Potassium chloride as a salt replacer in food products using rejection thresholds – how much is too much?

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Background

• High sodium consumption is linked to adverse health effects including hypertension, cardiovascular disease, and stroke.
• The recommended upper limit is 2,300 mg Na per day (equal to 5.8 g of salt), yet the average American male consumes almost twice this (10.4 g daily).
• NaCl is multifunctional, acting as a preservative, a source of saltiness, a bitter blocker, and as a functional processing ingredient, making reduction difficult.
• Processed products, including meat, fish, bread and bakery products, are the greatest contributors of sodium in the diet.
• Potassium chloride (KCl) has many similar physical properties to NaCl, and tastes salty.
• KCl does have side tastes however and functions slightly differently.
• Blends of NaCl and KCl are often used to strike a balance between healthfulness and desirable sensory properties.

Prior work in our laboratory

Work done by Harwood et al has shown that RjTs for chocolate spiked with a bitter compound (sucrose octaacetate) were segmented depending on individual chocolate preference. Those who preferred dark chocolate had a greater tolerance for the bitter compound in the spiked sample.

In this study, we hypothesized that bitterness detected from KCl in water might generalize to different RjTs across individuals in real food matrix.

Methods

Participants – Ninety reportedly healthy participants (26 men) were recruited from the campus of Pennsylvania State University and surrounding community via email. Participants were nonsmokers aged between 18–45 with normal taste and smell. Procedures were exempted from IRB review by the Penn State Office of Research Protections staff under the wholesome foods exemption in 45 CFR 46.101(b)(6). Participants provided implied informed consent and were compensated for their time.

Stimuli – No-Salt-Added vegetable juice (*Wegmans, Rochester, NY*) was chosen as the model system to replace NaCl with KCl. A range of samples (n = 6) were used, increasing the KCl from 0 – 100% while simultaneously decreasing the NaCl from 100 – 0% keeping overall molarity constant (see Table 1). The molarity target range was determined based on common levels of salt found in commercially available vegetable juices – 650 mg Na/240 mL serving. All samples (10 mL) were presented in small clear plastic soufflé cups marked with 3-digit blinding codes and served at room temperature (20 °C).

Table 1. The ratio of NaCl to KCl used in the "spiked" samples in the 2-AFC test presented as Molarity and % blend fractions.

Set	NaCl		KCl		Total Molarity
	Molarity (mol/L)	% Blend	Molarity (mol/L)	% Blend	(mol/L)
Control	0.118	100%	0	0%	0.118
1	0.1003	85%	0.0177	15%	0.118
2	0.0826	70%	0.0354	30%	0.118
3	0.059	50%	0.059	50%	0.118
4	0.0354	30%	0.0826	70%	0.118
5	0.0177	15%	0.1003	85%	0.118
6	0	0%	0.118	100%	0.118

Measuring Rejection Thresholds – Participants were presented with six pairs of juice samples on a single tray in a two-alternative forced choice (2-AFC) design.
The control in each pair contained only added sodium chloride; the other ("spiked") sample contained a blend of NaCl and KCl. Participants were instructed to move through the samples and indicate which of the samples they preferred from each pair. Best Estimate Thresholds (BETs) were calculated to determine the acceptable level of KCl replacement on a per individual basis.

KCl qualities – Following the 2-AFC preference tests, participants tasted a 10 mL sample of KCl in water (0.118 M), and rated the intensity of Saltiness, Bitterness, Metallic, and Other on the generalized Labeled Magnitude Scale (gLMS), following a brief orientation to the gLMS. The scale ranges from 0 ("no sensation") to 100 ("the strongest imaginable sensation of any kind"), with descriptors at 1.4 ("barely detectable"), 6 ("weak"), 17 ("moderate"), 35 ("strong"), and 51 ("very strong"), and a generalized non-taste context is encouraged via the orientation procedure.

Specific Aims

To determine how much NaCl can be replaced with KCl in a model food system (vegetable juice):

1. To determine the acceptable range for sodium replacement in vegetable juice
2. To examine KCl bitterness in water as a predictor of KCl tolerance in juice
3. To determine at what point replacement becomes objectionable to everyone.

Results

Finding 1

KCl in water was predominantly perceived as salty with a mean intensity rating of 40 ± 22.15 (SD) which is above 'Strong' and a modal rating of 52 on the gLMS, which is above 'Very Strong'. In contrast, the modal rating for 'bitterness', 'metallic', and 'other' was '0' ('no sensation'), while the respective means were all 17 ('Moderate') or less. Despite this, 44 of the 90 participants rated the bitterness as 'Moderate' or above.

