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Kinetic Approach of Saltiness Perception

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ABSTRACT

The perception of saltiness is mediated by sodium receptors in the oral cavity, primarily epithelial sodium channels (ENaC). This study investigates the kinetic and thermodynamic properties of various salt solutions (NaCl, KCl, $MgSO_4$, NaCl + KCl, NaCl + monosodium glutamate (MSG)) to understand their impact on saltiness perception. Solutions were evaluated by a trained panel using a reference scale. Michaelis-Menten constant (Km), maximum intensity (I_{max}), and Gibbs free energy (ΔG') were calculated for each solution. Results indicate that NaCl and NaCl + MSG have the highest saltiness perception, followed by NaCl + KCl and KCl, while $MgSO_4$ shows negligible saltiness. NaCl exhibited a lower Km compared to KCl, suggesting higher efficiency at lower concentrations. NaCl and MSG combination showed synergistic effects, enhancing saltiness perception. Lower ΔG' values for NaCl and NaCl + MSG indicate higher affinity for sodium ions. These findings highlight the potential for using alternative salts to enhance saltiness perception while reducing sodium intake.

1. Introduction

The human ability to perceive saltiness is mediated by specialized sodium receptors located on the taste cells of the tongue and other regions of the oral cavity [1]. These receptors are essential for detecting sodium ions and contribute to various physiological processes, including maintaining electrolyte balance and enhancing flavour perception [2-4]. Sodium, as a vital electrolyte, plays critical roles in nerve transmission, muscle function, and fluid balance [5]. However, excessive sodium intake is linked to various health issues, including hypertension, cardiovascular diseases, and renal disorders [6,7].

Recent research has highlighted the importance of understanding sodium receptors in the context of public health [4]. As dietary habits evolve, the consumption of high-sodium foods has increased, leading to a surge in sodium-related illnesses. This underscores the need to explore new sources and methods for salinity perception, potentially aiding in the development of healthier dietary options. By characterising the sodium receptors in the mouth, we can gain insights into how sodium intake can be better regulated through taste perception, thus contributing to improved dietary practices and health outcomes [8].

This paper aims to provide an in-depth analysis of the key constants associated with these sodium receptors, particularly the epithelial sodium channels (ENaC). Understanding these constants is crucial for advancing our knowledge of taste physiology and for developing strategies to mitigate the adverse effects of high sodium intake. By exploring the relationships between sodium receptor function and illness, we can identify potential interventions and new sources for salinity that align with healthier eating habits [4].

2. Experimental Methods

2.1 Solutions Preparation

The salts NaCl, KCl, $MgSO_4$, and sodium glutamate ($C_5H_8NO_4Na$; MSG) were prepared in stock solutions at a concentration of 1 mM, standardized with cations, using pure water. For the tasting sessions, serial dilutions were performed in a range from zero (control, pure water) to 600 mM.

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2.2 Sensorial Evaluation

A trained panel composed of seven trained panel lists evaluated salinity on an intensity scale, using 2.5% NaCl in water as a reference, scoring it as 9 (maximum saturation score) in sensorial perception. The sensorial evaluation was conducted following ethical guidelines and in compliance with ISO 8586:2012, which provides guidelines for the selection, training, and monitoring of qualified panel lists.

2.3 Kinetic Model

Plotted results were analysed using a kinetic approach, for this, we calculate different constants in order to explain the dynamics in the saltiness perception.

2.3.1 Kinetic Constants Calculation

Michaelis-Menten constant (Km), maximum intensity (I_{max}) values was calculated for each salt or salt mixtures using the kinetic model adjustment in the software GraphPad Prism 10.0 according to the following equation:

$I = \frac{I_{\max}[S]}{Km+[S]}$, I= intensity, [S] is concentration of salt, at this case normalized by cation concentration

2.3.2 Thermodynamic Calculations

The Gibbs free energy equation for the dissociation constant was employed as a model to determine the affinity of the interaction between the studied molecules, according to the following equation. This model allows for the calculation of the change in Gibbs free energy (ΔG') and temperature in Kelvin (T, 310.15 K for physiological conditions). For this study, it is assumed that Kd , which cannot be directly calculated due to the nature of the tasting experiment, should approximate the Km derived from kinetic models. This approach was applied to quantify the affinity and characterize the molecular interactions under the experimental conditions established.

$$\Delta G' = -RT\ln(Km)\,;Km \approx Kd \text{ and } T = 310.15\ (K)$$

2.4 Statistical Analysis

Data collected from the sensorial evaluations were subjected to statistical analysis to determine the significance of the differences observed among the different salt solutions tested. Statistical methods

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such as ANOVA and post-hoc tests were utilized to compare the mean salinity scores. The results were interpreted to understand the relative intensity of salinity perceived by the panel lists for each salt solution.

