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Comparing a range of potassium-enriched low sodium salt substitutes to common salt: Results of taste and visual tests in South African adults

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Abstract *Background and aims:* Potassium-enriched low sodium salt substitutes (LSSS), which replace a proportion of sodium chloride (NaCl) with potassium chloride (KCl), have been shown to reduce blood pressure and offer a potential solution to address the high burden of hypertension in South Africa. However, it is unknown which proportions of KCl in LSSS are acceptable. We compared the taste and visual acceptability of various LSSS in South African adults.

Methods and results: Fifty-six adults underwent double-blind taste and visual tests of four LSSS (35%KCl/65%NaCl; 50%KCl/50%NaCl; 66%KCl/34%NaCl; 100%KCl) in comparison to 100%NaCl (common salt). Participants scored each product by taste ranking, taste perception and likeliness to use. Participants then visually inspected the five products and attempted to identify which was which. Almost half (45 %) of participants ranked the taste of 50%KCl/50 %NaCl as fantastic or really good. Furthermore, 62 % of participants liked and would be happy to use the 50 % KCl/50 %NaCl or felt this tasted like common salt. Only 12 % rated the 100%KCl highly for taste, and over half reported being unlikely to use this. Most participants (57.3 % and 36.4 %) were able to visually identify 100%NaCl and 100%KCl, while identification of other blends was generally poor. Responses were similar for 35%KCl/65%NaCl and 66%KCl/34%NaCl throughout.

Conclusion: Our findings suggest that the taste of the 50%KCl salt substitute would be well tolerated by South African adults, most of which could not visually differentiate between this salt substitute and common salt.

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1. Introduction

The burden of non-communicable disease in Sub-Saharan Africa has rapidly increased in recent years with raised blood pressure (BP) being a key contributor to cardiovascular disease and stroke [1,3]. In Africa, BP levels have risen steadily, and are now amongst the highest in the world [2]. Dietary sodium is an established risk factor for the development of hypertension and cardiovascular disease [3,4]. Dietary potassium, on the other hand, has been shown to have a lowering effect on BP [5,6,7]. With this said, we have previously shown that more than two-thirds of South African adults exceed the recommended daily sodium intake (higher in young adults and urban populations), while 91 % do not meet the daily recommended minimum dietary potassium intake [8–10].

In low sodium salt substitutes (LSSS), a proportion of sodium chloride (NaCl) is typically replaced with potassium chloride (KCl). In the landmark Salt Substitute and Stroke Study (SSaSS) in China, salt substitutes reduced the risk of major adverse cardiovascular events (rate ratio, 0.87; 95%CI 0.80 to 0.94; $P < 0.001$), stroke (rate ratio, 0.86; 95%CI 0.77 to 0.96; $P = 0.006$), and led to a reduction in BP (mean difference in systolic BP; −3.34 mm Hg (95 % CI −4.51 to −2.18) over 5 years [11]. Similar BP reductions were shown in a salt substitute trial in India [12]. However, these trials used salt substitutes with different formulations, for instance, a 25%KCl; 75%NaCl formulation in China, whereas in India a formulation of 30 %KCl; 70 %NaCl was used.

Systematic reviews have shown that potassium supplementation can have the greatest BP lowering effects on individuals with low potassium intakes and high sodium intakes [13], such as those observed in South Africa [9]. However, with median potassium intakes at approximately only one-third of the current dietary recommendations [10], a higher proportion of KCl in a salt substitute may be necessary. As people of African descent have a greater likelihood of having raised BP due to sodium sensitivity [14,15], a salt substitute containing more potassium and less sodium may have profound effects on reducing BP in Africa. However, it is unknown whether formulations with higher proportions of KCl would be acceptable to the South African population based on taste and visual inspection. We, therefore, compared the taste and visual acceptability of 35 %, 50 %, 66 % and 100%KCl salt substitute formulations to common salt (100 %NaCl) in urban South African adults.

