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Research Article

A Graphical User Interface for Determining the Safe Consumption of Food based on the Concentration of SD, BA, and SA.

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Abstract: The increasing demand for canned foods has led to a higher reliance on preservatives to extend shelf life, maintain color, taste, texture, and overall quality. However, excessive use of food preservatives such as sulphur dioxide (SD), benzoic acid (BA), and sorbic acid (SA) can cause significant health risks, including cancer, allergies, and heart palpitations. Therefore, monitoring and controlling preservative levels is crucial to ensure food safety. This paper introduces a graphical user interface (GUI) based on a fuzzy logic framework designed to assess the concentrations of SD, BA, and SA in five food categories, in compliance with Malaysia's Food Act 1983 and Food Regulations 1985. The developed GUI allows users to input preservative concentrations and receive real-time feedback on whether the levels are within safe consumption limits. Validation of the system was conducted using both published journal data and laboratory results from industrial food samples. The outcomes demonstrate that the GUI can accurately predict preservative levels, ensuring they remain within legal thresholds and promoting safe consumption. This tool offers a practical solution for food industries and regulatory authorities to monitor preservative usage effectively.

Keywords: Graphical User Interface, Fuzzy Logic, Food Preservatives, Artificial Intelligence

1. Introduction

Food preservatives are widely used to inhibit microbial activity, prolong shelf life, and reduce food waste [1]. These preservatives are classified into two main groups where Class I, consisting of natural preservatives like salt, sugar, vinegar, and edible oils, and Class II, which includes synthetic preservatives such as sorbates, benzoates, nitrites, nitrates, and sulfites [2]. With the growing demand for safe, durable, and stable food products, the usage of preservatives in the food industry has increased significantly [3]. Their ability to maintain food quality and extend shelf life makes them indispensable in modern food processing [4].

Commonly used preservatives include sodium chloride in meats, cheese, and fish products, as well as sorbic acid, benzoic acid, and acetic acid in low-pH foods like tomato products and salad dressings [5]. Sulphur dioxide is often used in dried fruits to prevent spoilage, while preservatives like nisin and natamycin suppress fungal growth in various foods [5]. However, the excessive use of food preservatives can lead to adverse health effects such as allergies, headaches, cancer, and organ damage [6]. For instance, high levels of sulphur dioxide can cause allergic reactions, while an excess of benzoic acid can impact liver and kidney function [7]. Similarly, sorbic acid, when consumed in large quantities, can cause urticaria and contact dermatitis [8]. Given these risks, it is essential to monitor and control preservative levels to ensure food safety.

Several methods exist to detect preservative concentrations in foods, such as chromatography, capillary electrophoresis, and spectrophotometry. However, these traditional techniques are time-consuming, expensive, and often require expert personnel, making them impractical for large-scale use. This paper introduces a novel graphical user interface (GUI) developed to assess food safety based on the concentrations of preservatives which are sulphur dioxide (SD), benzoic acid (BA), and sorbic acid (SA) in alignment with Malaysia's Food Act 1983 and Food Regulations 1985. The innovation lies in the GUI, which simplifies the complex process of determining preservative levels, providing real-time, user-friendly feedback on whether these levels meet safe consumption standards.

While fuzzy logic (FL) is used as the underlying framework for decision-making, the focus of this study is the development of the GUI, which streamlines the safety evaluation process. The GUI enables non-expert users to input preservative data and instantly receive information on whether the preservative levels in the food are within the allowable limits. This makes it an accessible tool for both researchers and industry professionals. The GUI is built based on a fuzzy logic framework, which is well-suited for handling the uncertainties and variations in preservative concentrations. However, unlike previous studies that primarily focused on fuzzy logic applications [5], this research emphasizes the practical benefits of the GUI for food safety assessments. The GUI was developed to evaluate five categories of food products based on the legal limits for SD, BA, and SA, as outlined in the Malaysian regulations. This tool provides an efficient alternative to traditional laboratory methods, reducing the time and resources needed for food safety analysis.

