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Remote Organoleptic Testing System Using Pairwise Comparison Scale in Sensory Evaluation of Food Products

Markani Pato[1], Andryanto Aman[2*], Alauddin Yunus[3], Andi Ridwan Makkulawu[2], Nur Mustika[4], Syamsul Marlin Amir[5], Nuraida Latif[6], Ilham Ahmad[2]

[1] Department of Information Technology Education, Universitas Teknologi Akba Makassar, Makassar 90245, Indonesia
[2] Department of Agricultural Technology, Pangkep State Polytechnic of Agriculture, Pangkep 90655, Indonesia
[3] Department of Electrical Engineering, Universitas Muhammadiyah Parepare, Makassar, 91112, Indonesia
[4] Department of Computer Systems, Universitas Handayani Makassar, Makassar 90231, Indonesia
[5] Department of Maritime Technology, Pangkep State Polytechnic of Agriculture, Pangkep 90655, Indonesia
[6] Department of Informatics Engineering, Universitas Teknologi Akba Makassar, Makassar 90245, Indonesia

Corresponding Author Email: andryantoaman@polipangkep.ac.id

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ABSTRACT

This research aims to develop and evaluate a remote organoleptic testing system using a paired comparison scale. This research follows the Software Development Life Cycle (SDLC), which includes planning, analysis, design, implementation, and maintenance. The system was tested with 7 respondents: 5 sensory experts in the field of food science and 2 web developers. The main aspects assessed for system feasibility included system accessibility, handling of scaled questionnaires, questionnaire delivery and storage, user interface, functionality, performance, and user satisfaction. Developed using PHP, JavaScript, and MySQL, the system allows panellists to conduct remote evaluations from various locations. The evaluation results showed a total score of 457 out of 525, resulting in a feasibility rating of 87.0%. These findings indicate that the system is highly feasible for practical implementation, providing a robust solution for remote organoleptic testing.

1. INTRODUCTION

In the food industry or food service companies, product quality is a critical factor in determining market competitiveness [1]. The quality of food products is evaluated not only based on physical properties, chemical composition, and contamination levels (both microbiological and toxic substances) but also on sensory attributes such as taste, aroma, texture, and colour [2, 3]. Therefore, sensory evaluation is a crucial tool to ensure that food products meet consumer expectations and quality standards, reflecting the value for money.

Sensory evaluation is the science of measuring, analysing, and interpreting consumer reactions to products as perceived by the senses [4]. One method used to assess these sensory attributes is organoleptic testing, which heavily relies on human sensory perception [3].

However, the primary challenge in organoleptic testing is the subjectivity of assessment, which can affect the consistency and accuracy of results [5]. Each individual has different sensory perceptions, leading to potential variability in evaluations conducted by panelists [6]. This creates a need for more structured and objective methods in the execution of organoleptic tests. Moreover, the traditional approach to sensory evaluation requires panelists to be physically present in the same location, which can be logistically challenging and costly, especially when handling large-scale testing or testing across different geographic locations [7, 8]. The COVID-19 pandemic has further highlighted the limitations of in-person testing, driving the search for alternative approaches that enable sensory evaluation to continue remotely while maintaining data accuracy and reliability.

Remote sensory evaluation systems offer a promising solution by leveraging web-based platforms to allow panelists to perform evaluations from any location. Such systems reduce logistical burdens, minimize costs associated with travel and facility usage, and enable broader participation from geographically dispersed panelists. Remote systems also offer scalability, allowing for the recruitment of larger and more diverse samples, which can enhance the representativeness of sensory data. These practical applications are vital for food companies aiming to accelerate product development, optimize sensory testing workflows, and maintain business continuity during disruptions like pandemics.

