

Development and Preliminary Sensory Evaluation of Watermelon Rind-Based Dipping Sauce

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Submitted: 09/06/2026; Accepted: 12/06/2026; Published: 30/06/2026

Abstract—Food waste has become a major global concern, particularly in the agro-food industry where large quantities of fruit by-products are discarded despite their nutritional potential. Watermelon rind, which constitutes approximately 30% of the total fruit weight, is commonly treated as waste although it contains dietary fibre, antioxidants, and bioactive compounds. This study aimed to develop a watermelon rind-based dipping sauce and evaluate its sensory acceptability among consumers as an innovative approach for sustainable food waste valorisation. An experimental quantitative research design was employed involving product formulation and sensory evaluation using a 5-point hedonic scale. A total of 31 respondents participated in the sensory evaluation based on five attributes: colour, aroma, viscosity, taste, and overall acceptability. Descriptive statistical analysis using SPSS was conducted to determine the mean and standard deviation for each attribute. The findings revealed that overall acceptability obtained the highest mean score ($M = 4.58$, $SD = 0.56$), followed by colour ($M = 4.55$, $SD = 0.57$), aroma ($M = 4.35$, $SD = 0.80$), viscosity ($M = 4.26$, $SD = 0.77$), and taste ($M = 4.16$, $SD = 0.73$). The sensory evaluation results indicated favourable responses among the participating respondents, with mean scores exceeding 4.00 for all evaluated attributes. Within the limitations of a small convenience sample, the findings suggest that watermelon rind may be incorporated into a dipping sauce formulation with acceptable sensory characteristics. Further studies involving larger and more diverse consumer groups, together with physicochemical and shelf-life analyses, are required to confirm broader consumer acceptance and commercial feasibility.

Keywords: Watermelon Rind; Food Waste Valorisation; Dipping Sauce; Sensory Evaluation; Sustainable Food Innovation

1. INTRODUCTION

Food waste is one of the biggest worldwide sustainability concerns, especially in the food processing and agricultural sectors. The Food and Agriculture Organization (FAO) says that over one-third of all the food produced in the world is wasted every year, leading to environmental degradation, greenhouse gas emissions and economic losses. Fruit and vegetable waste represents a substantial proportion of this discarded material, including peels, seeds, and rinds that are often disposed of despite containing valuable nutritional compounds. Consequently, food waste valorisation has become an important strategy for promoting sustainable food systems and circular economy practices. Food waste valorisation has been seen as a sustainable approach to lessen environmental impacts while obtaining value-added goods from agricultural by-products. The potential of food waste upcycling in the context of circular economy to promote resource efficiency and sustainability has been recently demonstrated in studies (Betoret et al., 2024). According to Lau et al., (2021) the use of fruit and vegetable by-products as functional additives has increasingly received attention due to their nutritional value and possible contribution to food sustainability.

Watermelon (*Citrullus lanatus*) is among the most widely consumed fruits worldwide due to its refreshing taste and high-water content. However, the rind part, which makes up close to 30% of the overall weight of the fruit, is often thrown away in consuming and food processing activities. Previous studies have shown that watermelon rind contains significant amounts of dietary fibre, pectin, citrulline, antioxidants, vitamins, and phenolic compounds that may provide nutritional and functional benefits when incorporated into food products (Capossio et al., 2022). The disposal of watermelon rind not only contributes to food waste accumulation but also showed that the underutilisation of potentially valuable food resources. In addition of dietary fibre and citrulline, watermelon rind contains various phytochemicals and bioactive compounds that can be utilised in the development of functional food products, supporting both nutritional enhancement and waste reduction initiatives (Nirmal et al., 2023).

In recent years, researchers have studied different applications of watermelon rind in food product development. In watermelon rind chip research, Rezagholizade-Shirvan et al. (2023), has found favourable sensory and physicochemical properties when suitable coating formulations were applied. Similarly, studies on watermelon rind candy and confectionery products showed that watermelon rind can be transformed into acceptable value-added products while improving sustainability in food production (Jothilakshmi et al., 2026). Additionally, research by Zhang et al. (2021) highlighted the nutritional potential of watermelon rind in beverage use, although sensory quality remained an important challenge in consumer acceptance.

