Journal of Applied Science, Technology & Humanities
Volume 2, Issue 5, November, 2025, Pages 736-744

ISSN 3032-5765
DOI: https://doi.org/10.62535/nt94t493

Web Application Using Fuzzy Logic to Assess Recommended Intake Frequency of Extruded Chiki Snacks

Bayu Praditya[1]*
[1]*Food Quality Assurance, Vocational School, IPB University
pradityabayu@apps.ipb.ac.id

Hanifah Khusnul Syahida[2], Rubina Alleysha Putri Aulia[3], Aurellia Avisa Putri Alya[4], Fairuz Aliyya Khansa[5], Tulus Fernando Sihombing[6], Nazwa Salsabila[7], Rinunti Najwa Putri Minanti[8], Mrr Lukie Trianawati[9], Annisa Raihanah Maimun[10], Wuliddah Tamsil Barokah[11], Roma Juliana Arios[12]
[23456789]Food Quality Assurance, Vocational School, IPB University
[101112]Computer Engineering Technology, Vocational School, IPB University
[2]hanifahsyahida@apps.ipb.ac.id, [3]rualleysha@apps.ipb.ac.id, [4]aurelliaavisa@apps.ipb.ac.id, [5]fairuzzaliyya@apps.ipb.ac.id, [6]tulusfsihombing@apps.ipb.ac.id, [7]cuttiesnazwa@apps.ipb.ac.id, [8]rinuntinajwa@apps.ipb.ac.id, [9]mrr.lukietrianawati@apps.ipb.ac.id, [10]annisaraihanah@apps.ipb.ac.id, [11]19tamsilwuliddah@apps.ipb.ac.id, [12]romajarios@apps.ipb.ac.id

Abstract

Excessive consumption of extruded snacks, particularly *Chiki* products high in sugar, salt, and fat, increases the risk of obesity, hypertension, and metabolic disorders. This study aims to develop a web-based fuzzy logic application using the Mamdani inference system to determine the recommended frequency of consumption based on nutrient composition. The research employed a quantitative descriptive approach integrating three main input variables: sugar, salt, and fat, each represented by fuzzy sets of low, medium, and high levels. The output variable, consumption frequency, was classified into three linguistic terms: daily safe, moderate, and limited. A total of 27 fuzzy rules were constructed and simulated using MATLAB. The results showed that the model effectively translated quantitative nutritional data into qualitative recommendations, with higher nutrient concentrations corresponding to lower consumption frequency. The fuzzy Mamdani model provided smooth decision boundaries, demonstrating high interpretability and potential as a nutritional decision support system for consumer health guidance.

Keywords: fuzzy logic, Mamdani inference, extruded snacks, nutrition, decision support

INTRODUCTION

One type of ready-to-eat food that is widely favored by the public is extruded snacks, commonly known as chiki snack. These products are popular due to their porous, crispy texture, strong flavor, and easy availability (Yadav e*t al*., 2018). However, previous studies have shown that most commercial extruded products have low nutritional value (Budiman *et al*., 2009). They typically contain high levels of sugar, salt, and fat to enhance palatability, and excessive consumption may increase the risk of obesity, hypertension, and metabolic disorders. Moreover, extruded products are classified as ultra-processed foods, which are associated with a higher risk of chronic diseases such as obesity, cardiovascular diseases, and diabetes (Rauber *et al*., 2021).

In Indonesia, the consumption of ultra-processed foods, including packaged extruded snacks, has been shown to be associated with nutritional status and the risk of non-communicable diseases. For example, a study in Padang Panjang City found that high UPF consumption (≈43.4%) was significantly associated with obesity in adults (Fauziyyah *et al*., 2022). These findings indicate that excessive intake of extruded snacks can negatively impact public health, especially if consumption occurs without consideration of the product’s nutritional content.

Given the high levels of sugar, salt, and fat in extruded snacks, it is crucial to provide more specific and actionable consumption recommendations. Although general dietary guidelines exist, most snack consumption advice remains broad and does not account for differences in nutrient content between products or individual dietary needs. Therefore, approaches that can translate quantitative nutritional data into practical and understandable guidance are needed. Fuzzy logic offers an effective solution, as it can convert quantitative values such as sugar, salt, or fat content into linguistic categories such as low, medium, or high while generating flexible, rule-based recommendations tailored to individual consumption patterns.