2. Methods

2.1. Study population

Fifty-six ($N = 56$) individuals were recruited through a youth community centre based in the Soweto area of Johannesburg. Adults, aged 18 years or older, with no self-reported previous diagnosis of kidney disease, diminished kidney function or food allergies, residing in the local urban area were purposively sampled, with additional participants that met the eligibility criteria recruited through snowball sampling. Trained researchers who spoke the participant's home language explained the study and all participants provided written informed consent prior to participation. The study was conducted according to the principles of the Declaration of Helsinki [16] and the Human Research Ethics Committee (Medical) of the University of the Witwatersrand approved the protocol (M220652).

2.2. Study approach

Double-blinded taste and visual tests were conducted over 2 h. Participants were each provided with five sets of commercially available water crackers (sodium ±18mg/cracker; potassium ±7mg/cracker) accompanied by four sets of LSSS and usual table salt. Water crackers were chosen as they have no strong taste of their own. The salt formulations included (i) Cerebos (RSA) 100%NaCl, (ii) a Cerebos (RSA) 35%KCl; 65%NaCl blend, (iii) a Cerebos (RSA) 50%KCl; 50%NaCl blend, (iv) a Lo Salt (UK) 66%KCl; 34% NaCl blend and (v) a Nature's Source (RSA) 100%KCl. Each salt was alliquoted into clear packaging, sealed and labelled using only a coloured sticker. For the taste test only, the five salts were all ground to the same texture prior to packaging so as not to influence taste perceptions through differences in appearance.

Participants were asked to place a small pinch of each salt onto different water crackers. Participants were randomly assigned by a researcher present on the day to each station in a different order to negate influence from the order of testing. Participants were asked to provide feedback on rank, and compare the taste of each salt using a provided survey and score sheet. Between each station, participants were provided with a lemon-lime palette cleanser drink (the Vita-Sun Zero Sugar lemon-lime concentrate drink was mixed according to manufacturer guidelines in a ratio of 1L of concentrate to 4L of water) and were requested to wait 2 min before moving to their next assigned station. Following the taste test participants were informed of the differences between samples. Participants were then given the five salt samples to visually inspect and asked to determine if they could correctly identify all five samples. Questionnaires were administered to rank the perceived taste of the five versions of salt as well as the perceived salt content of each of the five formulations based on visual assessment. Additional questionnaires were administered to determine perceptions of typical salt use and nutritional habits related to typical salt use. Although the process of the taste test was fairly complex and the generally low education levels in South Africa [17], participants had not received any specific health literacy training. However, the full procedure was explained to participants during the consenting process and all participants were given the opportunity to ask questions. Instructions were reiterated at the start of the taste test and researcher assistants, who were blind to product allocations, were available to clarify any instructions in multiple languages and guided participants step by step through the testing process.

2.3. Statistical analyses

Study data were collected by trained researchers and captured into and managed using REDCap electronic data capture tools hosted at The University of the Witwatersrand [18]. Statistical data analysis was conducted in SPSS 28.0. Data was assessed for normality using visual inspection of histograms and skewness and kurtosis, with continuous data reported as the median and interquartile range (IQR). Categorical data were presented as absolute numbers and percentages. Percentage was calculated for each possible response for all likert scales. The top-2-box and bottom-2-box scores were calculated for each likert scale indicating the highest and lowest-ranking potassium-enriched LSSS. The top-2-box and bottom-2-box scores were used to conduct two proportion Z-tests to examine the difference between NaCl as a reference and the four various LSSS.

To determine the sample size needed for this crossover randomized study to detect a 20 % difference (D) in taste with a power of 80 % and an alpha significance level of 0.05, we used the formula for crossover design for proportions:

$$n = 2Z^2_{1-\frac{\alpha}{2}}.P(1-P)/D^2$$

Where Z is the Z-score, P is the estimated proportion in the population, and D is the desired proportion Z-score difference. Based on this calculation we required a minimum of 48 participants.

3. Results

The final sample included n = 56 participants with a median age of 21, of which 45.6 % were male and 54.4 % female (Table 1). Participants were asked to score salt formulations on taste ranking, perception and likeliness to use.