The structure of this paper is as follows. Section 2 explains the methodology behind the GUI and fuzzy logic framework, Section 3 discusses the results and findings, and the conclusion section summarizes the overall contributions of this study.

2. Materials and Methods

2.1. Data Collection

The selection of canned food samples was focused on specific products as a trial to observe the readiness of the GUI based fuzzy framework. The collected samples included chicken curry with potatoes, satay sauce, sardines in tomato sauce, anchovy paste, and sardine spread. A total of ten samples, with two replicates for each type, were obtained and sent to the laboratory for preservative analysis. The concentrations of benzoic acid (BA), sulphur dioxide (SD), and sorbic acid (SA) in the samples were determined. High-performance liquid chromatography (HPLC) was employed for detecting BA and SA, while SD was measured using standard chemical food analysis methods. The results from these analyses were used in subsequent stages of the study.

The samples were categorized into five groups based on product types: the first category comprised curry paste, the second included fish paste, shrimp paste, fermented shrimp or krill, fermented fish, and prawn paste. The third category consisted of soy sauce, hydrolyzed vegetable protein sauce, blended hydrolyzed plant protein sauce, and fish sauce. The fourth category encompassed sauces not specified in other schedules, while the fifth category contained tomato paste, pulp, and puree. These groupings were aligned with the Food Act.

In addition to the real samples, published data from relevant journals on the concentrations of BA, SA, and SD in various food products were also collected. This journal data was essential for testing and validating the developed graphical user interface (GUI). It provided a broader range of preservative concentrations, allowing for comprehensive validation of the fuzzy logic algorithm and ensuring the GUI's accuracy in predicting food safety based on a variety of preservative levels. The permissible maximum limits for BA, SA, and SD were sourced from the Food Act 1983 (reprinted version) and the Food Regulations 1985 (6th schedule, Regulation 20) for these five categories. Table 1 shows the allowable maximum concentrations of the preservatives according to Food Act 1983.

Table 1: Maximum concentration of preservatives allowed to be added in food.

Category	Foods	Maximum concentration of preservatives allowed (mg/kg)		
		Sulphur dioxide	**Benzoic acid**	**Sorbic acid**
One	Curry Paste	Nil	350	Nil
Two	Fish paste, shrimp paste, fermented shrimp or krill, prawn paste and fermented fish products	Nil	750	Nil
Three	Soy sauce, hydrolyzed vegetable protein sauce, hydrolyzed plant protein sauce, blended hydrolyzed vegetable protein sauce, blended hydrolyzed plant protein sauce, oyster sauce and fish sauce	400	1000	Nil
Four	Sauce not otherwise specified in the schedule	300	750	Nil
Five	Tomato - pulp, paste and puree	100	Nil	Nil

2.2. Fuzzy Logic Framework

The fuzzy logic framework used in this study was adapted from a previously developed system that evaluates food safety based on preservative concentrations of benzoic acid (BA), sulphur dioxide (SD), and sorbic acid (SA) [5]. This framework utilizes a Mamdani fuzzy inference system due to its interpretability and robustness in handling human data [9]. The Mamdani system was chosen over other inference systems such as Takagi-Sugeno-Kang due to its ability to provide easily interpretable rule-based outputs [10].

In the prior study, five key food categories were defined in alignment with the Sixth Schedule, Regulation 20 of the Food Regulations 1985. These categories cover a wide range of food types, including sauces, pastes, and tomato-based products. The framework uses triangular and trapezoidal membership functions for the input variables (SD, BA, SA), which are well-suited for classifying preservative concentrations into low, medium, and high levels [11]. A total of 90 fuzzy rules were defined to classify the safety of food items into "Safe" or "Unsafe." The fuzzy rules typically follow the format where if any of the preservatives in the input belongs to the high categories, then the output will show as unsafe. For example, in category one, IF SD is low, BA is high, and SA is low, THEN the output will be displayed as Unsafe. IF all the preservatives are in the medium or low range, THEN the output will be displayed as Safe.