Fuzzy logic methods have been applied in various nutrition and health domains in Indonesia, such as determining daily calorie requirements for diabetic patients using the Mamdani method, or in decision support systems for assessing nutritional status in young children. However, to date, no study has specifically applied fuzzy logic to determine the consumption frequency of extruded snacks based on their sugar, salt, and fat profiles. Therefore, this study aims to develop a fuzzy logic-based web application that allows users to evaluate extruded snack products based on sugar, salt, and fat content, providing recommendations for safer and more controlled consumption frequency. Through this approach, extruded snack intake can be more effectively managed, reducing the risk of excessive consumption-related issues such as obesity, hypertension, and metabolic disorders, while maintaining realistic dietary choices in the context of modern Indonesian lifestyles.

METHODS

Research Approach

This study uses a quantitative descriptive method with a fuzzy logic-based system development (development research) approach to recommend the frequency of consumption of extruded snacks (*Chiki*). The quantitative approach was chosen because it aims to determine the sugar, salt, and fat content listed on the nutritional information label, which is then analyzed using fuzzy logic through the measurement and processing of numerical data generated from simulations using MATLAB. This system development allows for systematic and measurable statistical analysis, so that the relationship between nutritional parameters can be identified and used to objectively assess the safety level of product consumption. The fuzzy logic method helps provide a more flexible interpretation of numerical data that contains uncertainty, while the use of MATLAB as a simulation tool makes it easy to conduct repeated and consistent experiments in a controlled environment and helps maintain the accuracy and reliability of internal research results (Pramudito, 2025)

Data Collection

Data collection in this study was conducted using the literature review method as part of a qualitative descriptive approach. The method used in this study was a literature review (library research), which is the collection of data by searching for, gathering, and compiling information from various relevant sources, such as books, journals, and existing research results (Adlini *et al*., 2022). Data sources were selected based on their relevance, validity, and credibility, so that they could support analysis from both theoretical and practical perspectives. By utilizing literature study, researchers can build a strong theoretical basis, review previous studies, and more easily understand important concepts related to Fuzzy Logic, especially those related to the food industry.

Data Analysis

Fuzzy logic is a method used to analyze systems when there is uncertainty or uncertain conditions. In this study, the Mamdani method was used to process data and generate decisions. This system was designed through several stages, namely: first, forming fuzzy sets; second, applying implication functions; third, compiling relevant rules; and finally, performing confirmation or defuzzification to obtain clear final results (Putri & Maulana, 2023). The following are the stages used in the *Chiki* product research:

1. Formation of Fuzzy Sets (Fuzzification)

The first stage serves to convert crisp inputs into fuzzy inputs. Before this process is carried out, it is necessary to first determine the variables to be used, both as input and output variables (Kurniadi *et al.*, 2022). In this study, the variables used are sugar, salt, and fat. Each variable is divided into three membership level categories, namely low, medium, and high, with certain value limits according to the input data. Each value in the variable will be given a membership degree (μ) between 0 and 1, which indicates how strongly the value belongs to a category. This process is carried out so that the system can recognize the conditions of each variable more flexibly and not rigidly as in binary logic.

2. Application of Implication Functions

The second stage involves formulating the rules to be applied, which are generally in the form of implications to map the relationship between input variables and output variables. The implication function used in this study is the MIN implication function (Kurniadi *et al*., 2022). This stage is used to connect input and output variables using IF–THEN logic rules. At this stage, the system determines the relationship between sugar, salt, and fat levels and the output or consumption category. The calculation process is performed using the "AND" (min) operator to see how true each rule is. The result value then becomes a fuzzy membership function in the output variable, which will be used in the next stage to determine the final result of the system.

3. Rule Composition (Aggregation)

The third stage is rule composition, which is the process of combining several rules that are fulfilled based on fuzzy values. If more than one rule applies, inference is determined from the set of rules and the relationships between the existing rules. A commonly used method is the Max method, which takes the highest output value from each applicable rule (Kurniadi *et al*., 2022). After all rules are applied, the results of each rule are then combined through a composition process to obtain the overall fuzzy output. In this system, there are many rules (as many as 27 combinations), so rules that have the same output categories, such as safe, moderate, or limited, will be combined using the maximum (max) operator. In this way, the system can determine the highest membership value for each output category before entering the final stage.