Several previous studies have examined remote sensory evaluation. Dinnella et al. [7] systematically compared laboratory-based and remote testing settings across various sensory evaluation techniques, generally providing support for the use of remote testing due to its flexibility and convenience for participants. Shi et al. [9] compared liking scores from home-based testing and central location testing, using repeated measures with the same panel to test the validity of cross-location comparisons. The comparison results indicated that higher scores were generally observed in home-based testing.

This suggests the feasibility of conducting sensory research in remote locations, facilitated by courier services and smart technology, while considering standard practices for remote sensory testing to ensure consistent comparisons across investigations [10].

1.1 Proposed solution

Based on the challenges encountered and supported by several studies on remote sensory evaluation, the authors designed a web-based organoleptic testing system that can be accessed remotely. This system implements the pairwise comparison scale method in organoleptic testing. This method allows for a more objective evaluation by directly comparing each pair of attributes [11], thereby reducing subjectivity and producing more accurate data. This study aims to develop and assess the feasibility of using a remote organoleptic testing system with the implementation of the pairwise comparison scale.

The remote organoleptic testing system was developed using PHP and JavaScript programming languages, with MySQL as the database. The system was tested using questionnaires distributed to Sensory Experts and Web Development Experts.

1.2 Theoretical study

Organoleptic testing is a sensory evaluation method used to assess the quality of a product based on human sensory perceptions, such as taste, aroma, texture, and colour [12]. This testing is typically conducted by panelists who use their senses to evaluate the sensory attributes of a product, particularly in the food industry [13, 14]. Sensory quality significantly influences consumer satisfaction and the competitiveness of a product in the market [15]. Consumers tend to prefer products that meet their expectations in terms of taste, aroma, texture, and colour. Additionally, organoleptic testing aids in the development of new products, the reformulation of existing products, and the monitoring of product quality consistency over time [16].

The pairwise comparison scale is a method used to directly compare two elements or attributes to determine which is superior or has a higher intensity [11]. This method is widely applied in various fields, such as decision-making, psychometrics, and criteria assessment in more complex evaluation processes like the Analytical Hierarchy Process (AHP) [17].

The principles of the pairwise comparison scale are based on the concept of relative comparison, where each element is evaluated against the other elements to establish a hierarchy of importance or intensity. This approach allows for more precise discrimination between attributes, compared to an absolute rating scale where panellists assign a value to each attribute separately. The scope of application of the pairwise comparison scale extends beyond sensory evaluation to areas such as decision-making, education, and psychology, where comparative judgement is essential. In sensory evaluation, the scale offers a systematic approach to identify the relative importance of sensory attributes (e.g., taste, aroma, colour, texture) in a structured manner.

Compared to other assessment methods such as hedonic scales or Likert scales, the pairwise comparison scale has unique advantages. While hedonic scales rely on subjective preferences and absolute ratings (e.g., 'like' or 'dislike'), pairwise comparisons force a direct relative judgement between two elements, reducing ambiguity and cognitive bias. This direct comparison method can reveal more subtle differences in sensory attributes, which may be missed in traditional judgement systems. However, this method also has limitations, such as increased time requirements for multiple comparisons and cognitive load on panellists as the number of attributes increases.

In the sensory evaluation of food products, more commonly used methods include structured rating scales such as the hedonic scale or intensity scale [18]. However, the pairwise comparison scale offers a more direct and systematic approach to comparing sensory elements, although its use has not yet become standard in traditional organoleptic testing.

The development of a web-based system involves the use of technologies such as PHP, JavaScript, and MySQL, which are core components in building dynamic and interactive web applications. PHP (Hypertext Preprocessor) is a server-side programming language used for managing data and executing business logic in web applications. JavaScript functions as a client-side programming language, enabling the creation of an interactive and responsive user interface. MySQL, as a relational database management system (RDBMS), is used to store and manage data [19].

2. METHODOLOGY

The system development method used in this study is the SDLC (Software Development Life Cycle) method. The SDLC consists of five commonly used stages: planning, analysis, design, implementation, and maintenance. These stages of the SDLC are essential for completing the development of a new information system or modifying an existing one [20], as illustrated in Figure 1.