The defuzzification process follows the centroid method, which provides a balanced output by calculating the center of gravity of the aggregated fuzzy sets [12]. This method was selected for its proven reliability and accuracy in previous studies [13], [14]. Figure 2.1 shows the developed fuzzy logic framework that will be used later in the development of a graphical user interface in determining food safety based on the concentrations of SD, BA, and SA [5].

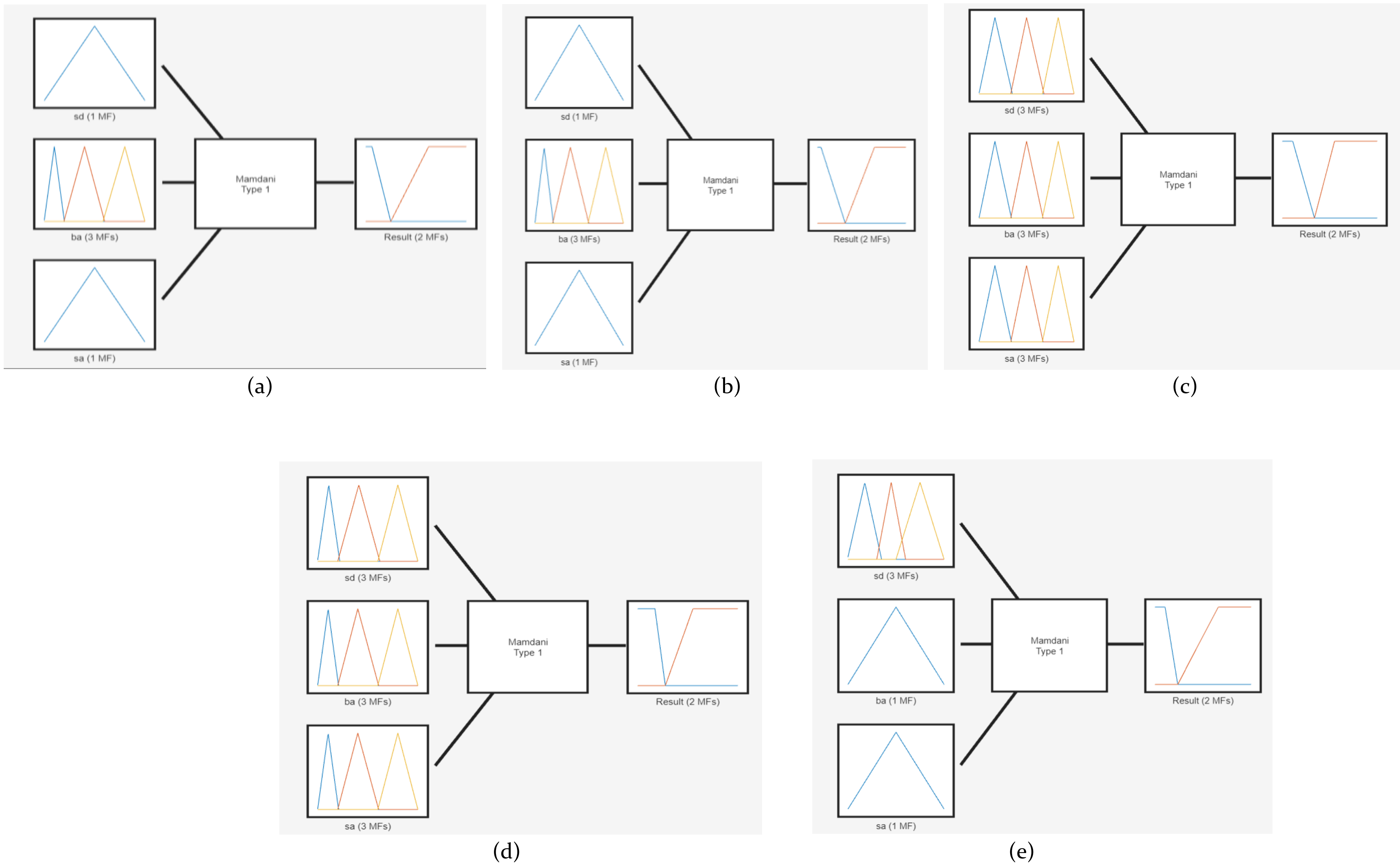

Figure 2.1: Fuzzy logic frameworks (a) Category one (b) Category two (c) Category three (d) Category four (e) Category five

2.3. Graphical user interface development

After the fuzzy logic (FL) model was successfully developed and tested, a graphical user interface (GUI) was created using MATLAB version 2021b to determine food safety based on the concentrations of SD, BA, and SA. The first step in building the GUI involved typing 'guide' in the command window, which generated a blank user interface. The development of the GUI then proceeded using various components such as edit text boxes, static text labels, push buttons, and panels.