3.1. Taste ranking

NaCl (100 %) had the highest top-2-box score for taste ranking (54.9 %) and taste perception (69.6 %) but not for likeliness to use. In terms of taste ranking of the salt substitutes (Fig. 1A), 45 % of participants ranked 50%KCl as either fantastic or really good. Only 12 % indicated the same for 100%KCl respectively. In contrast (Fig. 1B), 51 % of participants indicated they found the 100%KCl not very good or awful while only 22 % reported the same for 50% KCl. Responses were similar on either side for 35%KCl and 66%KCl. Top-2-box score proportions (Table 2) for 50%KCl ($p = 0.30$) did not differ significantly from NaCl while 35 % ($p = 0.012$), 66 % ($p \leq 0.001$) and 100%KCl ($p \leq 0.001$) did. Only 100%KCl ($p \leq 0.001$) differed from NaCl on the bottom-2-box score.

Table 1 Participant characteristics.

Characteristics	Total (n = 56)
Age, years (Median, IQR)	21 (19.5–24.0)
Sex, n (%)	
Male	26 (45.6)
Female	31 (54.4)

3.2. Taste perception

When examining taste perceptions of the salt substitutes (Fig. 2A) 62 % of participants indicated they liked and would be happy to use it or felt the 50 %KCl tasted like normal seasoning. Conversely (Fig. 2B), 71 % of participants indicated they would eat but did not like or would not eat the 100%KCl. Responses for 35%KCl and 66%KCl were split equally. For both top- and bottom-2-box scores (Table 2) proportions 35 % (Top: $p = 0.034$; Bottom $p = 0.034$), 66 % (Top: $p = 0.034$; Bottom: $p = 0.034$) and 100%KCl (Top: $p \leq 0.001$; Bottom: $p \leq 0.001$) differed significantly from NaCl while 50%KCl did not (Top: $p = 0.38$; Bottom $p = 0.39$).

3.3. Likeliness to use

Participants ranked salt substitutes on likeliness to use (Fig. 3A), 57 % ranked 50% KCl the most or second most likely to use. While 56 % of participants ranked the 100% KCl and 54 % ranked the 66 %KCl as the least or second least likely to use (Fig. 3B). Both top- and bottom-2-box score (Table 2) proportions for 66 % (Top: $p = 0.001$; Bottom: $p \leq 0.001$) and 100 % KCl (Top: $p = 0.001$; Bottom: $p = 0.001$) differed significantly from NaCl while neither 35 % (Top: $p = 0.056$; Bottom $p = 0.11$) or 50 %KCl differed (Top: $p = 0.92$; Bottom $p = 0.68$).

3.4. Visual identification

Participants were also asked to attempt to visually identification of the various salt formulations (results shown in Fig. 4). Most participants (57.3 % and 36.4 %) were able to accurately identify 100 %NaCl and 100 %KCl. As for the salt substitute blends 35 %KCl, 50 %KCl, and 66 %KCl accurate visual identification was generally poor.

4. Discussion

In this study, we asked 56 individuals to conduct a double-blind comparison of a range of potassium-enriched LSSS with common salt as a reference both visually and by taste. When examining potassium-enriched LSSS taste across three categories: taste ranking, taste perception and use ranking the 50%KCl performed the best. In all three categories for both the top-2-box score and bottom-2-box score proportions, the

