impacts

On designing the research project there was difficulty in carrying out in-person primary data collection as planned due to the impact of Covid 19, as the project started in October 2020. It was necessary to rely on online engagement, interviews and convenience sampling due to recruitment

challenges incurred because of the pandemic. Additionally, a systematic literature review enabled analysis of interventions that were not practical to conduct as primary research for the thesis due to Covid restrictions.

1.5   Thesis scope and structure

This thesis aims to optimise Hampshire householders' food waste behaviour by contributing evidence to guide and underpin effective and targeted food waste behaviour interventions to reduce avoidable and possibly avoidable food waste and improve food security, diet quality, and reduce greenhouse gas emissions.   The thesis adopts a three-paper structure with a final chapter that presents a collation of results within a framework to emphasise the thesis contribution to intervention planning. Chapter 6 also proposes a tool to inform food waste interventions for use in Hampshire or elsewhere.
Chapter 2 delivers a critical review of the literature and is divided into five sections. Several shortcomings of existing knowledge on food waste, diet quality and food insecurity were revealed. A limited focus in the literature on possibly avoidable food waste and inadequate focus on diet quality of wasted food at the household level in relation to sociodemographic characteristics is noted. Understanding possibly avoidable food waste and nutritional quality of wasted food by household characteristics is important because it offers solutions to improve food security (2.1). Limitations of the existing literature on behavioural insights (i.e., nudge techniques) and food waste behaviour change interventions were identified (2.2). Shortcomings of existing knowledge on motivation and food waste were revealed. A lack of research on how to align motivational drivers for food waste reduction with other priorities at home and inadequate use of motivational theories to guide findings in a European household context was evident (2.3). Three research questions were identified from this literature review, and are addressed in Chapters 3, 4 and 5 (2.4). Methods to address these research questions were discussed and decisions justified (2.6).

Chapter 3 comprises a systematic literature review of behavioural insights, specifically, *What Nudge Techniques Work for Food Waste Behaviour Change at the Consumer Level*. This chapter is based extensively on a published paper by the author (Barker *et al*., 2021).

Chapter 4 presents research that uses photographic food waste diary data, socio-demographic survey data and food insecurity data to test patterns of food waste in relation to socio-demographics and diet quality. This chapter is a facsimile of the published paper by the author (Barker *et al*., 2023).

Chapter 5 presents research that uses qualitative interview data to explore what drives food waste reduction behaviours and how motivational drivers for food waste reduction may align with other competing priorities at home, using self-determination theory. This chapter is planned to be

submitted for publication by the author in *The Journal of Consumer Studies* and titled: *Exploring motivation towards household food waste behaviour change using self-determination theory.*

Chapter 6 outlines the contribution of the original chapters 3, 4, 5 and sets out their limitations and suggestions for future research. The chapter integrates all data collected in the PhD to inform a framework of intervention implementation and design (6.4.2 to 6.4.8) and a tool (6.4.9) to personalise and tailor interventions for food waste reduction, for food insecurity and diet quality.

Chapter 2   Literature Review

This chapter provides a review of current literature on household food waste behaviour with a focus on behavioural insights (i.e., nudge techniques), food security, diet quality and motivational drivers. Section 2.1 critically reviews existing knowledge on food waste, food insecurity and diet quality. Section 2.1   demonstrates the need for understanding variation of household food waste, by household socio-demographics and by diet quality. Finally, section 2.1 identifies a need to understand food waste focused at the household level in a high-income European country such as England. Section 2.2 identifies what behavioural change techniques have been used in food waste behaviour change interventions in household settings. This builds the case for a systematic review to assess, using critical appraisal, the relative success and effectiveness of behavioural insights (i.e., nudge techniques) in interventions for food waste behaviour change.   Section 2.3 assesses existing knowledge on motivational drivers for food waste reduction in household settings. Section 2.4 describes the gaps identified in the literature review and presents three research questions that will contribute to understanding household food waste behaviour. The research questions are addressed in the following empirical thesis chapters. Section 2.6 summarises the rationale for the methods used in this thesis.

2.1   Existing knowledge on food waste, diet quality and food insecurity

2.1.1   Types of food waste with a focus on possibly avoidable food waste

Household food waste is complex to assess and measure, however, the literature does consistently categorise it as avoidable e.g., a slice of apple, unavoidable e.g., an egg shell and possibly avoidable e.g., carrot peel (Lebersorger and Schneider, 2011). 'Avoidable food waste' is the term describing food that could have been eaten but was discarded uneaten; 'unavoidable food waste' pertains to discarded food that is deemed customarily inedible (WRAP, 2008; Quested, Esteal and Ingle, 2013; Shaw, 2021). Behavioural or cultural factors may affect whether or not a food is deemed edible or inedible, for example potato peel, producing a category 'possibly avoidable' food waste relevant to consumers' individual choice, learned behaviour and preference influencing the quantity and type of food waste generated (Shaw, 2021). Ideally the intention of categorising food waste in this way is to guide the response usefully, i.e., 1) derive value from unavoidable food waste; 2) minimise or prevent avoidable food waste; 3) minimise or prevent possibly avoidable food waste (Shaw, 2021). For the purposes of this study the term 'Avoidability' is used to indicate the categories of avoidable, possibly avoidable and unavoidable food waste.

2.1.1.1   Written food waste diaries and possibly avoidable food waste

Written food waste diary studies at the household level have usually collected data on avoidable/unavoidable food waste but have not further categorised food waste as possibly avoidable (Koivupuro *et al.*, 2012; Silvennoinen *et al.*, 2014; Giordano, Alboni and Falasconi, 2019; Leverenz *et al.*, 2019; Herzberg, Schmidt and Schneider, 2020). Infrequently, other diary studies did measure possibly avoidable food waste (WRAP, 2008; Quested, Esteal and Ingle, 2013; Ilakovac *et al.*, 2020; Karunasena, Pearson and Fight Food Waste CRC, 2021), but typically did not account for other influencing factors such as sociodemographics in the analysis of the data. A study in Croatia did consider household size but did not calculate the statistical significance per person (Ilakovac *et al.*, 2020). Karunasena, Pearson and Fight Food Waste CRC (2021) did measure sociodemographic variables alongside possibly avoidable food waste; however, in the report proportions were comprehensively documented, but statistical methods to analyse the data were only used to assess behaviours in relation to food waste. Additionally, the methods for categorising possibly avoidable food waste were not stated in this report (Karunasena, Pearson and Fight Food Waste CRC, 2021). In the UK, diary studies by WRAP in 2007 and 2012 both measured possibly avoidable food waste; however, the WRAP 2007 Diary Study did not report on these findings in the results, focusing rather on avoidable food waste (WRAP, 2008). In the WRAP 2012 Diary Study, these data were combined with a waste compositional analysis (WCA) study and a synthesis of national compositional data to provide findings on food waste weight. However, the report did not calculate food waste weight per household size per person, or other sociodemographic variables, choosing to focus on food group categories of food waste by Avoidability instead (Quested, Ingle and Parry, 2013).

2.1.1.2   Food waste studies in the UK with a focus on possibly avoidable food waste

In the UK a large food waste study was conducted starting in July 2007, (the "WRAP 2007 WCA Study") (WRAP, 2008). Initially, door step interviews were carried out with householders in nine English and two Welsh local authorities. All householders in two areas of each local authority were sent a letter on the study objectives and offered a chance to opt out. Participants were interviewed on a random basis (WRAP, 2008). 2715 householders were interviewed several weeks after food waste was collected from 2138 of the householders (WRAP, 2008). Although respondents who were interviewed and subsequently had their waste analysed were selected on a random basis, there were some ways in which the sample was not representative of the national profile (WRAP, 2008). Specifically, smaller households were under-represented; flats were underrepresented; households with employment status of: part time, self-employed, unemployed, long-term sick or student household were under represented; and Asian households were over-represented (WRAP, 2008).

During the food WCA, sorters went through residual and food waste containers, extracting any food items that were thrown away, this included inedible foods (WRAP, 2008). From the WCA the food was described in detail on a data collection form and if possible included brand and unit e.g., 2 Bird's Eye breaded fish fingers. It was then categorised into thirteen groups (e.g., vegetables, meat and fish or bakery etc.), and assigned a category of food stage relating to how the food had been prepared prior to being wasted (See Appendix A Figure A1 Page 213, from (WRAP, 2008)). Once these textual data were returned to office-based Exodus researchers, food type, Avoidability and cost category were applied (See Appendix A Figure A1 Page 213, from (WRAP, 2008)). Thus, the application of rating Avoidability did not occur alongside a visual image of the primary data sample. Furthermore, despite recording these data, the findings in the report focus on avoidable food waste, i.e., excluding food that was unavoidable or possibly avoidable food waste such as carrot peelings or bread crusts. Thus, there remained a lack of insight into how possibly avoidable food waste differed with household characteristics. Possibly avoidable food waste is important to explore as it could be key to changing behaviours to reduce food waste in an affordable way, and that may offer nutritional benefits (Lebersorger and Schneider, 2011; Cooper *et al.*, 2018; Chen, Chaudhary and Mathys, 2020).

Prior to the WRAP 2007 WCA Study in February 2007, a diary study was conducted to understand better why food items were disposed (the "WRAP 2007 Diary Study"). The findings of the WRAP 2007 Diary Study were also reported in The Food We Waste report (WRAP, 2008), although the methods of participant recruitment were not described. However, there was a signpost to a different report that contained the methods for the WRAP 2007 Diary Study (WRAP, 2008). On searching using the signpost instructions the report could not be found online, here the researcher contacted WRAP by email for the information, however there was no response. Thus, it was unclear whether this sample was representative of the UK population. The sample size for the kitchen diary study was 284 and methods of diary entry were outlined (WRAP, 2008). For each incidence of food waste, householders were requested to document the type of food waste, the approximate amount (i.e., a cupful or flat handful where units were not expressed), alongside method and reason of disposal (WRAP, 2008). Data on possibly avoidable food waste were not reported on in the findings, rather only avoidable food waste was indicated (WRAP, 2008).

In 2012, two new large UK food and waste studies were conducted by WRAP. We will call this the WRAP 2012 WCA Study (n=1800) and the WRAP 2012 Diary Study (n=948) (Quested, Esteal and Ingle, 2013). In the WRAP 2012 WCA Study, the sample size was 1800 and a quota sampling approach was used to recruit participants (Quested, Esteal and Ingle, 2013). Data were collected across twelve local authorities in the UK, and five areas in each local authority. The study sample was representative of the UK population (Quested, Esteal and Ingle, 2013). However, the methods used for identifying avoidable, possibly avoidable and unavoidable food waste were not clearly outlined in the methods

report for the WCA study, (see Figure 8 on page 36, and section 4.4.3 Sorting The Waste, page 34-35 (Quested, Esteal and Ingle, 2013)). In the WRAP 2012 Diary Study the sample of 948 households was considered representative of the UK population. The recruitment process used a quota sampling approach; when quotas were reached, a random approach to ensure representativeness was conducted (Quested, Esteal and Ingle, 2013). The methods for the WRAP 2012 Diary Study were limited to food waste categorisation by Avoidability, stating only: "Information from the diaries was inputted manually into an Excel database and coded into food groups and food types, consistent with other elements of WRAP's household food waste" (Quested, Esteal and Ingle, 2013, p40). Thus, it seems researchers applied the Avoidability category following receipt of the diary data from participants, with no visual evidence to hand relating to what they were categorising. Finally, in the WRAP 2012 Diary Study, a £50 voucher was offered as an incentive to participants, with a non-completion rate of the diary of approximately 16% (Quested, Esteal and Ingle, 2013). The results from the WRAP 2012 WCA and Diary Studies were combined and reported in one document alongside a synthesis of national food waste compositional data; it was difficult to distinguish which section of the report related to the three sections of the large food waste study. However, the report showed UK food waste in detail with weights across food groups, and household size divided by avoidable, possibly avoidable and unavoidable food waste (Quested, Ingle and Parry, 2013). Calculation of other household characteristics such as educational attainment or income in relation to food waste Avoidability categories were not included in the data analysis and results of this report even though it was clear in the methods that these data were collected (Quested, Ingle and Parry, 2013).

As of 2023, 2012 was the most recent year that WRAP collected detailed information on food waste type and group. In the UK, since 2012, WRAP has continued to carry out regular synthesis of household food waste compositional data in 2014, 2015, and 2018 on a national level that is comparable year on year (Bridgwater and Quested, 2016; WRAP, 2020b). Data from local authorities that undertook WCA were collated and analysed with WasteDataFlow, the most up to date data on local authority household waste collections available (WRAP, 2020b). In 2018, these results were restated to classify food waste as wasted food and inedible parts (WRAP, 2020b). Thus, these high-level estimates and reporting on these data do not offer detailed information on food waste group or type nor useful data on possibly avoidable food waste currently in the UK (WRAP, 2020b).

2.1.2   Food security links to food waste

This section will discuss national and household food security. There are various definitions of national food security but three core pillars are agreed: food availability, access and utilisation (Opara, 2013). At a household level, affordability is typically included alongside utilisation to indicate food insecure households (Smith and Thompson, 2022). Actions to support food availability include

increasing efficiency of production systems, decreasing edible food wastage, and changing consumption habits to reduce demand for animal foods and adopt sustainable diets (Bowdren & Santo, 2019). Food wastage aggravates concerns around food security due to decreasing food availability, but also has direct effects on environmental resources through use of fertile soils, fresh water, energy, fertilisers and release of carbon emissions in production of food (FAO, 2013; Östergren *et al.*, 2014; Scherhaufer *et al.*, 2018; Szulecka *et al.*, 2019; Garske *et al.*, 2020). A growing population adds further pressure to these food availability concerns (Pinstrup-Andersen, Gitz and Meybeck, 2016). Physical access is a mix of system and household factors: proximity, ease of travel and means of transportation to a local market but also actors and infrastructure, or lack of, along the food system such as: transport, road networks, post-harvest handling and storage options (Opara, 2013). Insufficiencies in storage and transportation can cause FLW further reducing access to food (Bowdren & Santo, 2019). FLW also presents financial difficulties in food access along the food supply chain, those in production and manufacturing may be subject to FLW related income losses, and consumers may be subject to reduced food market and rising food prices (Opara, 2013).

Utilisation refers to consumption of food (quality and quantity) sufficient for calorie intake and nutrient requirements (Opara, 2013). Nutritional status is an outcome of food intake and health highlighting the importance of clean water, sanitation and health care as part of achieving effective utilisation of food. A United States (US) study measured self-reported diet healthiness, food security and food waste in 4826 households (using the US Department of Agriculture National Household Food Acquisition and Purchase Survey) and suggested 'healthy' diet practice and high food security leads to more food waste (Yu and Jaenicke, 2017). A pattern of lower food waste in insecure houses supports the narrative that food insecure households purchase fewer items likely to deteriorate quickly, which may include less healthy processed food (Yu & Jaenicke, 2017).

Relevant to UK food aid is the source of food offered to households which need support, which is often 'surplus' that is redistributed by a charity from a larger organisation such as FareShare. Currently food that is still edible but not appropriate for retail purposes is collected and delivered in this way, but the result is less choice in diet for food aid recipients. Acceptability of food available links with food utilisation including aspects of safety and skills and knowledge. It is a vital component encompassing prioritising the pursuit of human dignity for more vulnerable people in society (Bowdren & Santo, 2019; Opara, 2013). It is not a solution to give all wasted or surplus to those in need. Firstly, this does not adhere to the definition of food security - nutritious food meeting dietary needs without external intervention (Kneafsey et al 2011). Secondly, many foods donated are heavily processed and may not be healthy (Bowdren & Santo, 2019; Fisher & Jayaraman, 2017; Mirosa et al., 2016). It is also essential to consider the cultural and religious norms of food acceptability as this will affect whether the food will be eaten or wasted. For example, for a family of Islamic faith the

donation of pork sausages would likely go uneaten (Mirosa *et al.*, 2016). This model of redistribution also passes on the challenge of disposing of food which is not taken up in food aid to often smaller charities while the original source of the surplus food meets their food waste targets (Smith and Thompson, 2022).

Food security (here taken to mean household food security) means much more than meeting daily energy requirements (calories): a balance of macro and micronutrients for optimal health is essential. As foods vary broadly regarding nutritional content and environmental footprint (Chaudhary and Krishna, 2019; Willett *et al.*, 2019; Chen, Chaudhary and Mathys, 2020) quantifying food waste only as daily energy requirements or by mass does not show the true damage and loss to the system. Food and nutrition security is a complex issue, associated with health through malnutrition, but also sustainable economic development and the environment (Scherhaufer *et al.*, 2015; Garcia-Herrero *et al.*, 2019). The 1996 World Food Summit defined food security as existing when every person always has access to enough nutritious food for an active and healthy life (Pinstrup-Andersen, Gitz and Meybeck, 2016). Unequivocally, nutrition is an intrinsic part food security at whichever scale is relevant. While sustainable diets and changes in food waste behaviour could increase food availability, access and utilisation, and minimise environmental impacts of food production, realising a food secure future will also need actions to reduce inequalities and economic imbalances (Bowdren and Santo, 2019; Smith and Thompson, 2023; Reynolds *et al.*, 2020).

2.1.2.1   Food security, sociodemographic characteristics and food waste in the UK

There is a need for research that explains the food waste patterns in relation to demographic characteristics, if geographies of health inequalities and food insecurity are to be fully addressed. Such research must account for the influence of food waste both on diet quality and food insecurity.

Food security remains a concern for at least 8% of the population (Defra, 2021b; Smith and Thompson, 2023), though more recent (June 2023) surveys from the Food Foundation place this number at 17% (The Food Foundation, 2023a). Additionally, current rising costs of living (Harari *et al.*, 2022) may push households with formerly sufficient income to find affording food more difficult than before.

Food security means a household is unable to access food of necessary nutritional quality and amount by socially accepted means. These households may seek access to food via food aid, i.e., food banks or experience hunger (Bramley *et al.*, 2021; Smith *et al.*, 2022). Food poverty is another term frequently used interchangeably with food security as it reflects the economic constraints that often face people experiencing food insecurity (Smith *et al.*, 2022). Previous data on food insecurity in the UK indicated that low income, unemployment and disability were related to severe food

insecurity, and low educational attainment, younger age, and non-white ethnicity were related to food insecurity (Loopstra, Reeves and Tarasuk, 2019). Other surveys further indicated that health outcomes, i.e. mental wellbeing were connected with food insecurity (Loopstra, 2020; Parnham *et al.*, 2020) and identified socio-demographic risk factors including people renting or on lower incomes (Pool and Dooris, 2022). Data on household food insecurity have been collected biannually in the Food and You Surveys but after repeated campaigns, questions were added to the annual Family Resouce Survey to enable more regular monitoring (Food Standards Agency, 2023; Independent Food Aid Network, 2021). Since 2020, the Food Foundation has provided regular national surveys to provide snapshots of household food insecurity (The Food Foundation, 2023b).

Due to the association of food insecurity and sociodemographic characteristics, it is pertinent to observe food waste patterns by socio-demographic groups. This is so that groups most at risk of food insecurity might be targeted with food waste interventions sensitively and in a way that may also address other needs. This is important because groups of people at risk of food insecurity may have a greater need to save money and maximise their diets' nutritional quality, aspects that food waste interventions can address. Supporting public health messaging and social care initiatives to tackle food insecurity in tandem with food waste may address sustainability, health and social inequalities simultaneously.

Despite the links between sociodemographic characteristics and food security and the relevance that this could have towards food waste reduction interventions, focusing on a demographic approach in the context of food waste is contested (Boulet, Hoek and Raven, 2021a). One review states that the association of individual level factors such as attitudes and demographics is well established and therefore suggests that focus on research here should not be a priority, explaining that at the individual level food waste is positively associated with income and negatively associated with age (Boulet, Hoek and Raven, 2021a). However, these studies only measure a value of food waste that is self-reported via questionnaire (Stancu, Haugaard and Lähteenmäki, 2016; Visschers, Wickli and Siegrist, 2016; Falasconi *et al.*, 2019; van der Werf, Seabrook and Gilliland, 2019). It can be argued that these studies did not offer findings that connected household characteristics with data on food waste weight that were not reliant on memory and recall.

One self-reported survey used previously published methods that focused on food waste as an aggregate of behaviours related to food instead of self-reporting food waste amounts (Mondejar-Jimenez *et al.*, 2016; Grasso *et al.*, 2019). However, the results remain limited by participant's self-reported perception of their own behaviour which may not be accurate (Hebrok and Boks, 2017; van Herpen *et al.*, 2019). The study highlighted the importance of social and material contexts of everyday food waste practices, indicating that time, domestic divisions of labour regarding food

shopping and preparation, and infrastructure of provision influence food waste behaviours may be outside the control of consumers (Grasso *et al.*, 2019). This study suggested that socio-demographics explained only 7-13% of the variance regarding intention and behavioural control to reduce household food waste, indicating that these aspects may be improved across demographics (Grasso *et al.*, 2019). The findings indicated that being unemployed or working part time, being older or living in a household greater than or equal to four people was associated with behaviours generating lower food waste in Denmark and Spain, and that being male was connected to more food waste.

Despite the statement that demographics and food waste are well documented (Boulet, Hoek and Raven, 2021a), there remains limited experimental research. A recent review calculated that of the methods used in food waste literature, the majority used questionnaire methods (46%), interviews, ethnographic content and literature review were each used 17% of the time and experimental methods just 4% (Porpino, 2016).

2.1.3   Understanding nutritional losses along the food supply chain

Assessing nutritional content in food waste is key to knowing the type and amount of nutrients lost in food waste. First, if we know the dietary value of the food wasted, we can understand the impact of diet quality on food waste. Second, if we better understand the impact of food waste on diet quality, we can comment on how this may translate to health outcomes. This knowledge could inform policy and practice to effectively focus effort to reduce food waste that also elevates diet quality and improves food security.

Regarding food waste the assessment of nutrient loss in food is generally assessed in two key ways: energy i.e., Kcal and nutritional loss in food (Spiker *et al.*, 2017; Cooper *et al.*, 2018; Chalak *et al.*, 2019). Food waste is also assessed regarding loss of weight in food, i.e., loss of water or moisture content, which may link to nutrient loss; and loss in energy that powers the preservation of nutrients in food by storage, handling and processing (FAO, 2013; Khalid *et al.*, 2019; Szulecka *et al.*, 2019). Furthermore, along the food supply chain the nutrient density of fresh food diminishes post-harvest, during storage, particularly if handling is inadequate - the effect is more marked on fresh fruits and vegetables, especially vitamin C, which degrades rapidly post-harvest (Olsson, 2018); thus even if the food is eaten nutritional loss has occurred.

Food waste research was frequently limited to measuring nutritional loss in relation to calories or protein only and limited due to using data collection methods that were incomparable (Chen, Chaudhary and Mathys, 2020; Ellison and Prescott, 2021). A number of international publications have outlined the calories lost in food waste per person using different methods at the consumer level (Buzby, Wells and Hyman, 2014; Spiker *et al.*, 2017; Cooper *et al.*, 2018; Porat *et al.*, 2018;

Garcia-Herrero *et al.*, 2019; Khalid *et al.*, 2019; Vittuari *et al.*, 2020). A study in Pakistan, that used a WCA method with a sample of 51 households, showed that on average the total energy lost for all types of food waste was 54.42kcal per person per day (N.B. it was not clear whether this loss was calculated from only edible food waste or edible and inedible food waste) (Khalid *et al.*, 2019). In Turkey, a study with a sample of 500 households collected food waste data using a 24-hour recall interviewing technique: the person responsible for cooking and preparing food at home completed an interview for data referring to the day before (Peckan *et al.*, 2006). This study reported the mean daily energy loss from edible food waste per household per person was 215.7kcal/day; edible food waste comprised on average 9.8% of the daily energy intake per person (Peckan *et al.*, 2006). A US study in 2010 used data on the population from the US Department of Agriculture Economic Research Service to estimate food commodity available for consumption, then the Loss-Adjusted Food Availability (LAFA) data series was applied to analyse consumer level food loss (not food waste). The findings showed that 789 kcal of edible food per person per day were lost at the consumer level (Buzby, Wells and Hyman, 2014).

However, some studies using primary data (Cooper *et al.*, 2018; Chalak *et al.*, 2019) and secondary data (Spiker *et al.*, 2017), provided weights of nutritional loss of food waste as macronutrients, minerals and vitamins e.g., vitamin C, B12 and fibre within household food waste. It is useful to add further information to nutritional losses occurring in consumer food waste, specifically on the micro and macro nutrient level to make a comment on diet quality. Three papers across three countries: the UK, Pakistan and the US explored this (Cooper *et al*., 2018; Khalid *et al*., 2019; Spiker *et al*., 2017). The categories of nutrition lost were not comparable, the methods of FLW measurement differed, sample sizes were non comparable and the area of focus along the food supply chain varied i.e., household only (UK and Pakistan) or household and retail combined (US). However, in each country a large amount of nutrients were being lost, which arguably with better food management could be saved.

If we better understand links between food waste and diet quality in households, we can better comment on how this may address health outcomes. A study in the US analysed a national food database: What We Eat In America, and categorised diet quality using the Healthy Eating Index-2015. Edible and inedible FLW was estimated using the US Department of Agriculture LAFA data series. This provided data at the consumer level on the inedible food waste proportion of purchased food but the edible proportion of food wasted on consumption was not provided, therefore in this study these data were derived using other computations (Conrad *et al.*, 2018). The study showed that healthier diets were associated with more edible food waste: higher diet quality was associated with greater dairy food waste (P<0.001), vegetables and fruits and mixed dishes (P<0.001), soup P=0.001, nuts and seeds (P=0.017 and table oils and salad dressing (p<0.001, as well as salty snacks (p<0.001)

(Conrad et al., 2018). This may be due to peeled vegetables, or fresh produce/dairy products being wasted more often as they comprise more of the household diet.

In the UK WRAP reports (Section 2.1.1) food waste weight in relation to food groups was calculated and offered an indication of diet quality of food wasted in the UK. A subsequent study did analyse food waste nutritional content using WRAP 2012 WCA and Diary data, and presented findings on the loss of calcium, food folate, iron and fibre per person per day (Cooper *et al.*, 2018). The results also indicated that on average, over a year, food wasted per person in the UK provided nutrients to reach UK recommended nutrient intakes for 21 nutrients and energy over 42 days (Cooper *et al.*, 2018). However, this study suggested that finding other ways to categorise the nutritional value of food waste in a simple way that provides meaningful data would be worthwhile to more easily guide interventions (Cooper *et al.*, 2018). It could also be useful to address the issue of the shortcomings of comparable data that can be easily categorised to identify nutritional value and edible food waste across different countries. Thus, research that can categorise the diet quality of food waste in a simple and meaningful way has merit; this will be addressed in Chapter 4 of this thesis.

Previous food waste research has not used categories of food processing: ultra-processed, processed, minimally processed and unprocessed foods such as the NOVA classification to categorise the health potential of discarded food (Monteiro *et al.*, 2016) (See Chapter 4). It is known that there is a growing body of research linking the level of food processing negatively with health outcomes, where more processed food is associated with less desirable health as it affects diet quality (Monteiro et al., 2016; Poti et al., 2017). An association between high prevalence of obesity and poorer diet quality continues to be demonstrated (Nishtar, Gluckman and Armstrong, 2016; Smethers and Rolls, 2018; Swinburn *et al.*, 2019; Rauber *et al.*, 2021). A recent review indicated that higher purchases or consumption of ultra-processed food was associated with obesity and overweight, food intake, higher fasting glucose, metabolic syndrome, risk of hypertension and increases in total and low density lipid-protein cholesterol (Poti *et al.*, 2017). These studies and reports are informing a greater public engagement with ultra-processed foods and the possible health impacts recently.

In order to explore links between nutrition and food waste in a simple and meaningful way, categorising food waste by level of food processing could be a useful indicator due to its association with diet quality. This could provide insight that policy makers may apply when making food waste reduction recommendations that can simultaneously benefit health and food security.

It is also essential to compare nutrient losses along the food supply chain to understand at which stage most losses occur. A Spanish study showed nutritional food losses and waste per supply stage (Agricultural Production, Postharvest, Processing, Distribution, and Households) in terms of energy per capita per day using percentages of each nutrient and average overall loss at each stage in the

food supply chain (Garcia-Herrero *et al.*, 2019). Results were clear that for this high income, European country, the biggest losses in energy, vitamin A, vitamin C and protein occurred during agricultural production and at household level, indicating that these were prime areas of concern. In the UK, a study breaking down FLW by nutritional loss was not assessed in relation to the whole supply chain (Cooper *et al.*, 2018), but it is known that in the UK, post farm gate, 70% of edible food waste occurs at the household level (WRAP, 2021). Considering the probable similarity of another European county to the UK, and the high-level data from the UK itself, it is clear that a focus on household settings for a UK study is a high impact priority area.

2.1.4 Household size (number of people living in the household) and food waste

In this thesis the term household size is taken to mean the number of people living in a household. Some linear trends have been observed in the data relating to household size and amount of food waste in previous research in high income European countries (Herzberg, Schmidt and Schneider, 2020; Silvennoinen *et al.*, 2014; Quested, Ingle and Parry, 2013; WRAP, 2008). For example, the WRAP 2007 WCA Study showed that single person households (n=325) wasted the most averaging 1.9kg per week of avoidable food waste. Households of two or three people wasted on average 1.3kg of avoidable food waste per week per person (n=1105). Finally, households of four or more people wasted approximately 1kg of avoidable food waste per week per person (n=698). However, these data were not analysed to establish if the differences between household sizes were statistically significant (WRAP, 2008). In the representative WRAP 2012 WCA and Diary Study, the overall trend showed that per household larger households produced more food waste weight on average (Quested, Ingle and Parry, 2013).

Other European studies showed linear trends of household food waste by household size. A German study with a sample of 6853 households who participated in a diary study in 2016 and 2017 showed that the average per person weight of food waste reduced with increasing household size (Herzberg, Schmidt and Schneider, 2020). However, the study did not statistically analyse the data within each household size group per person. A Finnish study with a non-representative sample of 380 households used a kitchen diary method to measure food waste; it found that there was more food waste in households with more people (Silvennoinen *et al.*, 2014). The study calculated statistical significance by household size, but did not calculate the significance when household size was normalized per person (Silvennoinen *et al.*, 2014).

Other studies on European household food waste that calculated the effect of household size on the data did not all show a clear linear trend. A Danish study of 1474 households collected 12 tonnes of residual household waste (Edjabou et al., 2016). The study suggested there were no significant

differences of amounts of avoidable food waste per person by household size, although households of one person generated the most waste (Edjabou et al., 2016). A Finnish study of 380 households used a non-representative food waste diary method (Koivupuro *et al.*, 2012). The results showed that household size indicated differences between one person households and five or more person households (P<0.100) (Koivupuro *et al.*, 2012). There were no other significant differences between households. A Danish study that used a self-reported survey with a sample of 1062 household respondents stated there were no significant relationships (p=0.16) between household size and food waste behaviour at the p<0.05 level using correlation analysis (Stancu, Haugaard and Lähteenmäki, 2016); however, this study measured behaviour as a proxy for food waste amount rather than measuring the food waste amount directly.

Thus, calculating differences between households of different sizes when the data have been normalised per person is not frequently evident in the literature when exploring the relationships between household size and food waste amounts. This was the case regardless of data collection method: diaries, surveys and WCA. This aspect merits exploration to establish whether there are distinct differences relating to food waste when household size is normalised per person. This knowledge could usefully guide interventions to target households with the greatest per person food waste.

2.1.5   Discussion of common methods to measure household food waste

Considering how important and how complex food waste measurement is, there have been several initiatives to improve the quality of measuring household food waste (Hanson *et al.*, 2016; Tostivint *et al.*, 2016; CEC, 2019; Quested, 2020). Despite these initiatives comparable and reliable data on food waste continues to be a shortcoming due to inconsistent definitions, monitoring and reporting (Garske *et al.*, 2020). The type of methods to measure the quantity of food waste depends on the specific purpose:

- Understanding the nature of household food waste necessitates detailed data i.e., type of food wasted though not necessarily high-level accuracy
- Tracking progress of targets - requires accurate information but less detail (Quested, 2020)

The next section provides an overview of several key methods from the literature, noting the strengths and limitations of each.

Common methods to measure household food waste include survey, diary (written or online), photographic diary and WCA. Each method has strengths and weaknesses, and selection is best made on the basis of the function that is required.

Survey methods require participants to respond to survey questions by recalling their household food waste. A strength of this method is that these responses can be standardised and obtained from large samples to support robust statistical analysis to differentiate households according to the amount of food waste each produces (van Herpen and van der Lans, 2019). This survey method also offers flexibility in assessment, for example, pre-announced survey questions can ask about food waste regarding a specific time period e.g., food that has been wasted in the past week (van Herpen and van der Lans, 2019). Shortcomings include inaccuracies of reported food waste as this method requires subjective self-assessment based on memory; this weakness is well documented and has been shown to lead to underreporting of food waste in comparison with compositional analysis (Giordano *et al.*, 2018; Elimelech, Ert and Ayalon, 2019). Research indicates that what consumers actually do in relation to food waste at home, compared with what they recall or report they do differ due to the habitual/automatic nature of food related activities indicating social desirability bias (Gaiani *et al.*, 2018; Elimelech, Ert and Ayalon, 2019).

Written food waste diaries are another method of food waste measurement. Participants record their household food waste in real time by writing on paper or online (van Herpen *et al*., 2019; Quested *et al.*, 2020). Researchers sort recorded waste into categories, which may be subsequently estimated for weight and results collated to offer composition of the waste sample (Quested, Ingle and Parry, 2013). This is a useful method as participants can carry it out in their own homes and they can record their food waste in real time, making it a more objective method than a survey, which relies on memory. However, the written diary method is less objective than WCA unless it incorporates participants recording their weights of food waste; there, however would be more issues with standardised weighing practice than in WCA (Quested *et al.*, 2020). Another benefit of this method is that it can easily identify food that is wasted down the drain, in the compost or eaten by pets (Quested, 2020). Written food waste diaries can support a geographically diverse sample, though postage and printing costs would be incurred with hand-written diaries. Shortcomings include behavioural reactivity on account of the activity itself (Quested, 2020), misreporting (Quested, 2020) i.e., recording unit of measurement incorrectly. Other limitations include measurement biases and/or lack of engagement from all members of the household, which may contribute to underreporting (Quested, 2020). Research has shown that food waste recorded in written diaries is less than the amount measured in WCA (Quested, Ingle and Parry, 2013; van Herpen and van der Lans, 2019). Another issue is selection bias (Quested, 2020), i.e., the type of individuals to participate in the study may already be more interested in food waste reduction and changing their behavioural

habits. Finally, food waste diaries incur a burden of work for participants to complete a written food waste diary (van Herpen *et al.*, 2019).

Photographic diaries require participants to take photographs of their household food waste as it occurred. The method can enable a geographically diverse sample (van Herpen and van der Lans, 2019). It is a method that is carried out in the participants' own home in real time, thus not relying on memory in the way survey methods do. Additionally, it has been shown that this method is less of a burden and more easily assimilated into daily life by participants than a written diary (Roe *et al.*, 2020), because instead of the effort of writing, a photograph provides data needed. Compared to a written food diary there is less room for error, as the photograph takes the memory objectively rather than the participant repeating and writing it down incorrectly (van Herpen *et al.,* 2019). The photographic diary method is deemed less accurate than WCA for assessing the weight of food waste (Quested *et al.*, 2020). However, the method can incorporate participants' measuring and reporting food waste weight using scales at home, but the weighing would not be standardised across households, which is a possible weakness in comparison with WCA practice (Quested *et al.*, 2020).

Researchers can sort waste recorded on photographs into categories, which may be subsequently estimated for weight and results collated to offer composition of the waste sample (van Herpen and van der Lans, 2019). This method offers the option to researchers to categorise food waste in relation to how healthy the food is and its possibly avoidable, avoidable or unavoidable food category; because food is not degraded and photographs can offer a clear record. Furthermore, it is possible to easily measure food wasted in a variety of environments in the home, for example: in the sink, in the compost or eaten by pets (Quested, 2020). A shortcoming of the method is that coding photographs is time-consuming, it can lead to high costs of data handling of researchers and applicability to large samples may be difficult (van Herpen and van der Lans, 2019). There may also be bias introduced due to incorrect coding (van Herpen and van der Lans, 2019). Other shortcomings include the reliance on new, not yet fully tested, technology, privacy concerns for participants, and the required work in keeping track of and interpreting the data (van Herpen and van der Lans, 2019). Finally, for similar reasons to written diaries selection bias and behavioural reactivity may skew the results (Quested *et al.*, 2020). For example, individuals likely to agree to participate may be particularly motivated or diligent, and the act of photographing their own food waste may prompt change in their own behaviours.

WCA includes kitchen caddy sorting as well as larger household bins. This approach requires physically sorting waste by hand into categories, which are subsequently weighed and results collated to indicate composition of the waste sample. It is a longstanding and objective measure. One study provides an in-depth discussion of the methodology for determining food waste in waste-

composition studies (Lebersorger and Schneider, 2011). However, another study provides an overview of twenty known methods of WCA and indicates various sources of error (Dahlén and Lagerkvist, 2008). Issues such as selection bias and behavioural reactivity are lessened, as a routine, scheduled bin collection can be measured without much disruption to participants daily life (van Herpen and van der Lans, 2019). The weakness of the WCA methods is that it misses food waste not disposed of in food waste caddies i.e., liquids, home composting, the drain, feeding to animals (Parizeau, von Massow and Martin, 2015; van Herpen and van der Lans, 2019). Food also degrades rapidly: rot/mould can occur which could make it harder to distinguish between food types or whether the food waste is avoidable, possibly avoidable or unavoidable. The weight of the waste may also change due to weather conditions, for example, water evaporation when it is hot, or absorbing moisture in damp conditions. Additionally, food is often thrown away in packaging which causes inaccuracies for the weight measure. Finally, the costs involved are high, and the burden of work for researchers is extremely high (Quested, 2020).

Other food waste valuation methods include interviews (Chaboud and Daviron, 2017) field observations (Boulet, Hoek and Raven, 2021b) food consumption databases (Garcia-Herrero *et al.*, 2019) or extrapolation based on municipal solid waste (Bräutigam et al., 2014). These methods appear relatively uncommon and do not categorise as self-assessment or direct measurement method of food waste (Elimelech, Ert and Ayalon, 2019).

2.2   Behavioural insights (i.e., nudge techniques) in food waste behavioural change interventions

A variety of behaviour change approaches have been used in interventions for household food behaviour change. A recent paper evaluated behaviour change techniques in the development of a food waste intervention programme (Cooper *et al.*, 2023). These included prompts or cues, reformation of the physical environment, information on social and environmental consequences, material incentives, goal setting and action-planning, how-to instructions on performing behaviours, and saving mental resources (Cooper *et al.*, 2023). A randomised controlled trial tested an intervention for a personalised and tailored approach to achieve behaviour change that was pro-environmental, i.e., reducing food waste (Roe *et al.*, 2022), involving coaches working closely and time-intensively with individuals to create and apply personalised strategies for behaviour change (Roe *et al.*, 2022). This study responded to the success of many tailored lifestyle interventions for health that involved adjusting actions and messages to the needs of the individual (Heo *et al.*, 2015; Gram, Larbi and Wangberg, 2019; Ryan, Dockray and Linehan, 2019; Roe *et al.*, 2022).

Reynolds *et al*. (2019) examined what worked and how to design effective interventions to reduce consumption stage food waste; this review included interventions based in schools, universities, restaurants, as well as households from across the globe. Information-based approaches in food waste interventions were reviewed, and took a variety of forms: printed material (Manomaivibool, Chart-asa and Unroj, 2016) [similar to other intervention studies: (Shaw, Smith and Williams, 2018; van der Werf, Seabrook and Gilliland, 2021)], text messages (Whitehair, Shanklin and Brannon, 2013), collaborative workshops (Devaney and Davies, 2017) and cooking classes (Dyen and Sirieix, 2016). Printed materials have been shown to influence behavioural intention in relation to saving money (van der Werf, Seabrook and Gilliland, 2021), and can relate to a reduction in household food waste (Whitehair, Shanklin and Brannon, 2013; Devaney and Davies, 2017; van der Werf, Seabrook and Gilliland, 2021), though not always (Shaw, Smith and Williams, 2018; Reynolds *et al.*, 2019). Information delivery that was more passive was less promising than information-based interventions using more active approaches (Langen, Göbel and Waskow, 2015; Aschemann-Witzel *et al.*, 2017; Reynolds *et al.*, 2019; Nikravech *et al.*, 2022). A method of instilling more active approaches into information-based interventions could be achieved with behavioural insights such as nudging, a technique known to influence decision making for healthy eating (Cadario and Chandon, 2020). There is also evidence of the success of nudging to improve individuals' wellbeing and to support sustainable consumption, e.g., smaller portion sizes leading to healthier diets or public transport leading to money and energy saving (Lehner, Mont and Heiskanen, 2016). However, it is also pertinent to highlight that interventions leaning heavily on printed materials may exclude less literature groups, meanwhile interventions with a requirement to access a physical place may exclude populations with limited mobility (Smith and Thompson, 2023).

Nudge approaches were a notable part of policy development from 2010, with the establishment of a nudge unit in Public Health England (Rutter, 2020). Nudging offers a change in the presentation of choices, aiming to alter behaviour predictably without removing options or changing economic incentives considerably (Thaler and Sunstein, 2008). Nudging has been used in consumer food waste behaviour interventions, but it remains an evolving research area (Papargyropoulou *et al.*, 2016; Filimonau *et al.*, 2017; Linder, Lindahl and Borgström, 2018; Cooper *et al.*, 2023). Sunstein (2014) established ten effective nudges: default rules, simplification, use of social norms, increase in ease and convenience, disclosure, warnings, pre-commitment strategies, reminders, eliciting implementation intentions and informing people of the nature and consequences of their own past choices (Sunstein, 2014) (Table 2, Chapter 3). These definitions were applied to a household food waste study that explored the applicability of nudging for household level food waste reduction (von Kameke and Fischer, 2018), the study concluded from 101 personal self-reported questionnaires, that nudging can be a suitable tool, and offered ideas on how to use nudging in this area. Importantly

it identified the ability of nudging to provide opportunities to enable change after initial motivation for food waste reduction was initiated (von Kameke and Fischer, 2018). However, it was outside of the scope of the study to establish whether nudges were effective for behaviour change in household settings (von Kameke and Fischer, 2018).

A recent systematic literature review identified influences on consumer food waste behaviour through interventions (Simões, Carvalho and Gaspar de Matos, 2022). This review contained a summary of eighteen recent (2017 to 2023) interventions. Of these interventions, only two included nudging. Simões, Carvalho and Gaspar (2022) developed a conceptual map linking barriers and drivers to consumer behaviour on food waste and interventions. Here, it was clear that nudges, apart from information, were the most positive and flexible option to address action. Interventions were summarised as all offering information, and then also offering appeal, engagement, nudging, or social influence (Simões, Carvalho and Gaspar de Matos, 2022). It was suggested that nudging could support the following drivers for food waste behaviour: saving money, shopping lists and preference for sub-optimal products. With respect to barriers, nudges could address responses to date labels, overbuying and lack of time (Simões, Carvalho and Gaspar de Matos, 2022). Meanwhile, appeal (defined as gratitude appeals relating to having or not having environmental damage or appeals for donations) did not feature as a linking factor, and engagement and social influence were limited to support psycho-social concerns surrounding the environment or food waste, or guilt (note the terminology 'concerns' suggested a difficult emotion) (Simões, Carvalho and Gaspar de Matos, 2022). Other scholars indicate the ability of nudging to: link flexibly and positively to address new action (Aschemann-Witzel *et al.*, 2017; Cooper *et al.*, 2023); work alongside information-giving given that information alone is limited in creating behaviour change (Langen, Göbel and Waskow, 2015); and to create opportunities for change (von Kameke and Fischer, 2018). Based on these findings, that behavioural insights such as "nudging" offer opportunity to influence actions, nudge techniques in food waste behaviour change interventions need further study.