The edit text boxes in the GUI allow users to input preservative values into the provided fields. If the user enters non-digit values or negative values, a warning message will appear, prompting the user to input valid concentration values. This feature helps ensure that only appropriate numerical data is processed. Static text labels are used to display descriptions within the GUI that remain unchanged throughout its use. These labels include preservative types, inputs, outputs, relevant guideline information, and food categories. A push button was added to execute the input calculations and produce results in the output section. This button is crucial because it triggers the coding necessary to run the FL model in MATLAB.

Five food categories were created, and guidance for determining these categories was provided. Category A includes soy sauce, hydrolyzed vegetable protein sauce, hydrolyzed plant protein sauce, blended hydrolyzed vegetable and plant protein sauces, oyster sauce, and fish sauce. Category B covers sauces not listed in Category A. Category C consists of fish paste, shrimp paste, fermented shrimp, fermented fish, prawn paste, fish balls, and fish cakes. Category D includes tomato paste, tomato puree, and tomato pulp. Lastly, Category E refers to curry paste.

Three inputs which are the sulphur dioxide (SD), benzoic acid (BA), and sorbic acid (SA) were assigned for all five categories, and two outputs were configured to display results. A process button was developed to generate output values based on the entered inputs. Additionally, a reset button was included to clear all input and output fields, while a close button was added to exit the GUI.

Once the GUI was constructed, the FL algorithm was integrated by using callback buttons, and coding was done to link the FL model with the GUI. After the coding was completed, the GUI was tested using the collected data. This GUI design allows users without expertise in FL models to assess the safety of canned food products and other listed food items. The GUI design is illustrated in Figure 2.2.

Figure 2.2: Graphical user interface

3. Results and Discussion

3.1. Effectiveness of fuzzy logic framework

In a previous study, the fuzzy logic (FL) framework was extensively tested and proven to be both effective and highly useful in determining the safety of food products based on preservative concentrations [5]. This system demonstrated its ability to handle complex, real-world data by accurately classifying food items into safety categories using inputs such as benzoic acid, sulphur dioxide, and sorbic acid levels. The Mamdani fuzzy inference system, chosen for its interpretability and suitability for human-related data, was shown to provide reliable results, making it a practical tool for food safety assessments.

Given the success of this FL framework in the prior research, it serves as a solid foundation for further development in the current study. The robustness, flexibility, and accuracy of the fuzzy logic system provide an ideal basis for creating a graphical user interface (GUI) that builds on the same principles. The decision to reuse this framework is driven by its proven performance in managing varying preservative concentrations and generating understandable rule-based outputs. By incorporating this validated FL model into the GUI, the system becomes more accessible to users without technical expertise in fuzzy logic, allowing for real-time and user-friendly evaluations of food safety.

Thus, the effectiveness demonstrated in previous applications of the FL model justifies its use as the core computational engine for this study's GUI. The GUI will leverage the same principles and methods to expand the usability of the system, ensuring that it remains reliable while offering a more interactive and practical platform for industrial and regulatory purposes. This section may be divided by subheadings. It should provide a concise and precise description of the experimental results, interpretation, and conclusions that can be drawn.