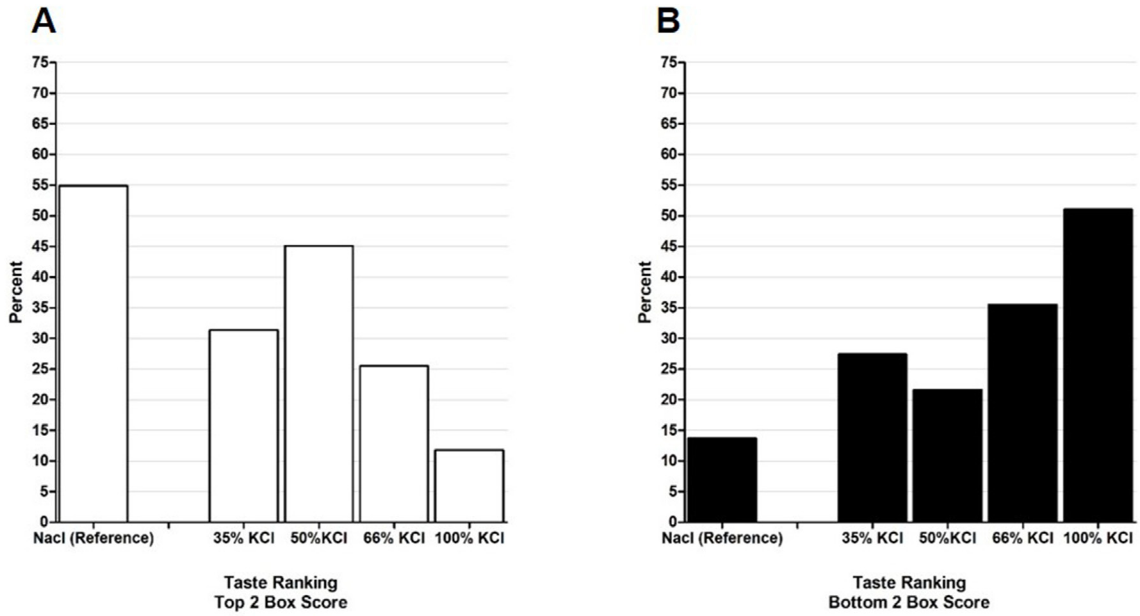

Figure 1 **A.** Top and **B.** bottom-2-box score of taste ranking of various salt formulations.

Table 2 Two Proportion Z-Test between the top-2-box score and bottom-2-box score of NaCl and various salt formulations.

	NaCl (Reference)	35 % KCl	50 % KCl	66 % KCl	100 % KCl
Top-2-Box Score					
Taste Ranking	–	z = 2.510	z = 1.037	z = 3.520	z = 4.837
		p = 0.012	p = 0.30	**p ≤ 0.001**	**p ≤ 0.001**
Taste Perception	–	z = 2.115	z = 0.865	z = 2.115	z = 4.340
		p = 0.034	p = 0.38	**p = 0.034**	**p ≤ 0.001**
Likeliness to use	–	z = 1.908	z = −0.096	z = 3.228	z = 3.228
		p = 0.056	p = 0.92	**p = 0.001**	**p = 0.001**
Bottom-2-Box Score					
Taste Ranking	–	z = −1.794	z = −1.096	z = −1.096	z = −4.219
		p = 0.073	p = 0.27	p = 0.27	**p ≤ 0.001**
Taste Perception	–	z = −2.115	z = −0.869	z = −2.115	z = −4.340
		p = 0.034	p = 0.39	**p = 0.034**	**p ≤ 0.001**
Likeliness to use	–	z = −1.602	z = −0.412	z = −3.456	z = −3.255
		p = 0.11	p = 0.68	**p ≤ 0.001**	**p = 0.001**

P values typeset in bold indicate statistical significance.

50%KCl did not differ significantly from common salt. Common salt (reference) scored higher than all the LSSS on taste perception and ranking. This may be as a result of the familiarity of the taste of common salt or the absence of a metallic taste reported to be associated with some LSSS [19]. While salts were ground to the same consistency prior to the taste tests, this was not the case for the visual tests and visually participants were able to accurately identify common salt most often followed by the 100 %KCl, while accurate identification of the 35 %, 50 % and 66%KCl was low and varied minimally.