Thus, understanding at the household level, what nudges have been shown to be effective in supporting food waste behaviour change has merit. To understand what has been shown to work in the available literature, a systematic review on this topic is appropriate.

2.3   Existing knowledge on motivation for food waste behaviour in household settings

2.3.1   Household food waste behaviour

Research on consumer behaviour and household food waste has substantially increased since 2010. A number of reviews have aimed to synthesise the existing evidence base (Hebrok and Boks, 2017; Roodhuyzen *et al.*, 2017; Schanes, Dobernig and Gözet, 2018; Stangherlin and de Barcellos, 2018; Principato *et al.*, 2020). A recent review uncovered three principal themes (Boulet, Hoek and Raven, 2021a). First theme, a variety of consumer food related behaviours are connected to household FLW (Schanes, Dobernig and Gözet, 2018). These behaviours are placed in the context of wider household food practices associated with planning, storage, purchasing, preparation, consumption and disposal (Roodhuyzen *et al.*, 2017). Second, a variety of factors drive consumer food-related behaviours influencing FLW (Schanes, Dobernig and Gözet, 2018) that may be categorised as internal (i.e., values, knowledge, attitudes, habits and skills) or external (i.e., retail environments, product characteristics, social norms and regulatory frameworks to the individual) (Secondi, Principato and Laureti, 2015). The number of factors identified is vast and diverse; one review assembles more than 90 factors connected with household FLW (Roodhuyzen *et al.*, 2017). Third, there is a complex network of potential interactions that are present between consumer food related behaviours and driving factors (Quested *et al.*, 2013), creating a diversity of potential pathways for the outcome of FLW (Hebrok and Boks, 2017). Research has also established there are trade-offs between avoiding FLW and achieving other food related goals e.g., food safety and healthy eating (Aschemann-Witzel *et al.*, 2018; Aschemann-Witzel, de Hooge and Almli, 2021), providing meals that are enjoyable and show care and appreciation (Graham-Rowe, Jessop and Sparks, 2014; Visschers, Wickli and Siegrist, 2016; Aschemann-Witzel, Gimenez and Ares, 2019), and flexibility and convenience in planning or preparing food (Romani *et al.*, 2018; Aschemann-Witzel, de Hooge and Almli, 2021).

The research in this area is also complicated because factors that predict FLW for one consumer in one household are irrelevant for other consumers in other households (Parizeau, von Massow and Martin, 2015; Gaiani *et al.*, 2018; Grasso *et al.*, 2019). Factors may also interact and influence behaviour via a combined effect (Roodhuyzen *et al.*, 2017; Jorgensen, Boulet and Hoek, 2020; Boulet, Hoek and Raven, 2021a). Despite growing understanding of the complex relationship between food waste and behaviour, most studies do not place behavioural drivers or influencing factors in an all-inclusive perspective, and few comprehensive frameworks for household food waste and consumer behaviour exist (Roodhuyzen *et al.*, 2017; Boulet, Hoek and Raven, 2021a). Thus, potential behaviours and factors that drive household FLW are collated in 'lists' without indication of which

may be prioritised in different contexts or of their potential combined influence (Boulet, Hoek and Raven, 2021a). Policy makers must 'cherry-pick' potential leverage points with small opportunity to tailor FLW interventions to audiences (Boulet, Hoek and Raven, 2021a).

Thus, it is established that a variety of behaviours are connected to household FLW; a variety of factors drive consumer food-related behaviours influencing FLW and there is a complex network of potential interactions present between behaviours and driving factors. More recently, research has revealed more concerning the complex network of interactions between behaviours and driving factors, specifically that there are trade-offs between driving factors or competing priorities that influence the food waste reduction behaviour (van Geffen *et al.*, 2020; Wang, McCarthy and Kapetanaki, 2021). We need more focus to understand how driving factors or motivations may align in order to compete effectively with priorities in the home.

Therefore, 1) messaging that taps into motivators that may be more or less appealing depending on personal values, lifestyle and lifecycle may support tailoring interventions effectively. Furthermore, 2) a focus on motivation may be an opportunity to move beyond context and straight to the root psyche of the behaviour. This focus may facilitate interventions that tap into motivational drivers for food waste reduction behaviour encouraging the alignment of food waste reduction behaviours within a myriad of household priorities.

2.3.2   Literature review on motivation and food waste

To support a primary theoretical objective a systematic search of the literature on motivation and food waste was undertaken. A literature search using the Scopus database on the 7th of Feb 2023, using the search terms: 'Motivation' AND 'Food Waste' identified 243 articles. The inclusion criteria were: all articles from 2010 to 2023, all countries, household settings only, consumers only, English language articles only, peer reviewed and published articles only and all study designs. As a proxy for inclusion of publications with outcome measures relating to motivation - papers were included that outlined direct relevance to exploring motivation and/or motivational barriers relating to consumer food waste behaviour in household settings. On initial title and abstract screening this revealed 58 papers. On further screening of the full text, 17 papers were found to be directly relevant to exploring motivation and/or barriers relating to consumer food waste behaviour in households. These papers are included in Table 1 alongside a description of study data collection methods and whether a theory or framework was used.

Table 1 Summary of articles exploring motivation and/or barriers relating directly to consumer food waste behaviour in household settings

Study	Country	Explores motivation and/or barriers relating to consumer food waste behaviour	Theory or framework used	Data collection method & Sample size
Graham-Rowe, Jessop and Sparks (2014)	UK	Yes	No	Qualitative interview; n=15
Graham-Rowe, Jessop and Sparks (2015)	UK	Yes	Theory of Planned Behaviour (TPB), Extended.	Quantitative questionnaire; n=204
Aschemann-Witzel *et al*. (2015)	Denmark, UK, Italy, Sweden, The Netherlands	Yes	No	Literature review & expert interviews; n=11
Fiore *et al*. (2017)	Italy	Yes	No	Quantitative Questionnaire; n=245
Setti *et al*. (2018)	Italy	Yes	Intention-Behaviour Gap	Quantitative three-year repeated cross-sectional survey; n= 1,706, 1,518, and 1502 respondents, respectively.
Urrutia, Dias and Clapp (2019)	Canada	Yes	Visceral-Material Framework	Qualitative interviews, participant observation, and quantitative food

Study	Country	Explores motivation and/or barriers relating to consumer food waste behaviour	Theory or framework used	Data collection method & Sample size
				waste measurements; n=13
Bravi *et al.* (2020)	UK, Spain & Italy	Yes	No	Quantitative questionnaire n=3323
Ilakovac, Cerjak and Voca (2020)	Croatia	Yes	No	Qualitative interviews, n=20
van Geffen *et al.* (2020)	Germany, Hungary, the Netherlands & Spain	Yes	The Motivation Opportunities and Abilities (MOA) Framework	Twenty-four qualitative focus groups, n=147
Zeinstra, van der Haar and van Bergen (2020)	NA	Yes	The MOA Framework	Literature review
Nabi, Karunasena and Pearson (2021)	Australia	Yes	No	Quantitative online survey n=5272
Wang, McCarthy and Kapetanaki (2021)	Australia and Singapore	Yes	Norm-Activation Model (NAM)	Quantitative survey of consumers (n=643)
Soma, Li and Maclaren (2021)	Canada	Yes	The MOA Framework	Two qualitative focus groups (n=44 participants)

Study	Country	Explores motivation and/or barriers relating to consumer food waste behaviour	Theory or framework used	Data collection method & Sample size
Matharu, Gupta and Swarnakar (2022)	India	Yes	TPB, Theory of Interpersonal Behaviour (TIB) and the MOA Framework	Questionnaire (n=95). Content analysis Decision-Making Trial and Evaluation Laboratory approach
Stancu and Lähteenmäki (2022)	Denmark	Yes	No	A quantitative cross-sectional online survey (n = 508)
Filimonau *et al.* (2022)	Poland	Yes	NAM	Self-reported questionnaire (n=566)
Chen (2023)	Taiwan	Yes	Extended TPB	Quantitative online self-reported Questionnaires (n=304)

Seventeen research papers were identified that explored motivations and barriers for consumer food waste reduction in household settings (Table 1). Of these research papers 11 used self-reported quantitative survey methods, 5 used qualitative methods and 2 were review articles. The study settings comprised 11 European countries, 3 Asian countries, Canada and Australia. All studies were relevant to consumers in household settings. The results from many of the papers indicated a network of complex drivers affecting food waste motivation (Graham-Rowe, Jessop and Sparks, 2014; Urrutia, Dias and Clapp, 2019; Bravi *et al.*, 2020; Soma, Li and Maclaren, 2021) and/or a conflict between other priorities at home and the prioritisation of food waste behaviours (Graham-Rowe, Jessop and Sparks, 2014; Aschemann-Witzel *et al.*, 2015; Fiore *et al.*, 2017; Setti *et al.*, 2018; van Geffen *et al.*, 2020; Wang, McCarthy and Kapetanaki, 2021). Other studies had results that focused on specific factors that either predicted or influenced food waste behaviour (Graham-Rowe, Jessop and Sparks, 2015; Ilakovac, Cerjak and Voca, 2020; Zeinstra, van der Haar and van Bergen, 2020;

Nabi, Karunasena and Pearson, 2021; Chen, 2023; Stancu and Lähteenmäki, 2022; Matharu, Gupta and Swarnakar, 2022; Filimonau *et al.*, 2022). Thus, research has established that drivers for food waste behaviour are complex, that they are frequently not prioritised in home settings despite good intentions due to conflicting personal goals, and some factors are known to have an influence on motivating food waste behaviour. However, what is missing is an understanding on how to align motivational drivers for food waste behaviour with other priorities in household settings.

Discussions on each theory applied in the selected studies are detailed below, and originally appeared in Chapter 5. Goal framing theory was limited to understanding internal goals by hedonic virtue (pleasure). It does not account for eudaimonic virtue (meaning); despite research showing that eudaimonic and hedonic motives were equally associated with life satisfaction and vitality (Henderson, Knight and Richardson, 2013; Hanley, Baker and Garland, 2017; Thiermann and Sheate, 2020). Goal framing theory also does not account for wider contextual factors in the environment that may influence goals, for example competence. Other theories and models used within food waste studies that explored motivations and barriers have usually focused on only one type of motivation. The Norm Activation Model posits that awareness of food waste as a problem alongside societal implications ascribes personal responsibility to take action, thereby activating personal norms (Swartz, 1977; Onwezen, Antonides and Bartels, 2013; Filimonau *et al.*, 2022). This indicates that motives for food waste reduction were mainly supported by morals and responsibility. The visceral-material framework focuses on visceral experiences and the environment (Urrutia, Dias and Clapp, 2019), indicating motives for food waste behaviour were largely supported by visceral experiences (colour, texture, taste or smell) shaped by our past and built environment. Theories of self-efficacy in the context of food waste reduction indicated that an individual who perceives greater control and confidence to manage competing priorities around food at home may manage the potential clash more effectively (Aschemann-Witzel *et al.*, 2020). This conclusion suggested that motives to reduce food waste and avoid convenience orientation were supported by self-efficacy (Aschemann-Witzel *et al.*, 2020).

The Theory of Planned Behaviour is a cognitive theory that proposes a person's decision to engage a behaviour is predicated by their intention to engage (Ajzen, 1991; Graham-Rowe, Jessop and Sparks, 2015). The Theory of Planned Behaviour has been shown to predict motivation, but to a lesser extent behaviour in relation to food waste (Graham-Rowe, Jessop and Sparks, 2015). The Theory of Interpersonal Behaviour expands the Theory of Planned Behaviour by adding focus to the role of social interactions, needs and expectations in creating intentions to enact a behaviour positing that social factors and beliefs explain the behavioural intention (Triandis, 1979; Matharu, Gupta and Swarnakar, 2022). It provides a helpful framework to link a greater variety of contributing drivers that affect intention to act. The Motivations, Opportunities and Abilities framework identifies further

contexts supporting motivation relating to abilities and opportunities (Ölander and Thøgersen, 1995), which adds to the Theory of Planned Behaviour and Theory of Interpersonal Behaviour in the context of food waste behaviour.

Ten out of the seventeen studies used a behaviour change theory or motivation framework (Table 1). None of the studies used a psychological theory that focused primarily on motivation and categorised motivation beyond extrinsic and intrinsic motivation. Neither do these theories account for the likelihood or strength of the motivation nor the role of emotions in motivation and decision making. These elements merit exploration to further understanding of how competing priorities might align with food waste reduction behaviour in household settings. A psychological theory of motivation that addresses these gaps and has not previously been used in studies specific to motivation for household food waste behaviours is Self-Determination Theory (SDT). Furthermore, the SDT has been used with success in other pro-environmental and pro-health behaviours (Ryan, Deci and Williams, 2007; Silva *et al.*, 2008; Patrick and Williams, 2012; Sweet *et al.*, 2012; Garrin, 2014; Gillison *et al.*, 2019; Zimmer-Gembeck *et al.*, 2019; Thiermann and Sheate, 2020). A recent systematic review established that interventions based on the self-determination theory were related to higher effectiveness for dietary interventions. Thus, as food waste relates to diet, evidence exists to support the use of self-determination theory in research that seeks to understand food waste (Dalgetty, Miller and Dombrowski, 2019).

2.4 Summary of research gaps and identified research questions

2.4.1 Summary of the research gaps identified

The summary of core research topics – food waste, insecurity and diet - identified a shortcoming of household food waste studies that measure and report on possibly avoidable food waste. However, two studies conducted by WRAP in the UK with relatively large sample sizes have categorised food waste into possibly avoidable categories (WRAP, 2008; Quested, Esteal and Ingel 2013). Specifically, the "possibly avoidable" food waste category was assigned following the primary data collection using WCA methods, in a research office setting, based on written descriptions and/or weights given. There was a lack of studies that categorise possibly avoidable food waste using a visual data source, such as a photograph. Instead, only written data sources have been used (WRAP, 2008; Quested, Esteal and Ingel 2013).

The literature reviewed in this section demonstrated a lack of household food waste diary studies that measure and report on: possibly avoidable food waste in relation to socio-demographic characteristics or, diet quality in relation to household sociodemographic characteristics. As diary

studies can assess categories of food waste before degradation occurs, this is an important method to understand food waste proportions in categories of Avoidability or diet quality by household sociodemographic characteristics. Although diary methods are considered less objective measures of food waste than WCA (Quested, 2020) they offer a comparison within the study sample of the amounts of food wasted by household sociodemographic characteristics (Quested 2020; van Herpen *et al.* 2019). Assessing categories of Avoidability and diet quality in food waste is an important research need that can focus food waste research with a socio-demographic approach to address food insecurity. Furthermore, there is a need for research with a focus on food waste in relation to diet quality. Few studies, assess in a simple yet meaningful way the nutritional loss contained in food waste so as to generate easily actionable interventions that benefit food security, dietary health and food waste reduction. Here NOVA can be instructive. In this thesis "diet quality" will be used as shorthand for the NOVA classification of food which was wasted as defined in Chapter 4, Table 6 . I acknowledge that it is a less than perfect term but its purpose is to convey the following meaning: although diet quality from food waste cannot be commented on, food waste composition in relation to level of processing (as categorised by NOVA) can be commented on. By extension this contributes to better diet quality for households if less unprocessed food is wasted (i.e., NOVA 1).

This review highlighted evidence that in Europe the nutritional loss in food waste was high at the household level in comparison with other stages along the food supply chain. Thus, there does remain a need for research focused on food waste composition in household settings in European countries. Furthermore, research is needed to understand the difference between household food waste generation by household size when the data are normalised per person in European settings. This is pertinent as a high-level strategy using household characteristics to readily identify who in the population may be most at risk of producing the most food waste, so that interventions may be targeted most effectively by local authorities who hold relevant data about households.

The review of literature on behavioural insights identified that "nudge" approaches merit exploration due to their widespread and successful use in other food related aspects at the household level, for example dietary behaviour change interventions (Cadario and Chandon, 2017). Although nudges have been used in food waste behaviour interventions understanding, their effectiveness is unclear in household settings (Chapter 3).

A review of the food waste motivation research identified that more research was required to further our understanding of how competing priorities may align with food waste reduction behaviour in household settings. This identified a motivational theory that differentiates motivation by more than a dichotomous type or by strength (the likelihood of the motivation type to maintain behaviours) has not been applied to explore household food waste behaviour (Chapter 5). The SDT

contains these features, and while it has been applied to other pro-environmental behaviour and dietary behaviour successfully, it has yet not been applied exclusively to food waste behaviour (Chapter 5).

2.4.2 Identified research questions

Three research questions were identified from the research gaps highlighted in this literature review. Each research question is reflected in work presented in Chapters 3, 4 and 5:

1. When applied to food waste interventions in household settings, what behavioural insights (i.e., nudge techniques) are effective to change food waste behaviour? (Chapter 3; Paper 1)

2. How does household food waste (in categories of diet quality and Avoidability) vary by household sociodemographic characteristics in a UK setting? (Chapter 4; Paper 2)

3. How do motivations for food waste reduction behaviour align with competing household priorities? (Chapter 5; Paper 3)

2.4.3 Positionality Statement

My background in work is healthcare, I have completed 2 years as a staff nurse working in the NHS in neuro intensive care, and cardiac and respiratory acute settings. I also read a Master of Science in Public Health with the University of Southampton. From here my journey in Health Science research commenced and I worked as a senior research assistant on a variety of projects that linked to compassionate working cultures and safe staffing. I really enjoyed the process of research and gained skills to answer research questions with quantitative survey data and qualitative interview and focus group data. On having my first child I developed a personal interest in sustainable lifestyle choices at the household level. I have also for a long time, since my teens, had a personal interest in nutrition which was cemented during a module in Public Health Nutrition as part of my MSc in Public Health. These three components made a PhD which had a focus on sustainability, diet, and health outcomes with similar methods of research that I had experience in very appealing to me. I wanted to develop my research skills further and have an academic career so a PhD was an obvious choice.

The relationship with the Hampshire County Council that I had via two of my PhD supervisors was invaluable to ensure that the research of this thesis was relevant to the end service user. This was an aspect of the PhD that I valued as I believe in research translating into practice. As the County Council

was a sector that I had not previously worked in having the direction from supervisors immersed in the sphere was very instructive to ensuring that the outputs of the PhD were useful and helpful to the waste prevention and recycling team in Hampshire. This offered significant purpose to the PhD and engaged my motivation and drive for the project.

2.5   Overview of thesis components

The diagram below shows how the systematic review in Chapter 3, the photographic diary and survey in Chapter 4 and the qualitative study in Chapter 5 lock together to form a coherent whole. Chapter 6 plays a key role in bringing the four datasets together to address the overarching aim of the thesis.

Figure 2 Diagram to show how the research fits together
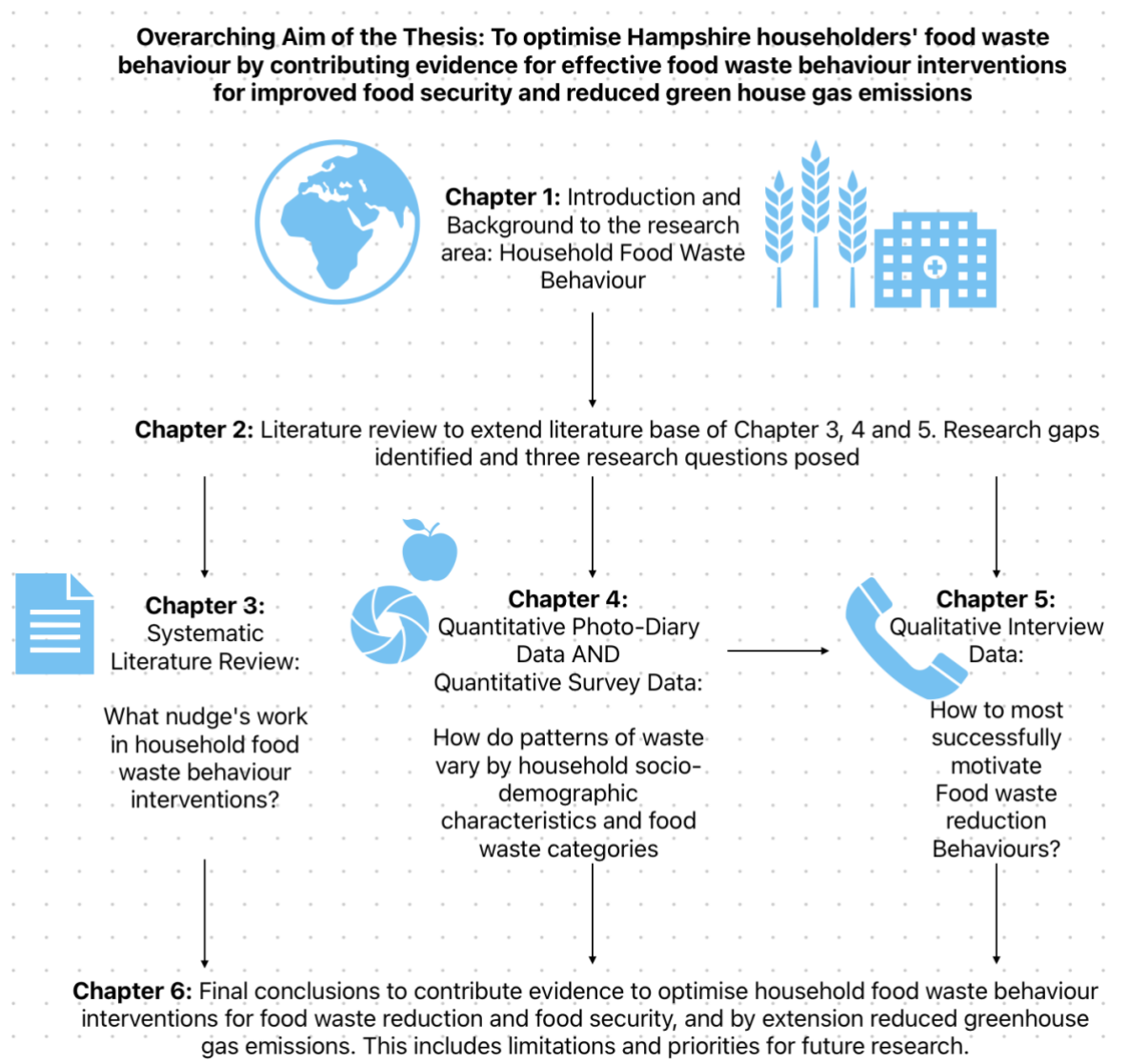
A Draft Study is attached in Appendix D. This study analysed the survey data from Chapter 4 in further detail in relation to household characteristics, and carried out a mixed methods triangulation

of the photo-diary data, the survey data and the qualitative interview data to strengthen conclusions. This study was eventually not included in the body of the thesis and is thus attached in Appendix D as supplementary material. The data for the thesis can be found as per the data access statement which is included in Appendix E.

2.6 Justification of research methods for identified research questions

2.6.1 Rationale for systematic literature review to answer research question 1

On reviewing the literature on interventions for food waste behaviour change it was identified that a focus on behaviour change insights, "nudging", had merit for household food waste interventions. However, consensus on understanding what nudges worked effectively for food waste behaviour change interventions at the household level was lacking. To understand whether behavioural insights (i.e., nudge techniques) worked in food waste behavioural change interventions, it was deemed appropriate to conduct a critical appraisal to assess the quality of the research that explored the effectiveness of interventions using nudge techniques. A systematic review was selected as the method which uses explicit, systematic approaches to collate and assess the evidence of available studies to address a clear research question (Higgins *et al.*, 2023). Systematic review methods sit at the top of the traditional hierarchy of evidence, as these methods synthesize all available findings to address the specific research question, indicating its usefulness for practice (Higgins *et al.*, 2023). Even publications that critique the relevance of the traditional hierarchy of evidence in some settings still maintain that to evaluate "does this work?", a systematic review is the best type of evidence to address this type of research question (Petticrew and Roberts, 2003). Thus, the systematic review method was deemed most beneficial to address research question 1.

2.6.2 Selection of photographic diary data collection methods for question 2

A variety of methods were assessed to address the research question: How does household food waste (in categories of diet quality and avoidability) vary by household socio-demographics?

WCA, although considered in some instances to be the most objective way to measure food waste weight, was not preferred due to how essential it would be to categorise foods by Avoidability and diet quality category in a straightforward way. The shortcoming of food degradation in food waste bins meant that WCA would not enable easy or accurate categorisation of food waste. Additionally, WCA methods do not capture food waste that falls down the drain, or is given to pets, thus other methods may offer a more complete picture of where and why food waste happens at home.

Survey methods on their own were not selected due to literature indicating that food waste measurements offered by recall and self-reporting were generally unreliable (van Herpen and van der Lans, 2019; van Herpen et al., 2019).

In household food waste research, written diaries have been frequently used to assess food waste (Quested *et al.*, 2011; Koivupuro *et al.*, 2012; Silvennoinen *et al.*, 2014; Giordano, Alboni and Falasconi, 2019; Herzberg, Schmidt and Schneider, 2020; Ilakovac *et al.*, 2020). However, a shortcoming of the written diary is the burden it puts on participants, in comparison the photographic diary has been indicated to be a lesser burden and to thus improve participant retention on studies (van Herpen and van der Lans, 2019; van Herpen *et al*., 2019). It has also been shown that diary, kitchen caddy, and photograph coding measures correlate strongly: the highest Pearson correlation was between diary and caddy (r=0.86); the combined measure of caddy plus diary correlated highly with photos (r=0.80) (van Herpen *et al.*, 2019).

The method of photographic diaries was selected for the present study, as the coding of photographs of food waste as a measurement can provide valid measures (van Herpen *et al*., 2019; Roe *et al.*, 2020), and has been used successfully in similar studies (Avramides, Craft and Luckin, 2016; Manomaivibool, Chart-asa and Unroj, 2016; Thompson *et al.*, 2016; Sirola *et al.*, 2019; Heidenstrøm and Hebrok, 2021; Masyhuroh, 2021; Boulet *et al.*, 2022). The method of photographic diaries has also been selected as it offers the researcher opportunity to visually see the food waste when applying categories of Avoidability of food processing to the data. This methodological difference, that seems to support accurate categorisation post data collection, is absent from the food waste literature when applied to food waste weight categories of Avoidability and diet quality making the photographic food waste diary novel and worthwhile (Chapter 2, 2.1.2 and 2.1.3).

Further detail on the rationale for selecting photographic diaries is contained in Chapter 4, Section 4.3.1.

2.6.3   Selection of socio-demographic variables for question 2

In previous research age, gender, education level, household size, household composition, employment status and income appeared to be the most common and relevant factors for food waste studies in households (van Geffen, van Herpen and van Trijp, 2016). Other pertinent characteristics were summarised in a literature review (Vittuari *et al.*, 2023) indicating that employment and age were established as influencing socio-demographic factors. The research consensus regarding age was that different age groups are reactive to different messaging (Parizeau, von Massow and Martin, 2015; Qi and Roe, 2016; van Geffen, van Herpen and van Trijp, 2016); the consensus with employment was that employed individuals wasted more food (Cecere, Mancinelli and Mazzanti, 2014; Secondi, Principato and Laureti, 2015). There was agreement between studies on household composition, specifically that other family members play a key role in supporting food waste behaviours (Parizeau, von Massow and Martin, 2015; van Geffen, van Herpen and van Trijp, 2016; Visschers, Wickli and Siegrist, 2016). Contrastingly studies did not have consensus on household size, income or educational level in relation to patterns of food waste behaviours (Vittuari *et al.*, 2023). This supports the rationale for the selection of these variables for focus to further understand patterns by socio-demographics in relation to food waste behaviour.

2.6.4   Rationale for qualitative interviews alongside a theory of motivation to interpret the analysis to answer research question 3

To answer a research question that sought to explore how and why, it is best to enquire broadly and openly to prevent stifling the truth (Nicholls, 2009a). A quantitative method limits itself in this context as questions and possible responses are established before the respondent contributes (Nicholls, 2009a). Qualitative methods allow researchers to explore the depths of possibility, which has merit when the subject is unknown (Nicholls, 2009c).

In qualitative research it was necessary to define the research epistemology as it will guide the data and inform how meaning will be theorised during analysis. Thus, to support the discovery of human motivation, a realist approach was considered the best option. Here motivations, experiences and meaning can be theorised in a straightforward approach; this is because a mostly linear relationship was assumed amidst experience, meaning and language. Specifically, it was assumed that language enabled humans to articulate experience and meaning (Potter and Wetherell, 1987; Braun and Clarke, 2006; Braun and Clarke, 2022).

Furthermore, a qualitative experiential analysis was deemed suitable to address the research question as it focused on the voice of the participants, highlighting their experience and perspectives.

This was suitable to address a research question that aimed to understand priorities and motivational drivers of an individuals' personal experience in a home setting.

Thus, to explore further on how motivations for food waste reduction behaviour align with competing household priorities, a qualitative realist approach and experiential analysis was deemed the optimal philosophical standpoint.

A number of qualitative methods exist for primary data collection, including interviews, focus groups or observations (Nicholls, 2009b). Given the individual drivers that affect food waste in the household settings (Schanes, Dobernig and Gözet, 2018; Boulet, Hoek and Raven, 2021a), interview methods were deemed a more appropriate option than focus groups (Nicholls, 2009b). Additionally, to engage with a wider variety of participants with a diversity of socio-demographics, interview methods were more suitable than deeper but narrower ethnographic observation methods (Nicholls, 2009b).

Thematic analysis methods were deemed ideal to analyse the interview transcripts, following the Braun and Clarke (2006) approach and recommendations in (Braun and Clarke, 2022). These methods are widely used to analyse qualitative data with a realist epistemology and support experiential analysis (Braun and Clarke, 2006).

The literature review showed the usefulness of applying a theoretical framework such as the SDT to understand motivation for food waste behaviour change to address the research question. Previous research on household food waste that used a theory to understand qualitative thematic analysis incorporated two coding phases, inductively analysing the data for themes and then also deductively coding the data as it corresponded to the theory category (Allison *et al.*, 2022; Manika *et al.*, 2022). Furthermore, thematic analysis for the second coding phase remained suitable due to the inherent flexibility of the method which is appropriate for inductive and deductive coding approaches (Braun and Clarke, 2006). Thus, this approach will be applied to analyse the qualitative data to the address the research question. Further detail providing a rationale for selecting qualitative interview methods with thematic analysis is provided in Chapter 5, Section 5.3.

Chapter 3   What Nudge Techniques Work for Food Waste Behaviour Change at the Consumer Level? A Systematic Review

3.1   Abstract

In European countries over 40% of food loss and waste occurs at the retail and consumer stages; this situation cannot be sustained and remediation is urgently needed; opportunities for change must be created. "Nudge" techniques have been shown to be effective in changing behaviour in areas related to food consumption (e.g., healthy diet), but the effectiveness of interventions using nudge techniques to change food waste behaviours remains unclear, despite a growing body of research. The aim of this review is to elucidate means to change household food waste behaviour using nudge approaches and identify priority needs for further research. Four databases, grey literature and reference lists were searched systematically to identify relevant research on nudges to change food waste behaviours. This search identified sixteen peer-reviewed research articles and two grey literature reports that were critically appraised using a critical appraisal checklist framework for descriptive/case series. Four studies deemed reliable show interventions using nudges of social norms, reminders or social norms with disclosure were effective in changing food waste behaviours at the household level, while disclosure alone, i.e., revealing environmental costs of food waste, was not. This review, unique in the application of a critical appraisal, suggests there is reliable information on the effectiveness of nudge for food waste recycling interventions when incorporating nudges of social norms, reminders or disclosure alongside use of social norms. If food waste recycling behaviour is considered an upstream measure to raise consumers' consciousness on the amount of food waste they produce, this may have a positive impact on food waste reduction and therefore has important policy implications for food waste behaviour change at the household level.

3.2   Introduction

Sustainability aims to protect the natural environment specifically human and environmental health, while compelling innovation so as not to compromise lifestyle for future generations (United Nations, 1987). Approaches to sustainability intend to maintain the delicate ecosystems of earth in balance, usually through encouraging renewable fuel sources, protecting physical environments and decreasing carbon emissions. At present, poor sustainability is a key concern affecting the global food system (Swinburn *et al.*, 2019). This situation is a significant problem globally for societies and

governments. Food processing and production create environmental problems along the entire food supply chain (Garcia-Herrero *et al.*, 2018; Springmann *et al.*, 2018) with direct effects on environmental resources through use of fertile soils, fresh water, energy, fertilisers and release of carbon emissions in the production and transport of food (Food and Agriculture Organization of the United Nations (FAO)., 2013; Östergren *et al.*, 2014; Scherhaufer *et al.*, 2018; Szulecka *et al.*, 2019; Garske *et al.*, 2020). Globally, approximately a third of total food produced is wasted or lost (Östergren *et al.*, 2014) along the food supply chain (Parfitt, Barthel and MacNaughton, 2010). In European countries 21–33% of food is lost during agricultural production, 21–25% during manufacturing, storage, processing and distribution, and over 40% at retail and consumer stage (Gustavsson, Cederberg and Sonesson, 2011; Flanagan, Robertson and Hanson, 2019; Zeinstra, van der Haar and van Bergen, 2020). In the UK, more than £19 billion worth of food is lost or wasted annually (WRAP, 2021). A focus on tackling this complex problem at consumer level is an essential part of the multifarious puzzle and supported by global targets (SDG 12.3) to halve per capita food waste at the consumer level by 2030 (Pérez-Escamilla, 2017).

To shift from the current situation of high household food waste to a more sustainable future for food waste, behaviour change will be necessary. General information can affect the motivation for and ability to change behaviour (van Trijp, 2014; Parry, James and LeRoux, 2015), for example information awareness campaigns (Halloran *et al.*, 2014; Langen, Göbel and Waskow, 2015) as frequently individuals lack awareness of environmental sustainability issues relating to food (Maciejewski, 2020). However, to create change at appropriate scale and speed, additional approaches to awareness campaigns would be required (Aschemann-Witzel *et al.*, 2017). Research shows that although information is valuable, when offered alone this is not where the key to motivating change lies (Langen, Göbel and Waskow, 2015). Opportunities for change must be created. Constructing opportunities to change household food waste behaviour can be simple, e.g., making preferred choices more accessible. Examples include positioning food waste caddies in households in easy reach to support recycling of food waste, offering household food deliveries containing optimal food amounts to avoid surplus, or encouraging food portioning tools that help to avoid over-portioning.

Psychologists and neuroscientists have developed a description of brain function based on two systems, system 1—processes that are automatic, unconscious and fast and system 2—reflective, controlled, slow and effortful (Strack and Deutsch, 2004; Evans, 2008; Vlaev *et al.*, 2016). This dual process is a theoretical basis for nudge theory, with nudge proposing that system 1, automatic decisions, can be systematically triggered to change behaviours and improve outcomes going with the flow of human nature (Marteau, Hollands and Fletcher, 2012; Vlaev *et al.*, 2016).

Nudging (Rutter, 2020) behaviours in this way, has considerable merit in this context. Nudging was developed from ideas advanced by Daniel Kahneman (Kahneman, 2011). It is challenging to offer a universal definition of the term nudge as understandings of nudge can vary broadly (Vlaev *et al.*, 2016). Economist Thaler and legal scholar Sunstein convey the concept of "nudging," defined as "any aspect of the choice architecture that alters people's behaviour in a predictable way without forbidding any options or significantly changing their economic incentives" (Thaler and Sunstein, 2008). There is a growing interest in nudging as despite usually incurring low cost, they can deliver results and be highly effective all the while negating unpopular rule setting (Sunstein, 2014). Subsequently, Bornemann and Smeddinck (2016) identify five criticisms of nudge: conceptual, normative, functional, empiric and practical (Bornemann and Smeddinck, 2016; von Kameke and Fischer, 2018). Conceptual criticisms question the reach of nudge and boundary between nudges and other behavioural influences, normative criticisms express concern over potential manipulation of moral concepts relevant to freedom, independence and objective information (von Kameke and Fischer, 2018). Functionality concerns the effectiveness of the nudge approach, while empiric broaches the efficiency of the method and long-term success (von Kameke and Fischer, 2018). Moreover, practical issues concerning knowledge on the decision context reflect resource demand and cost of implementation of nudge approaches (Barton and Grüne-Yanoff, 2015). These five concerns mainly centre around hard-to-avoid hidden automatic defaults, which is inconsistent with the definition offered by Thaler and Sunstein (Thaler and Sunstein, 2008), thus most normative, functional and empiric criticisms may be overcome with judicious planning and implementation (von Kameke and Fischer, 2018). If resources are available then practical issues may be overcome; this is the same as with countless other interventions. Conceptual concerns are reflective of the wide-reaching applications and understandings possible to the nudge approach and will always provoke discussion due to individual perspectives of nudge (von Kameke and Fischer, 2018).

In the food domain, nudging has been applied largely in response to the obesity epidemic (Broers *et al.*, 2017) and, to a lesser extent to encourage environmental initiatives affected by food consumption, e.g., reducing red meat consumption (Lehner, Mont and Heiskanen, 2016). For information on nudge interventions more broadly related to the food supply chain a systematic review shows that there is evidence to support "green nudging" as effective in leveraging more sustainable practices for farmers and consumers (Ferrari *et al.*, 2019). There remains minimal application of nudges in the context of household food waste behaviours, and those published tend to focus on eating-out options (Kallbekken and Sælen, 2013; Papargyropoulou *et al.*, 2016; Filimonau *et al.*, 2020). However, research on food waste behaviours has expanded in recent years, leading to a requirement for a systematic review to appraise critically the body of research evidence and to understand what works to change household food waste behaviours and what are the priority needs

for further research. A recent review developed a systematic map of existing research on behaviourally informed interventions targeting changes in consumer food waste and consumption behaviour (Reisch *et al.*, 2020). However, a feature missing was 'a critical appraisal of each individual study…(as)…this is not a common standard for systematic maps' (Reisch *et al.*, 2020). Previous reviews on food waste in households have not included a quality assessment of the studies included and have focused on policy actions, interventions for food waste reduction, food waste drivers, causal mechanisms for food waste behaviour, comparison of food waste amounts or avenues for future research. This review addresses the gap in critical assessment.

Frequently applied theoretical bases for behaviour change interventions include the transtheoretical model, social cognitive theory and the theory of planned behaviour (Michie *et al.*, 2014). This present review acknowledges that often these theoretical frameworks can work in parallel with nudges (Reynolds *et al.*, 2019) and these theories explain why various nudges may be effective. Self-monitoring and other self-regulatory techniques (goal-setting, prompting, self-monitoring, providing feedback on performance, goal review) are consistently reported as effective behaviour change tools (Michie *et al.*, 2009; Greaves *et al.*, 2011). Some of these elements also constitute nudges per se. From a policy perspective, nudge interventions have advantages. Firstly, relative affordability, and secondly, ease of implementation and scope for adaptation in different contexts (Thaler and Sunstein, 2008; Liu *et al.*, 2014; Sunstein, 2014). As shown (Liu *et al.*, 2014; Sunstein and Reisch, 2014; Ferrari *et al.*, 2019; Vecchio and Cavallo, 2019) nudges can be considered not as a replacement to firmer environmental and food policies, but rather as a complement.

Ten optimal nudges have been identified with examples to define the scope of nudge in this review as shown in Table 2. They are in line with definitions described by originators of the nudge concept (Sunstein, 2014), these definitions are also used specifically in the context of food waste in a peer-reviewed primary data study (von Kameke and Fischer, 2018).

Table 2 Identification of nudges (von Kameke and Fischer, 2018).

A.	Default rules, e.g., automatic enrolment in programs such as external meal planning and fee-based strategically portioned food ingredient delivery
B.	Simplification, e.g., reducing barriers of target behaviour
C.	Use of social norms, e.g., Regular exchange about personal experiences on the reduction in food waste with friends and neighbours
D.	Increase in ease and convenience, e.g., making low-waste food options visible
E.	Disclosure, e.g., revealing environmental costs associated with food waste
F.	Warnings, graphic, or otherwise, e.g., Pictures that demonstrate how food waste damages the environment
G.	Pre-commitment strategies, e.g., A challenge on household food waste reduction with a friend
H.	Reminders, e.g., Tips on shopping planning via email
I.	Eliciting implementation intentions, e.g., asking "do you plan to reduce food waste?"
J.	Informing people of the nature and consequences of their own past choices, e.g., Feedback on financial costs of an individual's food waste

The aim of this review is to determine what nudge techniques work for food waste behaviour change through comprehensive literature search, review, critical appraisal and discussion of relevant papers.

3.3   Materials and Methods

To identify the peer-reviewed literature on this topic, four databases were searched: Scopus, IBSS, Web of Science and Psych Info in March 2021. The search terms used were (Nudg* OR "Architect* OR Choice Architect* OR "Behavioural insights") AND ("Food Waste" OR "Food Loss") AND (Consumer* OR domest* OR Household*). Studies were identified on the basis of inclusion (Table 2) and exclusion criteria and then assessed as full text articles. Figure 3 shows the search process as conducted. For the initial screening of titles and abstracts the free website Rayyan, developed by Mourad Ouzzani, Hossam Hammady and Ahmed Elmagarmid, was used to sort and organise the literature; articles were included or excluded on the basis of the title and abstract fitting the inclusion criteria (Table 3) and exclusion criteria, i.e., not inclusion criteria and no review study designs. Next a file was created on Elsevier Mendeley reference manager for full text PDFs identified. The inclusion and exclusion criteria (Table 3) were applied again to these texts on full reading.
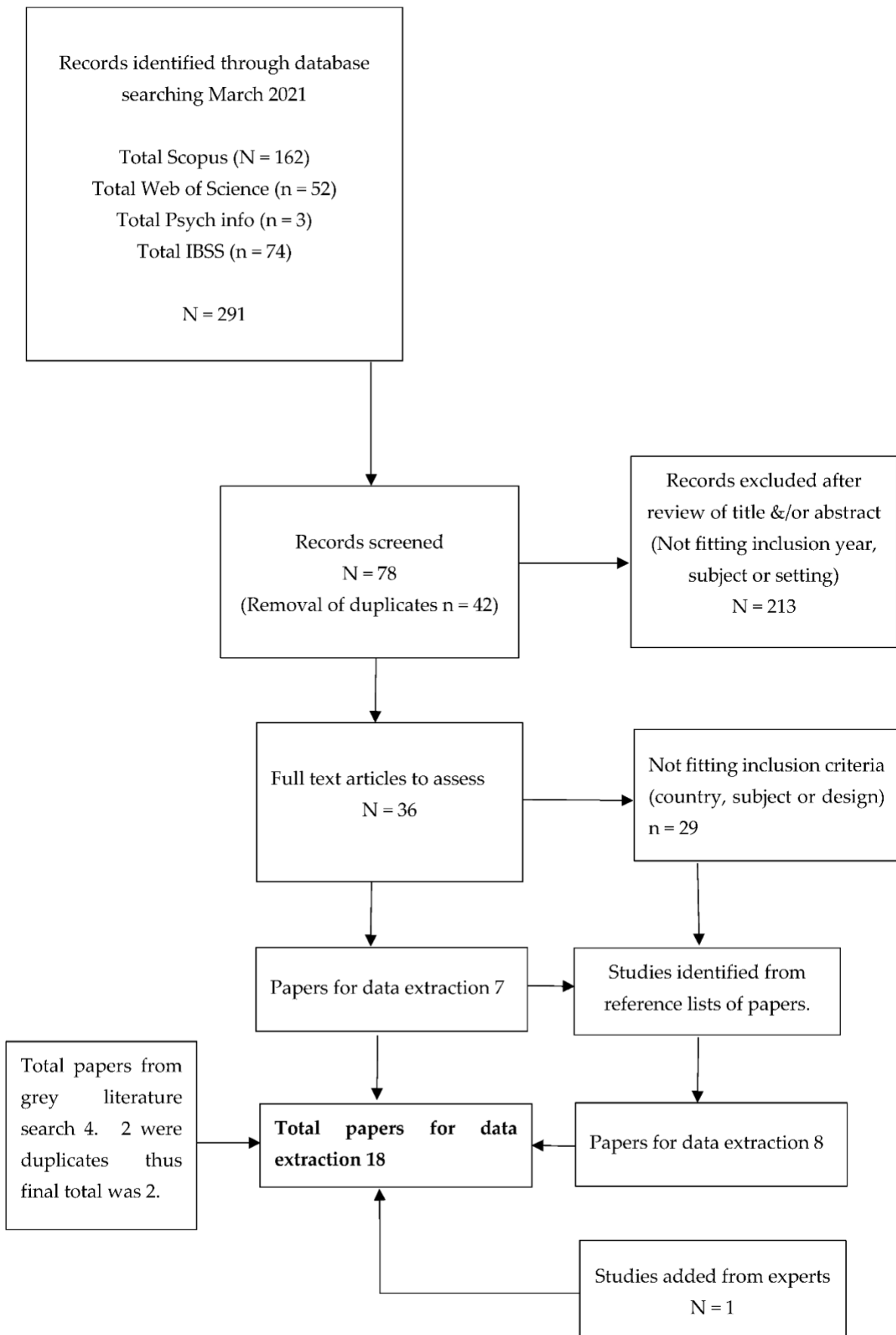
Figure 3 Search strategy and results to select relevant papers.