Food product innovation using agricultural by-products has gained increasing attention due to growing consumer awareness regarding sustainability and environmentally friendly food production. The development of new food products from food waste materials aligns with the Sustainable Development Goals (SDGs), particularly SDG 12 which focuses on responsible consumption and production. Valorisation of watermelon rind into edible products not only reduces waste generation but also creates opportunities for economic value creation within the food industry.

Dipping sauces are widely consumed condiments that complement various snacks and meals. The incorporation of watermelon rind into a dipping sauce formulation presents an innovative opportunity to develop a

nutritious and sustainable food product while enhancing the utilisation of agricultural waste. Despite growing studies on watermelon rind utilisation, limited research has focused specifically on the development and sensory acceptability of watermelon rind-based dipping sauces. Most previous studies concentrated on bakery products, candies, juices, or dried snacks rather than condiment applications.

Sensory evaluation is very important in determining consumer acceptance of newly developed food products. Attributes such as colour, aroma, texture, taste, and overall acceptability influence purchasing decisions and marketability. According to Stone et al. (2020), hedonic sensory evaluation remains one of the most reliable methods for assessing consumer preferences toward innovative food products. Therefore, evaluating sensory acceptance is essential in determining the feasibility of watermelon rind-based dipping sauce as a marketable product. Although fruit by-products offer considerable nutritional and environmental benefits, consumer acceptance remains a critical factor influencing the commercial success of waste-derived food products. Sensory quality, safety perception, and product familiarity have been identified as major determinants of consumer willingness to adopt such products (Hasan et al., 2024; Liu et al., 2023). Although watermelon rind utilisation has been widely investigated in bakery products, candies, beverages, and snack applications, limited information is available regarding its incorporation into dipping sauce formulations. Therefore, this study does not seek to establish the novelty of watermelon rind utilisation itself, but rather to explore the feasibility of applying watermelon rind in a condiment-based product and to obtain preliminary sensory feedback from potential consumers. The objectives of this study were: (1) to develop a watermelon rind-based dipping sauce formulation using food waste valorisation principles; (2) to evaluate consumer sensory acceptance of the developed product based on colour, aroma, viscosity, taste, and overall acceptability; and (3) to obtain preliminary consumer feedback on the sensory characteristics of the developed product. The findings of this research are expected to contribute to sustainable food product development, reduce agricultural waste, and promote innovative food processing practices.

2. RESEARCH METHODS

2.1 Research Design

The research design in this study was quantitative experimental design with product development and sensory evaluation. The study was focused on the development of a dipping sauce from watermelon rind and evaluation of its sensory acceptability by the respondents. A hedonic sensory evaluation method was used to determine respondents' perceptions towards the product attributes.

2.2 Material and Ingredients

Fresh watermelon were bought from local markets in North Malaysia. Then, the watermelon rind were removed from the flesh. The outer green skin was removed, and the white rind portion was cleaned thoroughly before processing. Additional ingredients used in the dipping sauce formulation included chilies, garlic, vinegar, sugar, salt, modified corn starch, to enhance flavour and texture, and sodium benzoate as the preservative.

2.3 Preparation of Watermelon Rind-Based Dipping Sauce

Figure 1 illustrates the process flow for the development of the watermelon rind-based dipping sauce. The appearance of the developed product is shown in Figure 2.