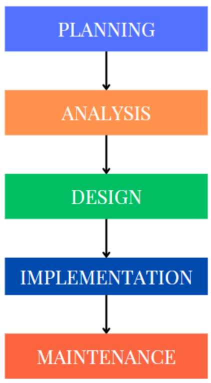

Figure 1. Software development life cycle

The architecture design of the remote organoleptic testing system follows a three-tier architecture consisting of a presentation layer, an application layer, and a data layer. The presentation layer serves as the user interface, which is developed using HTML, CSS, and JavaScript to create an interactive and user-friendly front end. The application layer, which handles the business logic, was developed using PHP, a server-side scripting language that facilitates communication between the user interface and the database. The data layer uses MySQL as a database management system to store and manage system data, including user accounts, questionnaire responses, and sensory evaluation results. Figure 2 shows the system architecture design.

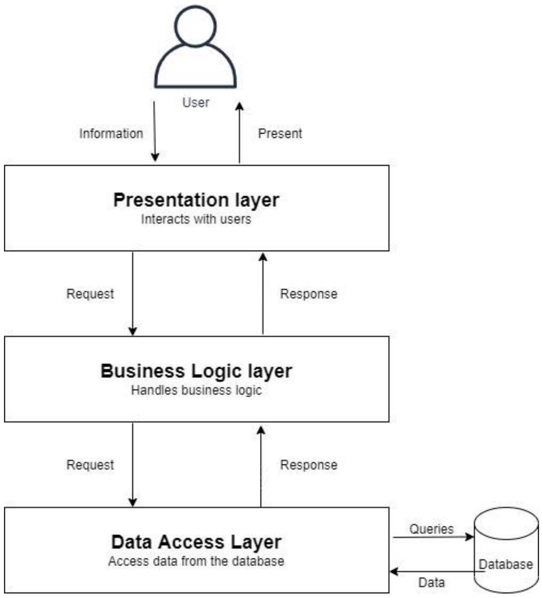

Figure 2. Architecture design of remote organoleptic testing system

2.1 Population and samples

The system testing in a limited environment involved seven respondents, consisting of five Sensory Experts with educational backgrounds in food science and technology, and two Web Development Experts with educational backgrounds in computer science. The Sensory Experts were professionals with extensive experience in food quality assessment, sensory testing, and sensory analysis methods. Their roles included food product development, quality control, and sensory evaluation in academic and industrial settings. Among these Sensory Experts, three held positions as university lecturers specializing in food science, while two were sensory consultants with over 10 years of experience in the field.

The Web Development Experts were responsible for evaluating system functionality, usability, and technical performance. Both of these experts held bachelor's degrees in computer science and had over 5 years of experience in web development and software engineering. Their feedback focused on system responsiveness, user interface design, and back-end performance. Table 1 presents the demographic characteristics of the sample, including gender, age, educational background, profession, and experience.

Table 1. Demographic information

Variable	Category	Frequency	(%)
Gender	Male	3	42.9
	Famale	4	57.1
Age	30-45 years	2	28.6
	45-55 years	3	42.9
	> 55 years	2	28.6
Profession	Sensory Consultant	2	28.6
	Quality Control	1	14.3
	University Lecturer	4	57.1
Experience	2-5 years	1	14.3
	5-10 years	3	42.9
	10+ years	3	42.9

2.2 Instruments and data analysis

The aspects evaluated in the assessment of the system's feasibility include System Accessibility (SA), Questionnaire Completion with Comparison Scale (CS), Questionnaire Submission and Storage (QS), User Interface (UI), Functionality (FU), Performance (PE), and User Satisfaction (US). The system feasibility assessment questionnaire is presented in Table 2.