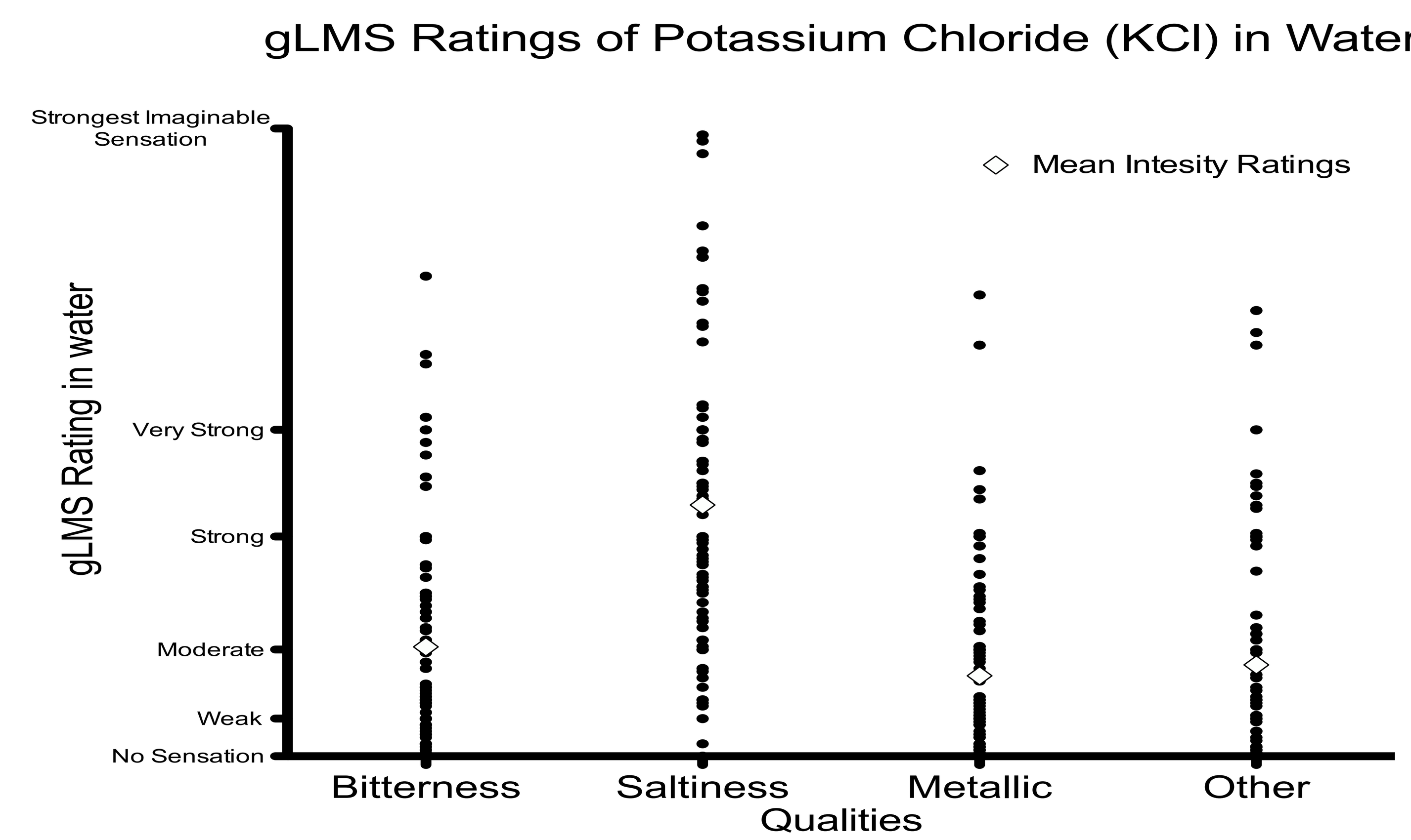

Figure 1. Generalized Labeled Magnitude Scale (gLMS) Ratings of 0.118M Potassium Chloride (KCl) in RO Water for Bitterness, Saltiness, Metallic and Other.

Finding 2

Figure 2 shows the proportion of participants preferring the control over the KCl-spiked sample grew as the concentration of KCl in the vegetable juice sample increased, as expected. The group rejection threshold (RjT) was defined as the concentration at which the chance-corrected proportion reported preferring the control sample was 75%. The group RjT occurred at 0.0855 M KCl or 6.37 g/L KCl.