Table 3 Inclusion criteria to select relevant papers.

Subject Inclusion Criteria	
Dates	2011 to March 2021. Rationale for 2011 cut off is that 2010 was the year the Nudge Unit was established in the UK government cabinet office (Rutter, 2020).
Subject intervention	Any intervention or exploratory study that investigates interventions using nudges to change household food waste behaviours. Food waste: the definition of food waste is taken as authors own definition and use of term "food waste" which was informed by the definition of food waste in FAO (2013). Rationale for this approach is due to heterogeneity of definitions of food waste in the literature (Garske *et al.,* 2020).
Setting/sample	Household
Published and peer reviewed	Europe
Language	English
Study design	Qualitative and quantitative studies

Reference lists were searched in all papers identified for full text articles. The grey literature search was carried out in UK-only institutions due to limitations of resource and English language inclusion. In this review eight major UK supermarket websites (Tesco, Sainsbury's, ASDA, ALDI, LIDL, Morrisons, Waitrose and Coop) and the UK's Waste and Resources Action Programme (WRAP) webpages were searched.

When all papers were collated and those meeting the criteria selected, a critical appraisal of the studies was completed. Previous systematic reviews on food waste have not included a critical appraisal (Porpino, 2016; Schanes, Dobernig and Gözet, 2018; Reynolds *et al.*, 2019; Boulet, Hoek and Raven, 2021a; Reisch *et al.*, 2020).

The quality appraisal is therefore a novel contribution and focused on aspects likely to affect the validity of the results including design, the methods of observation, adequate reporting, statistical analysis, sample sizes and allocation. A framework based on the Joanna Briggs Institute Critical Appraisal checklist for descriptive/case series (Munn *et al.*, 2014) was applied. No meta-analysis was carried out as the identified studies were heterogeneous in type of design and results. A process of assessment was carried out to determine quality studies, following formalised rules detailed in Table 4.

Table 4 Inclusion and exclusion criteria for critical appraisal of relevant papers.

Subject	Inclusion and Exclusion Criteria
Population	Include studies recruiting from a specific geographical area, social media or supermarket customer base. Exclude studies recruiting using personal contacts.
Population	Include studies that are representative demographically of the population. Include studies that represent demographics of a residential area (i.e., local authority) of a town/city even if not representative of the whole population.
Intervention	Include studies with a detailed description of methods
Comparison	Include studies with a control group
Outcome	Exclude all self-reported measures, i.e., self-reported surveys or qualitative interviews/focus groups
Outcome	Include studies with a clear description of statistical analysis and measure of precision, i.e., confidence interval, standard deviation or p value.

3.4   Results

Following the search strategy described above, a total of 291 potential articles were identified (Figure 3). The initial screening identified 78 research papers, of which 42 were duplicates (duplicated two, three or four times over the four databases), leaving 36 for full paper search. On reading the 36 papers fully the database search produced 7 papers for consideration. Reference list searching of the 36 papers for full paper search identified another 8 papers for data extraction. One extra paper was identified by an expert. Grey literature studies on food waste were discovered for three UK supermarkets: Tesco, Sainsburys and ASDA. The ASDA study was already captured in two journal publications. Thus, the grey literature search brought 2 extra studies for data extraction. The total number of papers identified for data extraction, from the database search, reference list search, expert advice and grey literature search was 18. Appendix A.1 shows the critical appraisal applied to the eighteen selected studies. Table 4 shows the key results of papers deemed higher quality from the review and illustrates good practice to be replicated. Appendix A.2, A.3 and A.4 show the summarised results of lower quality papers in the review. Appendix A.1 shows changes to food waste behaviours or perceptions of food waste behaviours in relation to food waste behaviour interventions using nudge techniques. Six studies were published between 2011 and 2016, and

twelve studies were published from 2017 to 2020, illustrating the increase in research on food waste in recent years. Ten of the studies were UK based, three were from Sweden, two from Germany, two from The Netherlands and one from Denmark.

3.4.1   Nudge Interventions

Nudge interventions and associated research were wide–ranging. Three studies did not run an intervention and instead discussed consumer perception(s) of food waste behaviour interventions (Aschemann-Witzel, 2018; von Kameke and Fischer, 2018; Wakefield and Axon, 2020). Eight studies used more than one key intervention (Bernstad, La Cour Jansen and Aspegren, 2013; Bernstad, 2014; Lim *et al.*, 2017; Sainsburys, 2017; Young *et al.*, 2017; Shaw, Smith and Williams, 2018; Young, Russell and Robinson, 2018; Hubbub and Tesco, 2020). Most frequently interventions used written information. Five studies used written information interventions incorporating a variety of nudges ranging from disclosure, e.g., environmental impact of food waste from an average household, to individualized consequences to the environment or financial impacts, to reminders, to descriptions of food waste behaviours of other people in the same community, i.e., social norms (Bernstad, La Cour Jansen and Aspegren, 2013; Bernstad, 2014; Lim *et al.*, 2017; Linder, Lindahl and Borgström, 2018; Shaw, Smith and Williams, 2018). Four studies with supermarket awareness campaigns all incorporated social norm and reminder nudges (Sainsburys, 2017; Young *et al.*, 2017; Young, Russell and Robinson, 2018; Hubbub and Tesco, 2020). One campaign also included pre-commitment strategies, e.g., making pledges on food waste behaviour (Young, Russell and Robinson, 2018) and another included a number of tools to increase the convenience of behaviour change e.g., food bag clips (Sainsburys, 2017). Another intervention included, in addition to nudge, economic marketing techniques, i.e., incentives and positive communication (Hubbub and Tesco, 2020). Three studies used a food waste sorting bin, arguably a visual prompt or reminder nudge for food waste behaviour (Metcalfe *et al.*, 2012; Comber and Thieme, 2013; Bernstad, 2014). Other interventions included: sticker prompts for a food waste bin, i.e., a visual reminder nudge (Shaw, Smith and Williams, 2018); social recipes whereby participants shared ingredients to make recipes together to reduce waste incorporating social norm nudges (Lim *et al.*, 2017); verbal information with environmental disclosure (Bernstad, La Cour Jansen and Aspegren, 2013); written social comparison feedback on food waste behaviours of nearby streets, i.e., social norms nudging (Nomura, John and Cotterill, 2011); written reminders and recommendations to change food waste behaviours, i.e., including nudges of pre-commitment strategies, reminders and setting implementation intentions (Schmidt, 2016); a measuring tool for portioning of rice and pasta, i.e., increase in ease of convenience (van Dooren *et al.*, 2020); and environmental impact feedback on food waste habits, i.e., a nudge informing people of their individual consequences (Lim *et al.*, 2017).

3.4.2   Study Design and Samples

Of the eighteen studies selected (Appendix A.1), fifteen were quantitative and three were qualitative. The most common sampling strategy used was convenience sampling (thirteen studies); however, purposive sampling (Metcalfe *et al.*, 2012), ad hoc sampling (von Kameke and Fischer, 2018), random sampling (Nomura, John and Cotterill, 2011; Shearer *et al.*, 2017) and unclear or unstated methods were also used (Bernstad, 2014; Sainsburys, 2017). Sixteen studies included participants who were self-selected. Total sample sizes of all eighteen studies ranged from 15 to 64,284, 9 studies used individuals (Comber and Thieme, 2013; Schmidt, 2016; Lim *et al.*, 2017; Young *et al.*, 2017; Aschemann-Witzel, 2018; von Kameke and Fischer, 2018; Young, Russell and Robinson, 2018; van Dooren *et al.*, 2020; Wakefield and Axon, 2020) and 8 studies used households as the sampling unit (Nomura, John and Cotterill, 2011; Metcalfe *et al.*, 2012; Bernstad, La Cour Jansen and Aspegren, 2013; Bernstad, 2014; Shearer *et al.*, 2017; Linder, Lindahl and Borgström, 2018; Shaw, Smith and Williams, 2018; Hubbub and Tesco, 2020) and 1 study was unclear (Sainsburys, 2017). Five studies had sample sizes of under 100 (Metcalfe *et al.*, 2012; Comber and Thieme, 2013; Lim *et al.*, 2017; Shaw, Smith and Williams, 2018; Hubbub and Tesco, 2020). Five studies had sample sizes between 100 and 500 (Bernstad, 2014; Schmidt, 2016; Linder, Lindahl and Borgström, 2018; von Kameke and Fischer, 2018; Wakefield and Axon, 2020). Seven studies had total sample sizes of over 500 (Nomura, John and Cotterill, 2011; Bernstad, La Cour Jansen and Aspegren, 2013; Shearer *et al.*, 2017; Young *et al.*, 2017; Aschemann-Witzel, 2018; Young, Russell and Robinson, 2018; van Dooren *et al.*, 2020).

Regarding the allocation of the interventions, nine studies used geographical area (Nomura, John and Cotterill, 2011; Metcalfe *et al.*, 2012; Bernstad, La Cour Jansen and Aspegren, 2013; Bernstad, 2014; Schmidt, 2016; Sainsburys, 2017; Linder, Lindahl and Borgström, 2018; Shaw, Smith and Williams, 2018; van Dooren *et al.*, 2020). Once the geographical area was selected, two studies used random sampling methods (Nomura, John and Cotterill, 2011; Shearer *et al.*, 2017). Four studies used convenience sampling (Bernstad, La Cour Jansen and Aspegren, 2013; Comber and Thieme, 2013; Schmidt, 2016; Linder, Lindahl and Borgström, 2018). Two studies used purposive sampling (Metcalfe *et al.,* 2012; Shaw, Smith and Williams, 2018) and two studies were unclear on sampling methods (Bernstad, 2014; Sainsburys, 2017). Five studies recruited from a supermarket customer base (Bernstad, La Cour Jansen and Aspegren, 2013; Young *et al.*, 2017; Aschemann-Witzel, 2018; Young, Russell and Robinson, 2018; van Dooren *et al.*, 2020). One study included random selection of customer base—all others used convenience sampling (van Dooren *et al.*, 2020). Two studies allocated their sampling strategy from specific locations, i.e., fair or shop (von Kameke and Fischer, 2018; van Dooren *et al.*, 2020) both studies used convenience sampling and ad hoc sampling, respectively. Two studies recruited from social media (Lim *et al.*, 2017; Wakefield and Axon, 2020),

both used convenience sampling. Two studies recruited from personal contacts (Comber and Thieme, 2013; Lim *et al.*, 2017), both used convenience sampling.

The studies largely did not have samples representative of the country's population in which they took place. Eight studies included no statement on how representative the sample was (Metcalfe *et al.*, 2012; Comber and Thieme, 2013; Lim *et al.*, 2017; Sainsburys, 2017; Young *et al.*, 2017; Young, Russell and Robinson, 2018; Hubbub and Tesco, 2020; Wakefield and Axon, 2020). Six studies included a detailed description on demographics indicating how representative the sample was in relation to the local town or area (Bernstad, La Cour Jansen and Aspegren, 2013; Bernstad, 2014; Schmidt, 2016; Linder, Lindahl and Borgström, 2018; Shaw, Smith and Williams, 2018; von Kameke and Fischer, 2018). Three were representative (Nomura, John and Cotterill, 2011; Shearer *et al.*, 2017; Aschemann-Witzel, 2018). Three studies had randomised samples (Nomura, John and Cotterill, 2011; Shearer *et al.*, 2017; van Dooren *et al.*, 2020). Two studies were random and representative (Nomura, John and Cotterill, 2011; Shearer *et al.*, 2017).

3.4.3   Methods of Assessment

The majority of studies were clear and transparent concerning their methods of assessment and inherent limitations. In Bernstad (2014), which measured food waste weight at multiple time points with comparisons taken over 10 weeks before and 33 weeks after campaigns A and B, the method description of how many households per intervention were included in the food waste weight measurement (written information or bin equipment) was ambiguous. Three studies had two methods of measurement clearly indicated (Bernstad, La Cour Jansen and Aspegren, 2013; Lim *et al.*, 2017; Hubbub and Tesco, 2020). Eleven studies used questionnaire methods (Bernstad, La Cour Jansen and Aspegren, 2013; Schmidt, 2016; Lim *et al.*, 2017; Sainsburys, 2017; Young *et al.*, 2017; Aschemann-Witzel, 2018; von Kameke and Fischer, 2018; Young, Russell and Robinson, 2018; Hubbub and Tesco, 2020; van Dooren *et al.*, 2020; Wakefield and Axon, 2020). Eight studies measured food waste weight to varying degrees of accuracy (Bernstad, La Cour Jansen and Aspegren, 2013; Bernstad, 2014; Lim *et al.*, 2017; Sainsburys, 2017; Shearer *et al.*, 2017; Linder, Lindahl and Borgström, 2018; Shaw, Smith and Williams, 2018; Hubbub and Tesco, 2020). Of these studies only one or two of five recommended methods for optimal physical measurement of food waste were used (Elimelech, Ayalon and Ert, 2018). One study used observations of food caddy placement (Nomura, John and Cotterill, 2011) and three studies used qualitative responses (Metcalfe *et al.*, 2012; Comber and Thieme, 2013; Wakefield and Axon, 2020). Nine studies relied solely on self-reported data (Metcalfe *et al.*, 2012; Comber and Thieme, 2013; Schmidt, 2016; Young *et al.*, 2017; Aschemann-Witzel, 2018; von Kameke and Fischer, 2018; Young, Russell and Robinson, 2018; van Dooren *et al.*, 2020; Wakefield and Axon, 2020). Nine studies used more objective methods of

measurement, specifically: eight studies used measures of food waste weight (Bernstad, La Cour Jansen and Aspegren, 2013; Bernstad, 2014; Lim *et al.*, 2017; Sainsburys, 2017; Shearer *et al.*, 2017; Linder, Lindahl and Borgström, 2018; Shaw, Smith and Williams, 2018; Hubbub and Tesco, 2020), and one study used counts of food waste caddies left on household kerbsides for food recycling collection (Nomura, John and Cotterill, 2011).

The majority of studies did not specify whether the food waste measured was inedible, or edible, unavoidable, avoidable or possibly avoidable food waste; a crucial oversight given the importance of these definitions in practically informing solutions to the issue of food waste. Seven studies did specify the food waste measured was either edible food waste or avoidable food waste (Schmidt, 2016; Lim *et al.*, 2017; Young *et al.*, 2017; Shaw, Smith and Williams, 2018; Young, Russell and Robinson, 2018; Hubbub and Tesco, 2020; van Dooren *et al.*, 2020). Five studies referred to the type of food that was wasted (Lim *et al.*, 2017; Young *et al.*, 2017; Shaw, Smith and Williams, 2018; Young, Russell and Robinson, 2018; van Dooren *et al.*, 2020). Hubbard and Tesco (2020) used a photo diary to measure food waste however these findings were not reported in the study summary accessed through grey literature searches.

In all fifteen quantitative studies drop-out rates from interventions were not indicated. It is unclear how easy interventions were for participants to complete. Four studies did report on missing data, i.e., missed bin collections (Shearer *et al.*, 2017; Linder, Lindahl and Borgström, 2018) and missed responses on online surveys (Young *et al.*, 2017; Young, Russell and Robinson, 2018).

3.4.4 Reliability and Precision

For the majority of studies, whether or not the assessment was reliable was unclear. It is established that self-reported measures of food waste behaviour change via questionnaire are not reliably accurate as a measure of food waste unless used purely for comparative methods to assess differences between households and ideally within a specified recent timeframe, i.e., the last week. Hence, all studies that used this method of measurement via questionnaire or interview or focus group were classified as "unclear" regarding reliability (van Herpen and van der Lans, 2019; van Herpen *et al.*, 2019). The results of the self-reported studies that used quantitative survey methods are summarised (Appendix A.2, A.3 and A.4). These studies all had relatively small sample sizes of approximately 0–500 and did tend to report positively with regard to the effect of intervention on food waste reduction, however it may be that the positive results from these smaller studies were subject to publication bias.

The nine studies that used more objective methods to measure food waste will be discussed in the following section (Nomura, John and Cotterill, 2011; Bernstad, La Cour Jansen and Aspegren, 2013;

Bernstad, 2014; Lim *et al.*, 2017; Sainsburys, 2017; Shearer *et al.*, 2017; Linder, Lindahl and Borgström, 2018; Shaw, Smith and Williams, 2018; Hubbub and Tesco, 2020). Sainsburys (2017) was not considered reliable as sample sizes, methods of recruitment and analysis were consistently unclear. In Bernstad (2014) the methods description of how many households per intervention were included in the food waste weight measurement (written information or bin equipment) was ambiguous, hence reliability was classified as unclear, although this study had merit in weighing food waste objectively at multiple time points before and after the intervention. The Hubbard and Tesco (2020) was classified unreliable and imprecise as the report did not clearly describe the statistical analysis for the results and there were no confidence intervals, standard deviations or p values indicated. There was a summary comparison of the average waste from the first week compared to the final week and no other data available. The Lim *et al* (2017) was marked as unreliable because the sample size was only fifteen and unrepresentative (all university students between the ages of 20–28). Furthermore, the study did not take travel into account for logistics involved with the social recipe intervention. Bernstad, La Cour Jansen and Aspegren (2013) split their sample into two intervention groups. One group consisted of 420 Swedish households and included an intervention using nudges of disclosure in written and oral information and nudges of increased ease and convenience, i.e., being given food waste recycling bags. The second group consisted of 210 Swedish households and the intervention included written information using disclosure nudges. Food waste weights were recorded at multiple time points over 24 months. P values were included along with clear details of statistical analysis. The results showed overall that there was no change in either group for food waste recycling. This study also included a clear description of the population and discussed how representative the sample was in comparison with the population average of the City of Malmo. However, the study did not include a control group in the design hence it was excluded on the application of quality rules (Table 4). Despite this exclusion, it was noted that there was no change in either group as both received nudge interventions, however without a control group it is difficult to know whether this would have been replicated or different with other households in the same community without any intervention. Four studies were considered reliable assessments on application of the quality rules applied (Table 4). Their results were summarised in Table 5 (Nomura, John and Cotterill, 2011; Shearer *et al.*, 2017; Linder, Lindahl and Borgström, 2018; Shaw, Smith and Williams, 2018). All four studies addressed food waste recycling or food waste reduction, their interventions were simple and well-articulated, sample sizes adequate or large and precision of results calculated. Three of these studies were based in the UK (Nomura, John and Cotterill, 2011; Shearer *et al.*, 2017; Shaw, Smith and Williams, 2018) and one in Sweden (Linder, Lindahl and Borgström, 2018).

Table 5 Results following application of inclusion and exclusion criteria for critical appraisal of

relevant papers.

Study Population	Intervention and Nudge Approach	Comparison	Outcome Measure and Methods	Results	Results Overall
Shaw, Smith & Williams (2018) UK N = 60 Purposive Sample; attempt at representative sample; allocation: geographical area	Intervention included households receiving a leaflet using nudge E: disclosure, either emphasizing financial impacts or environmental impacts of avoidable food waste in order to encourage avoidable food waste reduction.	Control and 2 Treatment Groups	Grams/household/week Pre- and Post-Intervention Only study in this table that differentiates between avoidable and unavoidable food waste and that breaks down food waste by food type.	No statistically significant difference in the weekly total weight of avoidable food waste before and after the intervention. Statistically significant? No	No change
Linder, Lindahl and Borgström (2018) Sweden N = 474 Convenience sample; clear detail on representative sample compared to population; allocation: geographical area	Intervention: Information leaflet and recycling station. Control group received no information leaflet and recycling station. Information leaflet used C: social norms, encouraging participants to 'Join your neighbours'; attitudes of residents described as considering FW recycling as very important. E: disclosure: vivid and tangible info on benefits of recycling FW to biofuel.	Control and Treatment Group	Kilograms of food waste/per sorting station/2 weeks Pre- and Post-Intervention Reported how missing data was managed.	Food waste Pre-intervention Control: 37.67 (29.76) Treatment: 57.31 (55.67) Difference 18.64 Food waste Post-intervention Control: 27.81 (13.67) Treatment: 59.77 (25.04) Difference 31.96 Statistically significant? Yes	Positive
Nomura, John & Cotterill (2011) UK N = 9082 RCT; Representative and random; allocation: geographical area	Households in the treatment group were sent two postcards that provided feedback on how their street performed on food waste recycling compared with the average for their neighbourhood (nudge was C: use of social norms)	Control and Treatment Group	Effect size (Regression) Pre- and Post-Intervention	Positive effect 2.8% Statistically significant? Yes	Positive

Study Population	Intervention and Nudge Approach	Comparison	Outcome Measure and Methods	Results	Results Overall
Shearer *et al.* (2017) UK N = 64,284 RCT; Representative and random; allocation geographical area	Intervention included stickers, affixed to the lids of refuse bins, to encourage the separate collection of household food waste for recycling. Nudge was H: reminder, i.e., a visual-prompt as a reminder to engage in a behaviour.	Control and Treatment Group	Mean tonnage of food waste/collection round/week Pre- and Post-Intervention Reported how missing data was managed.	Control: No change. Baseline: 1.24 (SD 0.36) and Experimental: 1.24 (SD 0.36). The difference was −0.0091%. Treatment: mean weight of food waste collected increased by 20% from 1.23 (SD = 0.35) to 1.49 (SD = 0.37) tonnes. Statistically significant? Yes	Positive

Nomura, John and Cotterill (2011) in a UK study incorporated a randomised control trial design with two groups, treatment and control, of 5009 and 4073, respectively. The intervention used social norms nudges by applying social feedback on local recycling rates. Regression analysis, standard errors and level of significance (p values) were calculated and showed a statistically significant positive effect of the intervention on household food waste recycling. Mode of measurement was one of observation of recycling food bin to indicate participation with food waste recycling. There were, however, no weight measures or compositional measures of the food waste. Whether the food waste was properly separated or what amount of food waste was to be recycled was not therefore specified.

Shearer *et al*. (2017) in their UK study included a randomised control trial design with treatment and control group of 33,716 and 30,568 participants, respectively. The treatment group received a visual prompt nudge reminder as a sticker on their food waste caddy. Weights of food waste were measured for both groups at multiple time points pre and post intervention and standard deviation and p values calculated, with statistically significant changes in food waste recycling observed.

Linder, Lindahl and Borgström (2018) in Sweden sent an information leaflet with nudges of social norms and disclosure for food waste recycling to the treatment group. Treatment and control groups (264 and 210, respectively) had food waste weighed pre and post intervention. Standard deviation was indicated and level of statistical significance (p values) calculated. A positive and statistically significant change in food waste recycling was noted in the treatment group.

The study by Shaw, Smith and Williams (2018) in the UK comprised a sample size of 60, including 3 groups (n = 20 for leaflet using the nudge disclosure for environmental impact, n = 20 for leaflet using

the nudge disclosure for economic impact and n = 20 for control). Food waste was measured via compositional analysis and weight. It was the only study, of the four studies (Table 5), that differentiated between avoidable and unavoidable food waste and that separated food waste by food type. A standard error was included in the results. The results showed a lack of differences between the three groups which negated the need to fully conduct statistical analyses usually involved with a before-after-control-impact experimental design.

3.5   Discussion

This systematic review aimed to gather and appraise the evidence around interventions using nudge for food waste behaviour change. The results contribute to this field of research by identifying the most effective nudge interventions for altering food waste behaviour in households in Europe, providing insights for future policy formation and nudge applications.

There were four studies that were determined to be of higher quality that showed reliable results with three nudges used: use of social norms, reminders and disclosure. The use of social norms and reminders were both shown to have positive influence on change in food waste behaviours (Nomura, John and Cotterill, 2011; Shearer *et al.*, 2017; Linder, Lindahl and Borgström, 2018). Disclosure was shown to have a positive influence when incorporated in an intervention for food waste recycling (Linder, Lindahl and Borgström, 2018; Shaw, Smith and Williams, 2018). However, disclosure showed no change for an intervention to reduce food waste (Shaw, Smith and Williams, 2018). Despite these interventions all using objective measures, optimal methods for physical measurement of food waste as outlined by Elimelech, Ayalon and Ert (2018) were not used in any of the studies indicating that although the results have rigorous elements there is room to increase rigor in the methods used to obtain a more robust result.

The outcomes of the present study provide some insight into the application of nudges in changing food waste behaviour, particularly in relation to food waste recycling. If food waste recycling is considered an upstream nudge (visual reminder) that increases awareness of food waste for the consumer the outcome could arguably be a reduction in food waste in households. There exist implications to local government and individuals, and for the practical application of the findings.

3.5.1   Explanation

Other reviews support the use of social norms as being one of the most influential elements affecting sustainable consumer behaviour (Schanes, Dobernig and Gözet, 2018; Reynolds *et al.*, 2019). It is well documented that consumer behaviour in relation to food is affected by a wide range of personal, social and environmental factors, i.e., personal beliefs, attitudes, knowledge and genetics; social

interaction with friends, family and community and the environment—shops, schools, work place, facilities, the economy and technology (von Kameke and Fischer, 2018). The theory of planned behaviour explains this phenomenon as it indicates that attitudes, social norms and perceived behavioural control influence intentions which predict behaviour (Michie *et al.*, 2014). Despite good intentions the value-action gap is well documented and it is broadly understood that behavioural nudges may help to bridge this gap. Social cognitive theory also explains why the use of social norms in nudging for food waste behaviour change is effective as it suggests that a focus on observing and learning from others has influence on positive and negative reinforcement of behaviour (Michie *et al.*, 2014). This also suggests that social norms should be used with care as social norms have the potential to reinforce negative behaviour (White, Habib and Hardisty, 2019).

Shearer *et al.* (2017) (Table 5) showed food waste behaviour was changed by the use of nudge reminders. This outcome was supported by other studies (Comber and Thieme, 2013; Bernstad, 2014; Schmidt, 2016; Lim *et al.*, 2017; Sainsburys, 2017; Young *et al.*, 2017; Young, Russell and Robinson, 2018; Hubbub and Tesco, 2020; van Dooren *et al.*, 2020) that were not considered for the purpose of this review as the method of measuring food waste was self-reported via survey or interview. However, the methods were clear and the sample sizes adequate, thus it was useful to understand the perspectives of consumers towards nudges for food waste reduction to explain the findings (Appendices A.1 and A.4). Aschemann-Witzel (2018) used a Likert scale of 1–7 (with 1 being least agreeable and 7 most agreeable) for four demographically different sample groups, the combined total N = 826. The fourth most accepted nudge interventions by all four groups out of thirteen nudges was: "I would like to avoid that food goes bad while stored at my home with the help of very easy tricks and tips". Von Kameke and Fischer (2018) used a 1–5 Likert scale (1 = great support; 5 = no support at all) N = 101. Participants were recruited by ad hoc sampling outside one organic and one discount food store in the City of Lüneburg in Germany. In contrast to Aschemann-Witzel (2018) one of the nudges that received the least support was: tips on shopping planning via mail/post (median = 4.49, standard deviation = 1.09); though it was better received online (median = 3.49, standard deviation = 1.69) but support was still lacking (Von Kameke and Fischer, 2018). It appears perceptions on nudge reminders are divided but certainly for some groups of people it is perceived as effective in changing behaviour.

This pattern can be explained by the transtheoretical model of behaviour change which splits receptivity to behaviour change into stages: precontemplation, contemplation, preparation, action, maintenance and termination (Prochaska and Velicer, 1997; Prochaska and DiClemente, 2005). This model outlines that an intervention may be successful—or not—depending on the stage in which an individual is at the time. If an individual is at the action stage a reminder may be well received and effective, but, if an individual is at the precontemplation stage, they may not be interested. Equally

some individuals may have more pressures from their environment and social background that may influence their response (Schanes, Dobernig and Gözet, 2018; Boulet, Hoek and Raven, 2021a). There would also be a difference between individuals which may be explained by the self-determination theory which references motivations and aspects required for lasting change. The theory suggests motivation 'exists in the individual and is driven by interest or enjoyment of the task itself'. The individual must believe the behaviour is enjoyable or compatible with their 'sense of self', values and life goals (Gillison *et al.*, 2019). This is also compatible with the SHIFT (Social influence, Habit formation, Individual self, Feelings and cognition, and Tangibility) framework of sustainable behaviour change whereby there is focus on the individual self, having powerful influences on consumer behaviour, i.e., positivity of self, self-interest, self-efficacy (White, Habib and Hardisty, 2019).

Two of the studies in Table 5 used disclosure. Linder, Lindahl and Borgström (2018) used disclosure and social norms and did show change in food waste behaviours while Shaw, Smith and Williams (2018) only used disclosure as a nudge and showed no change. This difference may be due to the type of food behaviour change the intervention aimed to disrupt, the former pertained to food waste recycling, while the latter pertained to food waste reduction behaviours. Alternatively, the dual use of social norms and disclosure may be more compelling than disclosure alone. One reason for this outcome may be that the use of social norms lends a positivity to the intervention that offsets the negativity often associated with disclosure. Disclosure may reveal environmental costs associated with food waste. This may not be effective due to the problem of abstractness, information on climate change can be fear-provoking and vague with overwhelmingly large-scale consequences making individual acts feel inconsequential which may lead to green fatigue or demotivate as a result of information overload (White, Habib and Hardisty, 2019).

In one study individuals' perceptions of nudges of warnings, i.e., pictures that demonstrate the extent of the food waste amounts were collected. Overall, the rating offered was 2.91 by 101 participants, the scale ranged from 1 ("great support") to 5 ("no support at all"). This was the only mention of the nudge warning within the review. It is unclear why this has not been used more frequently and whether it is a nudge that could be effective. The WRAP "love food hate waste" campaign commenced this line of engagement in social media campaigns (WRAP, 2022a). In other areas, i.e., cigarette smoking, the impact of pictures of tobacco health warnings is shown to have an effect (Fong, Hammond and Hitchman, 2009). As food waste connects to a lesser degree immediately with the individual it may be that this approach is less effective due to its relative abstractness. Highlighting minimisation of food waste as a way of boosting nutrition and saving money may be more immediately beneficial to the individual and therefore a useful angle to exploit for mutual benefit of changing food waste behaviours and improving health and food security.

Further explanation for why social norms and reminders can be effective relate to tangibility, that is bringing sustainable behaviour to the personal human level. Often green actions can seem vague, distant from the self or abstract, only for realisation in the future or not feasible in the face of daily challenges (Reczek, Trudel and White, 2018; White, Habib and Hardisty, 2019). Changes slowly emerge and uncertainty surrounds problems, solutions and outcomes. Social norms and simple reminders prompting actions at the individual and social level are tangible and key to individuals paying attention and taking part (White, Habib and Hardisty, 2019). There is much long-term thinking associated with sustainable behaviours regarding cost to current pleasure to promote a sustainable result in the future. This poses problems as people are often hesitant to sacrifice their own benefit (White, Habib and Hardisty, 2019). Yet, carrying out actions with others that help others can offer a positive feeling occasionally described the 'warm glow' effect (Giebelhausen *et al.*, 2016), focusing on these kinds of benefits to the self in the present may increase sustainable behaviours (White, Habib and Hardisty, 2019). Framing social norms or reminders as nudges for food waste reduction in this way, e.g., 'reducing food waste will benefit your children's future' may improve their effectiveness.

3.5.2   Implications for Policy

Nudges of social norms and reminders could be useful policy actions for changing food waste behaviours, particularly because they are inexpensive and adaptable approaches. Such approaches should not replace stricter policy measures for food waste reduction at the household level, but as a complement (Liu *et al.*, 2014; Ferrari *et al.*, 2019). This discussion will consider usage of these identified nudges for food waste behaviour change in local government contexts.

An implication of the research is that the evidence informs affordable and adaptable interventions for policy makers, for behaviour change in household food waste recycling. For food waste recycling interventions in household settings, it was established that nudges in interventions worked to change behaviours. This can contribute to designing effective interventions for local governments to use that support household food waste recycling behaviours in a useful and affordable way. This is timely considering the national roll out of kerbside food waste recycling collections proposed in England for 2023 (HM Government, 2021).

Governments and stakeholders are keen to find ways to effectively improve healthier food behaviours to encourage improvement in public health (Sunstein and Reisch, 2014). Interventions using nudges have gained increased attention in the international policy debate, particularly in the food context they have been applied successfully to promote healthier food patterns of consumption such as increased fruits and vegetables (Liu *et al.*, 2014; Wilson *et al.*, 2016; Stämpfli, Stöckli and Brunner, 2017; Carroll, Samek and Zepeda, 2018; Hollands *et al.*, 2018). Food waste is a point of

intersection between these key issues and could in this way support food security. Perhaps, by designing interventions for multiple purposes, for example, interventions using nudge to encourage consumers towards healthy plant-based diets could also incorporate nudges towards food waste behaviour change. This is especially key as it has been commonly shown that an increase in fresh fruit and vegetable consumption can lead to an increase in food waste (Conrad, 2020). A suggestion on how this could work would be to nudge consumers to buy fruit and vegetables in forms such as canned or frozen—items that are less often wasted compared with fresh produce but offer nutritional gains (Janssen *et al.*, 2017). Alternatively, nudging storage of apples in the fridge rather than a fruit bowl would increase their shelf life. Discussion about the approach of linking healthy nutrition and food waste awareness is often neglected in the discussion around food waste. It is an approach that may benefit health and environmental outcomes for local government.

3.5.3   Limitations and Priorities for Future Research

Overall, there is no assessment of study quality and robustness in previous reviews of food waste behaviour interventions. This review adds to the literature by indicating the paucity of quality primary studies using interventions with nudge for food waste behaviour change. This review indicates there is some information on the benefit of nudges (namely use of social norms, reminders or disclosure alongside use of social norms) for food waste recycling interventions, which as an upstream measure may have a positive impact on food waste reduction. However, there is currently limited information on the benefit of nudge for food waste reduction interventions.

There was lack of distinction, in the included studies, between whether or not food waste was edible or inedible, which is key information when considering the effectiveness of edible food waste reduction interventions. It is also key information for food waste recycling interventions as it is helpful to understand whether the increase in food waste recycling is due to edible or inedible food waste as this gives an indication of how to target food waste reduction interventions. Another key limitation included understanding the duration of effectiveness of nudge interventions as studies rarely evaluate long term outcomes (Bucher *et al.*, 2016); some research articles state nudge may only have short term effects (Allcott and Rogers, 2014). Thus, methods to attempt to measure the longer-term effect of interventions using nudge should be incorporated in future studies, studies in other areas, health not food consumption, have achieved this (Venema, Kroese and De Ridder, 2018) and could thus help to inform this methodology.

Regarding limitations to the current review, qualitative studies hold strength to uncover subject matter and anomalies to add to the body of research, however, they are not a reliable method to uncover whether or not nudge interventions are effective for food waste behaviour change in a

generalisable sample. Thus, despite robust qualitative methods from studies reviewed in this paper, we have not deemed them reliable for the purpose of this review and research question to hand (Metcalfe *et al.*, 2012; Comber and Thieme, 2013; Wakefield and Axon, 2020).

In the future we need more food waste behaviour studies that use nudge interventions and measure changes in food waste before and after the intervention using either physical weight measurements using robust methods (Elimelech, Ayalon and Ert, 2018), or written or photographic diary studies using appropriate methods (Quested *et al.*, 2020) to identify avoidable, unavoidable and possibly avoidable food waste, and capture more data on the types of food wasted. There is also a need for studies to use representative samples and control groups when testing the effectiveness of a nudge intervention to change food waste behaviours as well as precision in statistical analysis. There are different outcome measures and effect sizes in almost every paper included in the review; future research could work to overcome these challenges which a more standardised approach so that a synthesis of results could be undertaken with meta-analysis. Future research could also assess effectiveness of nudges to change food waste behaviours in different demographics to find out whether there are differences in the kinds of approaches that work depending on demographics.

3.6 Conclusions

In conclusion there is no assessment of study quality in previous reviews of food waste behaviour interventions, thus this review indicates a lack of quality primary studies using interventions with nudge for food waste behaviour change. This review suggests there is reliable information on the effectiveness of nudge for food waste recycling interventions when incorporating nudges of social norms, reminders or disclosure alongside use of social norms. If food waste recycling behaviour is considered an upstream measure to raise consumer consciousness on the topic of food waste this may have a positive impact on food waste reduction. This review illustrates the limited information on the effectiveness of nudge for food waste reduction interventions. Behaviour change models and frameworks indicate nudges work when they are tangible, relevant and beneficial to the individual and their lifestyle. Nudges are inherently flexible and adaptable which lends them to policy implementation in different contexts. Incorporating policy on food waste within policy for food security and public health nutrition may maximise impact.

Chapter 4   Towards Sustainable Food Systems: Exploring Household Food Waste by Photographic Diary in Relation to Unprocessed, Processed and Ultra-Processed Food

4.1   Abstract

Global society is wasting food at unsustainable levels, and unconsumed food is contributing markedly to carbon emissions. Simultaneously, food insecurity and obesity are increasingly prevalent concerns in high-income countries. This study aimed to evaluate food waste at the household level to understand relationships between discarded food, food processing and household characteristics. A sociodemographic and food security survey of householders in Hampshire (UK) was conducted alongside a seven-day photographic food waste diary. Of the total food waste from 94 participants, 87% was unprocessed, 51% was avoidable or possibly avoidable and 36% was unavoidable. Of the total food waste, 61% occurred during food preparation. Greater amounts of avoidable food waste occurred in one, three and four+ person households than in two-person households. Possibly avoidable food waste was greater in households educated to postgraduate and university degree level than others. The outcomes of this study indicate that the focus on interventions should vary demographically. Interventions that support food security, improving diet quality and saving money, while reducing avoidable and unprocessed food waste, in one, three and four+ person households during food preparation are one option. Reducing possibly avoidable unprocessed food waste is a priority in households educated to university degree level and above.

4.2   Introduction

Global society is producing an unsustainable 931 million tonnes of food waste each year, and 8–10% of global carbon emissions are linked to unconsumed produce (United Nations Environment Programme, 2021). Although food is wasted or lost throughout the food supply chain, the greatest percentage of food waste/loss in high-income countries occurs during the consumer stage, especially at the household level (Zeinstra, van der Haar and van Bergen, 2020; Jeswani, Figueroa-Torres and Azapagic, 2021). Household food insecurity, where people cannot feed themselves without external support, is a serious public health concern even in high-income countries (Loopstra, 2018; Smith and

Thompson, 2023). In the UK, for example, at least 6% of the population are food insecure, while households waste on average the equivalent of eight meals per week (WRAP, 2021; Department of Work and Pensions, 2022). With the backdrop of Brexit, the COVID-19 pandemic, the Russia–Ukraine war and rising costs of living (Harari *et al.*, 2022), even households with a previously sufficient income may experience difficulties in affording food in comparison to previous years. The United Nations Sustainable Development Goals (SDG) highlight both food insecurity and food waste as key concerns (SDG 2 Zero Hunger and Goal 12.3 Responsible Consumption and Production) (Pérez-Escamilla, 2017). Measures to mitigate food insecurity include welfare entitlements and food aid, such as food banks and other charitable food services whereby food deemed "surplus" is redistributed to those in need. Such measures may do little to address the underlying causes of food insecurity, which are largely economic (Smith and Thompson, 2023), and it has been proposed that 'solutions likely lie upstream in social protection policies' (Loopstra, 2018). It is known that societal, personal, product and behavioural factors influence food waste (Roodhuyzen *et al.*, 2017; Schanes, Dobernig and Gözet, 2018; Boulet, Hoek and Raven, 2021a); thus, for social context, aspects such as household size, educational attainment and household income should be considered in relation to food waste.

Additionally, the prevalence of obesity is increasing in every region of the world and is associated with poorer diet quality (Swinburn *et al.*, 2019). In the UK, the most recent National Diet and Nutrition Survey (NDNS) report confirms that overall, the population does not consume the recommended levels of fruit and vegetables or fibre and consumes more sugar and saturated fat than is recommended (Public Health England, 2020). The purchasing and consumption of ultra-processed food (typically with a longer shelf life) are associated with obesity (Rauber *et al.*, 2021), higher food intake, higher fasting glucose, metabolic syndrome, the risk of hypertension and increases in cholesterol (Poti *et al.*, 2017). There is, however, a paucity of research that explores the links between diet quality and food waste (Ellison and Prescott, 2021); both issues are distinct but implicitly connect to behaviour concerning food choices. We propose that supporting households to reduce avoidable food waste from unprocessed food could address food security by improving dietary health. Reducing unprocessed food waste could result in nutrients that are falling below recommended levels becoming available for consumption and would therefore improve the nutritional status of the population (Public Health England, 2020). In this regard, the NOVA Food Classification System (Table 6) is instructive, emphasising that "natural or minimally processed foods and freshly made dishes and meals" have higher health benefits than ultra-processed foods (p.35) (Monteiro *et al.*, 2016).

Table 6. Definition of the NOVA Food Classification System (Monteiro *et al.,* 2016).

NOVA Category	Definition	Examples
NOVA 1	Unprocessed or minimally processed foods. Undergoing no alteration following removal from nature. Minimally processed foods may involve cleaning, removal of unwanted or inedible parts, freezing or pasteurisation or other processes that affect the food but do not add oils, fats, sugars or salts.	Eggs, milk, dried fruits, nuts, frozen or chilled or packed whole foods, fresh and dried herbs and spices, flakes and flours made from corn
NOVA 2	Oils, fats, salt and sugar. Products extracted from natural foods by processes such as pressing, grinding, crushing or refining. Used for seasoning.	Honey, vegetable oils, coconut oil, butter, lard, maple syrup
NOVA 3	Processed foods manufactured by industry with the use of salt, sugar, oil or other substances (Group 2) added to natural or minimally processed foods (Group 1) to preserve or to make them more palatable. They are recognised as versions of the original food, generally containing two or three ingredients.	Canned or bottled legumes in vinegar or pickling, tomato paste, bacon, freshly made cheese, canned fish, cured meat, freshly made bread unpackaged, beer
NOVA 4	Ultra-processed foods are industrial formulations made entirely or mostly from substances extracted from foods (oils, fats, sugar, starch and proteins), derived from food constituents (hydrogenated fats and modified starch) or synthesised in laboratories from food substrates or other organic sources (flavour enhancers, colours and several food additives)	Chocolates, cakes, candies, fizzy drinks, chicken nuggets, pre-prepared pizza, breakfast cereals and bars, sweetened yogurts, packaged breads, margarine

Food waste cannot be avoided totally or changed due to inedible parts (Lebersorger and Schneider, 2011; Quested, Esteal and Ingle, 2013); however, when it comes to edible food waste, there is potential for positive change. Food waste can be separated into categories: unavoidable (inedible), possibly avoidable and avoidable (edible) food waste (Lebersorger and Schneider, 2011; Quested, Esteal and Ingle, 2013). In the present study, "Avoidability" (Table 7) was used to refer to these categories. Furthermore, to conceptualise the generation of consumer food waste, three categories from a theoretical framework were applied: preparation and serving, consumption and storage (Roodhuyzen *et al.*, 2017). In the present study, the "Food Waste Generation Phase" (Table 7) identifies these categories.