3.2. Effectiveness of graphical user interface

The graphical user interface (GUI) developed in this study was rigorously tested to ensure its functionality and reliability. A comprehensive testing phase was conducted using two sets of data to evaluate the performance of the GUI in determining food safety accurately. The first dataset consisted of 50 entries collected from various academic journals, where the concentrations of preservatives such as benzoic acid (BA), sulphur dioxide (SD), and sorbic acid (SA) were recorded for different food categories. These journal-based data provided a wide range of preservative concentrations, offering a valuable reference for assessing the GUI's ability to process varying levels and correctly classify food safety. Table 3.1 presents the results of testing conducted using the data collected from academic journals in the developed GUI. The dataset, which comprises of 50 entries detailing various concentrations of preservatives for benzoic acid (BA), sulphur dioxide (SD), and sorbic acid (SA), were input into the GUI for evaluation. The table showcases how the system processed these journal-based preservative concentrations, classified the food safety, and generated outputs accordingly. By using this diverse set of data, the testing phase highlighted the GUI's accuracy in applying the fuzzy logic framework to assess the safety of food products across different categories. The results in Table 3.1 reflect the consistency and reliability of the GUI when handling a broad range of preservative levels, further validating its functionality based on previously published data.

Table 3.1: GUI testing using data from journals

No.	References	Food Samples	Category	Amount of Preservatives (mg/kg)			Output	
				SD	BA	SA	Value	Safe/Unsafe
1	[15]	Soy Sauce	Third	-	250	256	0.17	Safe
2	[16]	Chilli Sauce	Fourth	-	900	-	0.64	Unsafe
3		Soy Sauce	Third	-	2941	-	0.5	Unsafe
4	[17]	Soy Sauce	Third	-	181	613	0.17	Safe
5		Fish Sauce	Third	-	391	0	0.17	Safe
6		Oyster Sauce	Third	-	728	0	0.17	Safe
7		Sweet Chilli Sauce	Fourth	-	384	0	0.14	Safe
8	[18]	Soy Sauce 1	Third	-	246	238	0.17	Safe
9		Soy Sauce 2	Third	-	0	336	0.17	Safe
10		Soy Sauce 3	Third	-	0	661	0.17	Safe
11	[19]	Soy Sauce 1	Third	-	0	214	0.17	Safe
12		Soy Sauce 2	Third	-	273	0	0.17	Safe
13		Soy Sauce 3	Third	0	82	140	0.17	Safe
14	[20]	Fish Sauce	Third	-	0	0	0.17	Safe
15		Soy Sauce	Third	-	0	8	0.17	Safe
16	[21]	Soy Sauce 1	Third	-	1	2	0.17	Safe
17		Soy Sauce 2	Third	-	3	0	0.17	Safe
18		Soy Sauce 3	Third	-	3	0	0.17	Safe
19	[22]	Soy Sauce 1	Third	-	597	0	0.17	Safe
20		Soy Sauce 2	Third	-	392	0	0.17	Safe
21	[23]	Soy Sauce	Third	10	-	-	0.17	Safe
22		Chilli Garlic Sauce	Fourth	65	-	-	0.14	Safe
23		Red Curry Paste 1	First	-	326	-	0.11	Safe
24		Red Curry Paste 2	First	-	348	-	0.12	Safe
25		Red Curry Paste Southern 1	First	-	296	-	0.10	Safe

26		Red Curry Paste Southern 2	First	-	342	-	0.12	Safe
27	[24]	Red Curry Paste Masam Southern 1	First	-	361	-	0.64	Unsafe
28		Red Curry Paste Masam Southern 2	First	-	398	-	0.66	Unsafe
29		Masam Southern Curry Paste	First	-	68	-	0.09	Safe
30		Red Curry Paste	First	-	79	-	0.09	Safe
31		Green Curry Paste	First	-	72	-	0.09	Safe
32	[25]	Soy Sauce	Third	-	871	-	0.17	Safe
33		Tomato Paste 1	Fifth	-	21	2	0.50	Unsafe
34		Tomato Paste 2	Fifth	-	17	0	0.50	Unsafe
35	[26]	Tomato Paste 3	Fifth	-	20	3	0.50	Unsafe
36		Tomato Paste 4	Fifth	-	14	0	0.50	Unsafe
37		Tomato Paste 5	Fifth	-	28	0	0.50	Unsafe
38		Soy Sauce 1	Third	-	0	0	0.17	Safe
39		Soy Sauce 2	Third	-	39	0	0.17	Safe
40	[27]	Soy Sauce 3	Third	-	32	0	0.17	Safe
41		Soy Sauce 4	Third	-	12	0	0.17	Safe
42		Soy Sauce 5	Third	-	10	65	0.17	Safe
43	[28]	Soy Sauce	Third	-	413	-	0.17	Safe
44	[29]	Tomato Paste	Fifth	-	0	-	0.12	Safe
45	[30]	Soy Sauce	Third	-	99	104	0.17	Safe
46		Fish Sauce	Third	-	10	10	0.17	Safe
47		Soy Sauce	Third	-	10	17	0.50	Unsafe
48	[31]	Shrimp Paste 1	Second	-	91	83	0.45	Unsafe
49		Shrimp Paste 2	Second	-	95	93	0.32	Unsafe
50		Shrimp Paste 3	Second	-	101	97	0.22	Unsafe