4. Confirmation (Defuzzification)

Defuzzification is the process of converting values from fuzzy sets into crisp values so that they can be used as clear and measurable outputs (Rahmawati, 2017). The method used is centroid (center of gravity), which is calculated by averaging all values in the output area. The result of this stage is a final decision that indicates the level of product consumption, namely "safe for daily consumption," "moderate (2-3 times a week)," and "limited (once a week)."

RESULTS AND DISCUSSION

Input Variables and Membership Function Design

The fuzzy inference system was developed using three nutritional inputs sugar, salt, and fat corresponding to common nutrient values found in extruded snack products. To ensure clarity and consistency, each variable is defined using a universe set (overall possible range), domain (operational fuzzy range), and triangular membership parameters (a, b, c). All units are expressed per 100 g product.

Sugar is modeled within a universe of 0–50 g, with fuzzy domains Low (0–10), Medium (9–22), and High (20–50).
Salt is modeled within 0–10 g, with the domains Low (0–1), Medium (0.9–3), and High (2.5–6).
Fat is modeled within 0–40 g, with domains Low (0–10), Medium (8–25), and High (20–40).
All fuzzy sets use triangular membership functions structured as follows:

Table 1. Variable input

Variable	Fuzzy Set	Domain	Parameters (a, b, c)
Sugar	Low	0–10	(0, 5, 10)
	Medium	9–22	(9, 16, 22)

Variable	Fuzzy Set	Domain	Parameters (a, b, c)
	High	20–50	(20, 35, 50)
Salt	Low	0–1	(0, 0.5, 1)
	Medium	0.9–3	(0.9, 2, 3)
	High	2.5–6	(2.5, 4, 6)
Fat	Low	0–10	(0, 5, 10)
	Medium	8–25	(8, 15, 25)
	High	20–40	(20, 30, 40)

The overlapping boundaries (e.g., sugar 9–10 g and 20–22 g) allow smooth transitions, reflecting uncertainty in product formulation and nutritional labeling.

Output Variable: Recommended Consumption Frequency

The output variable represents the recommended consumption frequency, defined over a universe of 0–50 with three linguistic categories: Daily-safe, Moderate, and Limited.

Table 2. Variable output

Output Set	Domain	Parameters (a, b, c)	Description
Daily-safe	0–20	(0, 10, 20)	Can be consumed daily
Moderate	15–35	(15, 25, 35)	2–3 times per week
Limited	30–50	(30, 40, 50)	Once per week

The overlaps at 15–20 and 30–35 reflect natural uncertainty and ensure continuity during inference.

Rule Base and Derivation of General Rule Patterns

The fuzzy system employs 27 rules generated from all combinations of the three input variables (3^3). These rules follow intuitive dietary moderation principles: as sugar, salt, or fat increase, the allowed consumption frequency decreases.

Table 3. Rules

No	Input			Output
	Sugar	Salt	Fat	Frequency Consumption
1	Low	Low	Low	Safe for daily consumption
2	Low	Low	Medium	Safe for daily consumption
3	Low	Low	High	Moderate consumption
4	Low	Medium	Low	Safe for daily consumption
5	Low	Medium	Medium	Moderate consumption
6	Low	Medium	High	Moderate consumption
7	Low	High	Low	Limited consumption
8	Low	High	Medium	Limited consumption
9	Low	High	High	Limited consumption
10	Medium	Low	Low	Safe for daily consumption
11	Medium	Low	Medium	Moderate consumption
12	Medium	Low	High	Moderate consumption
13	Medium	Medium	Low	Moderate consumption
14	Medium	Medium	Medium	Moderate consumption
15	Medium	Medium	High	Moderate consumption
16	Medium	High	Low	Limited consumption
17	Medium	High	Medium	Limited consumption
18	Medium	High	High	Limited consumption
19	High	Low	Low	Limited consumption
20	High	Low	Medium	Limited consumption
21	High	Low	High	Limited consumption

22	High	Medium	Low	Limited consumption
23	High	Medium	Medium	Limited consumption
24	High	Medium	High	Limited consumption
25	High	High	Low	Limited consumption
26	High	High	Medium	Limited consumption
27	High	High	High	Limited consumption

Upon examining the full rule table, the following general rule patterns emerge naturally, consistent with the reviewer's request for clarity:

1. Daily-safe
   Occurs when all three inputs are Low, or when only one input reaches Medium and the others remain Low.
2. Moderate
   Applies when at least one input is Medium and none are High.
3. Limited
   Automatically triggered when any of the inputs reaches High.

