

## A Double-Blind Randomized Crossover Trial on The Palatability Of A Multi-Mineral Low-Sodium Salt Substitute Among Adults In Pondicherry, India

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### Abstract

**Background:** Excessive discretionary salt intake drives the rising burden of early-onset hypertension in South India. While low-sodium salt substitutes (LSSS) lower blood pressure, widespread adoption is limited by the metallic aftertaste of potassium chloride (KCl). This study evaluated the sensory profile and palatability of a novel mineral-fortified 50/50 NaCl-KCl blend.

**Methodology:** A double-blind, randomized crossover trial was conducted at the East Coast Institute of Medical Sciences, Pondicherry, among 56 healthy adults (median age: 42 years; 60.7% male). Participants evaluated neutral-flavored plantain fries prepared with either standard table salt (Salt A) or an experimental LSSS blend fortified with calcium and magnesium masking agents (Salt B). Sensory attributes were quantified using a 9-point Hedonic scale.

**Results:** Salt A exhibited a distinct ceiling effect with a median overall palatability score of 9 (IQR: 0.0). Although the LSSS blend (Salt B) showed a statistically significant increase in sensory divergence ( $p < 0.001$ ), it maintained an exceptionally high median overall palatability score of 8 (IQR: 1.0), classifying it firmly within the "Like Very Much" category. Median scores for bitterness and metallic perception for Salt B remained remarkably minimal at 2 (IQR: 1.0) and 2 (IQR: 2.0), respectively. Furthermore, 91.1% ( $n=51$ ) of participants expressed a high likelihood of adopting the blend for daily household use.

**Conclusion:** A 50/50 NaCl-KCl substitute fortified with magnesium and calcium successfully masks undesirable metallic notes while preserving taste acceptability. Given high discretionary salt habits, this formulation represents a culturally seamless public health weapon against hypertensive heart disease.

**Keywords:** Sodium Chloride, Dietary, Potassium Chloride, Hypertension, Taste Perception, India

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### Introduction

Globally, the burden of non-communicable diseases (NCDs), particularly cardiovascular and renal complications, has escalated rapidly [1-3]. Hypertension and diabetes remain the primary drivers of these conditions [3-7]. In the Indian context, the prevalence of hypertension is increasing at an alarming rate, with the mean age of diagnosis dropping as low as 21 years [3- 8]. Recent evidence suggests that rapid dietary transitions are largely responsible for this early onset of hypertension and metabolic syndrome among young adults [7-9].

Excessive dietary sodium is a well-established risk factor for hypertension and cardiovascular disease, whereas adequate dietary potassium intake exerts a protective, blood pressure-lowering effect [3-7]. Despite global guidelines, a vast majority of the Indian population exceeds the recommended daily sodium limits while failing to meet the minimum requirements for potassium intake [8-10]. This nutritional imbalance is particularly acute in South India, where discretionary salt added during cooking accounts for over 80% of total intake [5,10,11].

Low-sodium salt substitutes (LSSS), where a proportion of sodium chloride (NaCl) is replaced with potassium chloride (KCl), have emerged as a powerful public health intervention [10,11]. The landmark Salt Substitute and Stroke Study in China demonstrated that LSSS significantly reduced the risk of stroke and major adverse cardiovascular events [12]. Similar efficacy in blood pressure reduction has been mirrored in trials across India [10,11,13-15]. However, a significant barrier to the widespread adoption of LSSS remains the distinct metallic aftertaste associated with KCl formulations.

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While previous international trials have utilized various blends, there is a critical need for population-specific investigations into the palatability of higher-ratio substitutes. This study, therefore, evaluates a unique 50/50 NaCl-KCl formulation fortified with Magnesium chloride and Calcium chloride to assess its sensory

profile and potential as a viable dietary intervention in the Puducherry population.