As mentioned, researchers in China [11] and India [12] have conducted trials comparing the effects of salt substitutes to traditional table salt (100 %NaCl) to lower blood pressure in large populations. However, these trials made use of salt substitutes with different formulations. Salt substitutes were effective in reducing blood pressure in these populations that are estimated to consume at least 50 % of their sodium intake through discretionary use, (i.e. at the table or during food preparation). A systematic review estimated China and India's average discretionary salt use to be 69 % and 86 %, respectively [20]. In South Africa, approximately 33–46 % of salt intake is from discretionary use [21]. It may thus be more appropriate to use a salt substitute with a higher proportion of KCl for discretionary use to offset the higher percentage of the population's salt intake from non-discretionary use. However, since it is unknown whether there is user preference for certain formulations in how these salt substitutes look or taste, our study in a local South Africa population provides important insights relevant to future implementation of salt substitutes.

Minimal research into taste perceptions of LSSS is available and to the best of our knowledge none within a

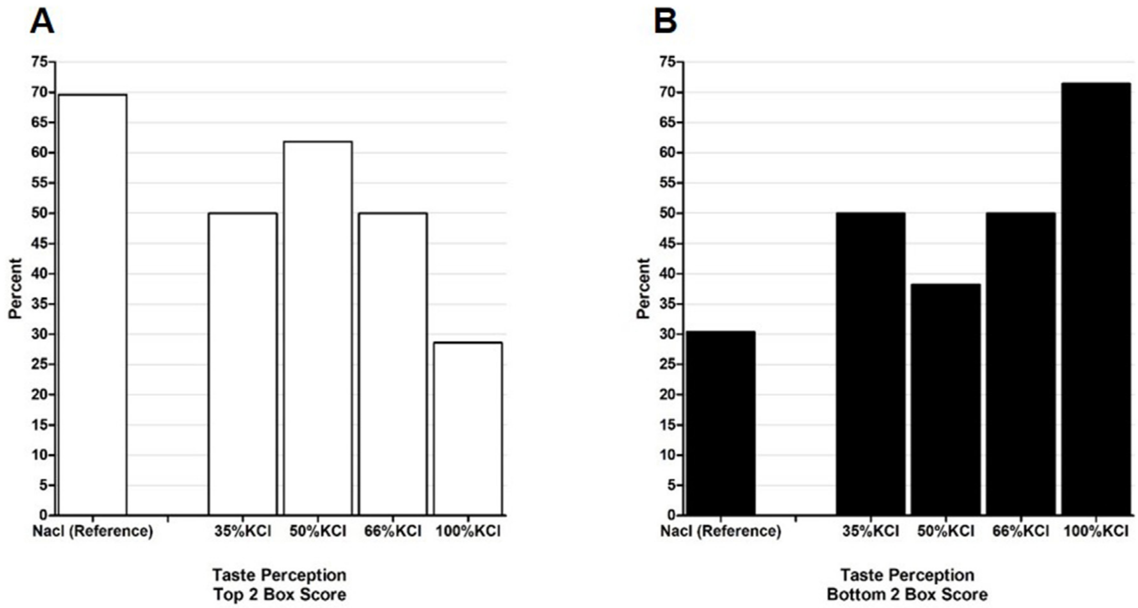

Figure 2 **A.** Top and **B.** bottom-2-box score of taste perception of various salt formulations.

South African context. Studies have suggested the gene Transient Receptor Potential Vanilloid 1 (TRPV1) rs8065080 may play a role in salt taste perceptions and preference. [22,23] Given the potential for unknown ethnic or regional differences in the expression of TRPV1, it is important to understand taste perceptions of LSSS within a South African context. A study conducted in Peru made use of a triangle method (a method in which participants are given three samples, two identical and one different, and asked to determine the odd one out) to determine whether LSSS were distinguishable from common salt [24]. They found that 25%KCl salt was indistinguishable from common salt with 63/156 participants accurately identifying it, while 33 % and 50%KCl were found to be significantly distinguishable from common salt with 69/156 and 82/156 participants accurately identifying the potassium-enriched salt substitute [24]. While statistically significant this does still indicate that almost half were unable to accurately identify the various substitutes. Furthermore, Saavedra-Garcia et al. [24] showed of those who correctly identified the LSSS, only 12.7, 5.8 and 6.1 % reported a high degree of difference for the 25 %, 33 % and 50%KCl with the majority reporting a moderate taste difference for all three. However, the ability to perceive a taste difference does not equate to acceptability or perception of taste [24]. This highlights the need for