These simplified rules are direct abstractions from the full 27-rule base and maintain logical consistency with nutritional risk patterns.

Example Case: Fuzzification, Rule Activation, Aggregation, Defuzzification

An example scenario is used to demonstrate the full fuzzy inference sequence:

- Sugar = 18 g
- Salt = 2.0 g
- Fat = 28 g

Table 3. Fuzzification Output

Variable	**Value**	**Fuzzy Set**	**Membership (μ)**
Sugar	18	Medium	0.67
Salt	2.0	Medium	1.00
Fat	28	High	0.80

From the rule base: IF Sugar = Medium AND Salt = Medium AND Fat = High
THEN Output = Moderate
Firing strength: **$\alpha = \min(0.67, 1.00, 0.80) = 0.67$**
The "Moderate" membership function (15, 25, 35) is clipped at $\mu = 0.67$.
Using the centroid method:
Crisp output = 25.0 → Moderate consumption (2–3× per week).

Table 4. **Summary Table**

Stage	**Result**
Fuzzification	{Sugar: 0.67, Salt: 1.00, Fat: 0.80}
Rule Fired	Moderate
Strength	0.67
Aggregation	Moderate set clipped
Defuzzification	25.0
Final Category	Moderate

Quantitative Interpretation of 3D Surface Plot

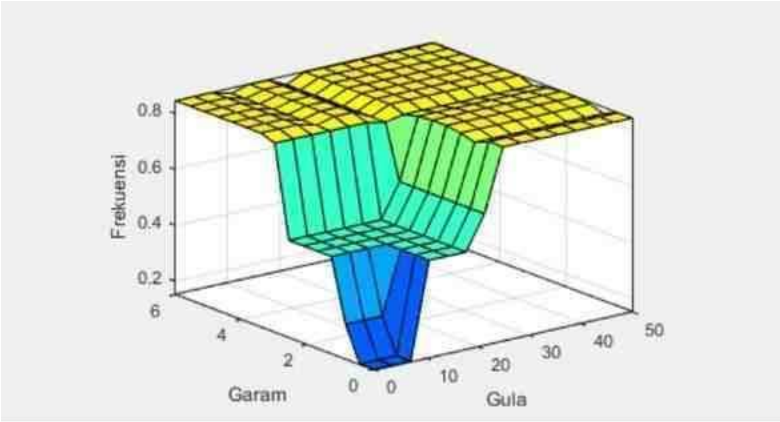

Figure 1. 3D Surface Visualization of Salt and Sugar Levels Against Consumption Frequency.

The 3D surface illustrating sugar–salt interactions displays a clear downward trend as nutrient levels increase. Numerical examination of the surface reveals:

- An average slope of −0.25 to −0.32 across sugar 10–30 g and salt 1–4 g.
- Daily-safe outputs (<15) occur only when sugar < 10 g and salt < 1.2 g.
- Moderate outputs (15–30) dominate when sugar is 10–22 g and salt is 1–3 g.
- Limited outputs (>30) emerge sharply when sugar > 20 g or salt > 3 g.

This gradient pattern indicates that both sugar and sodium exert cumulative effects, consistent with empirical findings that these nutrients jointly elevate metabolic and cardiovascular risks.

Analytical Discussion Supported by Empirical Literature

The model behavior strongly aligns with nutritional evidence:

- Sugar: High sugar content in extrudates increases energy density and promotes overeating; Dey et al. (2024) observed similar patterns in sugar-modified extrudates.
- Salt: Sodium excess is a leading contributor to hypertension; reductions in sodium intake reduce cardiovascular events (He et al., 2020).
- Fat: During extrusion and frying, products may reach 30–40% fat content, directly increasing obesity risk (Lumanlan et al., 2020).
- Ultra-processed foods: Rauber et al. (2021) and Fauziyyah et al. (2022) documented consistent associations between UPF consumption and obesity risk.

The fuzzy Mamdani system effectively mirrors these patterns, translating objective nutrient values into risk-sensitive consumption recommendations. The model's monotonicity, smooth transitions, and rule coherence make it suitable for nutritional decision support applications.