**Methodology**

The present research utilized a quantitative, experimental study approach with a double-blind, randomized crossover design to evaluate the sensory profile and palatability of a sodium-reduced, potassium-enriched salt substitute. This design was selected to enhance internal validity; by allowing each participant to serve as their own control, the study mitigated the confounding effects of individual taste threshold variations, thereby strengthening the statistical power of the results. The sample size of 56 participants was determined based on a precedent in recent literature [16] evaluating similar potassium-enriched salt substitutes in diverse adult populations, which identified this cohort size as adequate to detect meaningful differences in sensory perception using hedonic scaling. Recruitment was conducted at the East Coast Institute of Medical Sciences using a hybrid strategy of hospital-based outreach and snowball sampling. Inclusion criteria required participants to be adults aged 18 years or older with no self-reported history of cardiovascular disease, renal impairment, or food allergies. Prospective participants were screened for hypertension during the intake phase, and those meeting the criteria were enrolled via purposive sampling on a voluntary basis. The study protocol adhered strictly to the ethical principles outlined in the Declaration of Helsinki [17] and received formal approval from the Human Research Ethics Committee of the East Coast Institute of Medical Sciences (Ref:EC/NEW/INST/2024/4589/EIMS/2026/37). The code of conduct for sensory science has also been respected.

Prior to participation, all individuals provided informed consent following a detailed explanation of the study

objectives and procedures in Tamil, the local language. For the sensory evaluation, neutral-flavored plantain fries were utilized as the food carrier to isolate the sensory impact of the salt variants. Participants were randomized via a computer-generated sequence to receive two distinct snack sets: Salt A is the standard table salt (NaCl) and an experimental set Salt B is Low sodium salt substitute (LSSS) prepared with a sodium-reduced blend containing 1.9 g of sodium and 1.7g of potassium per 10 g of the formulation which is salt B. To eliminate order bias, the sequence of sample presentation was randomized. The procedure was conducted in a controlled environment where a standardized 2-minute washout period was mandated between assessments, during which participants cleansed their palates with distilled water to prevent carryover effects. Sensory acceptability was quantified using a 9-point Likert Hedonic scale, ranging from 1 (dislike extremely) to 9 (like extremely), measuring saltiness intensity, bitterness/metallic perception, taste perception, and overall palatability. Throughout the data collection, bilingual research assistants remained blinded to the salt allocations. Statistical analysis was performed using SPSS (Version 26.0), employing the Wilcoxon Signed-Rank test to compare the ordinal scores of the two salt variants, with a significance threshold set at  $p < 0.05$ .

**Results:** The final sample comprised N=56 participants with a median age of 42 years. The gender distribution included 60.7% males (n=34) and 39.3% females (n=22). Participants evaluated the salt formulations palatability across three primary sensory domains: taste, perception, and likelihood of use, as detailed in Table 1.

**Table 1: Demographic characteristics of the study participants (N=56).**

Variable	Value (N=56)
Age (Median)	42 years
Male	34 (60.7%)
Female	22 (39.3%)

**3.1. Taste Ranking and Sensory Intensity**

The first primary objective was to determine if the Low-Sodium Salt Substitute (Salt B) could match the sensory profile of standard table salt (Salt A).

- **Salt Intensity:** Participants reported a median score of 9 (IQR: 0.0) for table salt and 7 (IQR: 1.0) for the LSSS blend. While the intensity of the low-sodium variant was perceived as lower, the high median score indicates the blend provides a strong "salty" taste.
- **Bitterness and Metallic Perception:** A critical

challenge with potassium-based substitutes is the Associated metallic aftertaste. In this cohort, metallic perception for the LSSS remained low, with a median score of 2 (IQR: 2.0) on the 9-point scale. Bitterness levels were similarly minimal (Median 2, IQR: 1.0), indicating high sensory refinement.

*Taste Perception and Overall Palatability*

Overall palatability was assessed to determine the clinical and culinary viability of the low-sodium salt for regional dietary interventions.

**Table 2: Comparative Sensory Attribute Analysis (N=56).**

Sensory Attribute	Salt A (Median, IQR)	Salt B (Median, IQR)	p-value*
Saltiness Intensity	9 (0.0)	7 (1.0)	< 0.001*