Table 2. System feasibility assessment questionnaire

Aspects	Statements
SA1	The system can be accessed via various devices (PC, tablet, smartphone) without any problems.
SA2	The system loads the questionnaire page quickly and without interruption.
CS1	The comparison scale is clearly displayed and easily understood by users.
CS2	Users can easily fill in and adjust the comparison scale as needed.
CS3	The system ensures that the comparison scale is filled in correctly before the questionnaire can be sent.
QS1	The system successfully sent the completed questionnaire without error.
QS2	The questionnaire data is stored securely and can be accessed again when needed.
UI1	The user interface (UI) of the system looks clean and intuitive, making it easy for users to fill out the questionnaire.
UI2	The use of colours, fonts, and layout support comfort and readability during questionnaire completion.
FU1	The system functions properly according to the set specifications.
FU2	All the necessary features are available and can be used smoothly.
PE1	The system responds quickly to user inputs.
PE2	The system was stable and did not experience any crashes or errors during testing.
US1	Users are satisfied with the overall experience of using the system.
US2	The system fulfils user needs and expectations.

The aspect assessment uses a five-point Likert Scale, namely "Strongly Agree", "Agree", "Neutral", "Disagree", and "Strongly Disagree." The Likert Scale is presented in Table 3.

Table 3. Grading scale [21]

Valuation	Description	Score
SA	Strongly Agree	5
A	Agree	4
N	Neutral	3
D	Disagree	2
SD	Strongly Disagree	1

The data obtained from this study will be analysed and converted into a feasibility scale based on Table 4. The percentage scores are calculated using the five-point Likert Scale model, namely "Very Unworthy", "Not Worth It", "Neutral", "Proper", and "Very Decent".

Table 4. Feasibility scale [21]

(%)	Classification
<21	Very Unworthy
21-40	Not Worth It
41-60	Neutral
61-80	Proper
81-100	Very Decent

The feasibility percentage can be calculated using Eq. (1):

$$EP \frac{RS}{MS} \times 100\% \tag{1}$$

where EP is the Eligibility Percentage, RS is the Respondent Score, and MS is the Maximum Score.

3. RESULT

The remote organoleptic testing system was developed using PHP programming language, JavaScript for user interactivity, and MySQL for database management. This system is designed to facilitate the remote organoleptic testing process, enabling panelists to work from home.

Figure 3 illustrates the system design using a use case diagram, which is the result of gathering user requirements and technical specifications through interviews with sensory experts and web developers. The system involves two actors: admin and user. Users can register, input responses, and edit their profiles. Meanwhile, the admin can view respondent results and manage user data, such as editing passwords, resetting responses, and deleting data.

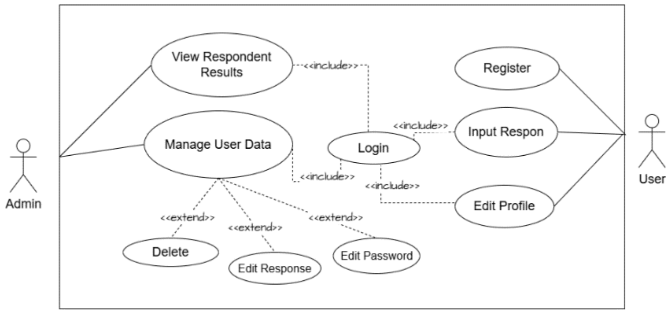

Figure 3. Use case diagram

Figure 4 illustrates the account registration page, where the user is required to enter important information such as full name, occupation, email address, gender, address, respondent/panellist category, age, and password. This information is required to create a user profile that will be used during the sensory evaluation process.

Figure 4. User account registration page

Once the registration process is complete, users can proceed to login using the email and password they provided during registration. Figure 5 shows the login page, where users must enter their registered email and password to access the system.

Figure 6 shows the organoleptic testing system using four criteria, namely: (1) taste, (2) aroma, (3) colour, and (4) texture. A pairwise comparison scale is then used to compare these four criteria.