CONCLUSION

This research successfully developed a fuzzy logic–based web application employing the Mamdani inference system to assess the recommended consumption frequency of extruded *Chiki* snacks based on sugar, salt, and fat content. The model effectively transformed quantitative nutritional data into qualitative recommendations categorized as daily safe, moderate, or limited consumption. The fuzzy inference process demonstrated that higher concentrations of sugar, salt, and fat consistently reduced the recommended frequency of intake, aligning with established dietary moderation principles. The Mamdani model provided interpretable and adaptive decision outputs, proving its potential as a nutritional decision-support tool for promoting healthier eating behavior. Future research is expected to integrate additional parameters such as calorie density, protein, and fiber to improve the precision and applicability of the system in broader food product assessments.

ACKNOWLEDGEMENT

The authors would like to express sincere gratitude to Dr. Ridwan Siskandar, S.Si., M.Si. for his valuable guidance, feedback, and continuous support throughout this research entitled *“Web Application Using Fuzzy Logic to Assess Recommended Intake Frequency of Extruded Chiki Snacks.”* Appreciation is also extended to the Food Quality Assurance, IPB University, for providing academic and technical support during the completion of this study.

REFERENCES

Adlini, M. N., Dinda, A. H., Yulinda, S., Chotimah, O., & Merliyana, S. J. (2022). Metode Penelitian Kualitatif Studi Pustaka. *Jurnal Pendidikan*, *6*(1), 974–980.

Budiman, Wulandari, Z., & Suryati, T. (2009). Suplementasi Tepung Putih Telur untuk Memperbaiki Nilai Nutrisi Snack Ekstrusi Berbahan Grits Jagung. *Media Peternakan*, *32*(3), 179–184.

Çunkaş, M., & Aydoğdu, O. (2010). Realization of Fuzzy Logic Controlled Brushless Dc Motor Drives Using Matlab/Simulink. *Mathematical and Computational Applications*, *15*(2), 218–229. https://doi.org/https://doi.org/10.3390/mca15020218

Dash, K. K., & Das, S. K. (2019). Puffing Quality and Sensory Evaluation of Reduced Sodium Puffed Rice. *Quality Assurance and Safety of Crops & Foods*, *11*(8), 757–768. https://doi.org/10.3920/QAS2018.1414

Dey, D., Gu, B.-J., Ek, P., Ross, C. F., Saunders, S. R., & Ganjyal, G. M. (2024). Sugar Inclusion Influences The Expansion Characteristics of Corn Starch Extrudates. *Journal of Food Science*, *89*(11), 7760–7775. https://doi.org/https://doi.org/10.1111/1750-3841.17403

El-atik, A. A., Abu-gdairi, R., Nasef, A. A., Jafari, S., & Badr, M. (2023). Fuzzy Soft Sets and Decision Making in Ideal Nutrition Abdelfattah. *Symmetry*, *15*(8), 1–10. https://doi.org/https://doi.org/10.3390/sym15081523

Fauziyyah, H., Diana, F. M., & Femelia, W. (2022). Hubungan Konsumsi Ultraprocessed Food, Kebiasaan Tidur, dan Praktik Pemesanan Makanan Online dengan Obesitas pada Orang Dewasa. *JGMI : The Journal of Indonesian Community Nutrition*, *11*(2). https://doi.org/https://doi.org/10.30597/jgmi.v11i2.23129

Fu, H., Chi Hyun Lee, Nolden, A. A., & Kinchla, A. J. (2024). Nutrient Density, Added Sugar, and Fiber Content of Commercially Available Fruit Snacks in the United States from 2017 to 2022. *Nutrients*, *16*(2), 292. https://doi.org/https://doi.org/10.3390/nu16020292

He, F. J., Tan, M., Ma, Y., & MacGregor, G. A. (2020). Salt Reduction to Prevent Hypertension and Cardiovascular Disease. *Journal of the American College of Cardiology*, *75*(6), 632–647. https://doi.org/https://doi.org/10.1016/j.jacc.2019.11.055

Huang, H., Xu, H., Chen, F., Zhang, C., & Mohammadzadeh, A. (2023). An Applied Type-3 Fuzzy Logic System: Practical Matlab Simulink and M-Files for Robotic, Control, and Modeling Applications. *Symmetry*, *15*(2), 475. https://doi.org/https://doi.org/10.3390/sym15020475

Kılınç, B., Kılınç, I., Takma, Ç. dem, & Gevrekçi, Y. (2024). Review: The Applications of Fuzzy Logic Models on Food and Marine Food Products. *Journal of Food Safety and Food Quality*, *75*, 52–63. https://doi.org/10.31083/0003-925X-75-52