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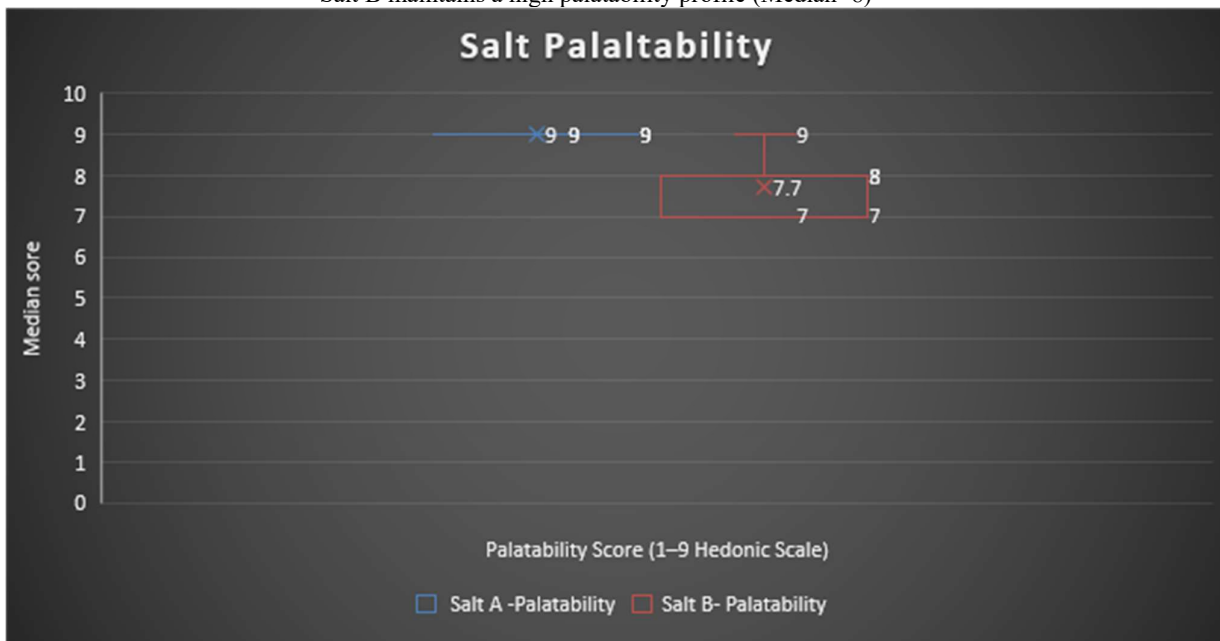
Bitterness Level	Among Adults In Pondicherry	India	< 0.001*
Metallic Perception	1 (0.0)	2 (2.0)	< 0.001*
Overall Palatability	9 (0.0)	8 (1.0)	< 0.001*

\*Data analyzed using the Wilcoxon Signed-Rank Test Statistically significant at  $p < 0.05$ .

Table 2 shows. LSSS exhibited a statistically significant increase in perceived bitterness and metallic perception compared to standard table salt, these sensory shifts did not adversely impact global acceptance. The median

Overall Palatability score for the substitute remained exceptionally high at 8 (IQR: 1.0), situating the formulation firmly within the "Like Very Much" category on the 9-point hedonic scale.

**Figure 1.** Comparative Palatability Scores of Salt A and Salt B (N=56). The Box Plot displays the median, interquartile range, and whiskers representing the score distribution. Salt A shows maximum palatability (Median=9, IQR=0) while Salt B maintains a high palatability profile (Median=8)



#### Likelihood of Use

On evaluating the participants likelihood for daily household use of low-sodium salt 91.1% (n=51) of participants expressed a high likelihood of use (scoring 8 or 9 on the scale). This suggests that the 50% sodium-potassium blend is highly compatible with local palates and could serve as an effective tool for community-level blood pressure management.

#### Visual Identification and Aesthetic Perception

Before the sensory evaluation, participants attempted to visually distinguish between the two samples. Much of the cohort could not identify any visual difference between the standard table salt and the LSSS blend. Physical characteristics, including color, grain size, and flowability, were perceived as identical. This ensures that a transition to low-sodium salt would face no aesthetic barriers regarding the "look and feel" of the product in a domestic kitchen setting.

#### Discussion

The sensory evaluation of low-sodium salt substitutes (LSSS) is a critical determinant of long-term dietary adherence, particularly in regions with high cardiovascular disease burdens. In the present study, the control group (common table salt) demonstrated a

distinct "ceiling effect," yielding a median palatability score of 9 with zero variance (IQR 0.0) as shown in Table 2. The study showed absolute consensus underscores the deep-seated sensory familiarity of a pure sodium chloride (NaCl) common salt. In contrast, the intervention blend (Low-Sodium Nutri-Salt) maintained a strong high-performance profile, scored a median score of 8 (IQR 1.0). While the substitute exhibited a slightly wider distribution (ranging from 7 to 9), the dense data clustering within the "Like Very Much" and "Like Extremely" categories confirms that the intervention remains highly palatable to the study population.