The aim of this research was to explore food waste and how it may relate to dietary health. This study therefore evaluated the type and amount of food waste at the household level to understand any relationships between household characteristics, the type of food that is discarded and level of food processing involved in the discarded food.

Specifically, this study sought to determine:

1. What links exist between nutritional quality and food waste; specifically, is the NOVA classification of a food item associated with categories of food waste in households, such as Avoidability or the Food Waste Generation Phase, i.e., preparation, consumption or storage?

2. Are household characteristics such as educational attainment, household income and household size associated with categories of avoidable, possibly avoidable and unavoidable food waste?

3. Are household characteristics such as household size, educational attainment and household income associated with food waste by NOVA classification?

Table 7 Categories applied to food waste analysis

Food Waste Category	Food Waste Category Definitions
Avoidability: Avoidable, Unavoidable and Possibly Avoidable	To categorise food waste as avoidable, unavoidable and possibly avoidable, seminal definitions were used (Lebersorger and Schneider, 2011; Quested, Esteal and Ingle, 2013). Possibly avoidable was further defined to include food with parts easily incorporated within a standard meal or turned in compote, soup or a smoothie, e.g., apple cores, pear cores, carrot peel and ends, broccoli stalk, heart of cabbage, ends of leeks, ends and centre of bell pepper and potato peel. Dry onion peel or garlic peel, citrus peel, banana peel, tea and coffee leftovers, eggshells and bones were all classed as unavoidable, as none of these foods could be categorised as possibly avoidable.
NOVA: NOVA 1, NOVA 2, NOVA 3 and NOVA 4	To categorise food as processed or unprocessed, the NOVA tool was used and the definitions of NOVA applied (Table 1).
Food Waste Generation Phase: Preparation and Serving/ Consumption/Storage	For the Food Waste Generation Phase: the framework and descriptions from the literature on preparation and serving, consumption and storage were used to categorise the data according to the photographs (Roodhuyzen *et al.,* 2017).
Food Group:	For the food group, the same categories and definitions used by WRAP were used as the data collection methods were similar (i.e., hand-written

Food Waste Category	Food Waste Category Definitions
Vegetables/ Drinks/ Bakery/ Meals/ Dairy/ Eggs/ Fruit/ White Meat/ Red Meat/ Seafood/ Processed Vegetables/ Sweet/ Oil/ Condiments/ Staple / Breakfast Cereal/ Confectionery/ Processed Fruit/ Other	diary) to the current study (Lebersorger and Schneider, 2011; Quested, Esteal and Ingle, 2013). One difference in the current study was the creation of a new category 'Breakfast Cereal', rather than coding this under "Staple", as breakfast cereals were frequently mixed with milk.

4.3   Materials and Methods

4.3.1   Selection of Data Collection Methods

To assess the complex picture of household food waste, clear guidance on feasible methods for measuring food waste are required (Withanage, Dias and Habib, 2021). The Circular Economy Action Plan set out the EU's ambitions to develop a sustainable economy by minimising waste and valuing resources, proposing that all member states measure their food waste and report annual estimates of food waste, alongside using more precise and robust direct food waste measurement methods, every four years (Reynolds *et al.*, 2020). Despite this initiative, reliable and comparable data along the supply chain are lacking due to inconsistent definitions, monitoring and reporting (Garske *et al.*, 2020). Various methods have been used to audit food waste (Thyberg and Tonjes, 2016), including the quantification of residual municipal waste, food waste diaries, photographs and qualitative research (Ilakovac *et al.*, 2020). Due to the high costs of measuring household food waste directly, many studies have used self-assessed questionnaire methods (Grainger *et al.*, 2018). There have been a number of initiatives to improve the quality of measuring household food waste (Tostivint *et al.*, 2016; Elimelech, Ayalon and Ert, 2018; Quested *et al.*, 2020). However, there remain few primary data studies on household food waste (Xue *et al.*, 2017; van Herpen and van der Lans, 2019). The methods selected to measure the quantity of food waste depend on the purpose; understanding the nature of household food waste necessitates composition-specific data, whilst tracking progress in relation to targets requires data at scale but with less detail (Quested *et al.*, 2020). For the present study, a range of research methods were considered. Weight compositional analysis, despite being a direct method for assessing food weight, was not selected as it was important to easily categorise the foods into NOVA 1, 2, 3 and 4 (Table 6) and the food degradation that inevitably occurs in food

waste caddies would make this impossible. A questionnaire method was not selected as this method has been deemed less reliable due to the limitations of self-reporting (van Herpen and van der Lans, 2019; van Herpen *et al.*, 2019). A number of studies relating to household food waste have used handwritten diaries to measure food waste amounts (WRAP, 2008; Quested, Ingle and Parry, 2013; Silvennoinen *et al.*, 2014; Giordano *et al.*, 2019; Herzberg, Schmidt and Schneider, 2020; Ilakovac *et al.*, 2020), and written diaries, kitchen caddies and photograph coding measures correlate strongly (van Herpen *et al.*, 2019). The method of photographic diaries was selected for the present study, as the coding of photographs of food waste as a measurement can provide valid measures (van Herpen and van der Lans, 2019; Roe *et al.*, 2020). Usefully, the photographic diary method reduces the burden on participants (in comparison with a handwritten diary) and can thereby improve the retention of participants in a study (van Herpen and van der Lans, 2019; van Herpen *et al.*, 2019). Thus, this method is well-suited to citizen science (Pateman *et al.*, 2020), which was preferred in order to capture data relating to daily activities in the household. Additionally, the photographic diary method provided a way of assessing the volume of wasted food, offering an opportunity to acquire data in the form of weight estimates. Using photographs to quantify food waste does incur substantial effort in data handling due to the time required for coding photographs (van Herpen, van Geffen, *et al.*, 2019). The photographic diary method has been used in the context of food waste relating to school and university canteens, although these settings restricted the photographs to plate waste (Manomaivibool, Chart-asa and Unroj, 2016; Boulet *et al.*, 2022). Photographs have also been used in qualitative research on household food waste in relation to food storage or food habits in the home as part of ethnography and other qualitative studies (Sirola *et al.*, 2019; Heidenstrøm and Hebrok, 2021; Masyhuroh, 2021) and have been used successfully in similar but different contexts, i.e., child nutrition, home energy usage and plastic recycling studies (Avramides, Craft and Luckin, 2016; Thompson *et al.*, 2016).

4.3.2   Study Area, Participant Recruitment and Data Collection

The county of Hampshire was selected based on its ability to represent a relatively affluent county in the UK and other affluent regions in high-income countries. Recruitment occurred across all ten districts in Hampshire, UK to ensure a diverse geographical spread and demographics by convenience sample. We reasoned that only individuals wanting to complete a photographic diary would participate, which surpassed the strategy used to recruit. Convenience sampling is also an established method in peer-reviewed research in this field (Barone, Grappi and Romani, 2019; Leverenz *et al.*, 2019; Ilakovac *et al.*, 2020; Williams *et al.*, 2020). As the study required some demands on time from participants, self-selection was deemed the most suitable method to avoid

the early drop-out of participators or incorrect reporting due to fatigue or lack of engagement with the study.

Potential respondents were recruited via social media (Facebook) and in targeted public locations where flyers were displayed. The advertisement was posted in each district of Hampshire on a Facebook group for the general community, the local council, a local food bank and a green community group; from here, the advertisement was further shared with local networks. In total, approximately eighty advertisements were shared on Hampshire Facebook groups and seven advertisements were shared in local newsletters. The advertisement was also posted in fast food outlets and food banks in Hampshire. The advertisement stated the study topic and its purpose, inviting participants to engage with the study either by email, text or phone call and included the incentive of a £10 (UK) voucher. The inclusion criteria for the study were that all participants were required to be adult residents aged 18 and above who buy and prepare food and who living in a private household, i.e., a non-institutional setting, in Hampshire UK. Once each respondent had self-selected to learn more about the study, they were screened according to the inclusion criteria and, if eligible, sent a participant information sheet and a consent form electronically. In total, 126 individuals self-selected, of whom 95 consented to be part of the study.

Participants received written and photographic instructions on the definition of food waste adopted for the study. Participants were asked to take a photograph of every item of edible or inedible food that was thrown in the bin, composted, disposed of down the drain or given to pets in their household. Images were captured over seven consecutive days between 15th and 28th of November 2021 alongside a photograph of their hand (providing the length of their hand from tallest finger to wrist) or a ruler for scale. Participants were also given the option to weigh the food waste in each photograph using scales available at home. Each participant and the researcher formed a WhatsApp group of two members to share the photographs. WhatsApp was selected as it is an encrypted app for image, text, audio and video messaging; all communication had end-to-end encryption and was GDPR compliant. The WhatsApp data were archived on the secure University of Southampton server. Throughout the collection of data, the researcher stayed in contact with each participant over WhatsApp, asking for clarification on any unclear pictures and ensuring participants remained engaged in the study. Alongside the food waste photographic diary, each participant also completed a telephone survey with the researcher to collect data on food insecurity and socio-demographics, i.e., age, nationality, gender, average household income, household size and highest educational attainment in the household. Of a sample of 95 participants who initially consented to be part of the study, 94 fully completed the data collection.

4.3.3   Data Processing

Food waste per household was calculated in accordance with prior research (Lebersorger and Schneider, 2011; Quested, Ingle and Parry, 2013; Monteiro *et al.*, 2016; Roodhuyzen *et al.*, 2017). The food waste data was recorded for each food on each photograph and comprised categories of food type and stage (Table 7). The researcher applied the food waste categories using the photographs and definitions described in Table 7. All data were collated onto a database and associated with a unique ID representing each participating household.

Every photograph was assessed visually to estimate the volume (by measure of scale contained in the photograph) and/or the weight of food waste (by direct weighing of the food observed in the photograph). Two tools were used to assist the visual estimate, a novel library of standard photographs and the FAO/INFOODS Density Database (Charrondiere, Haytowitz and Stadlmayr, 2012). Examples of food waste photographs with details on how they were analysed are included in Appendix B.1. The library of standard photographs was created by using photographs of foods with associated actual weights as weighed by the researcher and/or participants during the study. This tool supplemented the FAO/INFOODS Density Database, which has some limitations in terms of the foods listed (Charrondiere, Haytowitz and Stadlmayr, 2012). For foods included in the FAO/INFOODS Density Database, a volume estimate of the food waste was made using the photograph measure of scale (Charrondiere, Haytowitz and Stadlmayr, 2012). The volume estimate was multiplied by the density unit to derive a weight (Ilakovac *et al.*, 2020). The FAO/INFOODS Density Database was notably useful for estimating the weight of meals with mixed foods or mixed vegetables (Charrondiere, Haytowitz and Stadlmayr, 2012). For the purposes of the present study, a mean value of all the vegetable density units was calculated and applied to photographs that included mixed vegetables. Similarly, for meals with mixed foods, a mean value of all the mixed meals density units was calculated and applied to photographs that included mixed meals. For food items in their packaging, weights were clarified and estimated using the suppliers' websites.

4.3.4   Quantitative Data Analysis

The data were grouped by household. The food waste weight was calculated and stratified by key variables: NOVA (Table 6), Avoidability (Table 7), Food Waste Generation Phase (Table 7), household size (Table 8), educational attainment (Table 8) and average household income (Table 8). In SPSSv26 (IBM Corporation), a Shapiro–Wilk test of normality was conducted to determine whether food waste weight by household for the categories of NOVA, Avoidability and Food Waste Generation Phase data were normally distributed (Field, 2018). The results concluded that each set of data were not normally distributed. Thus, non-parametric statistical tests were applied in all cases. Data were

analysed using a Kruskal–Wallis H test (SPSSv26; IBM Corporation) to determine the significance of variation between the medians of specified independent groups. This test was selected as there were three or more groups to compare and the data in each group were continuous variables (Field, 2018). For Kruskal-Wallis H test statistics demonstrating a significant effect (at the 0.05 level), pairwise comparison tests and Bonferroni correction were run (Field, 2018).

Table 8 Demographics of sample participants and Hampshire.

Demographic	Demographic	Sample (n)	Percentage (%)	Hampshire Percentage or Average
Gender	Female	83	88.3	51.1%
	Male	11	11.7	48.9%
				(Office for National Statistics, 2022)
Number of people in a household	1	17	18.1	
	2	31	33.0	Average household size 2.4.
	3	16	17.0	
	4	28	29.8	(Nomis, 2011)
	5+	2	2.1	
Household income (relative to £29,900 p.a.) (Office for National Statistics, 2021)	Lower	20	21.3	Average earnings in Hampshire £32,500 p.a.
	Higher	65	69.1	
	About median level	8	8.5	(Hampshire County Council, 2020)
	No response	1	1.1	
Household education	NVQ, A and AS Level, GCSE or equivalent	10	10.6	29.7% have level 4 qualification and above (degree level or above)
	University degree	29	30.9	(Nomis, 2011)
	Postgraduate studies	55	58.5	
Ethnicity	White, UK and Ireland	81	86.2	

Demographic	Demographic	Sample (n)	Percentage (%)	Hampshire Percentage or Average
	White, not UK and Ireland	7	7.4	91.8%
		6	6.4	3.2%
	Not white			5.0%
				(Nomis, 2011)
Household tenure	Mortgage/own	73	77.7	71.5%
	Rent	18	19.1	26.3%
	Other	3	3.2	2.1%
				(Nomis, 2011)
Households with children (Under 18)	Partner and child/children	43	45.7	27.9%
	My children	4	4.3	Lone parent 8.7%
				(Nomis, 2011)
Age				23.2
	18–34	22	23.4	23.5
	35–49	45	47.9	26.2
	50–64	20	21.3	27.1
	65+	7	7.4	(Office for National Statistics, 2022)

4.4   Results

The participants in the present study had a broadly similar representation regarding household size, household income, ethnicity and housing tenure to the Hampshire average (Table 8). However, there were differences in representation regarding gender, education, number of families with children and age of participants. The majority of the 94 respondents participating in the research were female (88.3%), compared with 51% for Hampshire (Table 8) (Office for National Statistics, 2022). The

highest proportion of respondents were aged 35–49 (47.9%), and the smallest proportion were persons over 65 years of age (7.4%); those 18–34 represented 23.4% and 50–64 represented 21.3%.

The highest educational attainment for respondent households was postgraduate degree (58.5%), followed by university degree (30.9%). This differed to the Hampshire average of 29.7% acquiring qualifications to degree level or above (Nomis, 2011). Within the survey sample, the average size of households was 2.7 persons, which is similar to the Hampshire average of 2.4 (Nomis, 2011). The study included a proportion of households living with a partner and child or children that was higher than the Hampshire average: 45.7% in comparison with 27.9% (Nomis, 2011). The ethnicity of the sample was primarily UK and white (n = 81) or white not UK and Ireland (n = 7). In the participant sample, 21.3% of households reported an annual income lower than £29,900 and 69.1% reported one that was higher. Meanwhile, the average household annual earnings in Hampshire is £32,500. Of the participants, 77.7% owned or had a mortgage on their property, while 19.1% rented and 3.2% had other arrangements; these statistics are similar to Hampshire averages of 71.5%, 26.3% and 2.1%, respectively (Nomis, 2011). Of the participant sample, 94.7% reported never to all questions on experiencing food insecurity over the last year, while 5.3% stated that sometimes in the last 12 months "The food that (I/we) bought just didn't last, and (I/we) didn't have money to get more" (Economic Research Service: US Department of Agriculture, 2012). Government data from fiscal year ending in 2020 of households in the UK reported that 92% of households were food secure, 4% reported low food security and 4% very low food security (Defra, 2021b).

4.4.1   Food Waste in Relation to NOVA and Avoidability Category

Data from 94 households indicated that the majority of food waste was in the NOVA 1 category (Table 9) and that it was fairly evenly split between avoidable, possibly avoidable and unavoidable food waste. Of the total food waste, 11% was in the NOVA 4 category and was avoidable.

Table 9 Total weights and proportions of food waste for all participating households (n = 94) in relation to NOVA category (Table 6) and Avoidability (Table 7) over 7 days.

	Avoidable Food Waste (g)	Possibly Avoidable Food Waste (g)	Unavoidable Food Waste (g)	Proportion of Avoidable and Possibly Avoidable Waste by NOVA	Proportion of Total Food Waste by NOVA
NOVA 1	71,896 (31%)	47,174 (20%)	85,693 (36%)	51%	87%
NOVA 2	294 (0%)	61 (0%)	0 (0%)	0%	0%
NOVA 3	3517 (2%)	29 (0%)	113 (0%)	2%	2%
NOVA 4	26,698 (11%)	11 (0%)	23 (0%)	11%	11%

4.4.2　Food Waste in Relation to NOVA and Food Waste Generation Phase Category

Table 10 shows that the majority of food waste occurred during the preparation residue phase and in the NOVA 1 category. Consumption and storage were the least significant waste generation phases for NOVA 1 food, though, overall, the amount of food waste was still higher in both of these categories than for NOVA 4 food waste.

Table 10 Total weights of food waste for all participating households (n = 94) in relation to Food Waste Generation Phase (preparation, storage, consumption or unclear; Table 7) and NOVA category (Table 6) over 7 days.

	Food Waste During Preparation (g)	Food Waste During Storage (g)	Food Waste During Consumption (g)	Unclear (g)	Proportion of Total Food Waste by NOVA
NOVA 1	142,812 (61%)	37,147 (16%)	24,183 (10%)	622 (0%)	87%
NOVA 2	80 (0%)	225 (0%)	0 (0%)	50 (0%)	0%
NOVA 3	198 (0%)	2259 (1%)	1186 (1%)	16 (0%)	2%
NOVA 4	1083 (0%)	11,036 (5%)	14,573 (6%)	40 (0%)	11%
Total	144,173 (61%)	50,667 (22%)	39,942 (17%)	728 (0%)	100%

A Kruskal–Wallis test demonstrated a significant effect in terms of food waste weight by Food Waste Generation Phase: Kruskal–Wallis H 102.570, $p < 0.000$. Post-hoc analyses (Dunn's multiple comparison tests) were conducted to test pairwise comparisons; food waste was found to occur in

statistically significantly greater amounts due to preparation compared with storage (p < 0.000, Bonferroni correction p = 0.000) and consumption (p < 0.001, Bonferroni correction p = 0.000). Food waste quantities associated with storage and consumption were not significantly different (p = 0.249, Bonferroni correction p = 0.748).

4.4.3 Household Characteristics i.e., Household Size, Educational Attainment and Average Household Income in Relation to Food Waste by Avoidability Category

In relation to household size, the findings showed that on average, over seven days, people from households of four or more wasted more food per person than households of two or three (910 g, 763 g and 866 g, respectively) and that households of one wasted the most food per person (1353 g) (Table 11). However, households of four or more had the most unavoidable food waste and the least possibly avoidable food waste per person (369 g and 163 g, respectively) (Table 11). Regarding avoidable food waste, one person households wasted the most (688 g), followed by households of three (489 g) and households of four or more (378 g) (Table 11). Descriptive statistics on the variances between households in each household size group are included in the Appendix B.2.

Table 11 Avoidable, unavoidable or possibly avoidable food waste (Table 7) in relation to household size, educational attainment and average household income (Table 8) per person over seven days.

Category	Sub-Category	Avoidable Food Waste (g)	Unavoidable Food Waste (g)	Possibly Avoidable Food Waste (g)	Average Total Food Waste (g)
Household Size	1	**688**	**360**	305	1353
	2	**192**	**364**	207	763
	3	**489**	**207**	170	866
	4 or more	**378**	**369**	163	910
Highest educational attainment in the household	Postgraduate	339	328	**182**	849
	University degree	475	369	**293**	1138
	Below degree level	440	303	**71**	814
	Higher	320	352	213	885

Category	Sub-Category	Avoidable Food Waste (g)	Unavoidable Food Waste (g)	Possibly Avoidable Food Waste (g)	Average Total Food Waste (g)
Average median UK household income in 2020 £29,900 p.a.*	About median level	194	325	285	804
	Lower	701	286	151	1138

Table 11 Note: All household data (n = 94) were normalised per person per week and all data were normalised by number of households in each category. Categories demonstrating statistical significance in terms of the Kruskal–Wallis H test statistic are in bold. * (Office for National Statistics, 2021).

Kruskal–Wallis tests were run to explore the significant differences between the medians of avoidable, possibly avoidable and unavoidable food waste in relation to household sizes of one, two, three and four or more (Table 12).

Table 12 Null hypotheses and test statistics for avoidable, unavoidable or possibly avoidable food waste (Table 7) in relation to household size, educational attainment and average household income (Table 8).

Category		Avoidable Food Waste (g)	Unavoidable Food Waste (g)	Possibly Avoidable Food Waste (g)
Household size	Null hypothesis	The distribution of avoidable food waste is the same across categories of household size	The distribution of unavoidable food waste is the same across categories of household size	The distribution of possibly avoidable food waste is the same across categories of household size
	Null hypothesis retained or rejected	Rejected	Rejected	Retained
	Kruskal–Wallis H	**Kruskal–Wallis H 14.088, p = 0.003 ***	**Kruskal–Wallis H 7.922, p = 0.048 ***	Kruskal–Wallis H 0.957, p = 0.821 **
Highest educational attainment in the household	Null hypothesis	the distribution of avoidable food waste is the same across categories of educational attainment	the distribution of unavoidable food waste is the same across categories of educational attainment	The distribution of possibly avoidable food waste is the same across categories of educational attainment

Category	Avoidable Food Waste (g)	Unavoidable Food Waste (g)	Possibly Avoidable Food Waste (g)
	Null hypothesis retained or rejected	Retained	Retained	Rejected
	Kruskal–Wallis H	Kruskal–Wallis H 0.461, p = 0.794 **	Kruskal–Wallis H 3.948, p = 0.139 **	**Kruskal–Wallis H 7.732, p = 0.021 ***
Average median UK household income in 2020 £29,900 p.a.(Office for National Statistics, 2021)	Null hypothesis	The distribution of avoidable food waste is the same across categories of average household income	The distribution of unavoidable food waste is the same across categories of average household income	The distribution of possibly avoidable food waste is the same across categories of average household income
	Null hypothesis retained or rejected	Retained	Retained	Retained
	Kruskal–Wallis H	Kruskal–Wallis H 4.226, p = 0.238 **	Kruskal–Wallis H 2.069, p = 0.558 **	Kruskal–Wallis H 4.238, p = 0.237 **

Table 12 Note: each Kruskal–Wallis H test statistic was adjusted for ties; n = 94 households—data were normalised per person. Timeframe was 7 days. * Demonstrating a significant effect. ** Multiple comparisons were not performed because the overall test did not show significant differences across samples.

Significant differences for household size in relation to avoidable and unavoidable food waste were identified. Post-hoc analyses (Dunn's multiple comparison tests) were conducted to test pairwise comparisons. Avoidable food waste was statistically significantly higher in households of one, three and four or more people than in two person households: (p = 0.003; Bonferroni correction p =0.019), (p = 0.003; Bonferroni correction p =0.014) and (p = 0.009; Bonferroni correction p = 0.055), respectively (Table 12). Unavoidable food waste was significantly higher in households of two than in households of three (p = 0.009); however, when this value was adjusted by Bonfferoni correction it was close to but no longer at the level of 0.05 statistical significance (p = 0.057) (Table 12). The remaining results showed that once significance values had been adjusted for the Bonferroni correction for multiple tests, unavoidable food waste was not significantly different between other household sizes.

Observations indicated that, over seven days, per person, the most avoidable food waste occurred in the group educated to university degree level (475 g), followed by the group with below degree level

qualifications (440 g) and the group with postgraduate qualifications (339 g) (Table 11). Possibly avoidable food waste was lowest per person in the below degree level group (71 g) and highest in the university degree group (293 g) (Table 11). Overall food waste was greatest per person for the university degree group (1138 g), while the postgraduate and below degree level groups were similar (849 g and 814 g, respectively) (Table 11). Descriptive statistics on the variances between households in each educational attainment group are included in Appendix B.1.

Kruskal–Wallis tests determined significant differences between groups of different education level for possibly avoidable food waste (Table 12). Post-hoc Dunn's multiple comparison tests were conducted for pairwise comparisons. Possibly avoidable food waste occurred in statistically significantly greater amounts in the postgraduate and university degree groups than in the below degree group: ($p = 0.009$; Bonferroni correction $p = 0.026$), ($p = 0.008$; Bonferroni correction $p = 0.025$), respectively (Table 12).

Regarding average household income, avoidable food waste was greater per person for lower income households (701 g) in comparison with higher income households (320 g) (Table 11). Unavoidable and possibly avoidable food waste weight was lower per person for lower income households than for higher income households (286 g and 151 g compared with 352 g and 213 g, respectively) (Table 11). Overall, the total average amount of food waste per person per week was higher in lower income households than in higher income households (885 g and 1138 g, respectively) (Table 11). None of these differences, however, were found to be statistically significant (Table 12).

4.4.4   Household Characteristics, i.e., Household Size, Educational Attainment and Average Household Income in Relation to Food Waste by NOVA Category

For all household sizes, the majority of waste occurred in the NOVA 1 category. One- person households wasted the most food per person in the NOVA 1 category (1190 g) and households of four or more, three and two people wasted similar amounts per person (801 g, 763 g and 787 g, respectively) (Table 13). Households of four or more people wasted the most NOVA 4 food per person (129 g) (Table 13).

Table 13 NOVA category (Table 6) of food waste in relation to household size, educational attainment and average household income per person over seven days (Table 8).

		NOVA 1 Food Waste (g)	NOVA 2 Food Waste (g)	NOVA 3 Food Waste (g)	NOVA 4 Food Waste (g)
	1	1190	0	46	128
Household size	2	787	1	12	58
	3	763	5	14	101
	4 or more	801	1	12	129
Highest educational attainment in the household	Postgraduate	790	1	16	93
	University degree	1037	3	26	118
	Below degree level	738	0	11	92
Average median UK household income in 2020 £29,900 p.a.*	Higher	815	2	13	93
	About median level	896	2	0	76
	Lower	984	0	45	141

Table 13 Note: All household data (n = 94) were normalised per person per week and all data were normalised by number of households in each category. * (Office for National Statistics, 2021).

Kruskal–Wallis tests established that there were no significant differences between food waste by NOVA category across groups of different household sizes (Table 14).

Table 14 Null hypotheses and test statistics for avoidable, unavoidable or possibly avoidable food waste (Table 7) in relation to household size, educational attainment and average household income (Table 8).

Category		NOVA 1 Food Waste (g)	NOVA 2 Food Waste (g)	NOVA 3 Food Waste (g)	NOVA 4 Food Waste (g)
Household size	Null hypothesis	The distribution of NOVA 1 food waste is the same across	The distribution of NOVA 2 food waste is the same across	The distribution of NOVA 3 food waste is the same across	The distribution of NOVA 4 food waste is the same across

Category	NOVA 1 Food Waste (g)	NOVA 2 Food Waste (g)	NOVA 3 Food Waste (g)	NOVA 4 Food Waste (g)
	categories of household size	categories of household size	categories of household size	categories of household size
Null hypothesis retained or rejected	Retained	Retained	Retained	
Kruskal–Wallis H	Kruskal–Wallis H 2.404, *p* = 0.493 **	Kruskal–Wallis H 4.088, *p* = 0.252 **	Kruskal–Wallis H 1.482, *p* = 0.687 **	Kruskal–Wallis H 6.356, *p* = 0.095 **
Highest educational attainment in the household Null hypothesis	The distribution of NOVA 1 food waste is the same across categories of educational attainment	The distribution of NOVA 2 food waste is the same across categories of educational attainment	The distribution of NOVA 3 food waste is the same across categories of educational attainment	The distribution of NOVA 4 food waste is the same across categories of educational attainment
Null hypothesis retained or rejected	Retained	Retained	Retained	
Kruskal–Wallis H	Kruskal–Wallis H 0.780, *p* = 0.677 **	Kruskal–Wallis H 0.972, *p* = 0.615 **	Kruskal–Wallis H 1.731, *p* = 0.421 **	Kruskal–Wallis H 1.098, *p*= 0.577 **
Average median UK household income in 2020 £29,900 p.a.* Null hypothesis	The distribution of NOVA 1 food waste is the same across categories of average household income	The distribution of NOVA 2 food waste is the same across categories of average household income	The distribution of NOVA 3 food waste is the same across categories of average household income	The distribution of NOVA 4 food waste is the same across categories of average household income
Null hypothesis retained or rejected	Retained	Retained	Retained	
Kruskal–Wallis H	Kruskal–Wallis H 1.958, *p* = 0.376 **	Kruskal–Wallis H 2.176, *p* = 0.337 **	Kruskal–Wallis H 3.505, *p* = 0.173 **	Kruskal–Wallis H 0.763, *p* = 0.683 **

Table 14 Note: each Kruskal–Wallis H test statistic was adjusted for ties; n = 94 households—data were normalised per person. Timeframe 7 days. * (Office for National Statistics, 2021)** Multiple comparisons were not performed because the overall test did not show significant differences across samples.

In relation to all educational attainment categories, the majority of food waste was in the NOVA 1 category. The most food waste in NOVA 1 and NOVA 4 occurred per person in the university degree

group (1037 g and 118 g, respectively). The post graduate group and below degree level group wasted similar amounts per person of NOVA 1 (790 g and 93 g) and NOVA 4 (738 g and 92 g) (Table 13). Kruskal–Wallis tests established there were no significant differences between food waste by NOVA category across groups in terms of educational attainment (Table 14). The amounts of NOVA 1 food waste were similar in all household income groups but highest in the lower income group (984 g) (Table 13). The waste of NOVA 4 food was similar across all income groups but greatest in the lower income group (141 g) (Table 13). Kruskal–Wallis tests determined that there were no significant differences in terms of food waste by NOVA category across groups of average household income (Table 14).

4.5   Discussion

After extrapolation, the total edible and inedible food waste amount per person per year for the current study was equivalent to 48.62 kg. This amount was similar to the 44.6 kg per person per year calculated from a recent household kitchen diary study in Germany including edible and inedible food waste from a representative sample of 6853 households (Herzberg, Schmidt and Schneider, 2020). Other household kitchen diary studies on food waste have reported lower values, but observations are broadly similar as they only pertained to avoidable food waste: 27.5 kg per person per year (an Italian study of 385 households) (Giordano *et al.*, 2019) and 23 kg per person per year (a Finnish study of 380 households) (Silvennoinen *et al.*, 2014). Although the current study captured similar amounts of food waste to other kitchen diary studies, it differs from household food waste quantification methods using other disposal pathways and waste composition analyses in Europe. For example, in the UK, it was calculated that household food waste was 108 kg per capita per year (Gillick and Quested, 2018). A comprehensive review on household food waste quantification methods concluded that there is no 'one best' method of food waste quantification at household level, rather it depends on the study objective, which in the current study placed importance on the composition of food waste, lending to the strength of the kitchen diary method (Withanage, Dias and Habib, 2021).

The majority of all food waste was in the NOVA 1 category (87%) and during the preparation stage (61%) (Table 9 and Table 10). Analysis showed that significantly greater quantities of food waste occurred during preparation than during the storage and consumption phases. An explanation for the majority of NOVA 1 food waste occurring in the preparation residue phase may be that NOVA 1 food generally presents an inedible and edible component defined by cultural and individual differences (Lebersorger and Schneider, 2011). To reduce the loss of unprocessed foods, a focus on interventions during the food preparation residue phase that addresses cultural and social norms in

demonstrating how to minimise loss of edible components (e.g., ends of courgettes and skins of mushrooms) would have merit.

Of the total food waste, 51% was NOVA 1 and either avoidable or possibly avoidable. There is thus the opportunity for big gains in reducing unprocessed food waste. This includes important components of a diet high in fresh produce, providing nutrients including fibre (Public Health England, 2020). Currently, the UK is not reaching the recommended levels of fruits and vegetables or fibre (Public Health England, 2020) contained in NOVA 1 foods. A number of NOVA 1 foods are relatively cheap (e.g., carrots and potatoes), and therefore it may be that consumers feel more relaxed about wastage. Additionally, it requires time, organisation and expertise to prepare food in the NOVA 1 category (De Laurentiis, Corrado and Sala, 2018; Conrad, 2020). Time and organisation may be more challenging to manage in certain households in comparison with others. A recent study of 4214 consumers across five European countries concluded that lifestyle patterns regarding food are linked to variations in food waste and the choice of suboptimal food, contributing to an understanding of differences in food waste amounts by household (Aschemann-Witzel, de Hooge and Almli, 2021). The study clustered certain households into the 'well-planning cook and frugal food avoider' that reported generating less food waste (Aschemann-Witzel, de Hooge and Almli, 2021). In contrast, households described as 'uninvolved with food and not focused on price' (thus not organising or investing time in food waste reduction behaviours) reported generating more food waste; another group were described as food uninvolved but focused on price and preferred convenience food, with this group tending to report generating lower amounts of food waste (the focus on price indicated a degree of organisation and time invested here) (Aschemann-Witzel, de Hooge and Almli, 2021). Ultimately, the values upheld by the household may dictate the amount of organisation and focus devoted to food management and affect food waste.

Prior research has shown a linear trend towards food waste amounts and household size (Quested, Ingle and Parry, 2013; Parizeau, von Massow and Martin, 2015; Herzberg, Schmidt and Schneider, 2020). However, relatively few studies have analysed household size in relation to the per-person food waste generated. In this regard, studies show mixed outcomes, with certain studies showing a linear trend (Parizeau, von Massow and Martin, 2015) and others not (Koivupuro *et al.*, 2012; Edjabou *et al.*, 2016). A study of household food waste in Denmark using a self-reported survey demonstrated that there were statistically significant relationships (at the $p < 0.01$ level) between household sizes and a range of pertinent variables concerning food waste generation (Stancu, Haugaard and Lähteenmäki, 2016). A further study indicated that single person households in Denmark generated higher avoidable food waste than those containing two persons, three persons and more than three persons, though this difference was not statistically significant, thereby suggesting that there was no significant difference per person (Edjabou *et al.*, 2016). A kitchen diary

study in Finland showed that the influence of household size resulted in differences between households with one person and those with five or more people ($p < 0.100$) when the dependent variable was waste per capita, but otherwise there was no significant difference (Koivupuro *et al.*, 2012).

The present study showed that households of two persons wasted less food per person than households of other sizes did, indicating a possibly greater need for interventions to focus on households of one, three and four or more. This observation was statistically significant. An explanation for this may include a reduced logistical burden or less indication of convenience-oriented waste management strategies in small households (e.g., two-person households) in contrast to larger households, as they were more likely to report disposing of food waste in the garbage stream (rather than the organics stream; $p = 0.032$) (Parizeau, von Massow and Martin, 2015). Smaller households, for example, have fewer dependents such as children putting demands on time, with unpredictable behaviour, or fewer scheduled work, school or extra-curricular activities (Evans, 2011). In contrast to a one-person household, a two-person household can share the organisational load in terms of managing food at home, possibly improving organisation and planning and thereby increasing the use of efficiency measures. Additionally, if a two-person household has a double income, this finance may add extra options regarding food choice, storage or cooking facilities that benefit food waste reduction. Certain studies of household food behaviours have indeed shown that two-person households may behave differently to households of different sizes (Visschers, Wickli and Siegrist, 2016; Schoeppe *et al.*, 2018; Leverenz *et al.*, 2019). These observations indicate a greater need, at least in the case study herein, for interventions to focus on households of one, three and four or more persons. We note that research findings with regard to the relationship between household size and food waste generation are not entirely consistent and that the outcomes of the present study may be specific to the research setting and participant group. Further research may be required to establish if and why two-person households differ from other household sizes in terms of food waste generation.

Unavoidable food waste was not significantly different between households of different sizes. Considering that 36% of all food waste in the current study was unavoidable, interventions to reduce or offset the environmental impact of food waste (e.g., food waste collection) would have merit, especially if supplied for all households. One way of increasing householders' engagement with food waste recycling is via nudges in terms of social norms or social norms and reminders or social norms and disclosure (Barker *et al.*, 2021). Conformity to social norms around food may be driven by increases in reward-related activity in the brain as behaviour streamlines with other people, which is consistent with the more general idea that reward is central to social conformity (Higgs, 2015). It has been shown that agreeing with the preferences and decisions of others activates psychological

reward networks, while disagreement has the opposite effect (Higgs, 2015). Thus, food waste recycling interventions may incorporate this knowledge to achieve successful outcomes.

The influence of education was also explored in relation to food waste classified by NOVA category and Avoidability. Overall, NOVA 1 was the most prevalent category of food waste across all educational groups, and differences in food waste between NOVA categories were not statistically significant. This observation indicates that the overwhelming issue of food waste is mostly in the unprocessed category for all households regardless of educational attainment (Table 13). Statistical analyses showed that possibly avoidable food waste occurred in statistically significantly greater amounts in the post-graduate and university degree groups in comparison with the below degree group. The highest level of education in the household thus appears to be a meaningful predictor of possibly avoidable food waste. These findings are different to a recent survey of 1518 Danish and 1511 Spanish consumers; in both of these countries, the education level was not associated with food waste behaviour (Grasso *et al.*, 2019). This outcome was determined using a prediction model that created a comprehensive measure of food waste behaviour including self-reported food waste behaviour, e.g., planning routines, shopping routines and food preparation practices combined with self-reported household food waste (Grasso *et al.*, 2019). An explanation for the outcomes of this study could be that households where the highest educational attainment is at least a university degree may be buying more fruits and vegetables with possibly avoidable parts and/or buying less frozen or tinned NOVA 1 food that has a longer shelf life and requires minimal preparation, e.g., frozen peas or tinned sweetcorn. Previous studies have shown that pro-environmental behaviours and education level are linked (Qi and Roe, 2016), e.g., those with a higher level of education may consume a more plant-based diet which may have more possibly edible components or reduce packaging waste, i.e., they might not buy frozen vegetables due to plastic waste. However, perhaps the issue is that despite pro-environmental intentions, competence in this area and behaviours towards reduce food waste are lacking. This indicates a need for interventions to address this gap, particularly in households with educational attainment to degree or post-graduate level.

Although not statistically significant, avoidable food waste was greater per person for lower income households than for higher income households, and unavoidable and possibly avoidable food waste weights were lower per person for lower income households than for higher income households (Table 12). Explanations for wasting more avoidable food include difficulties in the portion sizing of meals, increases in intuitive eating, the desire not to overeat, a dislike of food or fussy children (Schanes, Dobernig and Gözet, 2018; Ellison and Prescott, 2021). Greater avoidable food waste may also be explained by difficulties in terms of equipment and infrastructure at the household level or perceived control, expertise and skill at the individual level regarding food storage, preparation and consumption, perhaps driven in part by social structural differences external to the household

(Boulet, Hoek and Raven, 2021a). This could be solved by a cross-organisational education approach in health, education and social care settings (Conrad, 2020). Increases in intuitive eating or a desire not to overeat, driven by health awareness, may be a greater factor for food waste in the NOVA 4 category (Ellison and Prescott, 2021). These aspects merit consideration in the design of interventions that aim to reduce food waste and improve health.

Although the current study showed significant results regarding food waste and household demographics, it remains important to consider alternative approaches to interventions given that households differ due to a variety of internal and external factors (Boulet, Hoek and Raven, 2021a). Prior research has concluded there is value in focusing on foods that are most often wasted rather than custom-fitting interventions to household demographics (Shaw, Smith and Williams, 2018). Thus, there is, for example, merit in the waste composition data categorised by NOVA. An alternative approach could be to reinforce interventions by types of food waste aligned with NOVA 1, which may offer important health benefits while supporting food waste reduction and improving food security (Conrad, 2020).

4.5.1   Implications

The present study provides the basis for recommendations to be made for affluent regions in high-income countries, most specifically for populations who are environmentally and/or socially aware and have agency, to direct resources or programs to simultaneously reduce food waste and improve nutrition. It is recommended to focus on avoidable unprocessed food waste in the preparation and serving phase, especially for households of one, three or four+ persons. Additionally, a focus on interventions to reduce possibly avoidable food waste should be targeted towards those with householders educated to university degree level or higher. Strategies could encourage, for example, the use of unprocessed foods, especially fruit and vegetables that have a longer shelf life and are easy to prepare or are pre-prepared, such as tinned and frozen fruits and vegetables. The present study identifies opportunities to coordinate household food waste recycling for unavoidable and unprocessed food waste, e.g., coffee grounds and tea leaves. A potential added benefit to engaging householders in food waste recycling likely includes an increased awareness of the amount of household waste that comprises food (Barker *et al.*, 2021). In some cases, this information, learning and knowledge may be in part a driver for change to reduce food waste (White, Habib and Hardisty, 2019).

Photograph diaries using social media and smart phones was feasible and acceptable to the participants recruited (Table 8), as evidenced by the study's high participant retention levels (99% of consenting participants fully completed the study). This method enables the acquisition of objective

and meaningful data that can be easily collected by participants as part of their daily routines. Additionally, the visual nature of the data collection means that language barriers may be circumvented (Amano *et al.*, 2021). The photographic diary method involved data entry that was time consuming for researchers but could be improved upon by simplifying the method, with improved instructions for participants, i.e., being more specific about participants providing photographs of foods separated by each category, e.g., recording images of fruit only, rather than mixed fruit and vegetable peelings. Furthermore, the photographic diary method could potentially be used alongside machine learning technology as a means to accelerate data capture (Espinoza, 2019; Frost *et al.*, 2019; Mazloumian, Rosenthal and Gelke, 2020).

The NOVA categorisation offers a simple and meaningful way to categorise food in terms of its value for nutrition and provides useful data in a way that can be generated more easily to guide interventions (Cooper *et al.*, 2018). Previous research has not used NOVA categories in relation to food waste as a way of identifying ultra-processed, processed, minimally processed and unprocessed foods that are discarded by householders without being consumed. Previous studies examining food waste and nutrition in the UK and Europe using primary data have provided a detailed analysis on the weights of specific nutrients such as vitamin C, B12 or fibre lost in food waste at home (Spiker *et al.*, 2017; Cooper *et al.*, 2018; Chalak *et al.*, 2019). More broadly, such approaches have the potential to contribute to efforts to achieve global sustainability objectives, particularly SDG 12.3 (Responsible Consumption and Production) and SDG 2 (Zero Hunger). Strategies that simultaneously address both of these goals have clear merit in terms of efficiency and resource effectiveness. We recommend that 1. efforts to review and revise household food waste data may benefit from the addition of NOVA classification and 2. the photographic diary methodology is adopted more widely as a cost-effective measure of data capture (WRAP, 2021). These methods may also have value for the regular measurement of household food waste required as part of the EU circular economy action plan (Reynolds *et al.*, 2020) or to assess the effectiveness of food waste interventions.

4.5.2   Limitations and Future Research

The time frame of the study was limited to seven consecutive days; nonetheless, this timeframe was valuable as it included working days and weekends. There remains a risk that participants may have changed their general food waste behaviour in response to active participation in the study (Quested *et al.*, 2020). Additionally, as each household's profile was reported by one person, it was possible that food waste from others in the household may have been missed. However, as the same methods were used by all participants, the data offered patterns of food waste that were comparable, as all participants were limited in a similar way.