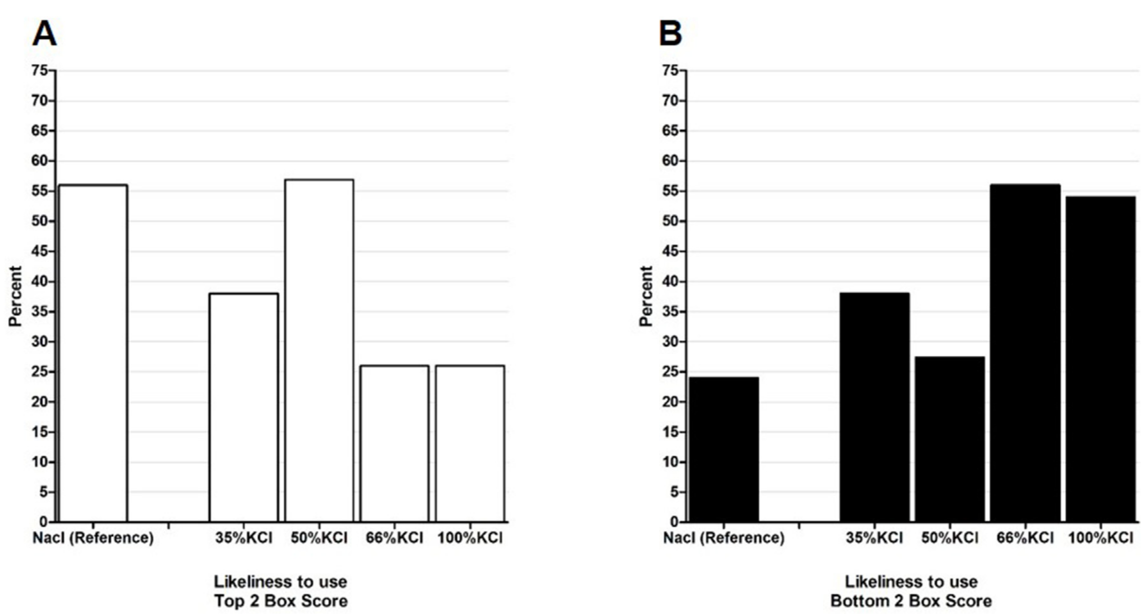

Figure 3 **A.** Top and **B.** bottom-2-box score of likeliness to use of various salt formulations.

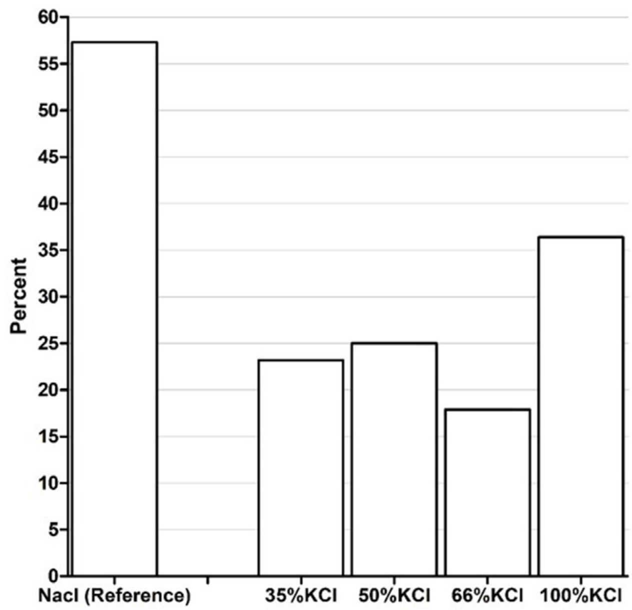

Figure 4 The percentage of participants who accurately identified salt formulations based on visual inspection.

studies to investigate acceptability, taste perception and willingness to use various LSSS.