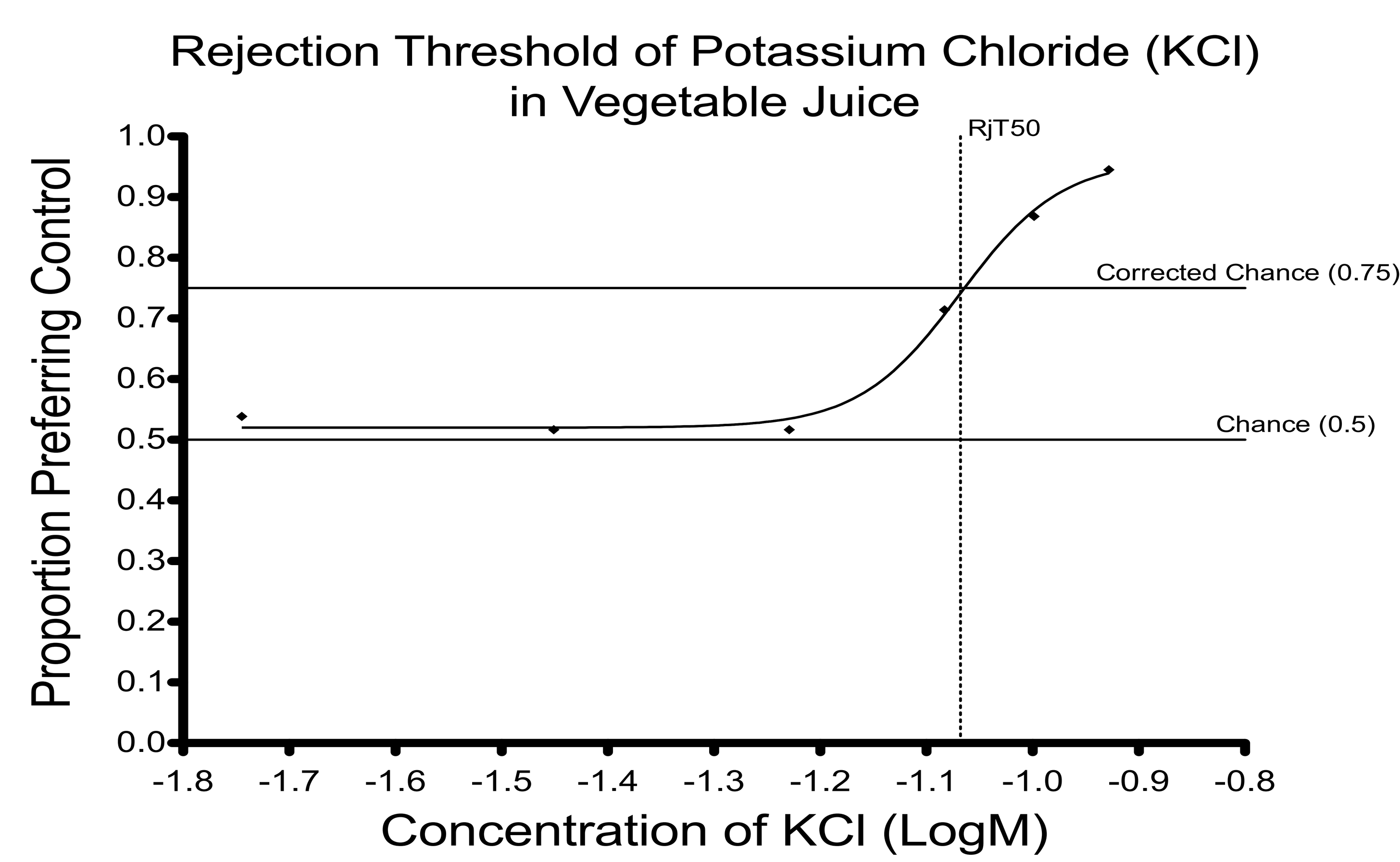

Figure 2. Proportion of participants (n = 90) preferring the control vegetable juice samples plotted against concentration of KCl in the spiked vegetable juice sample. The RjT_{50} represents the point at which the concentration of KCl crosses the chance corrected performance line (which occurs at 75%).

Results continued

Finding 3

A group BET is the geometric mean of the individual BETs – taken here to be the first point and all subsequent pairs at which the unspiked sample was chosen. BETs for the top and bottom 25% bitterness raters of KCl in water were examined in Figure 3, to determine if the rejection of the KCl spiked samples was due to perceived qualities other than saltiness, ($t(47) = 2.318$, $p = 0.025$). Those in the lower bitterness-perception group for KCl in water had a higher mean BETs than the higher perception group.