3. Results and Discussion

3.1 Sensory Evaluation Results

The results show that NaCl and NaCl + MSG have the highest saltiness perception, followed by NaCl + KCl, KCl alone, and $MgSO_4$, which shows negligible saltiness perception. The distinct differences in saltiness perception among the salts highlight the varying efficacy of different cations in eliciting the sensation of saltiness.

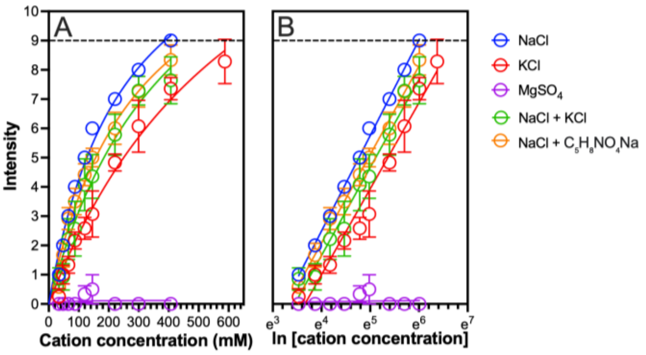

Fig. 1 Perception of saltiness intensity as a function of cation concentration for different salts. (A) The saltiness intensity is plotted against the cation concentration (mM) for different salt solutions: NaCl (blue), KCl (red), $MgSO_4$ (purple), NaCl + KCl (green), and NaCl + MSG (orange). The data points represent mean values, and the error bars indicate the standard deviation (n=3). (B) The same data are plotted on a semi-logarithmic scale where the x-axis represents the natural logarithm of the cation concentration. This transformation linearises the data, facilitating the comparison of different salts' effects on saltiness perception. The dashed line indicates the maximum intensity of nine. The results show that NaCl and NaCl + MSG have the highest saltiness perception, followed by NaCl + KCl, KCl alone, and $MgSO_4$, which shows negligible saltiness perception

3.2 Kinetic and Thermodynamic Determinations

The kinetic and thermodynamic properties of the different salt solutions were analysed based on the sensory evaluation data. The Michaelis-Menten constant (Km), maximum intensity (I_{max}), and Gibbs free energy change (biochemical) (ΔG’) were calculated for each salt solution (Table 1).

Table 1 Values of maximum inhibition (I_{max}) and Michaelis-Menten constant (Km) with their standard errors (SE) for different solutions. The Gibbs free energy (ΔG’) at physiological temperature (37°C) and its standard error are also provided, along with the coefficient of determination (R^2).

Salt	I_{max} ± SE	Km ± SE (mM)	ΔG’ ± SE (kJ/mol)	R^2
NaCl	14.75 ± 1.00^{c}	247.4 ± 24.57^{d}	-3.60 ± 0.26^{d}	0.9804
KCl	18.90 ± 1.15^{a}	694.2 ± 49.14^{a}	-0.94 ± 0.18^{a}	0.9514
NaCl + KCl	16.44 ± 1.10^{b}	420.9 ± 33.45^{b}	-2.23 ± -0.20^{b}	0.9071
NaCl + MSG	14.44 ± 1.04^{a}	295.2 ± 14.74^{c}	-3.15 ± -0.13^{c}	0.9506
$MgSO_4$	n.d	n.d	n.d	0.0150

The superscript letters (a, b, c, d) are used to indicate that the corresponding solutions are not significantly different from each other according to Tukey's HSD test (p < 0.05). Values marked as 'n.d' indicate that the measurement was not determined.

3.3 Discussion

The analysis of the sensory evaluation and kinetic parameters of different salt solutions has provided insightful results into the mechanisms underlying saltiness perception. The findings indicate that the type of cation significantly influences the perceived intensity of saltiness [9], as reflected in the I_{max}, Km, and Gibbs free energy (ΔG’) values obtained for each salt solution.

The sensory evaluation results show that sodium chloride and the combination of sodium chloride with monosodium glutamate solutions elicit the highest saltiness perception, while potassium chloride and the combination of sodium chloride with potassium chloride are moderately salty, and magnesium sulfate exhibits negligible saltiness. This is consistent with the known taste profiles of these salts, where sodium ions (Na^+) are more effective in eliciting a salty taste compared to potassium ions (K^+) and magnesium ions (Mg^{2+}) [10].