Kumar, C. S., Ali, A., & Manickavasagan, A. (2020). Health Benefits of Substituting Added Sugars with Fruits in Developing Value-Added Food Products : A Review. *International Journal of Nutrition, Pharmacology, Neurological Diseases*, *10*(3), 75–90. https://doi.org/10.4103/ijnpnd.ijnpnd_34_20

Kurniadi, D., Nuraeni, F., & Jaelani, D. (2022). Implementasi Logika Fuzzy Mamdani Pada Sistem Prediksi Calon Penerima Program Keluarga Harapan. *Jurnal Algoritma*, *19*(1), 160–171. https://doi.org/https://doi.org/10.33364/algoritma/v.19-1.1016

Lumanlan, J. C., Fernando, W. M. A. D. B., & Jayasena1, V. (2020). Mechanisms of Oil Uptake During Deep Frying and Applications of Predrying and Hydrocolloids in Reducing Fat Content of Chips. *International Journal of Food Science and Technology*, *55*, 1661–1670. https://doi.org/10.1111/ijfs.14435

Monge-Rojas, R., Rulamán Vargas-Quesada, Uriyoán Colón-Ramos, & Chinnock, A. (2022). Dietary Intake and Sources of Added Sugars in Various Food. *Nutrients*, *14*(5), 959. https://doi.org/https://doi.org/10.3390/nu14050959

Pavani, M., Singha, P., Rajamanickam, D. T., & Singh, S. K. (2023). Exploration of Foods and Foodomics Application of Fuzzy Logic Techniques for Sensory Evaluation of Plant-Based Extrudates Fortified with Bioactive Compounds. *Explor Foods Foodomics.*, *1*, 272–287. https://doi.org/https://doi.org/10.37349/eff.2023.00021

Pramudito, A. (2025). Analisis dan Simulasi Sistem Kontrol Suhu Otomatis Berbasis Fuzzy Logic Aditya. *Jurnal Teknik Elektro, 14*(1), 43–47. https://doi.org/https://doi.org/10.26740/jte.v14n1.p43-47

Putri, A. D., & Maulana, A. (2023). Penerapan Metode Mamdani Fuzzy Logic untuk Menentukan Pembelian Alat Berat dalam Proyek Migas di PT SMOE Indonesia. *Jurnal Desain Dan Analisis Teknologi*, *2*(2), 138–149. https://doi.org/https://doi.org/10.58520/jddat.v2i2.32

Rahmawati, S. (2017). Perancangan Aplikasi Fuzzy Logic dalam Menentukan Volume Produksi dengan Menggunakan Metode Mamdani. *Jurnal Teknologi Informasi & Pendidikan*, *10*(1).

Rauber, F., Chang, K., Vamos, E. P., Laura, M., Monteiro, C. A., Millett, C., & Levy, R. B. (2021). Ultra Processed Food Consumption and Risk of Obesity : A Prospective Cohort Study of UK Biobank. *European Journal of Nutrition*, *60*(4), 2169–2180. https://doi.org/https://doi.org/10.1007/s00394-020-02367-1

Tašić, J., Nagy-perjési, Z., & Takács, M. (2024). Multilevel Fuzzy Inference System for Estimating Risk of Type 2 Diabetes Multilevel Fuzzy Inference System for Estimating Risk. *Mathematics*, *12*, 1167. https://doi.org/https://doi.org/10.3390/math12081167

Wang, D., Xiao, H., Lyu, X., Chen, H., & Wei, F. (2023). Lipid Oxidation in Food Science and Nutritional Health: A Comprehensive Review. *Oil Crop Science*, *8*(1), 35–44.

Yadav, U., Singh, R. R. B., & Arora, S. (2018). Evaluation of Quality Changes in Nutritionally Enriched Extruded Snacks During Storage. *Journal of Food Science and Technology*, *55*(10), 3939–3948. https://doi.org/https://doi.org/10.1007/s13197-018-3319-3

Yang, S., Zheng, B., Huang, L., Zhang, Y., & Zeng, H. (2024). Saltiness Perception Mechanism and

Salt Reduction Strategies in Food. *Trends in Food Science & Technology*, *148*, 104521. https://doi.org/https://doi.org/10.1016/j.tifs.2024.104521