The demographics of the participant sample recruited to the research differed to the demographics of Hampshire with regard to gender, highest educational attainment, age and number of households with children. The majority of participants were female (Table 8), and this high female percentage may be related to how gender dynamics affect roles of food preparation in households or the social platforms used to recruit (Murphy and Parry, 2021). The number of participating households with the highest level of educational attainment level, post-graduate degree (Table 8), was higher than the Hampshire average (Nomis, 2011). This may be related to a correlation between level of education and environmental concerns, for example, surrounding food waste (Evans, 2011). The smallest proportion of participants were aged over 65 years. The lower number of participants over 65 years may be related to the study advertisement or recruitment platforms, as only 34% of adults over 65 in the UK access social networking (Office of National Statistics, 2020). The highest proportion of participants were aged 35–49, with this possibly being linked to the high number of households with children recruited to the study. The study sample was greater than the Hampshire average regarding households living with a partner and child or children: 45.7% compared with 27.9% (Table 8) (Nomis, 2011). It is possible that this was related to families with children having more issues with food waste. A review on household food practices showed that households with children generate more waste from meals given the unpredictable eating patterns and preferences of children alongside it being difficult to predict whether children will be eating at home at all (Schanes, Dobernig and Gözet, 2018). It is important to highlight that the observations and outcomes of the present study do not necessarily apply to everyone everywhere but are specific to the study; the generalisation of these outcomes is unlikely to be robust. However, there is value in the categorisation of food waste data by NOVA, the demographic analysis of the results, the method of collecting data, and insights that would be useful for future research in other settings.

The participant sample largely selected all responses relating to never experiencing food insecurity on the food security survey (94.7%). However, the results offer insights for targeting food wastage in currently food-secure households, and, with rising costs of living (Harari *et al.*, 2022), even households with a previously sufficient income may experience difficulties in affording food in comparison to previous years. For future research that includes more food insecure households, the current study will be useful as it showed that smartphones were acceptable for participants including those in lower income groups (21.3% of the sample) and those experiencing a level of food insecurity (5.3% of the participant sample answered yes to one relevant food insecurity question). For future research, smartphones with an internet connection could be loaned where needed. It may be that a greater financial incentive could be offered to make involvement in the research worthwhile for households experiencing food insecurity. In order to further research the linkages between food waste, food insecurity and diet quality, research on food waste patterns within populations

specifically experiencing food insecurity would have value, especially if we are to develop sustainable food systems.

The present study suggests specific areas of food waste to target in households for maximum food waste reduction. To follow on from this, to understand how to tailor interventions for effective food waste reduction, future research into how personal values affect lifestyle patterns or household cultures in terms of food management and food waste would have merit. A future study leading on from the present one may involve predicting unavoidable and possibly avoidable food waste from secondary data, i.e., the NDNS report (Public Health England, 2020). This could provide a measure of unavoidable food waste in the UK to understand requirements for food waste recycling. It could also provide an indication on a larger generalisable scale of how much possibly avoidable food waste arises in order to inform interventions targeting this problem.

4.6   Conclusions

In response to concerns regarding household food waste, diet quality and food insecurity in high-income countries, this study aimed to evaluate the type and amount of food waste at household level and by household characteristics. The study concludes that unprocessed foods form the largest portion of household food waste, particularly during preparation. Key focus points include a reduction in avoidable unprocessed food waste in one, three and four+ person households and a reduction in possibly avoidable unprocessed food waste in households with an educational attainment of at least a university degree. Solutions may include public health interventions encouraging healthy unprocessed food that require less preparation or are frozen. These interventions may become increasingly necessary in high-income countries where households with previously sufficient incomes may experience difficulties in budgeting for food in the face of increasing costs of living. Thus, targeted interventions to reduce food waste may provide an additional protective measure for food security and diet quality.

comply with requirements from the University Ethics Committee, the data are not publicly available due to ethical restrictions, and the PIS states that the data will not be shared.

Conflicts of Interest: The authors declare no conflict of interest.

Chapter 5 Exploring Motivation Towards Household Food Waste Behaviour Change Using Self-Determination Theory

5.1 Abstract

Food waste is responsible for a considerable 8-10% of total global greenhouse gas emissions and food insecurity is rising. In Europe the majority of food waste occurs at the household level. There is a disparity between related motivations for food waste reduction behaviour and actual practice at the household level. Competing priorities of conflicting goals at home can interfere with prioritising food waste reduction behaviours. The research aimed to use a theory of motivation to understand how motivations align with competing priorities in households, and uncover what supports and hinders daily motivation for food waste reduction. Twenty individuals were selected purposively for semi-structured qualitative interview and sixteen consented to participate. Interviews were transcribed verbatim, coded inductively and deductively using thematic analysis. Five themes materialised: personal day-to-day drivers that motivated food waste reduction behaviours, barriers to food waste reduction behaviours, perceived autonomy, perceived competence and perceived relatedness. Different types of motivation had different effects on food waste reduction behaviours. Motivation that effectively aligned with competing priorities inclined towards intrinsic or integrated regulatory processes comprising autonomous motivation, combined with an emotionally tangible reward, e.g., quality time with family. A multiplicity of motivations strengthened further the drive to change, e.g., motivations energised by identified, introjected or external regulatory processes (care for the earth, guilt, and money saving respectively) enhanced strength of the intrinsic/integrated motivation for food waste reduction behaviour, when alone they were less motivating. Barriers to food waste reduction behaviour included feeling overwhelmed by work and/or children, tiredness or disorganisation, thus supporting psychological wellbeing is essential for optimal motivational traits. Encouraging different types of motivations, alignment of motivations with competing priorities, and barrier mitigation techniques in food waste reduction interventions has merit to actualise food waste reduction behaviours. Additionally, to optimise individual motivations a personalised and tailored intervention approach could be suitable.

5.2 Introduction

Amidst the worldwide climate crisis (IPCC, 2018) food waste is responsible for a considerable 8-10% of total greenhouse gas (GHG) emissions (United Nations Environment Programme, 2021). GHG

emissions are expended in the management of resources, practices and transport during agriculture, harvesting and processing phases of food production, retail and consumption (United Nations Environment Programme, 2021). In Europe, the majority of food waste occurs at the household level post-farm gate (Zeinstra, van der Haar and van Bergen, 2020; Jeswani, Figueroa-Torres and Azapagic, 2021). In the UK, in 2021 approximately 8% of households experience food insecurity (Defra, 2021b), more recently it was estimated that 17% of households experience food insecurity (The Food Foundation, 2023a). Food waste contributes to this social injustice because edible food is wasted while food insecurity and hunger remain major concerns (Pérez-Escamilla, 2017; United Nations Environment Programme, 2021; Smith and Thompson, 2023). Additionally, previous research concluded that much edible food waste in the UK comprises unprocessed foods, which are important for a healthy diet and diet-related health (Barker *et al.*, 2023). Household food waste reduction strategies will likely have a positive impact via encouraging more consumption of typically healthier unprocessed foods that would have been discarded, which may improve diet quality and food security. Thus, improved food behaviours to reduce food waste, to address GHG emissions and food security, specifically at the household level in the UK, have merit. In the UK, the Courtauld 2025 commitment aims to reduce UK food waste (post-farm gate) by 20% per person by 2025 in comparison with a 2015 baseline (WRAP, 2020a). Furthermore, the 25 Year Environment Plan and Resources & Waste Strategy targets exist to eliminate food waste to landfill before 2030 and to eradicate avoidable food waste before 2050 (Defra, 2018; HM Government, 2018). Evidence for effective interventions at the household level in the UK to support these policies is limited.

Consumers' motivation to avoid food waste has extensive influence on their food waste behaviours (Aschemann-Witzel *et al.*, 2015). Studies on household food waste have shown that feeling in control and having self-efficacy supports food waste reduction behaviours (Stancu, Haugaard and Lähteenmäki, 2016; Visschers, Wickli and Siegrist, 2016; Aschemann-Witzel *et al.*, 2020). However, there is a disparity between related motivations and actual practice at the household level (Fiore *et al.*, 2017; Setti *et al.*, 2018; Hazuchová *et al.*, 2019; Elimelech *et al.*, 2023). Competing priorities of conflicting goals at home can interfere with prioritising food waste reduction behaviours (Ananda *et al.*, 2023), even if awareness of the environmental problems of food waste are known or pro-environmental intentions exist in the household (Graham-Rowe, Jessop and Sparks, 2014; Aschemann-Witzel *et al.*, 2015; van Geffen *et al.*, 2020; Wang, McCarthy and Kapetanaki, 2021). Goal framing theory may provide an explanation for this occurrence, i.e., reducing food waste is a normative goal (linked to acting in a pro-social or pro-environmental way), with gains that are non-personal and distant (Lindenberg and Steg, 2007; White, Habib and Hardisty, 2019; van Geffen *et al.*, 2020; Rohenkohl do Canto, Grunert and Dutra de Barcellos, 2023). Due to these distal 'gains', this goal may be overruled by more hedonic goals (linked to instant gratification or pleasure) or gain-

oriented (linked to maintaining resources such as one's health or money) (Vermeir and Verbeke, 2006; Nielsen, 2017; van Geffen *et al.*, 2020). Additionally, consumers will usually be less inclined to adopt a new goal or set an intention if they realise that this conflicts with existing goals (Nielsen, 2017; van Geffen *et al.*, 2020).

Previous studies have explored motivations and barriers for consumer food waste reduction (Graham-Rowe, Jessop and Sparks, 2014, 2015; Aschemann-Witzel *et al.*, 2015; Fiore *et al.*, 2017; Setti *et al.*, 2018; Urrutia, Dias and Clapp, 2019; Bravi *et al.*, 2020; Ilakovac, Cerjak and Voca, 2020; van Geffen *et al.*, 2020; Zeinstra, van der Haar and van Bergen, 2020; Nabi, Karunasena and Pearson, 2021; Soma, Li and Maclaren, 2021; Wang, McCarthy and Kapetanaki, 2021; Filimonau *et al.*, 2022; Matharu, Gupta and Swarnakar, 2022; Stancu and Lähteenmäki, 2022; Chen, 2023). In European settings, psychological theoretical frameworks have been applied to explore and understand food waste motivation and behaviour. These include the Theory of Planned Behaviour (TPB) (Ajzen, 1991; Graham-Rowe, Jessop and Sparks, 2015; Setti *et al.*, 2018), the Motivation, Opportunities and Abilities (MOA) framework (Ölander and Thøgersen, 1995; van Geffen *et al.*, 2020; Zeinstra, van der Haar and van Bergen, 2020) and the Norm Activation Model (NAM) (Schwartz, 1977; Filimonau *et al.*, 2022). Psychological theories of self-efficacy have also been identified as relevant to food waste reduction behaviours (Bandura, 1977); Aschemann-Witzel *et al.*, 2020). In high income cultures but non-European settings, the TPB and the MOA framework have also been used (Soma, Li and Maclaren, 2021; Chen, 2023). Other models used include the augmented NAM in Singapore and Australia (Wang, McCarthy and Kapetanaki, 2021); and, in Canada, the visceral-material framework (Urrutia, Dias and Clapp, 2019). In India, the TPB, the theory of interpersonal behaviour (TIB) (Triandis, 1979) and the MOA framework were used (Matharu, Gupta and Swarnakar, 2022).

However, none of these theories or frameworks differentiate motivation by 1) more than two types, for example, extrinsic and intrinsic motivation or 2) strength, for example, the likelihood of motivation to maintain behaviours. Neither do these theories take into account the emotional processes in decision making. These aspects merit exploration if we are to further our understanding of how competing priorities may align with food waste reduction behaviour.

5.2.1 Self Determination Theory

Self Determination Theory (SDT) stipulates that people work to attain integration of new material into their unique sense of self and that the environment can support or disrupt the process (Deci and Ryan, 2015). SDT states that all humans have three psychological needs: autonomy, competence and relatedness, the satisfaction of which promotes optimal motivational traits. The theory highlights distinction between autonomous and controlled motivation: autonomous motivation comprises

actions full of willingness, wholly endorsed due to interest, enjoyment or consistency with deeply integrated values; while controlled motivation comprises actions derived from seduction, coercion or obligation (Deci and Ryan, 2015). The SDT proposes the more internalised the value or belief is, the more the behaviour enacts autonomously, and that autonomous motivation predicts better the maintenance of behaviours, particularly for heuristic actions (Deci and Ryan, 2015). There is differentiation between motivational nuances depending on the regulatory process that energises the motivation (intrinsic, integrated, identified, introjected, external or non-regulation) (Thiermann and Sheate, 2020). To understand the emotional expression of these regulatory processes prior research has identified examples for pro-environmental behaviour: intrinsic (offers me pleasure), integrated (to me it feels meaningful), identified (to me it feels like the right thing to do), introjected (I fear criticism/I feel guilt), external (I receive financial reward/ I want to avoid punishment) and non-regulation (I don't understand why) (Thiermann and Sheate, 2020). For example, a feeling of duty based on guilt, anxiety avoidance or pride would comprise controlled motivation, however a feeling of duty based on loyalty, righteousness or responsibility to personal values could comprise autonomous motivation (Thiermann and Sheate, 2020). A motivational theory that allows for this level of nuance has not been applied to explore household food waste behaviour specifically.

5.2.2   Aims and Objectives

This research focuses on motivations for food waste behaviour change in the UK with a desire to reduce GHG emissions and strengthen household food security, with particular attention to diet quality. The research aimed to investigate how motivation for food waste reduction behaviour may align with competing priorities at home to influence food waste reduction behaviour. The objectives were:

1. To explain how motivations for food waste reduction behaviour align with competing household priorities to influence food waste reduction behaviour
2. To explain what may hinder or support daily motivation for food waste reduction
3. To provide an essential contribution to develop effective behaviour change interventions for food waste reduction

This study responds to the call for research to explore food waste behaviours more holistically, as well as behaviours relating more generally to a sustainable lifestyle (Roodhuyzen *et al.*, 2017; Schanes, Dobernig and Gözet, 2018; Aschemann-Witzel *et al.*, 2020; van Geffen *et al.*, 2020). It provides an essential contribution to develop effective behavioural-change interventions for food waste reduction (Stöckli, Dorn and Liechti, 2018; Reynolds *et al.*, 2019) that can support climate and food security goals in high income countries.

5.3 Materials and Methods

5.3.1 Participants and Sampling Procedures

Qualitative interview research methods were selected to provide insight of the experiences and emotions of people, offering richness, depth and breadth to explanations (Nicholls, 2009a). Participants were selected purposively from a sample of ninety four individuals who had previously participated in a one-week photographic food waste diary study in Hampshire, UK, see (Barker *et al.*, 2023) for sampling procedures and methods of data collection for sociodemographic characteristics. Purposive sampling led to a group of participants with diversity of sociodemographics, specifically income, education and housing tenure (Nicholls, 2009b). Twenty individuals were invited to the study via email, this included a participant information sheet and £10 voucher incentive as a token of appreciation for study completion. These recruitment methods were similar to previous qualitative studies on household food waste (Graham-Rowe, Jessop and Sparks, 2014; Ilakovac, Cerjak and Voca, 2020). Sixteen participants (Table 15) agreed to participate. The study was approved by the University's ethics committee (reference 66350).

5.3.2 Interview Procedure

The semi-structured interview schedule is available in Appendix C.1. The interviews lasted 30-45 minutes and this was consistent with other qualitative studies on household food waste (Graham-Rowe, Jessop and Sparks, 2014; Ilakovac, Cerjak and Voca, 2020). The conversations continued until saturation was reached to foster rigour in the data (Nicholls, 2009b). Data saturation was judged to have been reached when participants were repeating their perspectives rather than adding new ideas to the conversation or when they expressed clearly that they had nothing more to add on the topic. Additionally, the interviewer reflected on their personal perspectives (i.e., being a parent and educated to post-graduate level) prior to interviewing to raise self-awareness and promote neutrality and objectivity during the interviews (Nicholls, 2009b). This enabled the interviewer to guide the recorded conversations whilst allowing the direction of the conversation to be driven by participants. Questions were derived from and informed by available literature on motivation to reduce household food waste (Evans, 2011; Graham-Rowe, Jessop and Sparks, 2014; Ilakovac, Cerjak and Voca, 2020). The interviews were audio or video recorded, transcribed verbatim and checked for accuracy during transcription. All consent forms, recordings and transcriptions were stored in password protected folders on a secure network.

5.3.3   Thematic Analysis Procedure

The methods used align with recently published work in related fields using qualitative analysis with a theoretical framework (van Geffen *et al.*, 2020; Allison *et al.*, 2022; Manika *et al.*, 2022). Thematic analysis following Braun and Clarke (2006) and Braun and Clarke (2022) were applied. First, the interviewer familiarised themself with the data through conducting all sixteen interviews, transcribing five of the interviews verbatim (transcription of eleven interviews was outsourced) and reading and re-reading all sixteen transcripts. Initial codes were generated before searching for themes, reviewing themes and defining and naming themes (Braun and Clarke, 2006). The data were first coded inductively; themes from the data were actively identified by the researcher and a coding frame compiled (Appendix C.2) to generate clear definitions for each theme (Braun and Clarke, 2006; van Geffen *et al.*, 2020; Allison *et al.*, 2022; Manika *et al.*, 2022). Subsequently, the themes in the coding frame were further coded deductively based on corresponding categories relating to the SDT (Allison *et al.*, 2022; Manika *et al.*, 2022). The themes and coding frame were shared with authors (DS and PS). Each author commented on the agreement of the themes and the coding frame with the data and whether any additional themes needed to be added, renamed, split or merged.

5.4   Results

Sociodemographic characteristics of the sixteen participants are described in Table 15; the methods for this data collection are outlined in previous published work (Barker *et al.,* 2023). Eight households that had above average income were all home owners. Five respondents had lower than average household income: three were renting and two were home owners. All households with four or more people had higher than average income and all households with one person had lower than average income. Of the eight respondents living in households with children, seven had higher than average income and one had lower than average income. Seven respondents were from households with post-graduate as highest educational attainment. For each educational group there were a range of income and rental/home ownership demographics. All respondents who scored at least one response triggering a classification of food insecurity on the "Six-Item Food Security Module" (Economic Research Service: US Department of Agriculture, 2012) were renting, had average or lower than average income and none were from households with post-graduate qualification(s) as highest educational attainment.

Table 15 Socio-demographic characteristics of the interview participants (n=16)

ID	Housing Tenure	Gender	Age	House hold size	Children (age range)	Ethnicity	Household Income compared to average*	Education, highest in household	Food in-security **
FW9	Home owner	F	40-44	7	5-9;10-14;	Asian or Asian British	Higher	Post graduate studies	
FW23	Rent	M	25-29	2		White – UK & Ireland	Lower	Post graduate studies	
FW33	Home owner	F	45-49	4	10-14;15-18;	White – UK & Ireland	Higher	Post graduate studies	
FW34	Home owner	F	50-54	3	5-9;	White – UK & Ireland	Higher	GCSE/NVQ or equivalent	
FW36	Rent	F	35-39	2		White – UK & Ireland	Average	University degree	Yes
FW42	Home owner	F	35-39	4	0-4;	White – Not UK & Ireland	Higher	Post graduate studies	
FW56	Rent	F	45-49	2	15-18;	White – UK & Ireland	Lower	GCSE/NVQ or equivalent	Yes
FW51	Home owner	F	40-44	4	10-14;15-18;	White – UK & Ireland	Higher	Post graduate studies	
FW67	Rent	F	40-44	1		White – UK & Ireland	Lower	University degree	Yes
FW68	Rent	F	50-54	3		White – Not UK & Ireland	Average	GCSE/NVQ or equivalent	Yes
FW79	Home owner	F	35-39	4	0-4;5-9;	White – UK & Ireland	Higher	Post graduate studies	
FW75	Home owner	F	50-54	1		White – UK & Ireland	Lower	University degree	
FW86	Home owner	F	60-64	1		White – UK & Ireland	Lower	University degree	

ID	Housing Tenure	Gender	Age	House hold size	Children (age range)	Ethnicity	Household Income compared to average*	Education, highest in household	Food in-security **
FW82	Home owner	F	45-49	4	10-14;	White – UK & Ireland	Higher	University degree	
FW87	Home owner	F	50-54	2		White – UK & Ireland	Average	GCSE/NVQ or equivalent	
FW16	Home owner	F	70-74	2		White – UK & Ireland	Higher	Post graduate studies	

Note: Abbreviations: F = Female; M= Male. * Compared to UK household average median income of £29,000 per annum (Office for National Statistics, 2021) **Scored at least one positive response to the "Six-Item Food Security Module" (Economic Research Service: US Department of Agriculture, 2012)

To illustrate the food waste weight of participants households Table 16 shows the measured food waste weights per person per household for seven days alongside key socio-demographics. These data were calculated from a seven-day household photographic food waste diary that all the respondents had previously participated in, see (Barker *et al.*, 2023) for data collection procedures. Table 16 has been included to illustrate the persistence of food waste across all socio-demographic groups in the study sample. Table 16 shows that households on lower income or attaining one positive response on the food security survey (Economic Research Service: US Department of Agriculture, 2012) sometimes had high levels of avoidable food waste relative to the sample, as did highly educated high-income households. These findings offer support in developing food waste reduction interventions not only for highly educated and higher income households, but also for households that struggle to afford food.

Table 16 Normalised food waste weights per person per household over seven days and key socio-demographics

	Avoidable (g)	Possibly Avoidable (g)	Unavoidable (g)	Total (g)	Household Income compared to average* & Renting (R)	Household Size & Presence of Children (Ch)	Highest educational attainment in Household
FW9	389	**0**	106	**495**	Higher	(Ch) 7	Postgrad
FW23	**68**	174	255	496	(R) Lower	2	Postgrad
FW33	616	33	341	990	Higher	(Ch) 4	Postgrad
FW34	726	56	83	865	Higher	(Ch) 3	GCSE
FW36	106	**511**	455	1071	(R**) Average	2	Degree
FW42	372	165	227	764	Higher	(Ch) 4	Postgrad
FW56	**1402**	45	**5**	1451	(R**) Lower	(Ch) 2	GCSE
FW51	387	364	363	1114	Higher	(Ch) 4	Postgrad
FW67	895	215	71	1181	(R**) Lower	1	Degree
FW68	534	38	121	693	(R**) Average	3	GCSE
FW79	953	60	235	1248	Higher	(Ch) 4	Postgrad
FW75	894	283	511	1688	Lower	1	Degree
FW86	1110	0	**600**	**1710**	Lower	1	Degree
FW82	401	105	91	597	Higher	(Ch) 4	Degree
FW87	**68**	264	593	925	Average	2	GCSE
FW16	183	355	225	762	Higher	2	Postgrad

Note: Abbreviations: g = grams; Ch = children in the household; R = renting; GCSE = GCSE/NVQ or equivalent; Postgrad = Postgraduate studies; Degree = University Degree. In Bold: Largest and smallest weights in each category. * Compared to UK household average median income of £29,000 per annum (Office for National Statistics, 2021). ** Scored at least one positive response to the "Six-Item Food Security Module" (Economic Research Service: US Department of Agriculture, 2012).

Five core themes were actively selected based on the SDT and are summarised in the thematic analysis coding frame (Appendix C.2). The first theme highlighted the personal day-to-day drivers that motivated food waste reduction behaviours. Individuals were most strongly motivated to carry out food waste reduction behaviours because they found these behaviours either enjoyable or interesting, or consistent with integrated personal values. These autonomous motivations for food waste reduction were energised by intrinsic, integrated and identified regulation and comprised: time saving, efficiency measures, creative inspiration and money saving. This theme also included examples of controlled motivation for food waste reduction behaviour energised by introjection or external regulation, comprising of guilt or negative emotions or sole monetary gain. The second theme identified key social and lifestyle barriers to food waste reduction behaviours. These included: lack of time, tiredness, overwhelmed by work and/or children and disorganisation. The third theme was 'perceived autonomy'. Here, interviewees made changes to their behaviour as individuals despite living with other people in a family, and expressed self-belief in their ability to make a positive difference. The fourth theme was 'perceived competence', which indicated that perceived competence in understanding the food waste problem inspired motivation to seek new knowledge, perceived competence in self-education in new skills supported beneficial choices to reduce waste, and perceived competence in thinking consciously supported establishing new habits. The fifth theme illustrated 'perceived relatedness' (i.e., how relationships with other people, society and the environment were perceived) as a key factor in supporting and sustaining daily motivation for food waste reduction behaviours. Aspects that supported motivation for daily behaviour change included: social influence, particularly via social media; care for the earth and others; and upbringing. The five themes are described (sections 5.4.1 to 5.4.5) and illustrated with quotes, with indication as to their occurrence within one or more sociodemographic groups on the basis of household size, presence of children in the household, highest educational attainment in the household or average household income.

5.4.1   Personal day-to-day drivers that Motivated Food Waste Reduction Behaviours

5.4.1.1   Psychological Boost as a Motivational Driver

Positive influences on food waste reduction behaviours included a psychological boost (a tangible emotional expression) from a sense of satisfaction of achieving a desired value, for example, an efficiency measure, saving money or a creative inspiration twinned with the more tangible emotional expression of what the desired value brought in itself e.g., time-saving, money saving or a new novel dish to enjoy. When individuals cultivated behaviours (e.g., meal planning) that achieved immediate tangible goals e.g., saving time alongside the less tangible value of reducing food waste, it appeared to strengthen the motivation for food waste reduction behaviour. This theme was repeated across all

sociodemographic groups.

> "I feel good when I have used up everything and I kind of think: 'ah', it does give you that sense of satisfaction that whatever … you need to use up … put it together with something and rustle-up something … I just feel good about that … we're not wasting stuff, … we're eating something nutritional… it ticks every box really which … feels like an achievement" FW82

Creative inspiration derived from planning meals or using up leftovers was described as a 'psychological boost' and 'much more exciting', as well as a tool to reduce boredom. This driver tended towards individuals who enjoyed cooking and was repeated across all sociodemographic groups.

> "I'm like, 'Oh I need to plan my food for next week.' I always look forward to doing it. And then this week I've been to the library and got a new recipe book… generally I get bored if things are the same all the time … so I try and use that." FW34

> "It's a source for inspiration… having the leftover of something and recreating it into something else … Is much more exciting. It's a completely different part of me." FW33

> "I think, the cookery side … is a key thing… if you're only following a recipe then you get to a point of thinking: "oh, well", you only have eighty grams of mushrooms or--- or whatever it is and you won't use any more and--- and then you get the food waste whereas if you know if you chuck-in another few there or you cook something in something else it's not going to ruin that, … then that freedom …makes all the difference …that could really change both nutritional side but also food waste." FW82

Efficiency measures were important drivers and included: pre-baking and freezing potatoes for convenience another day, meal planning to save time on busy days, and preparing extra food at dinner so there were leftovers for lunch. Respondents reflected that these approaches supported food waste reduction because they improved the convenience of running a household by efficiency or ease. Furthermore, if behaviours worked by offering these benefits they were repeated. Time-saving measures improved quality of life, for example saving time by planning a quick easy meal on a busy day which reduced stress. The sub-theme of efficiency measures and time saving as driving motivational values was repeated across respondents regardless of sociodemographics.

"I think, 1) because I did see an impact in our food waste but 2) because actually … I didn't realise at the time but …[*batch cooking at the weekend*] it's more efficient and … it's easier for me to cook … one or two big things at the weekend and then … we'll have those … inter-dispersed with … freezer meals which have no waste and… then actually we do like reduce our waste." FW79

"I would maybe prep more so if then there are leftovers so he can take it for lunch the next day. So we do things like that to be a bit more efficient with like using food and cooking and time" FW34

5.4.1.2   Saving Money

Respondents across all sociodemographic groups appreciated saving money. The combination of wasting food and wasting money was perceived as a difficult emotion, or punishment. Some respondents prioritised saving money over other interests like food variety or the fun of shopping in store (opting for online shopping as it was easier to keep within a budget). Individuals from lower and average income households were more likely to discuss prioritising saving money over other interests, while respondents from higher income households were more likely to say they were more motivated by the environmental impact than money saving.

"Probably the trial and error that--- so, it's financially. I feel like I'm--- I don't want to spend my money on things I'm just going to throw away" FW75

"I do usually buy the same things every week but--- so, I don't (*laughing*) have a big variety of stuff which keeps my costings down" FW56

"It is partly to keep the bill down, like so we don't spend more money, but mostly it's to like reduce our impact on the planet" FW51

(*regarding being motivated by the environment)* "It does a little bit feed into it, but a lot of it is the time and the money saving, I'll be honest with you" FW87

5.4.1.3   Valuing Healthy Eating was a Motivational Driver for Planning and Conscious Decisions Around Food

Healthy eating values did not appear to motivate food waste reduction behaviours alone, but they were connected through cooking skills. This connection offered considerable capacity for alignment, particularly as the thinking and consciousness around food was increased. For example, some interviewees made meal plans to facilitate a healthy diet, and this planning facilitated better organisation which can lower the likelihood of waste. These patterns were observed among

respondents in all household income groups and larger and smaller household sizes. The interviews also showed that an interest in healthy eating and cooking, although not a high priority for everyone, was shared by individuals across socio-demographics of housing tenure, educational attainment and age. The idea that planning was helpful was expressed across all respondents, however the motivation to plan was different across respondents as some individuals did not enjoy planning in advance and preferred to live spontaneously.

> "…more planning and also realising that when I don't plan, I just eat toast and marmite so, there's a real idea around getting more organised" FW75

> "I cook from scratch more for the health factor and for the fact that it wasted less, and it was cheaper all round really… I've really got better at cooking so, I … don't need a recipe for a lot of stuff, I will just use up what's in the cupboard … So, it's been a conscious decision to waste less and to ensure that the quality of the food is there and that the nutritional value is better." FW82

5.4.1.4   Guilt or Other Negative Emotions Around Food Waste from Personal Action

Guilt had an effect on emotions at home and avoiding the negative emotion appeared to be a motivating factor to reduce food waste for respondents across all sociodemographic groups. However, guilt not only linked to motivating food waste reduction behaviours, but also linked to other unhealthy food behaviours. For example, two respondents who described considerable guilt in relation to food waste also described habits of overstocking food in cupboards.

> "…saving money because when you're throwing it (*food*) away if feels like I could just be throwing money in the bin. Also, the guilt over not having eaten that food and that you know it could have donated" FW67

> "…it makes me feel quite guilty, kind of bad for doing it (*wasting food*). It's why I try my hardest to make her portion of chicken smaller" FW23

5.4.2   Social and Lifestyle Barriers to Food Waste Reduction Behaviours

A key barrier included perceptions of being time poor, tired and overwhelmed by the demands of work and/or children. This led to feeling that "you can't be bothered to make that extra effort…because I'm tired" FW42. These barriers contributed to decisions around food that deviated from anticipated routines making it more likely that food wasn't used up before it deteriorated. Respondents across all sociodemographic groups experienced similar barriers. Respondents with

children in their households tended to cite the responsibility they had for their children as contributing to this overwhelm, which was different to households without children.

> "I think it's definitely depends…on my lifestyle at home. So, if I'm working in a very stressful job, I think I tend to get more takeaways when you have more money then … Whereas if I have a job where I've got a bit more time like I had a job before I was finishing at 4:00 o'clock and then I was much more likely to cook my own food and take that time" FW67

> "I would quite like to make my own stock out of peelings… But it's finding the time and I would say that is one thing that stops me doing some of the stuff …when you work and you've got a life… it is trying to find the time to fit everything in." FW36

Another barrier was disorganisation at home, for example unpredictable schedules or spontaneous eating "the classic of course is get takeaway for a few days and then the food you've got is too old" FW51 or forgetting about food or "the issue with having two people running a household" FW42. This theme of disorganisation was apparent across all sociodemographic groups. However, households with children indicated that children affected the organisation in their households. There were individual differences within sociodemographic groups. For example, people who communicated that they were highly organised were less affected by disorganisation even when they had children in their households.

> "One, I forget it's there and I've got other things or I'll--- I'll get stuff in and then realise I'm away for three days or I just haven't got the time to eat it" FW75

> "…my other half went shopping last weekend … to save money (picked up) some reduced vegan fishcakes…but they couldn't be frozen so I thought damn that's thrown my food plan" FW36

5.4.3   Perceived Autonomy

Individuals made their own behavioural changes, at their own pace, in their own way within the household. They felt able to make decisions that avoided or reduced food waste, and felt capable of applying these strategies. This was the case across households with one, two, three or four or more people, and in low, average and higher income households, and across households with different levels of education and tenure. Individuals made these changes individually even when the behaviours of others in the household was different, such as children or spouses.

"I'm quite good at like looking what's in the fridge and just going: "OK, I'm going add that--- that because I can see it's…", you know: "not--- not going to last long" where my husband and--- and (*son*)--- they don't do that or probably not as much as I do" FW68

Interviewees expressed self-belief in their ability to make a positive difference. This expression was evident regardless of income or education, and aligned with the wider movement towards environmental awareness: self-belief supported people to believe that their actions would have positive influence. Parents were additionally motivated to mirror pro-environmental behaviours for their children understanding that their own self-belief in making change happen would encourage them that they too could make a difference.

"I care about the environment; I care about my future. And I don't like not doing anything. And if there's something I can do, I know it seems trivial in the grand scheme of things. At least I know I'm doing something that does make a difference, quite simply." FW23

5.4.4 Perceived Competence

5.4.4.1 Perceived Competence in Understanding the Food Waste Issue

Raised awareness through new knowledge of the food waste problem was identified as a catalyst for change. Key influencers for all participants included the media, the news, documentaries and/or social media. Perceived competence in understanding the food waste issue supported motivation to seek new knowledge and to think consciously. It appeared that the realisation of how bad the state of global warming was and how food waste contributed to GHG emissions, motivated individuals to take remediate action.

"…it happened when the IPCC reports got published … I kind of just realised that we were in a very dire situation and so, I thought: "well, we need to do something about it"… I had to educate myself… the first thing I did was to just join some Facebook groups … zero-wasters and all of that … reading articles." FW42

"And then obviously over recent years it's become far more prominent in the media and social media and tv programs about food waste and how bad it is for the environment and for people's money and stuff. And that's sort of pushed me further to avoid wasting food whenever I can." FW23

5.4.4.2   Perceived Competence in Self-Education in New Skills

Where individuals perceived that they were competent to educate themselves to improve their actions, they acquired knowledge in a way that appealed and worked for them i.e., digesting bitesize pieces of new knowledge and pinpointing specifically in search bars on YouTube or Facebook groups for quick, resonating and relatable information. Individuals appeared driven to self-education by their interest and values. Regardless of household size, education level or level of income social media appeared to have a positive influence on food waste behaviours in households by supporting householders' competence in self-education to make beneficial choices to reduce food waste through accessible knowledge.

> "(on YouTube) I like it that's it like five, ten, fifteen minutes so, it's not very long. And I also like it that you can really pinpoint what you want, you know, in the search so, you can get that quick information. So, it's like you--- you know, it's like instead of having a whole heap of different magazines and a book, you've got it all on your TV." FW75

> "It's also much more bitesize because, you know, it's going to be a post here and a post there. It's something that you can digest slowly and dip in and out of." FW42

5.4.4.3   Perceived Competence in Thinking Consciously Supported Establishing New Habits

Establishing new habits required extra focus for them to become ingrained, changing behaviour was a very conscious decision. Competence in thinking consciously supported establishing new habits and competence in understanding behavioural change techniques supported habit change. Individuals appeared driven to think consciously about their habits by their interest and values. This phenomenon was consistent for respondents across all sociodemographics. Respondents turned their attention to thinking carefully about what food they would buy and how they would store and prepare it during the week, for example: making a shopping list after checking cupboards for food, only buying what was needed, storing the food optimally, prioritising eating food likely to deteriorate fastest, and not forgetting about food in the fridge. What worked and what didn't work was reflected on, and by trial-and-error over time lessons were learned, and habits and systems were honed.

> "I think, the planning. So, you know, making sure I don't just eat bread. So, that's become a bit of a--- and because of that there's less waste because I'm not just mindlessly getting stuff and then thinking: 'I can make that, that and that' and then not making it." FW75

"I've been really consciously trying not to do that but to look in my cupboards before I go out and make sure I'm not purchasing doubles of things" FW67

"So I have set meals every week…I'll buy the exact amount of fruit veg I need for the week to try and minimise how much waste I end up at… I put quite a lot of thought in it to buy what I need and reduce the waste" FW23

Similar to knowledge acquisition, taking small steps, establishing those, and then thinking of the next step, made forming new habits most manageable. In some instances, this included diet changes to reduce the impact on the environment facilitated by updated meal planning, which was then, over time, improved to contribute to food waste reduction. This pattern occurred with respondents across different household incomes.

"'…not trying to do it all at once', 'when you start you focus on one thing. Get that right and manageable and then take on the next small thing and get that right'. And understanding of being 'on that journey thinking: 'what next?' 'getting things embedded before doing the next thing really'." FW82

"…the first thing I attacked was food consumptions. So, I tried to get us to go more vegan and--- and vegetable-based diet. That's the first thing I did and that took a lot of energy, but I did do--- I guess, I did do straight away the meal planning" FW42

5.4.5 Perceived Relatedness

5.4.5.1 Social Influence Helpful for Maintaining Behaviours

Across all sociodemographic groups, individuals on a journey to reduce food waste were not necessarily influenced by whether their friends were undertaking the same journey. However, consistently across all sociodemographic groups, people often actively sought out a network of likeminded people through social media groups for inspiration and encouragement. The inspiration and encouragement offered in the social media groups supported individuals to create and sustain new behaviours. These important relational aspects intwine with the instructive role of social media highlighted in the theme perceived competence (*See 5.4.4)* to bolster motivation to make sustained changes.

"it was the social element and also the--- the supportive element of it. So--- because when you read something, like articles and things, it's all lovely but it's not real as--- as much as if its other people saying, you know: 'I've tried this, I've tried that'" FW42

"I think also it's more of a – encouragement that other people are thinking about it…so you know, cumulative kind of effect from everyone changing" FW51

5.4.5.2   Upbringing Affected Food Waste Behaviours

Upbringing connected to the relatedness of family influence and childhood on food waste behaviours. It was a major theme that covered numerous affected aspects such as composting, portion sizing, cooking skills, storage habits and guilt. Across all sociodemographic groups upbringing affected what was perceived as 'normal' behaviour around food, regardless of whether – objectively - it was healthy or otherwise. Some interviewees had to undergo the additional journey of unlearning unhelpful behaviours such as over-shopping, over-storing or over-portioning food; these changes were cited by respondents who considered their childhood experience to be low and high income. Other interviewees' habits were supported by helpful behaviours around food observed throughout their childhood such as composting, healthy portion sizing or using up leftovers. These behaviours were acknowledged by respondents who considered their childhood experience as both a struggle for money and comfortable for money. Thus, upbringing offered a distinction in starting point for food waste behaviour interventions: to unlearn first and then learn new habits, or simply to build upon prior knowledge across socio-demographic groups.

"My family are very much like if you are going to waste anything they will really guilt trip you, they will nag you like constantly about it" FW67

I'm particularly bad at portion sizes, I would say. I'm not so bad now but … I suppose, my family are feeders really so, … that's difficult then not to do that. So, *(my partner's)* mum, when I used to put the kids--- little one's meals out used to say: "it's just too much. You're giving them too much. Just put a bit out and then you can always give them more if they need it". FW82

5.4.5.3   Care for the Earth and Others was Important

Care for the earth and for others for the benefit of all in the future, consistent with integrated personal values of empathy and compassion, was perceived as motivating for food waste reduction behaviours. This sub-theme was relevant across all respondents, regardless of socio-demographics. However, interviewees who expressed a strong drive to save money admitted they were more strongly driven to make changes to food waste behaviours for saving money than for environment-related reasons, even when they acknowledged that they cared about the environment. Additionally, for parents, a desire to care for the earth for their children's futures was a more specific driver alongside a desire to guide their children to also care for the earth.

"I've got two boys now, and they – they're teenagers now, but they grow up and have to live in the world in whatever state it's in, so yeah, you could – yeah, we should have looked after it much better for them, you know, and their children." FW51

"It was more being at one with the environment. It's more taking your place in the environment and being in balance with it…we've got to live where we are and do what we do and give and take… in balance with where you're at. Not just consume, consume" FW33

"So, yeah, having them (children) cooking with me it's all part of that--- that big picture of how important food is and how essential it is. So, it's kind of one big message, isn't it?" FW42

5.5   Discussion

To consider the meaning and insight of the observations, we refer to the SDT (Deci and Ryan, 2015**)** to explore and explain what drives daily motivation for food waste reduction behaviours, what hinders personal day-to-day drivers of motivation for food waste reduction and how competing priorities may align. We will then address what supports personal day-to-day drivers of motivation for food waste reduction before discussing the intervention implications of the research, the limitations and conclusions.

In the results section socio-demographic variables were discussed alongside the themes. Having children in the household or lower income appeared to have some influence on food waste behaviour motivation in relation to different types of barriers and saving money respectively. Otherwise, there was little apparent variation in motivation by household size, income, housing tenure or education; instead differences seemed to be individual and personal. These findings support tailoring and personalising food waste behaviour interventions to the individual.

5.5.1   Food Waste Reduction Behaviours in Relation to Facets of Self-Determination Theory

In the "personal day-to-day drivers that motivated food waste reduction behaviours" theme (*see 5.4.1*), data indicated that in day-to-day life a psychological boost, or immediate tangible emotional experience or goal achievement was key to establishing and continuing food waste reduction behaviour (*see 5.4.1.1).* Tangibility has been identified as a psychological factor affecting eco-friendly behaviours; outcomes can seem distant from the self (Reczek, Trudel and White, 2018; White, Habib and Hardisty, 2019), often requiring individuals to prioritise behaviours with ill-defined consequences

for realisation in the future (Spence, Poortinga and Pidgeon, 2012; White, Habib and Hardisty, 2019). When individuals perceive the future environmental benefit as distant or vague it is less desirable in the moment (Hardisty and Weber, 2009; van Vugt, Griskevicius and Schultz, 2014; White, Habib and Hardisty, 2019). Therefore, immediately tangible emotional experiences or achievement of goals was motivating for pro-environmental behaviour change. The SDT supports this outcome; intrinsic motivation, emotionally experienced as satisfaction or pleasure, is the strongest motivation type most likely to ignite behavioural action (Deci and Ryan, 2015). It may be autonomously motivated by interest, enjoyment or consistency, with deeply integrated values (Deci and Ryan, 2015).

Saving money was different to other motivators as it moved across the continuum of autonomous and controlled motivations. It has been shown to be an important driver for food waste reduction behaviour in previous studies (van der Werf, Seabrook and Gilliland, 2021; Fragapane and Mortara, 2022). In the present study, saving money was a driver common to all respondents, even to the extent that some respondents prioritised saving money and made sacrifices on choices that they would otherwise have enjoyed *(see 5.4.1.2).* Prioritising saving money to this extent was more pronounced in the current study among respondents from lower income households. Saving money was internalised as a meaningful need and integrated with other values. The SDT explains this, asserting that integrated regulation is the most fully internalised extrinsic motivation; people integrate new identifications with other values and needs already integrated in their own sense of self (Deci and Ryan, 2015). However, internalisation may not always work perfectly, thus sometimes internalisation is partial and not fully integrated: the more internalised the value, the more the behaviour will be autonomous (Deci and Ryan, 2015). Thus, encouraging 'money saving' to be more internalised would be beneficial as a means to increase maintenance of food waste reduction behaviour.

Valuing 'healthy eating' was a motivational driver for behaviours of planning or making conscious decisions around food *(see 5.4.1.3).* However healthy eating was not a direct motivation for food waste reduction behaviours. Valuing 'healthy eating' did offer capacity for alignment with other values that did indeed drive food waste motivation reduction behaviours, for example saving money, saving time, or reducing food waste. In these instances, strategies for healthy eating that addressed those other values simultaneously tended to be sought after and used if they led to positive outcomes. A qualitative study of Australian consumer perceptions and experiences towards environmentally friendly and healthy foods with four target behaviours, including reducing food waste, found that the "four target food behaviours were primarily associated and motivated by an impact on health, except for not wasting foods" (Hoek *et al.*, 2017). People lacked a connection between gaining health benefits and reducing food waste, in the present study and the Australian

study (Hoek *et al.*, 2017), despite it being a significant motivating factor for other pro-environmental behaviours.