The kinetic analysis using the Michaelis-Menten model provided further insight into the dynamics of saltiness perception. The I_{max} values represent the maximum intensity of saltiness perceived, and the Km values indicate the concentration of cations at which the perception reaches half of its maximum intensity. Notably, NaCl exhibited a lower Km value compared to KCl, suggesting that sodium ions are more efficient at lower concentrations in eliciting a salty taste. The combination of NaCl and MSG also showed a relatively low Km value, indicating synergistic effects that enhance saltiness perception.

The ΔG’ calculations provided an understanding of the affinity between the cations and the taste receptors. Lower ΔG’ values for NaCl and NaCl + MSG indicate a higher affinity for sodium ions, which correlates with the higher perceived saltiness. In contrast, KCl and NaCl + KCl solutions had higher ΔG’ values, reflecting a lower affinity for potassium ions. The negligible saltiness perception and indeterminate kinetic parameters for $MgSO_4$ highlight its ineffectiveness in activating salt taste receptors [11].

The two-way ANOVA and Tukey's post-hoc test revealed statistically significant differences among the salt solutions. NaCl and NaCl + MSG solutions were grouped separately from KCl and NaCl + KCl, indicating significant differences in their saltiness perception. These findings underscore the importance of the type and concentration of cations in modulating salt taste.

3.4 Practical Implications

Understanding the kinetic and thermodynamic properties of different salt solutions has practical implications for food formulation and public health. The ability to enhance saltiness perception with lower sodium content, as demonstrated by the NaCl + MSG combination, can be leveraged to develop lower-sodium food products without compromising taste. This approach aligns with public health recommendations to reduce sodium intake and mitigate the risk of hypertension and cardiovascular diseases.

4. Conclusion

In conclusion, the detailed analysis of saltiness perception through sensory evaluation, kinetic modeling, and thermodynamic calculations provides a comprehensive understanding of how different cations influence taste. The findings highlight the potential for using alternative salts and synergistic combinations to enhance saltiness perception while reducing sodium intake. Further research should explore the molecular mechanisms of cation-receptor interactions and their implications for taste modulation and health outcomes.

References

[1] A. Bigiani, The origin of saltiness: oral detection of NaCl, Curr. Opin. Physiol. 19 (2021) 156-161.
[2] Y. Hu, L. Zhang, I. H. Badar, Q. Liu, H. Liu, Q. Chen, B. Kong, Insights into the flavor perception and enhancement of sodium-reduced fermented foods: A review, Crit. Rev. Food Sci. Nutr. 64 (2022) 2248-2262.
[3] X. Wang, Y. Yi, C. Guo, X. Wang, J. Yu, S. Xia, Enhanced sodium release and saltiness perception of surimi gels by microwave combined with water bath heating, Food Hydrocoll. 134 (2023) 108018.
[4] M.E. Doyle, H.U. Premathilake, Q. Yao, C.H. Mazucanti, J.M. Egan, Physiology of the tongue with emphasis on taste transduction, Physiol. Rev. 103 (2023) 1193-1246.
[5] D.A. Jaques, B. Ponte, Dietary sodium and human health, Nutrients 15 (2023) 3696.
[6] S. Borrelli, M. Provenzano, I. Gagliardi, A. Michael, M.E. Liberti, et al., Sodium intake and chronic kidney disease, Int. J. Mol. Sci. 21 (2020) 4744.
[7] Q. Wang, The role of dietary potassium and sodium in hypertension and cardiovascular damage and protection: A narrative review, Heart and Mind 6(1) (2022) 10-15.
[8] F.P. Cappuccio, N.R.C. Campbell, F.J. He, M.F. Jacobson, G.A. MacGregor, et al., Sodium and health: Old myths and a controversy based on denial, Public Health Nutr. 11 (2022) 172–184.
[9] B.J.D. Le Révérend, I.T. Norton, S. Bakalis, Modelling the human response to saltiness, Food Funct. 4 (2013) 880-888.
[10] O. Sahni, J. Didzbalis, J.P. Munafo Jr., Saltiness enhancement through the synergism of pyroglutamyl peptides and organic acids, J. Agric. Food Chem. 72 (2024) 625–633.
[11] H.H.L. Yang, H.T. Lawless, Descriptive analysis of divalent salts, J. Sens. Stud. 20 (2005) 97–113.

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