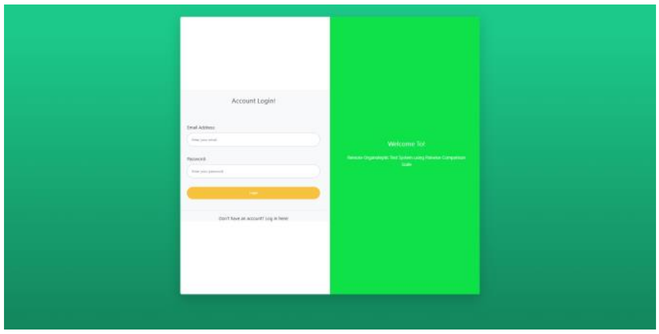

Figure 5. User login page

Figure 6. Organoleptic test with pairwise comparison scale

In pairwise comparison, each score provided by the respondent reflects the relative importance of one element (e.g., flavour) compared to another (e.g., colour). The scale used includes the values detailed in Table 5.

Table 5. Rating scale

Scale	9	8	7	..	1	1	..	7	8	9
Value	9	8	7	..	1	1/2	..	1/7	1/8	1/9

The scale ranges from 9 to 1 for positive ratings, and from 1/2 to 1/9 for negative ratings. If a respondent compares the flavour criterion with the colour criterion and assigns a score of 7 on the rating scale, it indicates that the flavour criterion is considered seven times more important than the colour criterion. However, if the comparison is made in the opposite direction, i.e., comparing colour with flavour, the score would be 1/7, approximately 0.143.

Figure 7 shows the admin menu interface. The admin can view all respondents from the organoleptic test. The collective results from the respondents will later be weighted to determine which criterion is the most important among the four criteria tested for the food product.

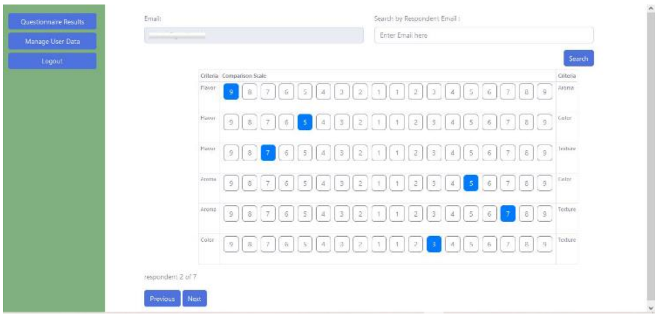

Figure 7. Organoleptic test respondent results

The system feasibility assessment was conducted using a structured questionnaire designed to evaluate various aspects of the system. The assessment focused on seven main criteria: System Accessibility (SA), Questionnaire Filling with Comparison Scale (CS), Questionnaire Submission and Storage (QS), User Interface (UI), Functionality (FU), Performance (PE), and User Satisfaction (US). Each criterion was assessed using several statements that were rated by respondents on a five-point Likert scale, ranging from 'Strongly Disagree' (1) to 'Strongly Agree' (5).

The rationale behind the design of this questionnaire is to ensure an evaluation that covers functionality, usability, and overall user satisfaction. Each criterion was selected based on its relevance to the success of the remote sensing evaluation system. For example, 'System Accessibility' assesses whether users can access the system on various devices, while 'Questionnaire Delivery and Storage' ensures that user responses are safely stored and retrievable.

Table 6 shows the results of the questionnaire assessment from 7 respondents, with a total score of 457 out of a maximum of 525, resulting in an overall percentage of 87.0%. According to the Feasibility Scale in Table 4, this result places the system in the "Very Decent" category (81-100%). The assessment results indicate that the tested system has a very high level of feasibility. The "User Satisfaction (US2)" aspect received the highest score with a percentage of 97.1%, indicating that the majority of users are very satisfied with the system. The "Questionnaire Completion with Comparison Scale (CS1)" aspect also showed very positive results with a percentage of 94.3%, reflecting the ease of use and clarity of the comparison scale.