In the interviews a theme of guilt materialised *(see 5.4.1.4)* most specifically related to failing to "care for the earth and others" (*see 5.4.1.3*) with the emotion made more intense by a feeling of punishment on failing to "save money" *(see 5.4.1.2).* These emotions were described under introjected regulation; thus, controlled motivators had an influence. However, the SDT, which differentiates between controlled and autonomous motivations, proposes autonomous motivation predicts better maintenance of behaviours, particularly for heuristic actions (Deci and Ryan, 2015). It proposes the more internalised the value is, the more the behaviour enacts autonomously (Deci and Ryan, 2015). Thus, although guilt has influence, it may not be the best approach for lasting and sustainable change. This is supported by recent research on emotions and food waste behaviour finding that negative emotions were related to greater intentions for food waste reduction and higher amounts of food waste (Russell *et al.*, 2017). Other research indicates that guilt has little influence for pro-environmental behaviour unless structures and system provision enable a person to act, thus it is limited in its motivational effectiveness (Bedford *et al.*, 2011).

Key barriers that offset motivations to reduce food waste included being tired, overwhelmed by work and/or children, running out of time, or disorganisation or unpredictable schedules at home *(see 5.4.2)*. Similar observations have been made in previous studies (Hebrok and Heidenstrøm, 2019; Boulet, Hoek and Raven, 2021b; Heidenstrøm and Hebrok, 2021). The SDT explains this outcome by proposing that social environmental factors can support or thwart behaviours (Deci and Ryan, 2015). Psychological wellbeing supports the delivery of behaviours; being tired and overwhelmed indicate less optimal psychological wellbeing and thus may have an impact on daily choices when experienced. As food waste reduction behaviours are daily actions at home, it is normal to expect that there will be some occasions or periods when mental pressure will be higher or lower depending on a multitude of external factors, for example illness, examinations, job interviews and relationship breakdowns (Evans, 2012; Quested *et al.*, 2013; Boulet, Hoek and Raven, 2021a, 2021b). These fluctuations are part of normal life and should therefore be anticipated and built into habits to reduce food waste, so when they arise the impact on food waste is diminished. For example, when shoppers buy more frozen vegetables and less fresh, there are fewer vegetables with a short shelf life to manage in the event that a last-minute take-away is purchased due to, for example, an unexpected change in plan leading to running out of time to cook a meal. Meal planners can add flexibility to their plans that allow for it to adapt when they are tired and less willing or able to expend time and effort in preparing meals. Results appertaining to relationships between different phases of the food consumption cycle suggest upstream phases (e.g., during shopping) have greater influence on household food waste generation than lower phases (Setti *et al.*, 2018). These findings

support our perspective that behaviours or decisions that take place upstream, or at earlier phases in the sequence of food consumption may be most effective, e.g., planning food shopping, because they are less susceptible to barriers of food waste reduction behaviour that may occur at home later on e.g., feeling tired or being disorganised.

A desire for healthy eating contributed to increased food waste where there were good intentions to eat healthily, but the intentions were not fulfilled due to tiredness, being overwhelmed by commitments, or disorganisation that adversely affected motivation for food waste reduction behaviours. For interventions, it may be worthwhile, therefore, to encourage healthy shopping choices for products with longer shelf life that lead to less waste if healthy intentions are not fulfilled. For parents, perhaps there is more potential for barriers to food waste prevention being present, particularly considering the complicated logistics that children incur (Schanes, Dobernig and Gözet, 2018; Boulet, Hoek and Raven, 2021b). For example, the unpredictable nature of portion sizing for growing children and/or children with a high level of food selectivity, particularly when parents aim to instil healthy eating behaviours. Thus, addressing barriers for parents may offer an increased chance of success in food waste reduction interventions.

The data showed that individuals made behavioural changes for food waste reduction largely autonomously, and were motivated uniquely by their own values *(see 5.4.3).* The SDT explains this observation by highlighting the sense of self in motivating behaviours. The SDT recognises that people inherently improve themselves through their actions to integrate their experiences, and that this developmental tendency is something people do for themselves (Deci and Ryan, 2015). This organismic perspective differs from more mechanistic theories such as the social cognitive and social learning theories, e.g. (Bandura, 1996) that focus more exclusively on environmental situational factors as affecting people's development (Deci and Ryan, 2015). Interventions can thus focus on promoting change at the individual level within a household. Individuals who made changes expressed strong self-belief in their ability to a) make a positive difference and to b) educate themselves on the problem and potential actions to solve the problem *(Cross Reference 5.4.3).* These findings are supported by previous research that has demonstrated the importance of self-belief as a core quality for competence (Garrin, 2014; Lavelle, Rau and Fahy, 2015; Aschemann-Witzel *et al.*, 2020).

Learning and unlearning required energy, and establishing new habits required focus and conscious decision-making *(see 5.4.4).* Previous research supported this idea indicating that key preventative food waste actions were related to attention during shopping, planning and care during cooking (Bravi *et al.*, 2019; Boulet, Hoek and Raven, 2021b). The SDT explains the success of this process in two ways, firstly it draws on intrinsic motivation emotionally expressed by interest and curiosity.

Secondly, by fostering competence psychological wellness is supported which underpins sustained motivations (Deci and Ryan, 2015). The process of learning, although satisfying, can be frustrating, and for this reason has been critiqued as unexplained by intrinsic motivation and a weakness of SDT (Reiss, 2004). We would highlight how autonomous motivations may be affected by: eudaimonia (human happiness or flourishing), achieved by a life dedicated to excellence, virtue and self-realisation (Waterman *et al.*, 2010) and central to virtue ethics (Thiermann and Sheate, 2020). In this sense, hedonic happiness for pure pleasure is a non-imperative consequence of a life of meaning (Thiermann and Sheate, 2020); both can be expressed emotionally by intrinsic motivations.

Key phases on the food waste behaviour change and habit formation journey identified were: 1) raised awareness of the problem 2) education, gaining a new idea of a behaviour to tackle the problem; 3) trial-and-error of the new behaviour, and then, if value was added; 4) sustaining the behaviour - taking small steps, establishing those, and then thinking of the next step *(see 5.4.4.3).* These phases incorporate behavioural change techniques championed by experts in the field as fundamentals of behaviours change: make it obvious, attractive, easy and satisfying (Clear, 2018). Phase 1 and 2: awareness and education was "satisfying" interest. Phase 3: trial-and-error was important to tailor methods of individuals for themselves; to add value, making the behaviour attractive. Phase 4: involved taking small steps and establishing those before taking new steps, making it easy and obvious. Thus, incorporating behavioural change techniques into food waste reduction interventions may be beneficial.

Although it was an individual journey, people sought social media and found it useful for starting and maintaining behaviours *(see 5.4.5.1)*. Social media served as a source of information and guidance by inspiring and encouraging behaviours through facilitating idea sharing and support between people. This helped respondents to trial and tailor new behaviours that worked for them. According to "The SHIFT framework" (a review of marketing and behavioural science literature that examines the most effective ways of shifting consumer behaviour towards sustainable choices), psychological factors provided leverage for engagement in pro-environmental behaviours and the first of these factors was social influence; comprising social norms, social identities and social desirability (White, Habib and Hardisty, 2019). In the present study, social norms and identities were developed on and through social media, regardless of whether friends in daily life were on a similar journey, which supported behaviour change *(see 5.4.5.1)*. Seeing other people make changes online was reported to be motivating: this can be explained by descriptive norms, a term referring to what other people are commonly doing (Cialdini, Reno and Kallgren, 1990; White, Habib and Hardisty, 2019). While people typically underestimate the influence of norms, these can be a stronger predictor of pro-environmental behaviour than self-interest (Nolan *et al.*, 2008; White, Habib and Hardisty, 2019). Perceiving the self as part of a green ingroup, is a determinant for aligned choices and actions (Van

der Werff, Steg and Keizer, 2014; White, Habib and Hardisty, 2019). Descriptive norms may be the reason for social media being important in the context of food waste behaviours. Interviewees did not commonly mention seeing their friends or colleagues making similar changes, which, in relation to descriptive norms, could be discouraging to their own change-making. Thus, finding a supportive and like-minded network online mitigated this contextual disturbance. Social desirability with regard to food waste behaviours did not feature in the interviews; it is logical that this was an unlikely motivator as most changes go unnoticed by others in the home. Behaviour patterns for waste reduction are seldom exposed to peer pressure or socially orientated in prior research (Cecere, Mancinelli and Mazzanti, 2014). These social influences were more distinct on social media platforms than in real life, possibly because they could be accessed saliently in the home where behaviours were being actioned. Thus, social media may play a positive role in developing social norms and identities that support food waste reduction behaviours.

Upbringing was a substantial theme in relation to perceived relatedness and was relevant to the likelihood of holding or carrying out food waste related attitudes and behaviours, respectively *(see 5.4.5.2)*. It is known that upbringing effects attitudes and behavioural norms. Upbringing has been shown to affect personal behaviour norms: pro-environmental and pro-social motives which influenced personal behaviour norms affected, in turn, food waste (Filimonau *et al.*, 2022). The present study showed that some respondents had detrimental behaviours acquired from their upbringing that needed to be unlearned, as well as new behaviours to learn *(see 5.4.5.2)*. By contrast, some other respondents needed to add new behaviours to other helpful behaviours acquired through their upbringing *(see 5.4.5.2).* Messages that parents and caregivers provide for their children on food waste contribute to attitudes, habits and behaviours exhibited in adulthood; thus widespread inclusion of food waste reduction messages for settings and people that nurture children may be worthwhile in supporting initiatives to reduce food waste.

For all respondents, compassion and empathy towards the earth and others remained a consistent theme considered to motivate food waste reduction behaviours *(see 5.4.5.3)*. For parents, a desire to look after the earth for their children's future, and to guide their children to care for the earth, were "closer to home" expressions of this driver *(see 5.4.5.3).* In relation to food waste behaviours, relatedness between compassion, empathy, the earth, and others was important. Research has presented a two-pathway model of pro-environmental behaviour developed from the 'comprehensive action determination model' combined with a relational pathway guided by the SDT (Thiermann and Sheate, 2020). The study indicated that as activation of the relational pathway (connection with nature, empathy and compassion) increased, internalised motivation for the behaviour was greater (Thiermann and Sheate, 2020). Thus, interventions that promote closeness

with nature, empathy and compassion may also offer potential to alter favourably food waste reduction behaviours.

The data were able to illuminate some of the complexity of competing goals and derive patterns in households where children were present that were different to child-free households. Prioritised personal day-to-day drivers, (efficiency measures or time saving), were frequently described in relation to other values such as healthy eating, reducing food waste or care of the earth and others. General and prioritised personal day-to-day drivers combined to increase the motivation for food waste reduction behaviour, where their influence alone was weaker. This resonated with research on goal framing theory, indicating that environmental behaviours result from multiple motivations (Lindenberg and Steg, 2007), i.e., that monetary incentives and personal norms affected recycling behaviour (Thøgersen, 2003). Social norms i.e., saving the planet and motivation, i.e., saving time or money, can have marked influence on food planning behaviours which in turn reduced food waste (Ananda *et al.*, 2023). It has also been demonstrated that usually no one single factor motivates behaviour, rather behaviour emerged from interactions of many factors simultaneously (Boulet, Hoek and Raven, 2021b). In the present study, for example, the value 'care for the earth and others' was less likely to sustain behaviour change for food waste reduction if a value with a more immediately tangible emotional gain was lacking, e.g., "saving time". However, in tandem it offered an extra incentive in the form of another intrinsically driven motivator, emotionally expressed as a "warm glow", to achieving compassionate goals. There are discrepancies between beliefs generally and in daily life, for example, previous research has shown that individuals might say they dislike food waste, but that they still feel positive despite wasting food if other important goals such as organisational or diet goals are achieved instead (van Geffen *et al.*, 2020). The present study using SDT offered insight on how these discrepancies may be addressed. For example, if time-saving techniques can be introduced that also reduce food waste and achieve diet goals, they may succeed because they can compete effectively on the same intrinsic level and with an immediate and tangible gain. Thus, framing food waste reduction behaviour messaging to add value to a priority in the individuals' daily home life supports change-making.

5.5.2   Implications

To address food waste reduction at the household level for national UK commitments and policy (the Courtauld 2025 commitment and UK targets to eliminate avoidable food waste by 2050) effective food waste reduction interventions are required (HM Government, 2018; WRAP, 2020a). The findings from this paper offer insight that can be applied to develop interventions that drive motivation for food waste reduction behaviours. Autonomy, competence and relatedness were essential for the optimal motivational traits to work unhindered. Interventions that incorporate attention to these

elements are consequently of particular merit. There were, however, implications specific to food waste reduction interventions. The perceived autonomy theme showed that for optimal motivation interventions can focus on promoting change at the individual level within a household, this could be actioned by personalising or tailoring interventions to the individual. The perceived competence theme indicated that behavioural change techniques were supportive in building habits; thus behavioural change techniques should be included within or alongside behaviour change suggestions in food waste reduction interventions. For example, highlighting the concept of 'trial-and-error' enables individuals to create habits for food waste reduction that add value to their unique lives. The perceived relatedness theme highlighted that social media has a positive role in developing social norms and identities that supported food waste reduction behaviours. Therefore, interventions that engage with social media groups that coach in this way may be effective.

By differentiating the type of motivation in the SDT framework for key values affecting food waste reduction actions and uncovering how these aligned or competed to drive behaviour, the present study contributes to the development of effective behavioural-change interventions. Interventions or campaigns to reduce food waste should, we propose, focus on autonomous motivations or internalising controlled motivations. These motivations will be personal to the individual, thus interventions that can tailor motivating factors to the individual have merit. Furthermore, these interventions and campaigns should draw on a variety of motivations, as a multiplicity of motivations appears to strengthen the drive to carry out food waste reduction behaviours. Interventions would benefit from highlighting intrinsically motivated and tangible goals, for example deriving pleasure from time-saving, efficiency measures or creative inspiration. And at the same time, highlighting money saving and environmental and health benefits would appeal to the greatest range of motivating values.

Encouraging messaging on money saving that support integrating this value with the self could be most effective. For example, asking individuals to reflect on their personal values, e.g., family time or financial freedom, to envisage how directing money saved from avoiding food waste could support these goals. The desire to save money was common across all respondents, although individuals from lower income households expressed more examples of prioritising money saving over other interests than individuals from higher income households. Those individuals who expressed a strong drive to save money were more motivated to save money in relation to food waste over environmental concerns, even if they also cared about the environment. These insights suggest that for lower income households more focus on money saving may have more motivational effect than focus on the environmental gains, while for higher income households a balance of focus on both money saving and the environment may be more motivating

Interventions should include ways of addressing barriers, incorporating the concept that tiredness and being overwhelmed cannot always be avoided and should therefore be expected. The SDT stipulates the importance of psychological wellness to maintain desired behaviours, thus tiredness and being overwhelmed will affect behaviours (Deci and Ryan, 2015). In light of this consideration, it is likely best to use upstream mitigation measures (Setti *et al.*, 2018). For example, interventions to reduce food waste could be focused at the shopping, planning and food storage stages, where food waste reduction behaviours can be carried out in advance of daily stressors.

The present study indicated that people lacked a connection between gaining health benefits and reducing food waste, despite health being a significant motivating factor for other pro-environmental behaviours (Hoek *et al.*, 2017). Food waste reduction interventions have perhaps not made obvious this connection and therefore highlighting health gains related to food waste reduction more effectively may enable this lever to be actuated. Furthermore, as health and cooking appeared to be linked, interventions that use health as a motivating factor could include more focus on cooking skills to good effect.

Another suggestion would be to adapt information for child-abiding and child-free households: households with children had a different combination of barriers compared with child-free households, and parents had motivating values distinct from other socio-demographic groups. Parents indicated a desire to leave the world a better place for their children and a desire to guide their children to care for it. Additionally, there were implications to include food waste reduction messages in settings and for people who nurture children with regard to the influence of upbringing on behavioural norms.

More broadly the present study responded to exploring food waste behaviours holistically and related this behaviour more generally to other pro-environmental behaviours. For example, interventions building autonomy, competence or relatedness perhaps through mindfulness, self-efficacy building, cookery, earth care, respect for others would appear to have a positive influence on building values that support motivation for not only food waste reduction but also other sustainable behaviours (Thiermann and Sheate, 2020). For example, self-efficacy has been shown to transfer across personal actions once instilled as a core belief (Aschemann-Witzel *et al.*, 2020).

5.5.3   Limitations and Suggestions for Future Research

Qualitative interviewing enabled collection of data on a range of facilitators and barriers affecting motivation. Due to the nature of the conversations, unconscious aspects affecting behaviour were unlikely to be mentioned by participants. However, individuals appeared to be candid and honest, highlighting strengths and weaknesses in their daily actions that affected their behaviours. Aspects

that individuals frequently underestimate such as descriptive norms, were included in the discussion of the research to account for potential unconscious elements. In the research design, only participants who had previously participated in a food waste diary study were eligible, and potentially more engaged with issues appertaining to food waste than the general public. For the purposes of the present research, this was not a hinderance as we were keen to understand what had worked to support lasting behaviour change in relation to food waste. To probe in this way we needed to include individuals who had changed food waste habits. However, it would be beneficial to hear from people with less engagement in this issue to inform interventions to find out whether/how motivational drivers for food waste reduction differ in these groups and if so, how alignment of drivers with other priorities differs in these groups. To understand whether messaging could have a positive influence or whether structural changes are the best answer for disengaged groups further targeted research is required.

Research should continue to investigate food waste in relation to motivation. The present study highlighted the value of understanding the type of motivational driver in the context of food waste reduction, in relation to competing priorities at home. However, behaviour change is a dynamic process, thus further research to extend and complement the SDT approach might be to use the Transtheoretical Model of Change (Prochaska and DiClemente, 2005) to detail motivation at different stages of the behavioural change journey. There is also merit in further research to develop understanding on how much self-efficacy is required to make a difference or self-efficacy impacts different stages of behaviour change in relation to the trans-theoretical model. Future research should aim to evaluate where different types of motivation are most prominent or best addressed in relation to the stages of household food waste: planning, shopping, storage, preparation and waste. In the current study feelings of guilt were most expressed in relation to when food was put in the bin and not in the stages before, i.e., storage, preparation or consumption. Finally, further research should aim to evaluate quantitatively suggested intervention implications from the current study to determine whether and how they influence the amount of food waste produced by households. Future research should use triangulation as an approach to combine findings from qualitative research with data from quantitative food waste research to inform practical implications in greater depth.

5.6   Conclusions

This study showed that different types of motivation affect food waste reduction behaviours and that they are personal to individuals. The type of motivation that successfully aligned with competing priorities tended to be energised by intrinsic or integrated regulatory processes comprising autonomous motivation, as well as offering an emotionally tangible reward, for example quality time

with family. Additionally, a multiplicity of motivations appeared to strengthen the drive to change behaviour further. For example, motivations that were energised by identified, introjected or external regulatory processes (care for the environment, guilt, and monetary reward, respectively) added strength to the intrinsically/integrated motivation for food waste reduction behaviour, but alone they were less motivating. The nuance in the SDT shows that externally regulated processes (e.g., money saving) may be integrated to the extent that they are autonomously motivated. Barriers such as tiredness and being overwhelmed pose a threat to food waste reduction behaviours as psychological wellbeing is essential to promote optimal motivational traits. These fluctuations can be expected as part of daily life and therefore behavioural interventions should be encouraged to hold adaptable and flexible features to account for these disturbances, so that when they inevitably arise the impact on food waste is less. Thus, these types of motivations and barrier mitigation techniques should be encouraged in food waste reduction interventions to align competing priorities with food waste reduction behaviours in home settings. Finally, to optimally harness personal motivations personalised and tailored interventions could be a suitable approach.

Chapter 6   A model for interventions and final reflections

6.1   Introduction

The aim of the thesis was to optimise Hampshire householders' food waste behaviour by contributing evidence for effective and targeted food waste behaviour interventions to reduce avoidable and possibly avoidable food waste and improve food security, diet quality, and as a result, reduce greenhouse gas emissions.

The literature review identified the potential for further research to support food waste behaviour change interventions in household settings. This review (Chapter 2), highlighted several key gaps. First, although behavioural insights approaches, i.e., nudge techniques, have been used in consumer food waste behaviour change interventions, a systematic review with a critical appraisal of the research methods to test the effectiveness of nudge for food waste behaviour change in household settings was lacking (Reisch *et al.*, 2020). Secondly, there were few studies that categorised possibly avoidable food waste using a visual data source, such as a photograph. Instead, only written data sources were used in most cases (WRAP, 2008; Quested, Esteal and Ingle, 2013; Ilakovac *et al.,* 2020). Developing methods to categorise possibly avoidable food waste is important due to the potential this food waste category has to improve nutrition; possibly avoidable food waste frequently comprises the skins or seeds or stalks of fruits or vegetables, each of which contains valuable nutrients (Lebersorger and Schneider, 2011; Cooper *et al.*, 2018; Conrad, 2020).

Further, the literature review indicated there was a shortcoming in studies applying statistical analysis on possibly avoidable food waste in relation to socio-demographics using primary food waste data collected by diary or Waste Composition Analysis (WCA) methods (Visschers, Wickli and Siegrist, 2016; Falasconi *et al.*, 2019; Boulet, Hoek and Raven, 2021a; Karunasena, Pearson and Fight Food Waste CRC, 2021). WCA involves physically sorting waste by hand into categories, which are then weighed to indicate the composition of the waste (Quested *et al.*, 2020). There was also a lack of WCA and diary studies that categorised the diet quality of food waste and analysed this statistically in relation to socio-demographic variables (WRAP, 2008; Koivupuro *et al.*, 2012; Quested, Esteal and Ingle, 2013; Leverenz *et al.*, 2019; Herzberg, Schmidt and Schneider, 2020; Karunasena, Pearson and Fight Food Waste CRC, 2021). Additionally, the literature review revealed that few studies assess, in a meaningful but simple approach, nutritional loss in food waste for easily actioned interventions that can improve diet quality and food security while reducing food waste (Cooper *et al.*, 2018). The literature review also identified a need to reduce food waste at the household level in

European settings and to improve understanding of food waste patterns in relation to household size (Stenmarck *et al.*, 2016; WRAP, 2021; Vittuari *et al.*, 2023). Finally, from the review it was clear that more research was needed to further knowledge on how competing priorities might align with motivation for food waste reduction behaviours at home (van Geffen *et al.*, 2020; Wang, McCarthy and Kapetanaki, 2021).

The review of research methods in Chapter 2 supported decisions that a systematic review, a photographic diary with a sociodemographic survey, and qualitative interviews were suitable to address these gaps. The photographic diary data collection method has been used in a limited capacity, adding a novel perspective in categorising the Avoidability of food waste and the diet quality of food waste (van Herpen *et al.*, 2019). Additionally, using NOVA to categorise the diet quality of food waste was novel, offering new insights that are relevant considering the growing attention afforded to NOVA (Monteiro *et al.*, 2019; Rauber *et al.*, 2021). Finally, exploring motivation for food waste behaviour and competing priorities using a theory of motivation such as Self Determination Theory (SDT) (van Geffen *et al.*, 2020; Thiermann and Sheate, 2020), has been conducted in a limited capacity in household food waste.

Each of the papers presented for this thesis (Chapter 3,Chapter 4 andChapter 5) contributes to furthering our understanding of food waste in household settings to illuminate how interventions may work most effectively and better target segments of the population. This combined understanding can inform successful intervention design for food waste behaviour change that also promotes diet quality and improves food security.

6.2   Summary of Covid Impacts

Covid had a substantial impact on the PhD work. It supported the decision not to use composition analysis as the method of food waste data collection as direct contact with food products was not advisable from a health security aspect at that time. Furthermore, behaviours of the respondents during the data collection phase may have been influenced by Covid 19 as changes in food waste in the UK were documented over the period of the pandemic (Wrap, 2022c). Finally, in regard to my personal circumstances Covid had an impact in relation to increasing my childcare commitments most substantially for the entire first year of the PhD. Specifically, my youngest was between 1 and 2 years old and unable to go to nursery, and my oldest was 4 years old and in year R but required school at home.

6.3   Assessment of outcomes in relation to the research questions

Three research questions are central to this thesis. These questions address key gaps in the literature and contribute to understanding links between household food waste, behaviour change techniques, socio-demographics, diet quality and motivational theory. To summarise the research gaps addressed by this thesis, it is essential to highlight the original contribution the thesis has presented. The questions are stated and the evidence and contributions from the analytical papers summarised are as follows:

Research question one was: *When applied to food waste interventions in household settings, what behavioural insights (i.e., nudge techniques) work to change food waste behaviour?* As presented in Chapter 3, nudge techniques were indicated as an adaptable and affordable tool for policy makers in behaviour change interventions, including food waste interventions (Just and Swigert, 2016; von Kameke and Fischer, 2018; Rutter, 2020). However, understanding how effective food waste behaviour change interventions using nudge were in household settings was under-researched (von Kameke and Fischer, 2018). Despite perceptions on using nudge in households for food waste being overwhelmingly positive (von Kameke and Fischer, 2018), previous studies had not used a systematic review and critical appraisal to assess the effectiveness of household food waste intervention studies using behavioural insights (i.e., nudge techniques) (Reisch *et al.*, 2020). This systematic review (Chapter 3) addressed this gap, and established there was a paucity of research on food waste reduction interventions using nudge with a research design that included a control group. This indicated opportunity and need for further research evaluating robustly the effectiveness of nudge in food waste reduction interventions. The systematic review also established that for engagement in food waste recycling, interventions containing nudges of reminders, social norms or disclosure with social norms were most effective. The contribution of this paper was to inform adaptable and affordable interventions for policy makers, for engagement in food waste recycling. This was timely research for the UK given that over the coming years it is planned that food waste recycling will be rolled out across England for all households (HM Government, 2021; Defra, 2023b).

Research question two addressed in Chapter 4 was: *How does household food waste (in categories of Avoidability and diet quality) vary by household socio-demographic characteristics in a UK setting?* The literature review (Chapter 2) highlighted shortcomings of food waste measured by diary studies being categorised by diet quality and possibly avoidable food groups and analysed in relation to sociodemographics. This was a valuable gap to address considering the potential links between food security and sociodemographics (Loopstra, Reeves and Tarasuk, 2019; Loopstra, 2020; Pool and Dooris, 2022), and the potential for food waste interventions to address

householders' diet quality and save them money through reducing food waste (Conrad *et al.*, 2018; Conrad, 2020; van der Werf, Seabrook and Gilliland, 2021). Furthermore, the photographic diary method was suitable to capture primary food waste data that could be easily categorised into groups of diet quality and Avoidability in advance of any food degradation (Quested *et al.*, 2020). This offers an important methodological contribution to food waste research, alongside the substantive contribution. The study found that patterns of food waste do indeed differ in relation to some sociodemographic variables. Per person, households of two people wasted significantly less avoidable food than other household sizes. Furthermore, households with at least one person educated to degree or post graduate level wasted significantly more possibly avoidable food waste compared with other educational levels when households of different sizes were normalised per person. Thus, the study showed there was value in exploring food waste categories in relation to sociodemographic variables. This indicates that, for future research, there is merit in exploring sociodemographics further with a representative sample, and that this could be useful to provide evidence to guide targeting food waste interventions with due regard to household sociodemographics.

The study also showed that of the total food waste the majority (87%) occurred in the healthy category for diet quality (NOVA 1). Most NOVA 1 food waste occurred during preparation residue phase (61%), and that approximately equal parts of NOVA 1 food waste were unavoidable (36%), possibly avoidable (20%) and avoidable (31%). This indicated that NOVA 1 food waste in all three Avoidability categories merits focus in interventions. This study had a number of novel contributions. The use of NOVA, as a simple way of classifying diet quality was practical to use, and insightful, highlighting clearly that the majority of food wasted was healthy. This provided confirmation that an approach to reduce food waste and improve diet quality is worthwhile. In the current study, the NOVA categories were found to be too broad to highlight differences between sociodemographic groups. Nonetheless, a contribution of the study was to recommend the use of NOVA to categorise food waste for food waste monitoring and reporting purposes, as it is a simple, potentially easy to replicate way of assessing the diet quality of food waste (Cooper *et al.*, 2018). This is a valuable contribution as a simple measure of diet quality is an aspect that is frequently overlooked in reports on food waste that are not mainly focused on detailed nutrition (e.g., studies that include micro and macro nutrients lost in the wasted food). Furthermore, studies that measure food waste and nutrition frequently tend to use heterogenous methods making comparisons between studies difficult (Spiker *et al.*, 2017; Conrad *et al.*, 2018; Cooper *et al.*, 2018; Khalid *et al.*, 2019), and NOVA may assist in addressing this issue. At the present time NOVA has gained attention in the media which can also support public engagement with this approach.

Research question three (Chapter 5) was: *How do motivations for food waste reduction behaviour align with competing household priorities?* The literature review in Chapter 2 highlighted there was a lack of motivational theories used to inform food waste behaviour change. There were also gaps in understanding how to align motivations for food waste reduction behaviours with other competing priorities at home (van Geffen *et al.*, 2020). The present study contributed to these gaps by applying a theory of motivation (SDT), to understand motivations for food waste reduction behaviours with thematic analysis of sixteen qualitative interviews. This research contributed to the knowledge base through using the SDT, which was novel, in two key ways: 1) through increasing understanding of how to align motivation for food waste behaviours with other priorities at home; and 2) to build knowledge of how to strengthen motivation for food waste reduction behaviour. This indicated the importance of tailoring and personalising household food waste interventions to the individual for optimal motivation.

6.4   Contributions to the literature

Work presented in Chapter 2 demonstrated a shortcoming of studies examining the effectiveness of nudge in food waste behaviour interventions using a critical appraisal. It also showed a lack of studies exploring food waste by categories of Avoidability and nutritional contribution in relation to social demographic variables using diary data collection methods. Finally, it indicated a lack of motivation theories used to understand food waste reduction behaviour motivations in household settings, and how these may align with other household priorities. Most research has evaluated studies using nudge for food waste behaviour change without a critical appraisal of methods in relation to other studies (Reisch *et al.*, 2020). Research has tended to examine socio-demographics and food waste using online or in-person self-reported questionnaire survey methods only. Research that used WCA or Diary methods and that did capture socio-demographic variables frequently overlooked categorising food waste as possibly avoidable (WRAP, 2008) or categorising food waste Avoidability using a visual data source or categorising food waste with a simple grouping of diet quality (WRAP, 2008; Quested, Esteal and Ingle, 2013). Quested, Esteal and Ingle (2013) used a very detailed and complex measure of diet quality by recording each individual food wasted e.g., lettuce, red pepper. The food waste was also categorised more simply into fifteen food groups; however, these did not offer an indication of diet quality as healthy and unhealthy food could be contained in many of the food groups – for example the group 'meat and fish' could include highly processed bacon alongside premium steak; likewise, bakery does not distinguish between an unpackaged wholegrain bread or a packaged white flour bread or croissant (Quested, Esteal and Ingle, 2013). The majority of research that was theory driven has used theories of behaviour change such as the theory of planned behaviour (Ajzen, 1991), or frameworks such as

the MOA (Ölander and Thøgersen, 1995), but did not examine food waste motivation for food waste behaviour using a theory of motivation, and not the SDT (van Geffen *et al.*, 2020; Thiermann and Sheate, 2020) (Section 5.2). This is despite the SDT's reported success in improving outcomes for dietary interventions (Dalgetty, Miller and Dombrowski, 2019).

This thesis provides evidence of which nudges are effective for behaviour change for food waste recycling interventions. It identifies statistically significant sociodemographic patterns of food waste by categories of avoidable and possibly avoidable food waste. It also provides evidence of the proportion of healthy (NOVA 1) food waste in total food waste and how this relates to categories of avoidable, unavoidable and possibly avoidable food waste. Finally, the thesis provides evidence on how to motivate and strengthen motivation for food waste reduction behaviours using the SDT. Taken together, the work in this thesis makes the case to support interventions using a personalised and tailored approach to optimise motivational drive for food waste behaviour change. This collection of research can inform behaviour change interventions to optimise food waste behaviour for health outcomes, food security and environmental impacts.

This thesis also contributes to understanding where to focus future research. Studies should, it is proposed, include more robust evaluations of food waste reduction interventions using nudge; future research should explore food waste categories of diet quality and Avoidability in relation to socio-demographics in a representative sample; and future research should test quantitatively the effectiveness of incorporating SDT, and a personalised tailored approach in food waste behaviour change interventions.

6.4.1 Policy implications for effective food waste behavioural change interventions

Targeting interventions using socio-demographic characteristics that affect food waste behaviour could be effective. The number of people in the household and highest level of educational attainment in the household were shown to impact food waste behaviour significantly (Chapter 4), while presence of children in the household and average household income affected the emotions, and perceived motivations and actions for food waste reduction behaviours (Chapter 5).

Personalisation of interventions to inspire and support motivations that may be at odds with competing priorities at home has merit. Personal perceived autonomy; personal perceived competence; personal perceived relatedness i.e., social influence, upbringing and care of the environment and other people; and addressing barriers; drove and/or supported personal motivation for behaviour change for food waste reduction (Chapter 5).

Involving food waste interventions with other dietary, cooking or broader sustainability interventions could be worthwhile. In the discussion of the research findings in Chapters 3, 4 and 5 this idea was supported. The discussion in Chapter 3 and Chapter 4 suggested designing dietary interventions that simultaneously encourage actions to reduce food waste. The outcomes of work presented in Chapter 5 reinforced the idea that there were benefits arising from broader sustainability interventions that could affect food waste behaviours. Overall, the work presented here can be used to support stronger policy: more effective design of interventions, clarity in motivations for food waste behaviours, consideration of health impacts through better data collection.

For food waste recycling interventions in household settings, it was established that nudges in interventions were effective to change behaviours (Chapter 3). This scrutiny was needed as the literature had not reviewed the evidence on nudge interventions for food waste behaviour on a systematic basis and with a critical appraisal to confirm what was known on the basis of the available evidence. Specifically, this contributes to policy implementation as nudge is a flexible, adaptable and affordable tool that can be incorporated, with proven success, into food waste behavioural change interventions (Chapter 3). It was also shown that unavoidable food waste occurred at high levels in the healthy NOVA 1 food group (36%), establishing the requirement for food waste recycling interventions (Chapter 4).

Methods for evaluating food waste behavioural change interventions that are acceptable and practical were highlighted. NOVA worked well to categorise diet quality in a simple way that was easily replicable (Chapter 4). Thus, indicating that NOVA thus has merit to assess the potential health benefit of food waste interventions. This aspect of the thesis contributes to implementation as it can be added into routine measuring or observation of food waste to provide another simple, but functional, aspect to food waste analysis (Chapter 4). This adds to analysis of future data collection because food waste losses that also equate to loss of diet quality may be targeted due to the potential benefit(s) to food security.

Photographic diaries were found to be an acceptable way of collecting household food waste data for participants, regardless of average household income or highest level of educational attainment or number of people in the household or whether there were children in the household (Chapter 4). Understanding the acceptability of the photographic diary method was needed as the method was under-researched (van Herpen *et al.*, 2019) and in previous food waste diary studies rates of drop-out have been high (Quested, Ingle and Parry, 2013), thus developing acceptable methods with a reduced drop-out rate is useful (van Herpen and van der Lans, 2019). The research contributed to the literature by indicating that for populations in the UK with varying sociodemographics, photographic

diaries were acceptable. This may inform future research aiming to explore food waste in populations with sociodemographics that put them at higher risk of food insecurity.

Finally, it was established that the SDT was useful when applied to the analysis of food waste motivations. This was needed as a theory of motivation, the SDT, had not been previously used to understand motivations for food waste behaviours in household settings. This adds to prior research as the work indicates that the use of the SDT in the design of future food waste behavioural interventions would be worthwhile (Chapter 5).

6.4.2   How the research contributions and implications link and inter-link using MOA

The framework of motivation, opportunities and abilities (MOA), was introduced by Ölander and Thøgersen (1995). This framework recognises: motivational drivers e.g., values, attitudes or subjective norms (Motivation); environmental structures e.g., food infrastructure, lifestyle (i.e., social life, child care, household size, access to education and work) or technical appliances or kitchen layout at home (Opportunity); and the importance of skills and knowledge to perform a behaviour successfully, e.g., planning skills for savvy shopping, cooking skills, understanding how to store food correctly, ability to self-learn, or knowledge about changing habits (Abilities) (van Geffen *et al.*, 2020). The MOA framework has been used successfully across food waste behaviour research (van Geffen *et al.*, 2020; Soma, Li and Maclaren, 2021), and is thus useful to collate the contributions of the outcomes of this Thesis under one umbrella (Figure 4). Motivation was understood further in Chapter 5 using the SDT. These findings form the basis of Motivation as part of the MOA framework, specifically that some types of motivation have more influence than others, that perceived autonomy, competence and relatedness support motivation, and that all of these aspects are personal to the individual. Opportunity links to Motivation in the MOA framework (Figure 4). Social media influence was an Opportunity that was Motivating for individuals as it could align with intrinsic autonomous motivation, "feeling good", which energised motivation to make changes. Likewise, where Opportunities were created through interventions connecting to wider sustainability issues (i.e., diet or nature or care of other people or food waste recycling) and food waste concerns, if natural interest was sparked this contributed to increase Motivation for change. Additionally, addressing barriers was linked to Motivation as creating Opportunities by mitigating barriers to food waste reduction motivation was helpful for sustaining Motivation. Ability was linked to Motivation on the MOA framework, as the individuals' personal motivation drove interest to learning and developing capabilities (Figure 4). Opportunities helped to facilitate or inspire and grow Motivation, and then Motivation drove competence supporting Ability (Figure 4). Motivation, Opportunity and Ability all contributed to optimise food waste behaviours in households (Figure 4).

Optimising Householders' Food Waste Behaviour

Abilities

Personal competence to self-learn contributes to successful personalisation of food waste behaviour change interventions.

Supported by evidence: Theme Perceived Competence (Chapter 5)

Motivation

A tailored and personalised approach to food waste behaviour change interventions to exploit optimal motivation.

Supported by evidence: Theme Perceived Autonomy and Daily Values that Motivated Food Waste Reduction Behaviours (Chapter 5)

Opportunities

Targeting food waste interventions by socio demographics for future intelligence. Supported by evidence: Socio-demographics (e.g., children in the household, household size, education) (Chapter 4 and 5)

Reducing waste of healthy NOVA 1 food within dietary interventions to assist food security. Supported by evidence on NOVA 1 food waste (Chapter 4), and nudge (Chapter 3)

Evidence of nudges working for behaviour change in food waste recycling interventions. Supported by evidence: Nudge creates opportunities (e.g., kitchen layout can contribute as a reminder nudge) (Chapter 3)

Evidence on how to address barriers to motivation for food waste reduction behaviours; and evidence to support social media use in food waste behaviour interventions. Supported by evidence: Theme Barriers to Food Waste Reduction Behaviours, and Perceived Relatedness (Chapter 5)

Figure 4 Contribution of the thesis using MOA

6.4.3 Motivation: a tailored and personalised approach to food waste behaviour change interventions to exploit optimal motivation

Chapter 5 provides evidence of the benefit of a tailored and personalised approach to food waste behaviour change interventions to exploit optimal motivation, and thus contributes to the development of effective food waste behavioural change interventions. The research indicated that a focus on autonomous motivations or internalising controlled motivations in food waste interventions would support stronger motivation that aligns most effectively or competes most effectively with other priorities at home. This research was needed as there was a knowledge gap in understanding how motivations for food waste reduction might align with competing priorities at home (van Geffen *et al.*, 2020). Thus, these findings contributed to building understanding of how motivations for food waste reduction behaviours can be successfully aligned which can inform the design of future interventions.

Understanding motivation for food waste behaviour change using the SDT was lacking in the literature. Chapter 5 found that interventions should draw on a multiplicity of motivations to strengthen drive for food waste reduction behaviours. Thus, the theory derived from the thematic analysis may help to inform more effective interventions that harness stronger motivations. These interventions will need to be tested for effectiveness with robust quantitative methods.

The use of the SDT was needed as a theory of motivation was lacking from the household food waste behaviour literature, and it has been shown to be effective in other similar sectors (e.g., pro-environmental behaviour and dietary behaviour) (Dalgetty, Miller and Dombrowski, 2019; Thiermann and Sheate, 2020). In Chapter 5 the SDT was included in the thematic analysis, and indicated the connection of personal autonomy, competence and relatedness in the data on food waste behaviours for motivation to operate unhindered. Perceived autonomy was a theme that showed the individualised nature of food waste behaviour change despite people often living with others in a household. Thus, it significantly added to the literature by indicating how autonomy, competence and relatedness support interventions focusing on promoting change on a personalised and individual level in the household.

6.4.4 Opportunity: targeting Food Waste Interventions by Sociodemographics for future intelligence

Overall, the participant samples for parts of this thesis were relatively affluent. Thus, the results from this case study are of particular use to high income countries, with populations who have agency, to direct resources for food waste behaviour change. In relation to food security, it is known that households with previously sufficient income for food may find affording food more challenging with the rising costs of living (Harari *et al.*, 2022; Smith and Thompson, 2023). Ensuring food secure practices in households, even in affluent areas, has real value. Food waste interventions that make food more affordable through reduced waste and address, in particular, reducing wastage of foods that benefit diet quality are necessary.

The quantitative research highlighted patterns that were statistically significant based on broad sociodemographic household characteristics. These were that per person households of two persons wasted statistically significantly less avoidable food than households of one, three or more persons (Chapter 4). Additionally, households that had a least one member who was educated to degree or post-graduate degree level wasted significantly more possibly avoidable food waste than other educational groups (Chapter 4). This result contributes to practice by indicating that it is helpful to focus all households other than two persons for interventions on avoidable food waste reduction, and to target households educated to degree or post-graduate level with interventions for possibly avoidable food waste reduction. The qualitative research indicated that households with children experienced different barriers to food waste behaviour than child-free households (Chapter 5). Care-givers also specifically expressed wanting to support their children to care for the earth and others, as well as a desire to care for the Earth for their children's futures (Chapter 5). Thus, this contributes to policy implementation by providing evidence that tailoring messaging for households with children differently to child-free households has merit.

6.4.5 Opportunity: reducing waste of healthy NOVA 1 food within dietary interventions to assist food security

A focus on healthy NOVA 1 food wasted during all phases of Avoidability has merit especially as this can not only align with healthy diet promotion but also affordability, offering a tool to assist food security. The evidence showed that NOVA 1 food waste accounted for 87% of all food waste, and that this was fairly evenly divided between possibly avoidable, unavoidable and avoidable food waste categories (Chapter 4). Dietary interventions that focus on eating more healthy foods may also highlight benefits of nutrition that can be lost in possibly avoidable and avoidable food waste (Conrad, 2020). Avoiding this waste would have nutritional benefits and offer money savings which can support food security (Conrad *et al.*, 2018; van der Werf, Seabrook and Gilliland, 2021). Thus, Chapter 4 contributes to implementation by providing broad evidence that addressing food waste in tandem with dietary interventions has merit. Furthermore, healthcare providers such as dieticians should be looking to create more sustainable strategies to their practice, to respond appropriately to the carbon targets set by the UK government (HM Government, 2022). Finally, Chapter 4 provides evidence to support a food waste initiative within dietary interventions as a high proportion of possibly avoidable healthy food was wasted among the sample.