Figure 1. Process Flow of Watermelon Rind Dipping Sauce Development



Figure 2. Final Watermelon Rind-Based Dipping Sauce Product

The watermelon rind was washed, peeled, and cut into small pieces. Then, the watermelon rind pieces were blanched at approximately 90°C for 5 minutes before being blended into a puree with chillies and garlic. Blanching is commonly applied in fruit and vegetable processing to inactivate enzymes, reduce microbial load, and improve texture prior to further processing (Ueda et al., 2022). The puree was then cooked with vinegar, sugar, and salt at 90–95°C for approximately 20 minutes under controlled heating conditions. Modified corn starch (1.51%) was gradually added to achieve the desired viscosity and consistency of the dipping sauce. The mixture was continuously stirred throughout the cooking process to ensure homogeneity and prevent lump formation. A food-grade preservative (0.1% sodium benzoate) was added during the final stage of cooking. The sauce was subsequently removed from heat and hot-filled into sterilised glass bottles at approximately 85°C before being allowed to cool at room temperature.

2.4 Sensory Evaluation

Sensory evaluation was conducted using a 5-point hedonic scale ranging from 1 (strongly dislike) to 5 (strongly like). A total of 31 respondents participated in the evaluation process. The sensory evaluation was intended as a preliminary acceptability assessment rather than a formal consumer preference study. Respondents were randomly selected through convenience sampling from among students and staff members who were readily available during the evaluation period. Consequently, the findings should be interpreted as exploratory and may not be representative of the wider consumer population. The respondents evaluated the dipping sauce based on five sensory attributes:

- a. Colour
- b. Aroma
- c. Viscosity
- d. Taste
- e. Overall acceptability

Each respondent received a sample of the dipping sauce and was instructed to evaluate each attribute independently. Drinking water was provided to cleanse the palate between evaluations. The study for comparative sensory evaluation did not include a commercial dipping sauce as a control sample. As such the results reflect respondents’ perception of the developed product solely, and not comparative preference against commercially available alternatives.

2.5 Data Analysis

The collected data were analysed using Statistical Package for Social Sciences (SPSS). Descriptive statistical analysis was performed to determine the mean and standard deviation values for each sensory attribute. Table 1 presents the evaluation attributes used in this study.

Table 1. Sensory Evaluation Attributes

Attribute	Description
Colour	Visual attractiveness of the dipping sauce
Aroma	Smell and fragrance of the product
Viscosity	Thickness and texture consistency
Taste	Flavour acceptability of the product
Overall Acceptability	General acceptance of the dipping sauce

2.6 Basic Research Framework

This study used the product development and sensory evaluation approach to evaluate the feasibility of using watermelon rind as a value-added ingredient in the production of dipping sauce. The framework was divided into four main stages, preparation of raw material, development of product, evaluation of sensory and analysis of data. The first step in the research work was the collection and preparation of watermelon rind as the main raw material. The rind was washed, peeled, boiled and processed to form a puree and then added to the formulation of the dipping sauce. Additional ingredients such as chillies, garlic, vinegar, sugar, salt, modified corn starch and preservative were added to improve the flavour, texture and shelf stability of the product.

The second phase of product development was cooking and formulating the watermelon rind puree into a dipping sauce. The cooking was carefully controlled to give the desired viscosity, consistency and sensory characteristics. The final product was bottled and cooled before evaluation. The third step was the sensory evaluation of the product developed. A total of 31 respondents participated in the hedonic test using a 5-point hedonic scale (1 = strongly dislike, 5 = strongly like). The product was assessed by the respondents on five sensory attributes i.e. colour, aroma, viscosity, taste and overall acceptability. The last stage was the data analysis using Statistical Package for Social Sciences (SPSS). Descriptive statistics were calculated, such as mean and standard deviation values, to assess the level of consumer acceptance of each sensory attribute. Descriptive data analysis was done using mean and standard deviation. The research framework used in this study is shown in Figure 3.



Figure 3. Research Framework of the Study

3. RESULTS AND DISCUSSION

3.1 Sensory Evaluation Results

Descriptive statistical analysis was used to determine the level of acceptance of the respondents towards the watermelon rind based dipping sauce. The sensory parameters investigated were colour, aroma, viscosity, taste and overall acceptability. The descriptive analysis results are presented in Table 3.