A study in China assessed the changes in perceptions of saltiness, flavour and acceptability of home-cooked foods and a standard salt-seasoned soup between a control group provided with common salt and an intervention group provided with a salt substitute (65%NaCl; 25 %KCl; 10 % magnesium sulphate) for use in all cooking, pickling and other uses within the household over a 12 month period [25]. They found that changes in the perceptions of saltiness, flavour and overall acceptability did not differ between groups [25]. However, secondary analysis did show rating of flavour was lower in the salt substitute group, this did not appear to discourage the use of the potassium-enriched salt substitute [25]. In contrast, a study conducted by Braschi et al. in the United Kingdom, examined perceptions of appearance, odour, texture, aftertaste, flavour and overall acceptability of standard bread and bread made with a 50 %KCl substitute [26]. They found that while scores varied across test factors, the overall acceptability of bread made with a 50 %KCl substitute did not differ significantly from the breads scored as non-acceptable [26]. This difference in findings within studies as well as between studies conducted in different populations, highlights the need not only for investigation into this topic but for population-specific investigation. Amongst other things, patterns of salt usage, cooking patterns and preferences as well as potential genetic differences may all contribute to differences in response to various LSSS.

One important factor to acknowledge when evaluating potassium-enriched LSSS is chronic kidney disease (CKD). In South Africa, the prevalence of CKD is estimated to be around 6.4–8.7 % [27], however the prevalence of undiagnosed CKD is high in many LMICs [28]. While higher potassium LSSS may compensate for the lower discretionary salt use in countries such as South Africa (as currently LSSS are available for consumer purchase but rarely used in product manufacturing), higher potassium levels may pose a risk in undiagnosed CKD patients [29]. However, a recent study has shown kaliuresis not to be correlated to eGFR in stage 1–4 CKD patients, not supporting the need for strict dietary potassium control in the regulation of kalemia in CKD patients [30]. With this said, as potassium handling may differ between various populations [31], it remains important to ensure adequate screening and evaluation in high-risk populations. CKD patients are also advised to moderate sodium intake and as such, both sodium and potassium may pose individual risks [29]. The LSSS in this study are not iodised. Iodine is important for fetal and child growth, neurological and motor development [32]. To counter iodine deficiencies, the World Health Organisation endorsed universal salt iodisation for all salt consumed by humans and animals [33,34]. In 1995 South Africa implemented mandatory salt iodisation replacing voluntary iodisation [35]. Charlton el al. [36], suggested South Africa's salt reduction strategies may impact the adequacy of iodine supplementation strategies and recommended iodine status of populations undergoing salt reduction strategies should be closely monitored. As such, if LSSS are rolled out on a population level, iodisation of the LSSS would be required.

Our study should be interpreted within the context of its strengths and limitations. This study included a convenience sample of South African adults, where samples were tasted in a random order to ensure no consistent influence of the order of tasting. However, participants may have experienced sensory overload or taste fatigue. In an attempt to counter this participants were provided with a lemon-lime drink between salt samples and were requested to wait 2 min between each tasting. This taste test was conducted using water crackers as they served as a flavour neutral option. However, this may not reflect typical scenarios where LSSS are used, such as in cooking and the response to LSSS in other food combinations may differ. Due the young age of the participants (median 21 years), taste perceptions may differ from that of older adults, however, literature has suggested that perceived taste intensity decreases with age, though research in African populations is limited [37]. It is unknown whether iodisation of LSSS may result in changes in taste perceptions and ranking. As such, taste testing would need to be repeated.

Our findings suggest that the 50%KCl salt substitute would be well tolerated from a taste perspective within a South African context. In addition, the 50%KCl was not visually distinguishable by the majority of participants and as such would be well suited for general home use.

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Authors' contributions

The authors confirm contribution to the paper as follows: study conception and design: SHC, LJW, SAN and AES; data collection and management: SHC and LJW; analysis and interpretation of results: SHC and SAN; draft manuscript preparation: SHC; critical review of manuscript: LJW, SAN and AES. All authors reviewed the results and approved the final version of the manuscript.

Conflict of interest

None to declare.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.numecd.2023.12.015.

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