In addition to the journal data, the GUI was also tested using 10 real-world industrial samples. These samples, obtained from a partnered company, included canned food products such as chicken curry with potatoes, sardine spread, and tomato-based items. The concentrations of preservatives in these industrial samples were analyzed in a laboratory using high-performance liquid chromatography (HPLC) and chemical analysis methods. By testing the GUI with actual industry data, the system's practical applicability in real-life scenarios could be observed, ensuring it could handle diverse food types and preservative levels typically encountered in production environments. Table 3.2 shows the results for the industrial samples that were tested inside the developed GUI.

Table 3.2: GUI testing using data for industrial samples

Food Samples	Input			Output	
	SD (-)	**BA (-)**	**SA (-)**	**Results (-)**	**Safe/Unsafe**
Chicken curry with potatoes 1	1.2796	45.8841	0	0.1560	Safe
Chicken curry with potatoes 2	1.2796	44.9665	0	0.1570	Safe
Satay sauce 1	1.2797	74.7303	0	0.1350	Safe
Satay sauce 2	1.2797	75.0334	0	0.1350	Safe
Sardine in tomato sauce 1	0	0	0	0.1150	Safe
Sardine in tomato sauce 2	0	0	0	0.1150	Safe
Anchovies paste 1	0	101.3578	0	0.1100	Safe
Anchovies paste 2	0	102.5859	0	0.1100	Safe
Sardine spread 1	0	0	0	0.1550	Safe
Sardine spread 2	0	0	0	0.1550	Safe

This testing approach, utilizing data from journals and industrial samples has allowed for a comprehensive validation of the GUI. It demonstrated that the system is not only grounded in theoretical data but also capable of performing effectively in real-world applications. This ensures that the GUI can provide accurate, reliable results for both academic and industrial users in assessing food safety based on preservative concentrations.

4. Conclusions

In conclusion, this study successfully developed and validated a graphical user interface (GUI) based on a previously established fuzzy logic (FL) framework for determining food safety. GUI has been created as a user-friendly tool capable of assessing preservative concentration specifically benzoic acid (BA), sulphur dioxide (SD), and sorbic acid (SA) in various food categories. The GUI was tested with a comprehensive dataset consisting of 50 entries from academic journals and 10 industrial samples, demonstrating its accuracy and reliability in real-world applications.

The system not only streamlines the process of food safety evaluation but also offers a practical solution for non-technical users, making it accessible for industrial and regulatory use. By leveraging fuzzy logic's interpretability and flexibility, the GUI enables accurate, real-time assessments of food safety based on preservative concentrations. However, one limitation of the system is the dependency on the quality of comprehensiveness of the fuzzy rules and membership functions. In cases where preservative concentrations fall near the boundaries of "Low", "Medium", or "High", or when unexpected combinations of inputs occur, the system may produce less accurate results. This limitation can be addressed through the expansion of the fuzzy rule base, adaptive membership functions, and validation with more real-world data could enhance the system's robustness and accuracy. The successful integration of this framework lays the groundwork for future expansion to include additional food categories and further optimization of the system for broader industrial applications.

Conflict of interest

The authors declare that there is no conflict of interest.

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