Crucially, the definitive breakthrough of this evaluation rests upon the sharp distinction between statistical and clinical significance. A Wilcoxon signed-rank test (Table 2) revealed a statistically significant difference in palatability scores between common salt and the LSSS alternative ( $p < 0.001$ ). However, from a clinical and behavioral perspective, the critical takeaway is the proximity of the substitute to the maximum score. The substantial overlap in the high-score region demonstrates that the LSSS is a sensory-viable candidate for long-term dietary sodium reduction without

compromising participant satisfaction or requiring disruptive shifts in culinary habits.

These sensory outcomes strongly align with existing international literature on potassium-enriched blends. For instance, Simone H. Crouch et al. observed that nearly half of their participants (45%) ranked a 50/50 NaCl/KCl blend as "really good," while 62% reported they would gladly use it regularly or found it indistinguishable from common table salt [16]. The high median score of 7 for absolute saltiness in our study reinforces this trend, confirming that a 50% potassium chloride (KCl) substitution can deliver a potent, satisfying "salty hit" that mirrors traditional formulations.

Crucially, our formulation successfully mitigated the metallic aftertaste and bitter off notes that frequently act as primary barriers to KCl adoption [18]. While metallic perception was statistically higher in the LSSS group, the median score remained remarkably low at 2.0, indicating that off-notes were perceived only "slightly." This successful mitigation is largely attributable to the strategic addition of magnesium chloride (MgCl<sub>2</sub>) and calcium chloride (CaCl<sub>2</sub>) within the nutraceutical blend, which function as sensory masking agents while simultaneously providing essential minerals often deficient in the regional diet.

Furthermore, the sensory acceptance observed here is highly perspective dependent. While historical European trials, such as those by Braschi et al., frequently highlight metallic barriers as a cause for rejection [19], an overwhelming 91.1% (n = 56) of participants in our cohort reported a high likelihood of regular use (scoring 8–9). This discrepancy suggests that the integration of masking agents, combined with the specific regional food matrix used during testing (plantain fries), successfully shielded against undesirable flavor notes. From a public health implementation standpoint, these findings carry profound implications for regional stroke and hypertension management. Large-scale clinical trials across Asia have robustly established that the consistent use of low-sodium salt substitutes significantly lowers blood pressure [20,21]. However, the real-world efficacy of these interventions depends heavily on how a population consumes its salt. LSSS strategies are most effective in communities that consume at least 50% of their daily sodium through discretionary use—meaning salt added at the table or during cooking.

A landmark systematic review estimated that discretionary salt use accounts for roughly 69% of total sodium intake in China and a staggering 86% in India [22] with South Indian populations averaging a high daily intake of 8–10 g [5]. Conversely, in regions like South Africa, discretionary use is much lower, sitting between 33% and 46%, with the remainder hidden in processed, non-discretionary food matrices [16,22,23]. This geographic variance suggests that while South African strategies might require shifting focus toward commercial food reformulation, local populations in India and China are uniquely primed for discretionary LSSS interventions.

Because minimal research has explored the granular taste perceptions of LSSS globally—and to the best of our knowledge, none within a South Indian context—this study fills a critical gap. Introducing a highly acceptable, 50% reduced-sodium substitute that preserves traditional flavor profiles provides public health frameworks in regions like Pondicherry with a powerful, culturally seamless weapon against hypertensive heart disease.

### Conclusion

This study affirmatively demonstrates that a 50/50 NaCl-KCl salt substitute, strategically fortified with Magnesium chloride and Calcium chloride, maintains high consumer acceptability among a cohort of 56 participants. While potassium-enriched salts are often limited by a distinct metallic aftertaste, the inclusion of these additional minerals functions as an effective sensory masking agent, successfully mitigating bitterness while maintaining a median saltiness intensity of 7.0.

Beyond its primary role in sodium reduction, this multi-mineral formulation offers a significant secondary health benefit by contributing to daily mineral requirements. Given the high prevalence of discretionary salt use in South India, this LSSS blend represents a culturally appropriate and palatably viable strategy for hypertension management and long-term metabolic health interventions in the region.

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