Studies on food waste behaviour change interventions that used behavioural insights i.e., nudge techniques were previously not evaluated with a systematic review and critical appraisal (Chapter 3). Since then, interventions have been developed that use nudge and create a significant reduction in self-reported food waste at the household level in comparison with control groups (Cooper *et al.*, 2023). It has been identified that nudge has the potential to create opportunities after initial motivation has incurred (von Kameke and Fischer, 2018). Due to the success of nudge in food waste recycling (Chapter 3), dietary interventions (Campbell-Arvai, Arvai and Kalof, 2014; Vecchio and Cavallo, 2019), and self-reported household food waste reduction (Cooper *et al.*, 2023), it can also be acknowledged there is merit in including nudges in interventions for diet or food waste recycling that also affect food waste reduction.

6.4.6 Opportunity: evidence of nudges working for behaviour change in food waste recycling interventions

For food waste recycling interventions in household settings, it was established that nudges in interventions were effective as a means to change behaviours (Chapter 3). This research was needed to address gaps in the literature on what was known on the effectiveness of nudge for food waste recycling interventions, using critical appraisal and systematic review. It contributes to implementation by informing policy with the evidence base on nudges that work to change food

waste recycling behaviour. This is timely to include in affordable interventions to engage the English population in food waste recycling, considering the national roll out of kerbside food waste collections proposed for the end of 2023 (HM Government, 2021) with the roll out completed for most households by 2026 (Defra, 2023b). This is important to optimise the benefits that can be gained from unavoidable food waste in households.

6.4.7 Opportunity: evidence on how to address barriers to motivation for food waste reduction behaviours; and evidence to support social media use in food waste behaviour interventions

Chapter 5 indicated that interventions should be designed to expect barriers, such as tiredness or overwhelm, using tools that have built in flexibility, upstream mitigation measures and encouragement that imperfect practice can be part of the journey rather than a signal to give up. Incorporating these aspects may all encourage more sustained change in food waste behaviour interventions (Chapter 5). This adds new theory-driven evidence-based approaches that can be incorporated and evaluated for success in household food waste interventions.

Social influence was a key factor that was highlighted in the findings of Chapter 5. Daily social networks outside of the home had little influence on behaviours on food waste at home, according to respondents. However, social influence was still a strong contributor to food waste behaviours. These tended to be specifically focused, either through social media groups with a focus on food waste or similar, i.e., low waste, zero waste, low consumption, sustainable or green living groups. Likewise, some people had attended face to face workshops for food waste, and these also had positive influence. Not everyone used social media, but those who did expressed it was a useful tool to motivate and sustain food behaviour change. Social media was perceived as instantly accessible at home, user friendly as it could be consumed in "bite-sized chunks", and a useful educational tool or coaching system with real time feedback via group messages. These findings (Chapter 5) add evidence to include sign posts to social media groups involved with food waste as a useful and affordable intervention for household food waste that can easily be incorporated as an interventional response to policy.

6.4.8 Ability: personal competence to self-learn contributes to successful personalisation of food waste behaviour change interventions

Chapter 5 indicated that the ability to self-learn is crucial in behaviour change for food waste reduction at home. Through self-learning individuals found ideas for changes that worked for them, adding value to their unique lives and fitting with their interests and routines. This knowledge was

needed because understanding how to support motivation for food waste reduction behaviours using a motivational theory was lacking from the literature (Chapter 2, Section 2.3.2). This added to the literature aspects that supported personal motivation for behaviour change. It also contributed to the knowledge that a personalised approach in interventions has benefit for sustained habit changes in household food waste behaviours.

Individuals who understood behaviour change techniques, discussed using and reflecting on these techniques to establish food waste behaviour change. This observation indicated the importance of incorporating behavioural change techniques into interventions to help individuals understand how they may most easily make changes. For example, if change and a new habit have been previously established individuals may be better equipped to use similar mechanisms to establish change again with less energy. These research findings add to the application of policy because it implies how similar interventions may support each other efficiently (Thiermann and Sheate, 2020).

6.4.9   Development of an Interventional Tool based on the Contributions of the Thesis

Using the summary of the above implications of the research for effective food waste behaviour change interventions a tool has been developed (Figure 5). This tool is in the format of a quiz for Councils to consider and then adapt to work best for their audience (for example, changing the language or removing some questions or responses or adding a similar response based on local knowledge). It has been created to assist decision making for the Hampshire County Council to target, personalise and tailor food waste reduction advice for individuals. It could also be used elsewhere in a similar setting or less similar settings with adaptations or "fine-tuning". Certainly, the quiz can be developed with language that is most suitable for the audience, this can be informed by local council expertise. The idea is that on completion of the quiz, Hampshire County Council will, using the information gained, suggest two or three specific tailored options for food waste that could be made at home that would resonate with the individual and be effective for food waste reduction. The tool draws on data relating to sociodemographic characteristics and food waste behaviour, and data relating to how motivations can work to align with competing priorities (Chapter 4 and Chapter 5), bringing together aspects from the quantitative and qualitative research in a useful way for end service users. Findings from the systematic review (Chapter 3) could be used as part of the tailored options for food waste action for respondents.

Important: **During this quiz when we say "your household", we mean the number of people that you usually shop and prepare food for in your home.**

Please select the number of people that you usually shop and prepare food for in your home. For example:

If you are a student living with 5 others in a house but you shop and prepare food usually for yourself, please select 1 for your household
If you live in a shared house with your partner and always shop and prepare food together then select 2 for your household.
If you live in a flat with one child and you usually shop and prepare food for the both of you, please select 2 for your household.

| 1 | 2 | 3 | 4 | 5 or more |

Do you have children living in **your household**? Yes/No
If Yes, are they 12 years or less or 13-18 years?
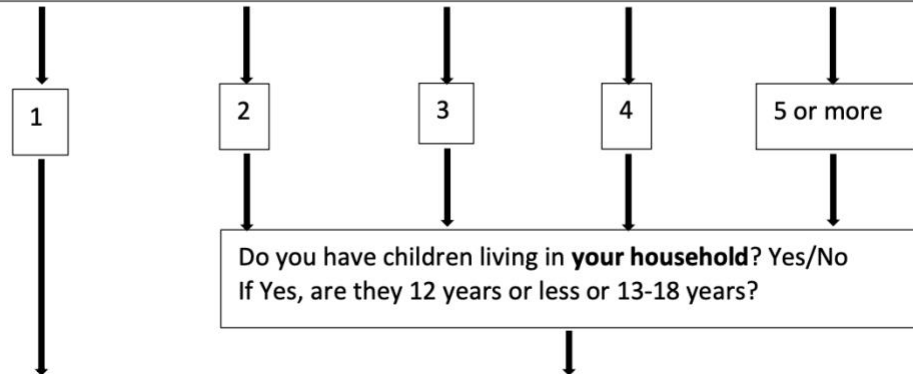
Do you or someone else in **your household** have a university degree or equivalent, or higher educational qualification?
Yes/No

Your organisational style. Select the option that best describes you
I enjoy planning and being organised with my food shopping and preparation.
I enjoy being organised with my food management and cooking at home, but I do not enjoy planning for food.
I enjoy being spontaneous with food and cooking at home and gain no satisfaction from being organised with food and I do not enjoy planning for food.

Your preferred reward for food chores. Select the option that best describes you

If given the option to either save time with my food shopping and preparation at home, or to gain creative enjoyment from food shopping or preparation. I would find saving time a better reward.
If given the option to either save time with my food shopping and preparation at home, or to gain creative enjoyment from food shopping or preparation. I would find gaining creative enjoyment a better reward.

Your upbringing. Select all that apply

I learnt many skills to reduce food waste during my upbringing
I learnt some skills to reduce food waste during my upbringing
I learnt few or no skills to reduce food waste during my upbringing
During my upbringing I usually finished all the food on my plate
I feel that I need help with portion sizes for meals because of my upbringing
I tend to overstore food because of my upbringing
None of the above

Your interest in healthy eating. Select the response that best applies

I have a keen interest in healthy eating and I feel that usually I eat healthily
I have a keen interest in healthy eating but I do not feel that I eat very healthily
I have some interest in healthy eating and I feel that usually I eat healthily
I have some interest in healthy eating but I do not feel that I eat very healthily
I have no interest in healthy eating

Your food practices. Please select all that apply

I have tried to reduce plastic in food packaging over the last 2 years
I have tried to reduce meat intake over the last 2 years
I can cook a diverse range of meals and can experiment with new recipes
I can cook simple meals that I know confidently but new recipes intimidate me
I cannot cook
I am vegan
I am vegetarian
I am flexitarian
None of the above

Your self-learning (here self-learning means to teach yourself something through reading, watching or listening to content in books, videos, online, journals, news, audio books, podcasts etc). Select the response that best applies

I enjoy self-learning
I sometimes enjoy self-learning
I do not enjoy self-learning

Your experience with behavioural change techniques. Select the response that best applies

I have consumed at lot of content (such as online articles, videos, or books) on behavioural change techniques and have applied them previously to my life with success
I have consumed some content on behavioural change techniques and have applied them previously to my life with success
I do not know anything about behavioural change techniques

Figure 5 Tool to assist decision making for local councils

6.4.9.1   Two worked examples of how the tool could work including quiz responses and tailored options for food waste actions

Example 1

We have a mother of two children under ten years of age, who also lives with her husband. She is the main provider for food management and shopping in her household. She and her husband have university degrees. She enjoys being spontaneous with food and cooking at home. She gains no satisfaction from being organised with food and she does not enjoy planning for food. She would prefer to save time for her food chores over creative enjoyment. She has learnt some skills during her upbringing to reduce food waste, and she tends to overstore food because her mother had the same habit. She has a keen interest in healthy eating, but does not feel that she eats healthily. She is confident with cooking, has an interest in reducing plastic waste and has a vegetarian daughter. She sometimes enjoys self-learning. She does not feel she knows much about behaviour change techniques.

From these responses we understand that she is motivated by time saving, and the environment, and we know that everyone is driven by saving money. She has competence in regard to some skills for food waste behaviour learned in her upbringing (although she does also tend to overstore food due to her upbringing) and she has cooking abilities. From a relational aspect she has an interest in caring for the earth and looking after her children.

We might suggest that for her to save time she could stop peeling vegetables. This would make the vegetables healthier for her family and is something that she does not need to plan for and saves time.

A second suggestion would be to swap out some fresh vegetables for frozen as this means she doesn't need to remember how long the food has been stored for, thus less energy is required to manage it thereby saving time. Additionally, because we know she sometimes overstores food, we could also make a suggestion on checking cupboards for foods she already has before shopping. This can be described as a spur of the moment action, rather than requiring sitting down to plan with pen and paper. Perhaps also add some comparison with the GHG emissions of the plastic packaging in comparison to wasting half a cauliflower because we know that she is keen to reduce packaging waste. It would also be important to highlight the potential environmental and health benefits, and money saving that could occur from these changes to strengthen motivation.

Example 2

We have a dad living with his son who is 7 years old. He has no degree. He enjoys being planned and organised with food shopping and preparation. He would prefer to save time than have creative enjoyment as an outcome for food management. He has learnt some skills to reduce food waste during his upbringing. He has some interest in healthy eating, and feels that usually he eats healthily. He can cook simple meals but new recipes intimidate him. He sometimes enjoys self-learning, he has consumed and succeeded in implementing some behavioural change techniques in his life.

From the responses above we understand that he is motivated by time-saving; and we know everyone is motivated by saving money. He has competence in organisation, planning and behaviour change techniques. Relationally he has his son who he wants to take good care of, and for this reason may be driven from an environmental perspective.

We might suggest meal planning in advance of shopping, so that he can work out exactly what he and his son will eat during the week so he can buy the correct amount of food to achieve this. This will save him time in the week as he will already know what he will be eating in advance. He can schedule it so that on busier days he can prepare quicker meals.

We might also suggest a few simple easy recipes that are quick to prepare and low on waste to include in the meal plan. For example, recipes that use measurements that are frequently sold in the supermarkets and using canned or frozen products. We should make sure these suggestions are the type of meals that are easy and safe to store and reheat for another day, and include instructions on how to do this.

It would be important to highlight the potential money saving, environmental benefits and health benefits of making these changes to strengthen motivation.

6.5   Limitations

The thesis was subject to some limitations. In Chapter 3, an important limitation comprised difficulty in separating nudge within an intervention for food waste behaviour. Thus, studies that use nudge for food waste behaviour change interventions and have been evaluated robustly may have been omitted from the database search if key words for behavioural insights, nudge or choice architect or architect were not indicated in the title or abstract of the study. However, searching four databases, and including manual reference list searching, a grey literature search, and expert insight added strength to the search. The implications here are that the outcomes of Chapter 3 could have differed if valid studies were omitted. For example, food waste reduction behaviour may have been shown to have been evaluated robustly and with success; or food waste recycling behaviour may have been shown to have been evaluated robustly and without success.

A key limitation of Chapter 4 is that the results cannot be generalised to apply to all populations, but remain specific to the study sample or populations with similar demographics to the study sample. This limitation likely arose from the use of convenience sampling and self-selection which incur risk of selection bias (Berndt, 2020). The resultant participant sample were not representative of Hampshire or the UK generally (Nomis, 2011). Specifically, the majority of respondents who self-selected to join the study were from households where at least one member was educated to post-graduate degree level and had a higher than UK average household income. However, a homogenous convenience sample has arguably more value than a heterogenous convenience sample for applying findings to a select group (Jager, Putnick and Bornstein, 2017; Emerson, 2021).

Furthermore, due to the higher proportion of participants with sociodemographics protective of food insecurity, the data offered less insight than may have otherwise been possible into patterns of food waste behaviours by these factors (Loopstra, Reeves and Tarasuk, 2019; Loopstra, 2020). That said, there were patterns observed within the sample that showed significant differences relating to food waste behaviour within the sample, and there was a percentage (5.3%) of participants who responded yes to one food insecurity question (Economic Research Service: US Department of Agriculture, 2012). For these participants, involvement in the study was the same as those with different sociodemographics, indicating that the photographic diary method was well suited across most populations in Hampshire and could be used successfully elsewhere.

The relatively modest sample size of 94 was another limitation in understanding food waste differences in relation to food security. This relatively small sample size affected the capacity to highlight more statistical differences in the data, or to offer meaningful insight when statistical differences were not shown (Field, 2018). However, data from 94 households over 7 consecutive days still offered a substantial amount of data that informed the findings of Chapter 4 and on which statistical analyses were possible.

Additionally, as photographic food waste diary methods are developing, there were few validated methods to follow (van Herpen and van der Lans, 2019). This impacts on the comparability of this study with other food waste studies. Despite this, widely used UK national measures, as much as possible were applied. These included using definitions on food waste Avoidability as set out by WRAP (Lebersorger and Schneider, 2011).

In Chapter 5, the key limitations were limitations inherent of qualitative methods. Despite using robust qualitative methods such as reflection on potential biases and verification strategies (Nicholls, 2009b), there remains potential for researcher bias to be reflected in the findings. Additionally, the sample size prevents generalisability of the results. To mitigate this participants' representing a range of sociodemographic groups were purposively selected for qualitative interviews. Nonetheless, the

limitation remains that these are the views of just sixteen individuals. However, the aim was for the qualitative work was depth of insight rather than breadth, which was achieved. A further limitation could be that in conversation people may be influenced by social constructs when trying to explain and understand their own behaviours or personality (Burr, 1995). However, measures to ensure that participants felt safe and comfortable to speak openly and honestly were taken during recruitment and data collection (Nicholls, 2009c).

Furthermore, it is prudent to reflect on the potential impact of having myself as a single researcher conducting the systematic literature review to screen and characterise the studies in Chapter 3. It is less than optimal to screen in this way as human error is perhaps less likely to be noted and addressed (Higgins *et al.*, 2023). Thus, this could affect the rigour of the findings. It is also worthwhile to reflect on the impact of myself as a single researcher to encode the data, e.g. for the NOVA classification and for the Avoidability classification of food waste in Chapter 4. Here food waste is complex, for example there are instances whereby classifying whether a food is ultra-processed or unprocessed can be difficult for example, whether or not a tomato sauce is homemade or not. Therefore, a second or third researcher could add to the quality of the research by adding more variety of thought to effectively critique and categorise food. However, it is also worth mentioning that for consistency across participants the work of classifying food as a single researcher may also be a strength.

In Chapter 5 there was discussion of the key themes with other researchers to support robust findings (Nicholls, 2009b). However, I would like to further reflect on my positionality to the data importantly because I used qualitative methods to analyse the data. My position is as a woman and a working parent. This positionality was twinned with a participant base that were largely female. Thus, it would be fair to conclude that for the qualitative work the findings were most aligned and relevant for females. This is not so much a limitation but an observation and suggestion that the findings may best be remembered and applied with this in mind.

6.6   Future research

It is important to note that Figure 4 indicated how the research in the thesis may link into the MOA framework. However, it does not establish that the research in this thesis is effective. To evaluate whether the research is effective it would be important to carry out further research and/or literature reviews to further test the ideas that were put forward from the research in this thesis. Further research on the effectiveness of interventions using the SDT to influence motivation for food waste reduction at home would be worthwhile. Additionally, more research on the effectiveness of tailoring and personalising the approach to food waste reduction in interventions is necessary.

Future work to understand the impact of competence on food waste behaviour has merit, and extra research on the effectiveness of interventions that combine healthy dietary outcomes with food waste reduction would be valuable. Finally, future research on how effectively social media impacts food waste behaviour would be necessary. Each of these aspects could be explored in relation to outcomes for people of different demographics. These findings could strengthen the development of future targeted interventions.

Through future research the food waste photo diary approach could be developed. First, there are machine learning applications that could be applied to the photographs (Espinoza, 2019; Frost *et al.*, 2019; Mazloumian, Rosenthal and Gelke, 2020). This could ensure photographic food waste diaries are practical for the time-resource available to researchers as in the current thesis it took an inordinate and impractical amount of time to manually categorise food waste in every photograph. However, as it is a complex process for a computer to read photographs most effectively it would be helpful to further refine rules in relation to how the photographs are taken. For example, further instruction could be offered on how the food could be separated out as clearly as possible for the photograph and additionally instruction and attention could be offered to the depth of the food photographed as this is difficult to assess in 2D (Mazloumian, Rosenthal and Gelke, 2020). To this end future research should include refinement of initial instructions or training given to participants to ensure concise, clear and replicable data collection. Future research could also improve on research data management, for example ethical approval for the data to be included in a data repository should be sought at the very beginning of future research endeavours.

It is also worth considering for the future whether combining the food diary with food purchase receipts or tools such as a food frequency questionnaire would be worthwhile. Clearly, this would need to be balanced with the burden on participants and whether extra 'work' affects attrition. However, these aspects could be helpful in two ways: 1. To offer an indication of diet quality alongside food waste; and 2. To offer insight into products at the retail level that most often end up being wasted (for example, are washed salad bags associated with higher food waste?). Furthermore, although in this study the photographic diary method was shown to be very acceptable to participants it would be valuable to also test for acceptability of the method in a study with a representative sample design.

If the photographic diary method proves acceptable in a study with a representative sample design it would be worthwhile to conduct future research to validate the photographic food waste diary method especially given how appropriate the method is for categorising, using primary data, detailed categories of food waste (Quested *et al.*, 2020). Methods for the photographic food waste diary could be refined in a pilot study, the photographic method could be carried out with different

users and inter-reliability testing could be applied. Additionally, reliability testing to compare the food waste measurements in contrast to weighed measures of the same food could be calculated.

Considering the potential benefits to addressing food security it would be worthwhile to carry out further research on sociodemographics in relation to food waste Avoidability and possible impact on diet quality with a representative sample and a sample large enough to carry out robust statistical analysis to capture available patterns or a lack of in the data.

Future research can test the application of tailoring interventions to capture autonomous motivations or internalised controlled motivations that resonate with the individual, to find out (using robust quantitative methods) whether personalising the motivational approach enables more effective alignment of food waste behaviours with other priorities in households. Additionally, future research could test the effect of using a multiplicity of motivational factors to drive an intervention for food waste reduction in one group, in comparison with a control group using just one tailored motivational factor. Such work should aid understanding of which approach(es) produce(s) more significant behaviour change.

Future research could test the effectiveness of the Hampshire Country Council Tool through direct observation of outcomes in a controlled environment. A population with similar sociodemographics of income, education and household size could be recruited to the research. This sample could be randomised to either receive the Hampshire County Council Quiz intervention or to receive previous messaging on household food waste provided by the Hampshire County Council. The photographic food waste diary method applied in this thesis could also be used to compare food waste longitudinally to further understand the long-term impact of the intervention.

Future research could also explore how best to maximise the uptake of routine kerbside food waste recycling that will likely be collected nationally in England imminently (HM Government, 2021; Defra, 2023b). In addition, further work to develop procedures on using kerbside food waste data optimally (perhaps with photographic diary methods) could support future local authority intelligence on food waste data that links to food security.

6.7   Final thoughts

This thesis has explored food waste behaviour in relation to behavioural insights (i.e., nudge techniques), household characteristic social demographic variables, diet quality and a theory of motivation. It has used primary and secondary data, and was largely driven by the shortcoming of research that systematically reviewed household food waste interventions using behavioural insights (i.e., nudge techniques) with a critical appraisal, a lack of research that examined the diet

quality of food waste for food security, and minimal research that examined possibly avoidable food waste in relation to socio-demographics. Finally, the thesis was driven by limited published research on how motivations for food waste reduction behaviours were aligned with other priorities at home and how these motivations could be strengthened. These aspects contributed together to understand further how to design more effective interventions in household settings for food waste, that also assist to address issues of food security and promote diet quality. The research presented here demonstrates that a personalised and tailored approach to household food waste interventions is worthwhile. The hope is that this thesis will progress research to understand: patterns of sociodemographics, diet quality and food waste; and behavioural insights and motivational drivers in relation to food waste behaviour; to inform effective food waste behaviour interventions that also support food security.

Appendix A Chapter 3

A.1   Critical Appraisal of Selected Studies

Key: FW=Food Waste; HH=Household; No=N; Yes=Y; Unclear=U; Weight=W; Self-Report=SR;

Observation=O

Study & country	Topic + intervention	Sample size, design and outcome measure	Impact	Random or representative sample?	Clear methods of assessment?	Weight/ Self-Report/ Observation	Was assessment reliable?	Precision of estimate?	Nudge
Bernstad et al., 2013 Sweden	Food waste recycling nudge intervention Intervention: Group 1 - Written + oral info using disclosure, along with vessel for FW separation and first set of paper bags; Group 2 - written info only using disclosure. No control group.	Allocation: Convenience sample of household area. Participants self-selected. Design: Quantitative/Questionnaire Weekly Average of waste over 24 months: kilogram/household/week. Sample size: Group 1: 420; Group 2: 210.	No change in either group	N Detailed discussion of representative sample included.	U Drop out/loss to follow up not mentioned.	SR W	Y	N	E: Disclosure: Focus on environmental benefits of FW recycling. D: Increase in ease & convenience via a vessel for FW separation and first set of paper bags
Comber & Thieme 2013 UK	Food waste recycling nudge intervention Intervention: BinCam leveraged social influence through uploading photos to a Facebook photo-stream accessible to view by other participants. Feedback on FW reduction and recycling habits was offered similarly. No control group, all participants experienced the intervention.	Sample: Convenience. Participants self-selected. Sample size: 22 Design: Qualitative. Focus groups semi-structured. Allocation: Participants were all young adults chosen from households of people known to the researcher, 16 of whom were students.	Positive. Increased awareness of FW saving & recycling habits in the HH & re-evaluation of behavioural control.	N	Y Drop out/loss to follow up not mentioned.	SR	U	N	C: Use of social norms & J: Informing people of the nature of their choices: The Facebook BinCam photostream aimed to leverage social influence. Relative feedback of FW savings & recycling achievements were displayed similarly to motivate competition between Bincam HHs.
Linder et al., 2018 Sweden	Food waste recycling nudge intervention Intervention: Information leaflet & recycling station	Sample: Convenience sample. Participants self-selected. Allocation was geographical for intervention and control. Design: Quantitative. Longitudinal Food waste weight data. Sample size (number of times rubbish is collected from	Positive. Increased food waste recycling.	N A city district in Stockholm. Demographic data of	Y No record of collection was recorded as	W	Y	Y	The leaflet used C: Social Norms, i.e. subtitle stated "Join your neighbours on Hovmästargatan, recycle your food waste";

Study & country	Topic + intervention	Sample size, design and outcome measure	Impact	Random or representative sample?	Clear methods of assessment?	Weight/ Self-Report/ Observation	Was assessment reliable?	Precision of estimate?	Nudge
	Control group received no information leaflet & recycling station.	sorting stations): Treatment 264 & control group 210. Kilogram/Group/Pre-& Post intervention		district compared to Stockholm average was included. Sample was an area-typical apartment complex of the district.	missing data.				attitudes of residents described as considering FW recycling as very important E: Disclosure: vivid & tangible info on benefits of recycling FW to biofuel. Recycling station used nudge D: an increase in ease and convenience
Shearer et al., 2017 UK	Food waste recycling nudge intervention Intervention included stickers, affixed to the lids of refuse bins, as a visual prompt to encourage the separate collection of household food waste for recycling. Control: No sticker prompt on food recycling caddies.	Design: Quantitative. Randomised control trial. Unit of randomisation was waste collection round. Sample size: Treatment (33,716 households/29 collection rounds) and Control Group (30,568 households/26 collection rounds). Mean tonnage/Group/Week.	Positive. Increased food waste recycling & statistically significant	Y Broadly representative. Demographics described in detail.	Y Drop out/loss to follow up not mentioned. Missing waste collection was accounted for.	W	Y	Y	The nudge included was a H:Reminder i.e. a visual-prompt as a reminder to engage in a behaviour.
Bernstad 2014	Food waste recycling nudge intervention	Sample strategy: Unclear. Allocation: The case study area, both campaigns were performed in the same area. Design: Quantitative. Cross Sectional Design at	Campaign A – Positive. Increased	N Detailed discussion of	Y Drop out/loss to follow up	W	U	Y	For Brochure: E: Disclosure of environmental gains to separate collection of FW.

Study & country	Topic + intervention	Sample size, design and outcome measure	Impact	Random or representative sample?	Clear methods of assessment?	Weight/ Self-Report/ Observation	Was assessment reliable?	Precision of estimate?	Nudge
Sweden	Intervention: Campaign A – Brochure; Campaign B Recycling equipment - a metal hanger & a vessel for paper bags used for separate collection of FW. No control group.	numerous time points. Food waste composition analyses; accuracy of ±10 kilogram. Sample size: 320 with 'weight compositional analysis' for Campaign A; Unclear for Campaign B. Pre-& Post Intervention.	food waste recycling, not significant Campaign B – Positive change. Increased food waste recycling & statistically significant	representative sample included.	not mentioned.				For recycling equipment: A: Default rules; Installation of recycling equipment in HH kitchens D: Increase in ease and convenience, making HH FW separate collection more accessible.
Nomura et al., 2011 UK	Food waste recycling nudge intervention. Intervention: Households in the treatment group were sent two postcards that provided feedback on how their street performed on food waste recycling compared with the average for their neighbourhood. Control group received no feedback cards on their street's food waste container recycling performance.	Design: Quantitative. Randomised control trial; Sample size: Treatment (5009) & Control (4073) Group; Allocation: council area in local Manchester – randomly allocated by street Food recycling. Participation was measured by observing which households put out a food waste container for collection.	Positive. Increased food waste recycling & statistically significant	Y Power calculation for sample size adhered to.	Y Drop out/loss to follow up not mentioned.	O	Y	Y	Appeals to collective norms by nudging with C: use of social norms.
Shaw et al., 2018	Food waste reduction nudge intervention	Design: "before-after-control-impact" (BACI)	No change	N Sample includes	Y Drop out/loss to	W	Y	Y	The nudge used was E: Disclosure i.e. revealing environmental cost or

Study & country	Topic + intervention	Sample size, design and outcome measure	Impact	Random or representative sample?	Clear methods of assessment?	Weight/ Self-Report/ Observation	Was assessment reliable?	Precision of estimate?	Nudge
UK	Intervention: Three treatment groups were assessed contemporaneously; two groups received a leaflet highlighting either the economic costs or environmental impacts of avoidable food waste and a third group acted as an experimental control	Sample size: n=60 [Control (n=20) No intervention; Leaflet: financial costs of food (n=20); Leaflet: environmental impacts (n=20). Allocation: Specific locations for these groups were identified using Mosaic classifications supplied by Eastleigh Borough Council. Allocation: first 30 households in each of the survey areas that set out a food waste container were selected for monitoring. Sample was divided into low income and affluent (n=30 and n=30 respectively). Collection of food waste samples took place over four weeks (8th July to 2nd August) in 2012. Food waste compositional analysis and weight used.		deliberate inclusion of economically diverse participants.	follow up not mentioned.				financial costs associated with avoidable food waste.
Schmidt et al., 2016 Germany	Food waste reduction nudge intervention Intervention: individualised recommendations for relevant FW reduction behaviours, a public commitment & goal setting measures were sent online to the treatment group. Control group: received no intervention measures.	Sampling strategy: adverts sent to town of Madgeburg via social media/newspapers/ Newsletters. Convenience sample. Participants self-selected. Design: Quantitative. Sample size and allocation: Treatment (108) and control group (109) were randomly divided. Online survey. Pre & Post Test.	Positive. Increased food waste reduction	N Detailed discussion of representative sample included.	Y Drop out/loss to follow up not mentioned.	SR	U	Y	The intervention incorporated 3 nudges. G: Pre-commitment strategies and goal setting i.e. I: Eliciting implementation intentions. Alongside individualised recommendations of FW reduction behaviours i.e. nudge H: reminders.
Sainsburys 2017.	Food waste reduction nudge intervention	Swadlincote – a small market town in South Derbyshire – was chosen to receive a £1 million investment and as well as advice and	Positive. Increase in food waste	U No detail on	N Drop out/loss to	W	U	N	-Winnow: used J: informing people of the nature and consequences

Study & country	Topic + intervention	Sample size, design and outcome measure	Impact	Random or representative sample?	Clear methods of assessment?	Weight/ Self-Report/ Observation	Was assessment reliable?	Precision of estimate?	Nudge
Waste less save more UK	Six interventions -Winnow: Tool that calculates financial value of food wasted at home. -Council welcome pack: Tools to help reduce FW i.e. spaghetti measure. -Picnic rescue: Tools i.e. ice packs, cool bags & crisp bag clips. Tips to use leftovers & info on cash value of leftovers. -Innovation challenge: Various FW reduction tools, i.e. spiraliser, measurers, vacuum packing, food labels. -Zero waste kitchen challenge: tools i.e. sealable food containers, measurers, meal planners, kitchen scales. Facebook group to share ideas & experiences. -Sainsburys smart planner app: iPhone app that uses Nectar data to remind users of the food they may have in their cupboards/fridge & suggests recipes	support for an intense year of activity.Six interventions are reported in Appendix B.2. Other interventions are not included here as they contain no numeric results pertaining to food waste. In these 6 interventions quantitative questionnaires were used, however allocation of participants, sample sizes and strategy unstated and thus unclear.	reduction for all six interventions except for the Sainsburys smart planner app which was unclear.	demographics	follow up not mentioned.				of FW costs in their own HH. -Council welcome pack: uses tools that D: increase in ease and convenience to prepare & store food well for FW. -Picnic rescue: uses tools that D: increase in ease and convenience to preserve food and leftovers. H: Reminders for leftover use. E: Disclosure: info on cash value of leftovers. -Innovation challenge: uses tools to reduce FW that D: increase in ease and convenience -Zero waste kitchen challenge: uses tools to reduce FW that D: increase in ease and convenience. Uses C: social norms by social media. -Sainsburys smart planner app: uses nudge H: Reminders.
Hubbub &	Food waste reduction nudge intervention	Sample self-selected from Tesco's customer base – convenience sample. Sample size: 53	Positive. Increased	N	Y	W	U	U	The nudge C: use of social norms was used in the

Study & country	Topic + intervention	Sample size, design and outcome measure	Impact	Random or representative sample?	Clear methods of assessment?	Weight/ Self-Report/ Observation	Was assessment reliable?	Precision of estimate?	Nudge
Tesco 2020. No time for waste challenge UK	Intervention: 3 weeks of accessible simple information, tools i.e. tip & hack sheets & meal planners; and activity challenges with prizes on FW themes. Participants joined a private Facebook group which acted as a social hub & peer support during the intervention No control group.	households. Study stated participants were from a range of demographics. Quantitative design. Survey and Food diary with weight of edible food waste. Pre-& Post intervention.	food waste reduction	Minimal detail on demographics.	Drop out/loss to follow up not mentioned.				Facebook group by peer support and social interaction i.e. by encouraging social interactions around the activity challenges. Tools used i.e. tip & hack sheets & meal planners pertaining to H:reminders.. There was also focus on positive communication & use of incentives to motivate behaviour change.
Lim et al., 2017 The Netherlands	Food waste reduction nudge intervention Intervention Study: 15 Participants, split into 4 groups, received Social Recipes. This aimed to encourage food sharing by suggesting groups of related consumers recipes that are based on ingredients from different individuals or HHs. 2 of the 4 groups also received eco-feedback on servings of	Recruitment & Sample: Convenience sample by University - Facebook pages, letter & personal networks. Demographics. Self-selected Participants: all students/young professionals 20-28 years. Sample size: 15 Design: Quantitative. Cross sectional. 1 time point. Questionnaire Likert scale. Average weight of food waste in bin per person per week calculated. This paper also included two other studies: 1) Interviews on perceptions of social	Mixed: Receiving eco-feedback increased food waste reduction; Social Recipes alone showed no change	N No attempt to discuss representative sample. Minimal demographical detail.	Y Drop out/loss to follow up not mentioned.	SR W	N	N	Eco-feedback incorporated nudges of C: use of social norms and J: informing people of the nature and consequences of their own past choices. The participant's own servings of FW were visualised in comparison to others in the study.

Study & country	Topic + intervention	Sample size, design and outcome measure	Impact	Random or representative sample?	Clear methods of assessment?	Weight/ Self-Report/ Observation	Was assessment reliable?	Precision of estimate?	Nudge
	food wasted, the visualization showing negative feedback & positive feedback relatively to others. No control groups.	recipes concept; 2) Focus groups on perceptions of social recipes concept.							
Van Dooren et al., 2020 The Netherlands	Food waste reduction nudge intervention Intervention: Eetmaatje – a measuring tool for pasta and rice portioning. No control groups.	Design: Quantitative. Sample: a) random selection from client panels at supermarket & b) convenience sample from visitors at a fair. • (a) Client Panel Albert Heijn supermarket survey February 2014 (n = 336) and October 2014 (n = 330). (the supermarket loyal client panel were randomly invited to participate in survey for consumer research) • (b) Online Facebook questionnaire visitors at 2018 edition of Huishoudbeurs, a large annual fair for household products in Amsterdam, where 60,000 visitors received an Eetmaatje for free. The questionnaire resulted in n = 445 responses, unrepresentative sample as mostly women of low socio-economic status	Positive. Increased food waste reduction	U Discussion of representative sample a) representative. b) not representative	Y Drop out/loss to follow up not mentioned.	SR	U	U	The Eetmaatje measuring tool for pasta and rice **increases the ease and convenience** of portion sizing meals accurately, i.e. **nudge D**.
Young et al., 2017 UK	Food waste reduction nudge intervention Intervention: 3 interventions with messaging to encourage FW reduction.	Convenience sample from customer base (Asda magazine 1.9 million readers; Asda e-newsletter 1.4 million customers; Asda's Facebook 1.4 million 'likes'. Design: Quantitative. Allocation: Participants self-selecting. Sample size of each intervention group: None/Control 469	Mixed. Social media, e-letter and control group all showed reduction	U Description of demographics, no mention of representa	Y Description of removal of cases with missing responses from 1 or	SR	U	N	The social influence intervention aimed to encourage discussion of FW reduction behaviours on Facebook incorporating nudge C: **use of social norms.** The e-letter and magazine aimed to offer

Study & country	Topic + intervention	Sample size, design and outcome measure	Impact	Random or representative sample?	Clear methods of assessment?	Weight/ Self-Report/ Observation	Was assessment reliable?	Precision of estimate?	Nudge
	1/Social influence intervention using Facebook to encourage consumer interaction 2/ Information intervention: retailer's print/digital magazine 3/Information intervention: e-newsletter. Control group – received none of the 3 interventions described above.	E newsletter 105 Facebook 510 Magazine 327 E newsletter and Facebook 134 E newsletter and magazine 116 Facebook and magazine 250 All interventions 107 Method: Online questionnaire: 3 time points: at Time 1 (one month before intervention), Time 2 (two weeks after intervention) and Time 3 (five months after intervention).	in self reported FW.	tive sample.	more surveys. All analyses reported refer to participants who responded to all 3 surveys.				FW reduction tips to consumers, encouraging nudge H: **reminders.**
Young et al., 2018 UK	Food waste reduction nudge intervention Intervention: Food waste reduction campaign for ASDA, incorporating 6 interventions: 1/ASDA magazine 2014 – Tips to reduce HH FW 2/ASDA magazine 2015 = Tips to reduce HH FW 3/ASDA e-newletter – Tips to reduce HH FW 4/ ASDA Facebook page – to encourage use of leftovers and facilitate discussion of this issue between consumers	Convenience sample. Design: Quantitative. Online surveys sent to 20,000 customers on Asda's everyday experts' panel at 6 time points. Response rate 14-40%. Final sample included 631 matching responses across all six surveys.	Positive. Communication channels combined & repeated over time using standard messaging had a significant effect on levels of reported FW of shoppers	U Some demographics described. No mention of representative sample.	Y Description of removal of cases with missing responses. Results report matched responses for all 6 surveys.	SR	U	N	All 6 interventions use food waste tips consistent with the nudge H: **reminders.** Interventions 4, 5 and 6 use nudges of **C use of social norms.** Intervention 6 also uses **G: pre-commitment strategies** by prompting pledges to reduce FW.

Study & country	Topic + intervention	Sample size, design and outcome measure	Impact	Random or representative sample?	Clear methods of assessment?	Weight/ Self-Report/ Observation	Was assessment reliable?	Precision of estimate?	Nudge
	5/ On-pack stickers- stickers on foods most often wasted with subjective norm messaging i.e. 75% of shoppers avoid wasting by storing in the fridge & tips for reducing FW 6/In store event: food waste tips, pledges and subjective norms messaging		who say they saw a message						
Asche mann- Witzel 2018 Denma rk	Perception of interventions using nudge techniques for food waste reduction

Interventions in question: - A service providing recipes with the food ingredients packed in just the right amounts. - Food labels indicating the food was produced in a FW positive way. -Being offered tips and tricks to reduce FW - Discussing with friends about importance of reducing FW - Retailers selling misshapen food items, dented items, food items close to expiry or with minor flaws, | Sample & Design: Convenience sample. Quantitative. Danish online panel (of the market research agency 'user needs') that are representative of the Danish population were quota-sampled according to age, gender, and region of residence. 10-minute online survey in September 2016. Sample size: 1(n = 251) 2 (n = 187) 3 (n = 182) 4 (n = 206). 16 participants were eliminated on basis of completing online survey in<3 minutes. | Mixed: Overall positive support of nudge interventio ns using default rules, simplificati on and disclosure. There was some interest in Reminders. But Nudges involving social norms | Y Represent ative sample establishe d | Y Description of eliminated online surveys from analyses. | SR | U | N | A: Default rules - a service providing recipes with the food ingredients packed in just the right amounts. E: Disclosure –food labels indicating the food was produced in a FW positive way. H: Reminders – being offered tips and tricks to reduce FW C: Use of social norms - discussing with friends about importance of reducing FW B: Simplification - reduction of barrier to purchasing misshapen food items, dented items, food items close to expiry or with minor flaws, |

Study & country	Topic + intervention	Sample size, design and outcome measure	Impact	Random or representative sample?	Clear methods of assessment?	Weight/ Self-Report/ Observation	Was assessment reliable?	Precision of estimate?	Nudge
			were less popular.						
Von Kamek e & Fischer 2018 Germa ny	Perception of nudge intervention for food waste reduction

Interventions in question: - external meal planning and fee-based food ingredient delivery -Tips on shopping planning, suggestions for weekly meal planning -Feedback on financial costs of the individual food waste produced/ -Feedback on the actual FW amounts generated by the individual HH. -Pictures that demonstrate the extent of the FW amounts. -Regular exchange about personal experiences on the reduction of FW with friends. -A challenge on HH FW reduction with a friends | Participant recruitment: outside two food stores, one organic and one discount store via ad-hoc sampling. Sample size: 101 Quantitative questionnaire design: Section of results relevant to this review included a rating of proposed nudges on a scale from 1 ("great support")to 5 ("no support at all"). | Mixed: Most support for nudges of social norms, disclosure & informing people of nature and consequen ce of their own past choices and warnings.

Least support for reminders and default rules. | U Sample includes deliberate inclusion of economica lly diverse participant s | Y | SR | U | N | A: Default rules – meal planning program/food ingredient delivery.; H: Reminders: Tips for FW reduction; J: Informing people or E: Disclosure: feedback on financial costs of FW/FW amounts of the individual/HH; F: Warnings: pictures that demonstrate the extent of FW; C Social norms - regular exchange about personal experiences on the reduction of FW with friends/ a challenge on HH FW reduction with a friends |
| Wakefi eld & Axon, UK 2020 | Perception of nudge intervention for food waste recycling

Interventions discussed -HH receiving FW bins | Recruited on Facebook & word of mouth. Facebook group "The Liverpool Vegetarian and Vegan Society". Convenience sample. Responses showed unrepresentative sample. Main age categories 18-24 and 25-34. | Mixed: Default rules: recycling schemes = positive; | N No attempt to include representa tive | Y Unclear description of how missing data | SR | N | N | A: default rules, i.e. government led recycling food waste schemes, distribution of FW bins; C: use of social norms i.e. |

Study & country	Topic + intervention	Sample size, design and outcome measure	Impact	Random or representative sample?	Clear methods of assessment?	Weight/ Self-Report/ Observation	Was assessment reliable?	Precision of estimate?	Nudge	
	-Government led FW recycling schemes -Education of FW in schools -Sharing about FW on social media to increase interest	Design: Mixed methods, but section of results relevant to this review were all qualitative. Q – questionnaire response (2 open ended questions) (100 Participants were recruited to take part via a web link distributed over social media & e-mail] L / W – focus group response = 10.	concern remained re lack of instructions or raising awareness of FW. FW in school & sharing on social media was positive.	sample in survey. Column NA for qualitative section of study.	were dealt with.					sharing about FW on social media to increase interest.
Metcalfe et al., 2013 UK	Perception of nudge intervention for food waste recycling Intervention: Food waste caddy No control groups.	Design: Qualitative; Interviews with 27 households. Allocation: research area = 1 local authority area Kingston upon Thames in South London. Surveys sent to 10% of resident's households followed by interviews of a cross section of respondents. Purposive Sampling: Potential participants were distinguished so that a range of social characteristics were covered such as age, household size, occupation, education, housing tenure, income, ethnicity and fundamentally their 'waste grouping', that is, 'composters', 'garden wasters', and so on.	Mixed: Some parts were accepted, some not. Some required individual flexibility to accommodate intervention	N Demographics described in detail. Column NA as study qualitative.	Y Drop out/loss to follow up not mentioned.	SR	N	N	A: default rules – automatic enrolment in food waste caddy program.	