Table 6. Questionnaire assessment results

Aspects	Respondents' Scores	Maximum Scores	(%)
SA1	28	35	80.0
SA2	27	35	77.1
CS1	33	35	94.3
CS2	31	35	88.6
CS3	29	35	82.9
QS1	32	35	91.4
QS2	30	35	85.7
UI1	32	35	91.4
UI2	29	35	82.9
FU1	30	35	85.7
FU2	29	35	82.9
PE1	30	35	85.7
PE2	31	35	88.6
US1	32	35	91.4
US2	34	35	97.1
Total	457	525	87.0

Other aspects such as "User Interface (UI1)" and "Questionnaire Submission and Storage (QS1)" also demonstrated strong results, with percentages above 90%, indicating that the user interface is considered intuitive and the system reliable in managing questionnaire data. Some aspects, such as "System Accessibility (SA2)" with a percentage of 77.1%, still require some improvement. Overall, the assessment indicates that this system is highly feasible for implementation in real-world operational scenarios.

The use of technology in sensory evaluation, particularly in remote organoleptic testing, offers several advantages. One key advantage is the increased efficiency and accuracy in data collection and processing. A web-based system allows researchers to collect data from a large number of panelists simultaneously, without the logistical challenges typically associated with conventional testing. Flexibility is also a significant benefit of using technology in organoleptic testing. This study aligns with references [7, 9], where the system can be accessed from anywhere, and panelists are not required to be in a specific location to conduct assessments. This flexibility opens up opportunities to involve panelists from diverse backgrounds and geographical locations, enriching the variety of data obtained and enabling more representative testing of a broader population.

However, the implementation of this technology also faces challenges, consistent with the findings [10], which require strict technical and procedural considerations. These include ensuring that the devices used by panelists meet the necessary standards for sensory evaluation. For instance, screen quality for visual assessments or audio devices for sound evaluation must be consistent among panelists to avoid biased results. Additionally, factors such as internet connectivity, system reliability, and the panelists' ability to use the system must be taken into account. Therefore, training and support for panelists in using the web-based system are essential to ensure that the organoleptic testing process runs smoothly and yields accurate data.

4. CONCLUSIONS

The remote organoleptic testing system was developed using PHP programming language, JavaScript for user interactivity, and MySQL for database management. This system is designed to facilitate the remote organoleptic testing process, enabling panelists to work from home. The system's feasibility was also tested by respondents, including sensory experts and web developers. The questionnaire assessment results from 7 respondents yielded a total score of 457 out of a maximum of 525, resulting in an overall percentage of 87.0%. This result places the system in the "Very Decent" category (81-100%). The assessment indicates that the tested system has a very high feasibility level for implementation in real-world operational scenarios. This research introduces a novel approach to conducting sensory evaluation remotely, addressing the limitations of traditional in-person organoleptic testing. The main contribution of this research lies in the development of a web-based sensory testing system that incorporates a paired comparison scale, enabling more objective and precise evaluation of sensory attributes. Unlike conventional methods, this system allows for decentralized testing, reducing logistical burdens, operational costs, and geographical constraints. The potential impact of this research extends to several related fields, particularly in food science, quality control and sensory evaluation. Remote sensory testing allows food companies and research institutions to conduct a wider range of sensory studies with more diverse participants. This can result in faster product development cycles, cost savings in testing logistics, and the ability to maintain continuity in the sensory evaluation process during emergencies, such as a pandemic. In addition, the system offers a scalable platform that can be adapted for other sensory evaluations, such as cosmetic testing, beverage analysis, and consumer preference studies. Some future works that can be developed from this research include: (1) conducting organoleptic tests using the AHP method to determine the consistency of the final results of sensory evaluation, (2) testing the system in a real-world environment to enable more representative testing of a wider population, and (3) enhancing the system by integrating machine learning algorithms to analyse sensory data and predict consumer preferences.

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