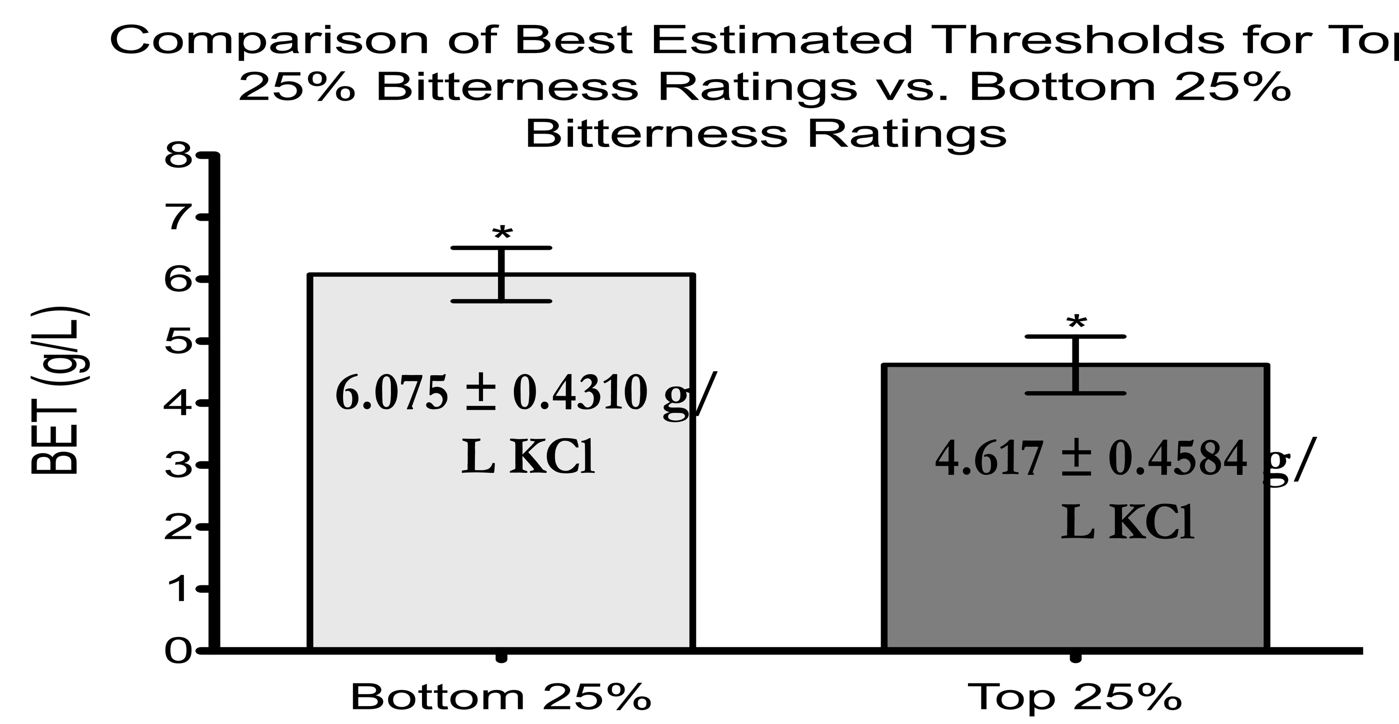

Figure 3. Best Estimate Threshold (g/L) comparison between Bottom 25% Bitterness Ratings and Top 25% Bitterness ratings of KCl in water (p=0.025).

Discussion and Future Work

• The highest concentration at which there was no clear preference between the samples was the third sample, which is equivalent to a 48% reduction (Aim 1).

• Here, we did not measure detection thresholds, thus, it is not clear whether the participants could tell the difference between the spiked and unspiked sample. Other work in RjT for spiked bitterness in a food matrix showed that the RjT was much higher than the detection threshold (Harwood et al, 2012). It would be interesting to see if this too is the case for KCl.
• We found that when comparing the vegetable juice RjT's to bitterness ratings in water, there was no significant difference between the top and bottom quartiles for bitterness ratings of KCl in water. This suggests that the ratings of a negatively associated quality in water may not predict the preference of a complex food system like vegetable juice (Aim 2).
• As shown in Figure 3, there was a significant difference between the BETs of the same two groups based upon bitterness ratings in water, which would suggest that there might be some segmentation in the population for KCl acceptance based upon bitterness (Aim 2).
• 100% replacement of NaCl with KCl for all of the participants was not feasible (Aim 3), as the top concentration of KCl presented presumably adds unappealing side tastes that made it objectionable to most of the participants. Indeed, there may not be a single optimal replacement level that suits an entire population since there were both those who seemed sensitive and insensitive to the amount of KCl added to the juice.
• Bitterness may influence the rejection of KCl in a food, but other qualities likely also affect acceptance. It is important to consider that perception and taste response is context-dependent in a model system verses a complex food system.
•The food matrix, individual differences, potential drivers of rejection, how people value food and how they make food choices (i.e. eating for pleasure verses eating for health benefits) should be evaluated in conjunction with one another, not independently, in order to properly address this issue.

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