A.2 Food waste weight/household or individual/timeframe reported for food waste reduction

Study	Sample Size	Food Waste Weight/Household/Timeframe	Overall	Nudge (Code from Table 2)
Sainsburys 2017 (Winnow)	Not Known	During the trial average food waste fell from 16.6kilogram to 13kilogram. (22%) (No Time scale given; Participants by families or HH) Kilogram/Household/total length of trial unspecified	Positive	J
Sainsburys 2017 (Innovation Challenge)	50	Average food waste per day fell by 71g (a reduction of 18%). Average: Grams/Household/Day	Positive	D
Sainsburys 2017 (Zero waste kitchen)	50	The trial delivered an average waste reduction of 60g per household, per day) (20% reduction) Average: Grams/Household/Day	Positive	D, C
Hubbub &Tesco 2020	53	Average decrease in edible food waste of 1.46kilogram per household (or 76%) across the cohort, between week 1 and 6.	Positive	C, H

Study	Sample Size	Food Waste Weight/Household/Timeframe 155	Overall	Nudge (Code from Table 2)
		Kilograms/Household/5 weeks		
Bernstad 2014	320	Kilograms of Food Waste (Standard Deviation) /Household/Week [amount of separately collected food waste] Average Before: (-10 to 0 weeks) A: 0.61 (0.04) B: 0.66 (0.06) Average After: (11-20 weeks; 21-30 weeks) A: 0.68 (0.05); 0.66(0.06) B: 0.98 (0.06); 0.96 (0.05)	No change	E, A, D
Lim *et al*., 2017	15	An average of 332 g of food waste went into the bin per person per week (excluding 2 participants who were only using the mobile application). Grams/Person/Week	Unclear. Only measured at one time point.	C, J

A.3   Percentages reported for food waste reduction

Study	Sample Size	Percentage	Overall	Nudge (Code from Table 2)
Sainsburys 2017 (Winnow)	Not Known	During the trial average food waste fell by 22%. If excluding one anomaly though (one family saw an increase in food waste) this rises to 59%	Positive	J
Sainsburys 2017 (Council Tenant Welcome Pack)	Not Known	66% of participants reported a reduction in the amount of food they waste	Positive	D

Study	Sample Size	Percentage 156	Overall	Nudge (Code from Table 2)
Sainsburys 2017 Picnic rescue	Not Known	98% of respondents reported to have reduced their picnic waste by at least 75%	Positive	D, H, E
Sainsburys 2017 Picnic rescue	Not Known	70% of respondents reported that following the trial they did not waste any picnic food	Positive	D, H, E
Sainsburys 2017 (Innovation Challenge)	50	Average food waste per day fell by a reduction of 18%.	Positive	D
Sainsburys 2017 Zero waste kitchen	50	The trial delivered an average waste reduction of 20%	Positive	D, C
Sainsburys 2017 Zero waste kitchen	50	80% of respondents said they're wasting less food as a result.	Positive	D, C
Sainsbury's 2017 (Smart Planner app)	Not Known	43% of users said the Smart Planner helped them reduce food waste; whilst 52% said it was too early to tell	Neutral	H
Sainsburys 2017 (All other interventions)	Not Known	Not included as there were no percentages of food waste reduction included in the results.	NA	NA
Hubbub & Tesco 2020	53	Average decrease in edible food waste of 76% across the cohort, between week 1 and 6.	Positive	C, H
Hubbub & Tesco 2020	50	One-month post pilot surveyed for participant cohort: 94% said they were wasting less food than before the pilot	Positive	C, H
Bernstad 2014	B Unclear	Food waste separately collected increased by 49% in first two rounds (weeks 3-5 and 12-14 post B) and 44% in last round (week 23-25 post B). This was statistically significant (t-test, 2-tailed) ($p < 0.01$).	Positive	E, A, D
Bernstad 2014	A 320	increase of 12% in the weekly collection of food waste over 10 weeks post campaign. This was not statistically significant.	No change	E, A, D
Van Dooren *et al.,* 2020	336	83% convinced about food waste reduction.	Positive	D

Study	Sample Size	Percentage 157	Overall	Nudge (Code from Table 2)
(Albert Heijn's customers)				
Van Dooren *et al.*, 2020 (Albert Heijn's customers)	330	77% said they are convinced that it helps them reduce food waste	Positive	D
Van Dooren *et al.*, 2020 (Huishoudbeurs large annual fair)	445	of 87% of the respondents was convinced that the tool helps them reduce their food waste in terms of pasta and rice	Positive	D

A.4 Likert scales measuring nudge intervention on food waste behaviour change

Study	Sample size	Scale used	Scores	Overall	Nudge (Code from Table 2)
Young *et al.*, 2017 (No intervention)	469	5-point scale	Time 1 (M = 1.27, SD = 0.1.42) to Time 3 (M = 1.14, SD = 1.31); t (2.32, p = < 0.05).	NA	NA
Young *et al.*, 2017 (E- Newsletters)	105	5-point scale	Time 2 (M = 2.47, SD = 0.910) to Time 3 (M = 2.41, SD = 0.910); t (2.19, p = < 0.05). No significant reduction from baseline to time 1. Time 1 (M = 1.43, SD = 1.34) to Time 3 (M = 1.16, SD = 1.26); t (2.29, p = < 0.05).	Time 2 to time 3 & Time 1 to Time 3 = Positive Baseline to Time 1: No change	H

Study	Sample size	Scale used	Scores 158	Overall	Nudge (Code from Table 2)
Young *et al.*, 2017 (Facebook)	510	5-point scale	Quantity of food waste from Time 2 (M = 1.36, SD = 1.49) to Time 3 (M = 1.17, SD = 1.33); t (3.47, p = < 0.05). Still significantly different at Time 3 (M = 1.17, SD = 1.33) when compared to their initial food waste quantity at Time 1 (M = 1.28, SD = 1.36); t (1.99, p = < 0.05)	Time 1 and Time 2 to time 3 = Positive	C
Young *et al.*, 2017 (Magazine online and instore)	327	5-point scale	Reduction in reported food waste from Time 2 (M = 1.29, SD = 1.44) to Time 3 (M = 1.16, SD = 1.38); t (2.06, p = < 0.05). difference was not significant at baseline to Time 1.	Time 2 to time 3 = Positive Baseline to Time 1: No change	C, H
Young *et al.*, 2017 (Electronic newsletter and the Facebook interventions)	134	5-point scale	reported a significant difference in the quantity of food waste from Time 2 (M = 1.58, SD = 1.63) to Time 3 (M = 1.31, SD = 1.49); t (2.47, p = < 0.05). The change, however, was not significantly different from Time 1 to Time 3.	Time 2 to time 3 = Positive Time 1 to Time 3: No change	C, H
Young *et al.*, 2017 (Facebook intervention and the magazine)	250	5-point scale	significant difference in the quantity of food waste Time 2 (M = 1.43, SD = 1.31) to Time 3 (M = 1.22, SD = 1.24); t (3.20, p = < 0.05). The difference was not, however, significant across Time 1 and Time 3	Time 2 to time 3 = Positive Time 1 to Time 3: No change	C, H
Schmidt 2016	217 Control N=109 Experimental	6-point scale	Control Group: Time 1: 4.79 (1.11) Time 2: 4.77 (1.10) Difference: - 0.02	Positive	G, I, H

Study	Sample size	Scale used	Scores	Overall	Nudge (Code from Table 2)
	N=108		Experimental Group: Value (SD) Time 1: 4.56 (1.32) Time 2: 5.21 (0.95) Difference: 0.75		
Lim *et al.*, 2017	15	Likert scale: 7 to 1, very much to not at all respectively. Survey administered Post intervention which lasted for 1 month	Do Social Recipe suggestions influence your individual behaviour regarding dealing with leftovers? (median 4.5) Do Social Recipe suggestions influence the group behaviour regarding dealing with leftovers? (median 5.0) How much is your level of motivation to change your behaviour around food practices at this point? (median 5.0) Does Eco-feedback provide an additional impact on the group behaviour? (median 5.0) Does Eco-feedback provide an additional impact on effectiveness? (median 5.0) Are social recipe suggestions efficient in reducing overall food waste? (Median 3.5.)	Positive for eco feedback Neutral for social recipes	C, J

Appendix B   Chapter 4

B.1   Examples of how the photographic data were classified

For individuals who used their hands as a measure of scale, a measurement of the hand by ruler was included.	
The researcher categorised the food as teabag, drinks category, NOVA 1, preparation phase and unavoidable. Weight of teabag was estimated using the novel library of standard photographs, by direct weighing of the food observed in the photograph.	
The researcher categorised the food as red pepper, vegetable category, NOVA 1, preparation phase and potentially avoidable. Weight of pepper was estimated using the novel library of standard photographs, by direct weighing of the food observed in the photograph.	
The researcher categorised the food as peas, vegetable category, NOVA 1, consumption phase and avoidable. Weight of one pea was estimated using the novel library of standard photographs, by direct weighing of one pea and then counting the peas in the photograph and multiplying accordingly.	
The researcher categorised each food separately. First, cucumber, vegetable category, NOVA 1, preparation phase and avoidable. Weight of cucumber slice was estimated using the novel library of standard photographs, by direct weighing of the food observed in the photograph. Second, red onion, vegetable category, NOVA 1, preparation phase, unavoidable. Weight of red onion peeling was estimated by using the novel library of standard photographs, by direct weighing of the estimated volume of food as calculated by measure of scale observed in the photograph.	
The researcher categorised the food as cake, sweet category, NOVA 4, consumption phase and avoidable. As cake (density unit of 0.415) is included in the FAO/INFOODS Density Database, the approximate volume of cake was estimated based on a visual estimate of the photograph and applied to the density unit to calculate a weight.	

B.2   Measure of variance: mean and standard deviation of household groups showing statistical significance

Demographic Variable	Food Waste Category	Minimum (g)	Maximum (g)	Mean (g)	Standard deviation (g)
One-person household	Avoidable	0	3418	688	828
	Unavoidable	27	657	360	219
	Potentially Avoidable	0	2544	305	604
Two-person household	Avoidable	0	1402	192	281
	Unavoidable	5	1053	364	225
	Potentially Avoidable	4	719	208	179
Three-person household	Avoidable	3	1489	489	414
	Unavoidable	0	811	207	221
	Potentially Avoidable	19	543	170	166
Four or more person household	Avoidable	13	1693	378	354
	Unavoidable	36	2953	369	519
	Potentially Avoidable	0	661	163	161
Post-graduate group	Avoidable	0	1489	339	355
	Unavoidable	0	2953	328	397
	Potentially Avoidable	0	701	182	155
Degree group	Avoidable	0	3418	475	686
	Unavoidable	4	811	370	220
	Potentially Avoidable	0	2544	293	478
Below degree group	Avoidable	0	1402	440	481
	Unavoidable	5	1053	303	375
	Potentially Avoidable	0	264	71	82

Appendix B.2 Note: Abbreviation, g = grams.

Appendix C   Chapter 5

C.1   Interview Schedule

I am interested in your perspectives and emotions regarding throwing away food at home. Food that has been brought into the home with the intention of being eaten but is thrown away either in the compost, down the drain, given to animals or put in the bin. I have some questions to help explore this. I'm going to start by asking you some questions about your perspectives and emotions on food shopping in your household. Is this okay with you?

1. Perspectives and emotions about food purchasing and food choices.
   - Can you tell me about how you shop for food for your household? Describe to me your last household food shopping experience.
   - What kinds of emotions do you feel when shopping for food?
   - How do you decide what food you will buy?
   - Tell me how your thoughts and feelings towards food shopping may have changed over recent years, and why?

2. Perspectives and emotions about food storage and preparation at home.
   - At home, how are decisions made for how the food is stored? How do these decisions differ, if at all, for different types of food?
   - At home, how do you or members of your household decide what food will be eaten and when? How are decisions made for what food is going to be prepared and when?
   - Tell me how your thoughts and feelings towards food storage and preparation at home may have changed over recent years, and why?

3. Perspectives and emotions about throwing food away
   - At home, when, if at all, does food get thrown out? Can you tell me why you think this happens?
   - Tell me about how it makes you feel to throw food away at home? What thoughts enter your mind when you throw food away at home, if any? Tell me about how these perspectives and emotions may have changed over time. Tell me how your thoughts and feelings may have changed over recent years, and why?
   - How do you think the way you feel about throwing food away is similar or different to other people that you know?

4. Perspectives and emotions about reducing food waste
   - If any, what kinds of actions do you carry out at home that you feel helps to avoid or reduce food getting thrown away? How does it make you feel to carry out these actions? If there are times when you don't carry out these actions, why is this?
   - If any, what kinds of perspectives or ideas motivate you to avoid or reduce getting food thrown away?
   - Is there anything else that you've not talked about that you would like to add to the conversation?

C.2   Coding Framework

Theme 1 personal day-to-day drivers that motivated food waste reduction behaviours		
Sub-theme	Sub-theme detail	Link to SDT
Psychological boost was a motivational driver	A key motivational driver for food waste reduction behaviours arose from the psychological boost or sense of satisfaction from achieving a desired value at the same time as reducing food waste: for example, an efficiency measure that saves food waste and saves time.	Example of autonomous motivation: intrinsic and integrated
Saving money	Saving money was a common value that drove motivation to carry out food waste reduction behaviours	Example of autonomous and controlled motivation
Valuing 'healthy eating' was a motivational driver for planning and conscious decisions around food	'Healthy eating' values were connected to food management, but not directly connected to motivating food waste reduction behaviours.	Example of autonomous motivation: identified and/or integrated
Guilt or other negative emotions around food waste from personal action	Guilt had an effect on emotions at home and avoiding the negative emotion appeared to be a motivating factor to reduce food waste.	Example of controlled motivation
Theme 2 Social and lifestyle barriers to food waste reduction behaviours		
	Theme detail	Link to SDT
	Perceptions of being time poor, tired and overwhelmed by the demands of work and/or children. This led to feeling of not being bothered to make extra effort. It also led to good intentions not being fulfilled. Another barrier was disorganisation at home, for example unpredictable schedules or spontaneous eating, or forgetting about food, or the issue with having two people running a household.	Psychological wellbeing was required to support motivation. Factors in the environment, for example disorganisation or unpredictable events, can support or hinder motivations
Theme 3 Perceived Autonomy		
	Theme detail	Link to SDT
	People made changes to their behaviour as individuals despite living with other people in a family. Interviewees expressed self-belief in their ability to make a positive difference.	The satisfaction of autonomy promotes optimal motivational traits; integrating material into their own sense of self
Theme 4 Perceived Competence		
Sub-theme	Sub-theme detail	Link to SDT
Perceived competence in understanding the food waste issue	Raised awareness through new knowledge was a catalyst for change. Perceived competence in understanding the food waste issue supported motivation to seek new knowledge and to think consciously.	Competence in understanding the food waste issue supported motivation to seek information and to think consciously
Perceived competence in self-education in new skills	Perceived competence in self-education through knowledge seeking on new skills supported motivation for food waste reduction behaviours. Individuals were driven to self-education by their interest and values.	Competence in seeking information was supported by autonomy and driven by autonomous motivation: intrinsic and integrated
Perceived competence in thinking consciously supported establishing new habits.	Competence in thinking consciously supported establishing new habits. Competence in understanding behavioural insights supported habit change. Individuals were driven to think consciously about their habits by their interest and values.	Competence in conscious thinking; and habit formation was supported by autonomy and driven by autonomous motivation: intrinsic and integrated.
Theme 5 Perceived Relatedness		
Sub-theme	Sub-theme detail	Link to SDT
Social influence helpful for maintaining behaviours	Social influence, particularly via social media, appeared helpful for maintaining behaviours	The relatedness of social influence supported autonomous motivation
Upbringing affected food waste behaviours	Upbringing and childhood or family influence were perceived as supportive or unsupportive to food waste behaviours in current life.	The relatedness of upbringing affected behavioural norms which influenced motivation
Care for the earth and others was important	Care for the earth and others for the benefit of all in the future, consistent with integrated personal values of empathy and compassion, was perceived as motivating for food waste reduction behaviours.	The relatedness to the earth and others supported autonomous motivation

Appendix D   Draft Failed Study

Development of effective interventions to reduce household food waste

1.0 Introduction

Food waste is a global issue. One third of all food produced is wasted incurring significant greenhouse gas emissions that contribute to global warming (United Nations Environment Programme, 2021). Abundant food waste showcases a mismanagement of food and energy resources as it includes loss and waste of the food itself and all the resources utilised in its production, transportation and processing (Vittuari, De Menna and Pagani, 2016; Chaboud, Daviron and Chaboud, G.; Daviron, 2017; FAO and Food and Agriculture Organization of the United Nations (FAO)., 2019). This is a travesty considering worldwide food insecurity, nutritional deficiencies and hunger (Pérez-Escamilla, 2017) and the climate change crisis (IPCC, 2018).

In the UK, 70% of food wasted post farm gate occurs at the household level with substantial financial loss for citizens (Jeswani, Figueroa-Torres and Azapagic, 2021; WRAP, 2021). Meanwhile food security remains a concern for the UK population (DEFRA, 2021; Smith and Thompson, 2023). Rising costs of living (Harari *et al.*, 2022) may push households with formerly sufficient income to find food less affordable than before.

Food insecurity means a household is unable to access food of necessary nutritional quality and amount by socially accepted means. These households may seek access to food via food aid, i.e., food banks or high interest loans, or experience hunger (Bramley *et al.*, 2021; Smith *et al.*, 2022). Food poverty is another term used interchangeably with food security as it reflects the economic constraints that people experiencing food insecurity often experience (Smith *et al.*, 2022). Previous data on food insecurity in the UK indicated that low income, unemployment and disability were related to severe food insecurity, and low educational attainment, younger age, and non-white ethnicity were related to food insecurity (Loopstra, Reeves and Tarasuk, 2019). Other surveys further indicated that health outcomes such as mental ill health were connected with food insecurity (Loopstra, 2020; Parnham *et al.*, 2020) and identified socio-demographic risk factors including people renting their homes or on lower incomes (Pool and Dooris, 2022).

Due to the association of food insecurity and socio-demographic characteristics, it is pertinent to collect data on food waste patterns by socio-demographic groups to identify any overlap in groups likely to be food insecure and to waste food. This is important because groups of people at risk of food insecurity may have a greater need to save money and maximise their nutritional quality, aspects that food waste interventions can address. Supporting public health messaging and social initiatives to tackle food

insecurity in tandem with food waste reduction may address sustainability, health and social inequalities simultaneously.

Despite the links between socio-demographics and food security and the relevance that this could have towards food waste reduction interventions, focusing on a demographic approach in the context of food waste is contested (Boulet, Hoek and Raven, 2020). Prior research states that the association of individual level factors such as attitudes and demographics is well established and therefore focus on research here should not be a priority, explaining that at the individual level food waste is positively associated with income and negatively associated with age (Boulet, Hoek and Raven, 2020). However, research that triangulates different types of data on household food waste with socio-demographic characteristics is lacking. The studies largely reporting on the impact of socio-demographics on food waste behaviours used self-reported questionnaire data collection methods (Mondejar-Jimenez *et al.*, 2016; Stancu, Haugaard and Lähteenmäki, 2016; Visschers, Wickli and Siegrist, 2016; Falasconi *et al.*, 2019; Grasso *et al.*, 2019; van der Werf, Seabrook and Gilliland, 2019). These studies lack accuracy in comparison to more robust reporting of food waste weight, such as diary methods or weight compositional analysis (Quested *et al.*, 2020). Moreover, few studies triangulate diary methods or weight compositional analysis methods with qualitative insights to understand the behaviours or motivations contributing to food wastage, with a focus on socio-demographics. Focus on socio-demographics and food waste using multiple data sources is important as there are many drivers, competing goals and motivations for food waste at the household level (Quested *et al.*, 2013; van Geffen *et al.*, 2020).

This paper aims to describe how food waste motivation or behaviour varies by socio-demographic characteristics in households (such size, presence of children, educational attainment or average household income) in a Hampshire, UK, case study. Original survey data and other data sources are triangulated to guide the development of effective interventions to target household food waste reduction in Hampshire and similar settings.

2.0 Methods

The present paper comprises a mixed methods research design comprising survey, qualitative interview and photographic food waste diary methods in a group of 97 participants.

2.1 Study region, Sampling and Recruitment

Hampshire, UK was selected as it represented a high-income region, comparable to other areas in Europe. See published work for sampling and recruitment procedures (Barker *et al.*, 2023). Participants were asked to take photographs of all food wasted in their household for seven consecutive days

between 15-28 November 2021; specific instructions of what participants were asked to do are outlined in published research (Barker *et al*, 2023). Alongside the photographic food waste diary participants were asked to complete a 15 to 20 minute telephone survey to collect data on socio-demographics and food waste behaviours. Of 126 respondents, 95 consented to participate, 94 of whom completed the 7-day photographic food waste diary and the phone survey. For the qualitative interviews participants were purposively selected to represent a variety of socio-demographics from the 94 participants who completed the 7-day photographic food waste diary and the phone survey. Twenty individuals were invited via email comprising a participant information sheet and incentive of a £10 voucher, and sixteen respondents consented and completed the interviews. The University's ethical committee approved the study: 66350.

2.2 Participants, Measures, Data Processing and Analysis

2.2.1 Survey Data

A total of 94 respondents completed the survey on food waste motivations; of the 94 respondents, 3 respondents completed the survey with missing data and were thus excluded from data analysis. The sample for survey analysis comprised 91 individuals living in households in Hampshire, UK.

To measure socio-demographic characteristics a survey instrument was designed. To assess motivations for food waste reduction in household settings in Hampshire, UK, one question with ten optional responses from WRAP's annual Food Waste Trends Survey 2019: Citizen Behaviours, Attitudes and Awareness around Food Waste was used (Table 2).

Table 2. Survey response

Question	Ten Response Options	Abbreviated Response Options	Code	**Code**
Which of the following are your main motivation(s) to carry out food waste reduction behaviours? Select all that apply	To save/not waste money	Save Money	1= selected	0= Not selected
	Unfair to people who can't afford to eat	Unfair to People	1= selected	0= Not selected
	More spare time	Time	1= selected	0= Not selected
	The lockdown has made me think more about the value of food/importance of not wasting it	Lockdown	1= selected	0= Not selected
	It's a waste of food food/ingredients	Waste	1= selected	0= Not selected
	To be more organised/in control of food in the home	Organisation	1= selected	0= Not selected
	To be healthier/eat better;	Health	1= selected	0= Not selected
	To do my bit for the environment	Environment	1= selected	0= Not selected
	More people at home eating meals/to cook for	More People	1= selected	0= Not selected
	Worry about Covid infection (e.g. avoid trips to supermarket, have a stock of food	Covid worry	1= selected	0= Not selected

During a telephone survey data were entered into Microsoft Forms. Data analysis was undertaken using IBM SPSS Statistics V27. Chi-Square tests were run on selected socio-demographic variables by each dependent variable (Field, 2018). Where the Chi-Square test was invalidated due to a low number of cases, Fisher's exact test was used (Field, 2018). Further enquiry using statistical tests of logistical regression was desired, however on testing multicollinearity in IBM SPSS Statistics V27: using Spearman's correlation for ordinal categorical data, and Cram's V for nominal categorical data (Field, 2018), multicollinearity was present (Table 3). Thus, the required assumptions for logistic regression were not met.

Table 3. Testing for multi-collinearity between socio-demographic groups

	Household size	Presence of Children in the household	Highest educational attainment in household	Average household income	Respondents age group
Household size		Cramer's V: 0.828, p<0.001	No statistically significant correlation	Spearman's Correlation Coefficient: 0.395, p<0.001	No statistically significant correlation
Presence of Children in the household	Cramer's V: 0.828, p<0.001		No statistically significant correlation	Cramer's V: 0.397, p<0.001	Cramer's V: 0.659, p<0.001
Highest educational attainment in household	No statistically significant correlation	No statistically significant correlation		Spearman's Correlation Coefficient: 0.218, p=0.038	No statistically significant correlation
Average household income	Spearman's Correlation Coefficient: 0.395, p<0.001	Cramer's V: 0.397, p<0.001	Spearman's Correlation Coefficient: 0.218, p=0.038		No statistically significant correlation
Respondents age group	No statistically significant correlation	Cramer's V: 0.659, p<0.001	No statistically significant correlation	No statistically significant correlation	

From the counts of the selected responses to the question (Which of the following are your main motivation(s) to carry out food waste reduction behaviours? Select all that apply) percentages were calculated for each socio-demographic group and trends were described. The socio-demographic groups selected included: household size (number of people in the household), highest educational attainment in the household, average household income, presence of children in the household and age of respondent. The rationale for focus on these five groups included aligned comparison with previous data analysis on the same sample, and known relevance of these socio-demographics to food waste behaviour as identified in literature (van Geffen, van Herpen and van Trijp, 2016; Vittuari *et al.*, 2023).

2.2.2 Qualitative Interview Data

Details on the methods for the qualitative interviews can be found in Chapter 5 of this Thesis.

2.2.3 Quantitative Data from Photographic Food Waste Diary

Ninety-four participants completed the photographic food waste diary and were included in the analysis. The food waste weight per household was estimated with the photographs using methods outlined in published research (Barker *et al.*, 2023). The data were analysed per household by two key categories: NOVA and Avoidability (Table 4).

Table 4. Food waste categories used in data analysis

Food Waste Category	Definitions
Avoidability: Avoidable, Unavoidable and Potentially Avoidable	To categorise food waste as avoidable, unavoidable and potentially avoidable, seminal definitions were used (Lebersorger and Schneider, 2011). Potentially avoidable was further defined to include food with parts easily incorporated within a standard meal or turned in compote, soup or a smoothie, e.g., apple cores, pear cores, carrot peel and ends, broccoli stalk, heart of cabbage, ends of leeks, ends and centre of bell pepper, used chilli peppers and potato peel. Dry onion peel or garlic peel, citrus peel, banana peel, tea and coffee leftovers, eggshells and bones were all classed as unavoidable, as none of these foods could be categorised as potentially avoidable.
NOVA: NOVA 1, NOVA 2, NOVA 3, NOVA 4	To categorise food as processed or unprocessed, the NOVA tool was used and the definitions of NOVA applied. The NOVA Food Classification System emphasises that "natural or minimally processed foods and freshly made dishes and meals" have higher health benefits than ultra-processed foods (Monteiro et al., 2016, p35) Examples of the NOVA food classification system: NOVA 1 = unprocessed foods e.g., fruit, vegetables, eggs; NOVA 2 = Oils, fats, salt, sugar e.g., vegetable oil, butter; NOVA 3 = minimally processed food e.g., tomato paste, tinned fish, cured meat. NOVA 4 = ultra-processed food e.g., fizzy drinks, chocolate, chicken nuggets, packaged breads.

Statistical analysis was used to assess differences of food waste weight in NOVA and Avoidability categories stratified by three socio-demographic groups: number of people in the household, highest educational attainment in household and average household income. Data analysis comprised Kruskal-Wallis H test (SPSSv26; IBM Corporation) to determine significant difference between mean food waste weight of the socio-demographic groups in NOVA and Avoidability categories. The test was selected as the independent variables were in three or more groups, and the dependent variables were continuous (Field, 2018). When Kruskal-Wallis H tests demonstrated significance at 0.05, pairwise comparison tests and Bonferroni correction were applied (Field, 2018).

2.2.4 Triangulated data using a convergence model

A triangulation design was selected using a convergence model (Creswell et al., 2011). In this design there is equal priority offered to qualitative and quantitative data that were collected concurrently (Creswell et al., 2011). The triangulation aims to merge the data during the interpretation of the results following distinct qualitative and quantitative analysis, to compare and contrast the findings. The rationale for using triangulation is that of greater validity, the method seeks corroboration between quantitative and

170

qualitative data, to provide a more complete picture of the research with a greater repertoire of tools to meet the aim of the study by neutralising weaknesses of one research method alone and strengthening inferences by combining multiple data perspectives (Creswell et al., 2011).

3. Results

Find a summary table of participant characteristics in Chapter 4, Table 8 of this Thesis.

3.1. Survey Data

3.1.1. Chi-Square Test

A chi-square test of independence was performed to examine the relation between number of people in the household and 'Health' as a motivator to reduce food waste (Table 5). The relation between these variables was significant, X^2 (1, N = 91) = 6.955, p = 0.008. Households of one to two persons were more likely than households of three or more persons to believe that Health was a main motivator in reducing food waste. A chi-square test of independence showed that there was significant association between presence of children in the household and Health as a main motivating factor to reduce food waste, X^2 (1, N = 91) = 5.968, p = 0.015. Child-free households were more likely than households with children to perceive Health as a key motivator for food waste reduction behaviour.

Table 5. Table of significance identified through Pearson Chi-Square tests.

Independent Variable	Dependent Variable	Pearson Chi-Square	df	Asymptotic Significance (2- sided)
Binary household size	Selected Health as a main motivator	6.955	1	0.008
Presence of children in household	Selected Health as a main motivator	5.968	1	0.015

Note: Test assumptions: (p<0.05 & 20% or less cells have expected count less than 5)

3.1.2 Percentages calculated from counts of survey response

This paragraph presents results of the survey consistent across the five socio-demographic groups: household size, presence of children in the household, highest educational attainment in the household, average household income

and age of respondent. The Environment, to Save Money and not to Waste were most frequently selected as main motivators for food waste reduction across all socio-demographic groups. Improved Health and Organisation, and Unfair to People were selected by a moderate number of participants as main motivators for food waste reduction behaviour across all socio-demographic groups. Participants selected Time saving, Lock Down, Covid Worry and More People in the household infrequently as main motivators for food waste reduction across socio-demographic groups. These results are shown in Tables 6 to 10. Further highlights of notable results and any differences identified for each socio-demographic group are described below each table.

Table 6. Percentages of responses selected as main motivators for food waste reduction behaviour by household size group (n=91)

Household Size	Sample size of group	Save Money	Organisation	Health	Environment	Unfair to People	Waste	Time	Lock down	Covid Worry	More People
1-2 person	44	89%	43%	50%	91%	32%	82%	14%	7%	7%	0%
3 or more persons	47	74%	40%	23%	85%	34%	87%	2%	9%	6%	9%
Total Sample Size	91										

Larger households selected Health as a key motivator less often than smaller households. In 1 to 2 person households, n=44, 50% of respondents selected Health; in 3 or more person households, n=47, 23% of respondents selected Health.

Table 7. Percentages of responses selected as main motivators for food waste reduction behaviour by presence of children in household group (n=91)

Presence of children in household	Sample size of group	Save Money	Organisation	Health	Environment	Unfair to People	Waste	Time	Lock down	Covid Worry	More People
Child-free household	48	81%	44%	48%	92%	33%	83%	13%	10%	8%	2%
Children in Household	43	81%	40%	23%	84%	33%	86%	2%	5%	5%	7%
Total Sample Size	91										

Only 23% of respondents from households with children selected Health as a main motivator, whereas in the child-free household group 48% of respondents selected Health as a key motivator for food waste reduction. Otherwise, results were similar between groups.

172

Table 8. Percentages of responses selected as main motivators for food waste reduction behaviour by highest educational attainment in household group (n=91)

Highest Educational attainment in Household	Sample size of group	Save Money	Organisation	Health	Environment	Unfair to People	Waste	Time	Lock down	Covid Worry	More People
Below Degree	10	70%	30%	50%	100%	40%	90%	10%	20%	10%	0%
University Degree	27	81%	44%	44%	81%	30%	81%	15%	7%	7%	4%
Post-Graduate	54	83%	43%	30%	89%	33%	85%	4%	6%	6%	6%
Total Sample Size	91										

Results showing the main motivators by households' highest educational attainment were similar across the groups. To Save Money, the Environment and not to Waste were consistent main drivers in all groups.

Table 9. Percentages of responses selected as main motivators for food waste reduction behaviour by average household income group (n=91)

Household income	Sample size of group	Save Money	Organisation	Health	Environment	Unfair to People	Waste	Time	Lock down	Covid Worry	More People
Lower than average	19	84%	47%	47%	95%	47%	74%	5%	16%	5%	0%
Average level	8	88%	25%	38%	88%	0%	100%	25%	0%	0%	0%
Higher than average	64	80%	42%	33%	86%	33%	86%	6%	6%	8%	6%
Total Sample Size	91										

Respondents with an average household income selected Organisation and Unfair to People as a key motivator for food waste reduction less often than other groups; respondents in this category also selected it's a Waste and to save Time more often than other groups. However, the sample size for the average household income group was much smaller (n=8) than the higher-than-average household income group (n=64) and the lower-than-average household income group (n=19) thus it is difficult to draw conclusions when comparing these groups.

Table 10. Percentages of responses selected as main motivators for food waste reduction behaviour by age of respondent group (n=91)

Age Range (Years)	Sample size of group	Save Money	Organisation	Health	Environment	Unfair to People	Waste	Time	Lock down	Covid Worry	More People
18-34	22	77%	50%	36%	86%	27%	77%	0%	9%	0%	0%
35-49	45	82%	38%	31%	87%	33%	84%	7%	4%	4%	7%
50-64	17	76%	47%	41%	88%	35%	88%	12%	18%	18%	6%
65+	7	100%	29%	57%	100%	43%	100%	29%	0%	14%	0%
Total Sample Size	91										

Results for main motivators of respondent by age group were similar across the age groups. All age groups selected to Save Money, the Environment and not to Waste as top motivators. There were upward trends of respondents selecting Health, Unfair to People and Time saving as main motivators for food waste reduction as the age of the respondent increased.

3.2 Qualitative Interview Data

The qualitative interviews explored motivation towards household food waste behaviour change and the full results have been outlined in Chapter 5. For the present paper these results were summarised by presenting the interpretation of the main themes and sub-themes in the data, with examples of verbatim interview quotes. Five themes emerged from the analysis, Theme 1: daily emotions and values that motivated food waste reduction behaviours. This theme identified a psychological boost or sense of satisfaction from aligning values and/or priorities at home. For example, carrying out an efficiency measure task because it aligned values of saving food waste and time. Aligning values and priorities in this way made food waste reduction behaviours competitive choices during daily life at home. The theme showed that valuing healthy eating was a driver for planning and conscious decisions around food and that valuing saving money appeared to drive motivation for food waste reduction behaviours during day-to-day life. Guilt or other negative emotions arising from personal action or inaction were also described as motivating factors to reduce food waste.

> "I would maybe prep more so if then there are leftovers so he can take it for lunch the next day. So, we do things like that to be a bit more efficient with like using food and cooking and time" FW34

> "...put it together with something and rustle-up something … I just feel good about that … we're not wasting stuff, … we're eating something nutritional... it ticks every box really which … feels like an achievement" FW82

Theme 2: Barriers to food waste reduction behaviours: being time poor, tired and overwhelmed, and disorganisation were common themes that caused food waste reduction behaviours to be ignored or unprioritised in daily life at home.

> "One, I forget it's there and I've got other things or I'll--- I'll get stuff in and then realise I'm away for three days or I just haven't got the time to eat it" FW75

Theme 3, Perceived Autonomy, highlighted that changes were made individually for food waste reduction behaviours, and that individuals had self-belief in their own ability to make a positive difference.

> "At least I know I'm doing something that does make a difference, quite simply." FW23

Theme 4, Perceived Competence. Perceived competence in understanding the food waste issue through raised awareness supported motivation to seek new knowledge and to think consciously. Perceived competence in self-education through seeking new knowledge and skills supported motivation for food waste reduction behaviours. Competence in thinking consciously and understanding behavioural insights supported establishing new habits.

> "'not trying to do it all at once', 'when you start you focus on one thing. Get that right and manageable and then take on the next small thing and get that right'. FW82

Theme 5, Perceived Relatedness, indicated how perceived relatedness supported food waste reduction behaviours. Social influence was helpful for maintaining behaviours, upbringing affected food waste behaviours by establishing norms that were either helpful or unhelpful and care for the earth and others was important as a motivating factor to reduce food waste.

> "I've got two boys now, and they – they're teenagers now, but they grow up and have to live in the world in whatever state it's in, so yeah, you could – yeah, we should have looked after it much better for them, you know, and their children." FW51

3.3 Photographic Diary Data

The photographic diary data study aimed to highlight patterns of food waste in relation to different socio-demographic groups. The full results are detailed in (Barker *et al*, 2023), but we summarise the key findings in the following paragraph and Table 11 and 12.

Total food waste results unrelated to socio-demographic groups

Overall food waste weight by NOVA and Avoidability category: The majority of food waste was NOVA 1 (87%), and was fairly evenly split between avoidable, potentially avoidable and unavoidable food waste. Of the total food waste weight, 11% was NOVA 4 and was all avoidable. Of the total food waste, the majority occurred during preparation (61%) and this was shown to be significant. Statistical analysis showed that food waste weight incurred during preparation was statistically significantly greater compared to during storage or consumption (p<0.001).

Table 11. Avoidable, unavoidable and potentially avoidable food waste weight by socio-demographic group

Socio-demographic group	Trend	Significant results
Household size	Per person avoidable food waste was greater in household sizes of 1,3 and 4 or more people: this evidences households of 2 people behaving differently.	Avoidable food waste in households of one, three and four or more people was statistically significantly higher than in two person households.
Highest educational attainment in household	Avoidable and overall food waste was highest in households educated to University Degree. Potentially avoidable food waste was highest in the University Degree Group and least in the Below Degree Group.	Potentially avoidable food waste was found to be statistically significantly greater in the Post-Graduate Group and University Degree Group than the Below Degree Group.
Average household income	Lower income households wasted overall per person the most, driven by avoidable waste. Lower income households had lower unavoidable and potentially avoidable food waste per person, with higher amounts of avoidable food waste per person, than higher income households.	None found.

Table 12. NOVA 1, 2, 3 and 4 food waste weight by socio-demographic group

Socio-demographic group	Trend	Statistical Significance
Household size	Households with one person wasted the most NOVA 1 food per person. Households of two, three and four or more wasted similar amounts of NOVA 1 food per person. Households with four or more persons wasted the most NOVA 4 food per person	None found
Highest educational attainment in household	University Degree Group wasted the most NOVA 1 and NOVA 4 food.	None found
Average household income	Lower Income Group wasted the most NOVA 1 and NOVA 4 food per person	None found

3.4 Triangulation using convergence model

3.4.1 Similarities of survey & interview data across all five socio-demographic groups

Some findings were present across the demographic groups in both the survey and the qualitative interview data. Environment was a common and important theme across all socio-demographic groups in the survey data and the qualitative interview data; however, the interviews identified how the environment as a motivator alone did not compete effectively with other priorities at home to push food waste reduction behaviour change. Money-saving was a very strong motivator across the survey and qualitative interviews for all socio-demographic groups. The SDT showed how this motivator could be integrated to autonomous motivation which furthered the likelihood of real action. The desire not to waste was another frequently selected main motivator across all socio-demographic groups, and a strong theme in the qualitative interviews. Indicating that people across society do not like waste. Time saving was selected as a main motivator by less than 26% of respondents across all socio-demographic groups in the survey, despite this being a strong theme for motivation in qualitative interviews. It was also a theme in the qualitative survey data, lack of time was described as a barrier to getting organised for food waste reduction behaviour (n=94). Organisation was selected as a main motivator across all socio-demographic groups 25-50% of the time. Interestingly disorganisation was a strong barrier to food waste reduction identified in the qualitative interviews, and in the qualitative survey

data (n=94). Lock down, worry about covid and more people in the houses as key drivers for food waste reduction behaviour were rarely selected across all socio-demographic groups in the survey, and were not key themes in the qualitative interviews; these ideas did not arise naturally in the discussions.

3.4.2 Similarities and differences between survey, interviews and diary data in relation to Household Size

Health as a main motivator for food waste reduction was selected more or less often in the surveys depending on household size, and this was found to be a statistically significant relationship. In interviews, health was motivating for dietary choices and cooking, but it was rarely expressed solely in relation to wasting less food.

In the survey data one to two person households were more motivated by health than larger households, and in the photographic diary data 2-person household produced the least avoidable food waste compared to other household sizes. Both findings were statistically significant. While one person households were more motivated by health than larger households, the photographic diary data showed one person households wasted similar amounts of avoidable food as 3 and 4 or more person households. These findings also aligned with the photographic diary data indicating that one person households wasted the most NOVA 1 food per person, although, this trend was not significant.

Otherwise, the main motivators for food waste reduction were similar across different household sizes in the survey data. Similarly, in the qualitative interview data household size did not appear to affect the motivational drivers for food waste reduction, there were similar themes across household sizes. However, in the qualitative interviews it was clear that barriers and motivators were slightly different for households with children compared to child-free households, and frequently households with children were larger households. These differences can be summarized as: managing food waste from fussy children, a desire to instill values to care about the earth and health in their children through activities such as cooking or intuitive eating and a wider variety of schedules within the household to manage.

3.4.3 Similarities and differences between survey, interviews and diary data in relation to Presence of Children in the household

Health as a main motivator for food waste reduction was selected more or less often depending on presence of children in the household, and this difference was statistically significant. Child-free households were more likely to select Health as a main motivating factor for food waste reduction. This is further understood in the qualitative interviews. Health was a motivating factor for household with children, however the motivation for healthy eating rather than for food waste reduction; parents discussed wanting to encourage their children to pursue intuitive eating (to stop eating when they're full) and to get involved in cooking to understand food better. Child-

free households tended to talk about health in relation to food management, for example planning shopping and meals to ensure healthier food was eaten, rather than reaching for unhealthy convenience food. In the interviews, the planning and organisation was seen to facilitate reducing food waste behaviour, so viewing the survey data with the interviews allows us to see that Health does motivate food waste reduction, and we can see more clearly that it is planning and organisation that bridges this link. This is a new insight, as purely looking at the qualitative data, the links for Health as a direct motivator to food waste reduction were not as clearly evident.

3.4.4 Similarities and differences between survey, interviews and diary data in relation to Highest Educational Attainment in the household

The survey and qualitative data did not indicate patterns of key motivators that were aligned according to educational attainment group. However, the photographic diary study did show that more potentially avoidable food waste occurred in statistically significantly greater amounts for the university degree group and post graduate group in comparison to the below degree group. There were also non-significant trends in the data indicating the university degree group wasted the most food overall per person. According to the survey main motivators were similar across educational socio-demographic groups. The qualitative interviews did not show any patterns of motivation being driven differently in relation to educational attainment in the household. Specifically, main motivators for Health were not different between educational attainment groups, which aligned with the photographic diary data indicating there were no significant differences between the type of NOVA 1, 2, 3, or 4 food waste by educational attainment group.

3.4.5 Similarities and differences between survey, interviews and diary data in relation to Average Household Income

The qualitative interviews indicated that if respondents had a lower income and were strongly driven to save money that this tended to be a stronger reason to reduce food waste that for the environment, even when the pro-environmental values existed. The photo-diary study showed no statistically significant difference in food waste between income groups. However, non-significant trends showed that lower than average income households wasted the most food overall and the most avoidable food waste; while higher than average income households wasted the most unavoidable and potentially avoidable food waste.

According to the survey, the main motivators tended to be similar across the income groups. While the photographic diary data indicated lower income groups tended to waste the most NOVA 1 and NOVA 4, the survey data showed they were very strongly motivated by the environment, unfair to people, it's a waste and to save money, similar to other socio-demographic groups. However, none of these trends were significant.

3.4.6 Similarities and differences between survey, interviews and diary data in relation to Age of Respondent

There were no statistically significant trends in the data regarding age of the respondent and their food waste drivers, and no themes identified showing differences in food waste behaviour or drivers between respondents of different age groups.

3.5 Summary of the Triangulation

- Saving money motivates everyone and alone has a strong influence on behaviour
- Environment motivates everyone and alone has a weak influence on behaviour
- Two person households waste the least and are more motivated by health
- Households with children have different barriers
- Households with education of university degree and above wasted more potentially avoidable food waste.
- Non-significant trends showed that lower than average income households wasted the most food overall and the most avoidable food waste; while higher than average income households wasted the most unavoidable and potentially avoidable food waste.
- Saving time was a strong motivator in the qualitative interviews, even though this was not clear in the quantitative data.
- Disorganisation was a strong barrier in the qualitative interviews and the qualitative survey data although it wasn't described as a strong motivator. Organisation as a motivating factor was as frequently selected as a main motivator compared to other main motivators in the quantitative survey data but it was selected 25-50% of the time across all socio-demographic groups.

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Appendix E   Data Access Statement

Appendix F   List of Conferences

List of Conferences in which the work of this Thesis was presented by Hannah Barker

Barker, H. (2021). 'Exploring Household Food Waste by Photographic Diary', *School of Geography PGR Conference*. University of Southampton, 10 June.

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