Table 3. Descriptive Analysis of Sensory Evaluation

Sensory Attribute	Mean	Standard Deviation
Colour	4.55	0.57
Aroma	4.35	0.80
Viscosity	4.26	0.77
Taste	4.16	0.73
Overall Acceptability	4.58	0.56

The results showed that all sensory attributes obtained mean scores above 4.00, indicating that the respondents in the sensory evaluation liked the attributes. The overall acceptability had the highest mean score ($M = 4.58$, $SD = 0.56$) which means that the respondents generally liked the product and found it acceptable for consumption.

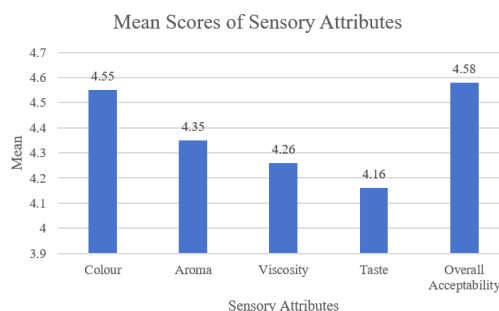


Figure 4. Mean Scores of Sensory Attributes Evaluated by Respondents (n=31)

Figure 4 shows the mean scores for the five sensory attributes evaluated by the respondents. The highest mean score was obtained by the overall acceptability (4.58) and colour (4.55), indicating the developed watermelon rind based dipping sauce was of a high level of consumer acceptability. Aroma (4.35) and viscosity (4.26) scored positively as well while taste had the lowest mean score of 4.16. However, all attributes had a mean score of above 4.00 indicating a high level of overall consumer acceptance toward the product.

3.1.1 Colour

The colour attribute achieved a mean score of 4.55 with a standard deviation of 0.57, suggesting that respondents were highly satisfied with the visual appearance of the dipping sauce. Colour is a key sensory attribute influencing first impressions and consumer purchasing behaviour. The appealing colour of the dipping sauce may be attributed to the incorporation of chili and the natural pigmentation of the watermelon rind puree. The low standard deviation value indicates consistency in respondents' evaluations, demonstrating that most participants shared similar positive perceptions regarding the product's appearance. This finding is consistent with previous studies that found a strong effect of visual quality on the adoption of new food products made from agricultural waste resources. Similar observations have been reported in fruit by-product-based foods, where visual appearance significantly influenced consumer acceptance and overall perception of product quality (Hasan et al., 2024).

3.1.2 Aroma

The aroma attribute recorded a mean value of 4.35 and a standard deviation of 0.80. The findings indicate that respondents generally liked the smell and fragrance of the dipping sauce. Aromas have a huge impact on hunger stimulation and flavor anticipation. The addition of garlic, spices and vinegar probably led to a good scent profile of the product. Although the aroma attribute showed slightly higher variation compared to colour, the mean score remained within the acceptable range. Similar findings were reported by Jothilakshmi et al. (2026), who found that watermelon rind-based confectionery products achieved favourable aroma acceptance among consumers. Aroma attributes are strongly associated with flavour expectations and have been identified as one of the key sensory drivers influencing acceptance of innovative food products developed from agricultural waste materials (Hasan et al., 2024).

3.1.3 Viscosity

The viscosity attribute achieved a mean score of 4.26 with a standard deviation of 0.77. This indicates that respondents positively perceived the texture and consistency of the dipping sauce. Appropriate viscosity is essential for dipping sauce functionality because it affects ease of consumption and mouthfeel. The use of corn starch during formulation likely contributed to the stable texture and desirable thickness of the product. Previous studies on watermelon rind processing have shown that the functional qualities of pectin and fibre content improve food texture and stability. (Capossio et al., 2022).

3.1.4 Taste

Taste had the lowest mean score among the tested attributes ($M = 4.16$, $SD = 0.73$), but the number nevertheless indicated strong consumer acceptability. Taste is commonly seen as the most significant factor influencing food acceptance because it directly impacts consumer satisfaction and repurchase intention. The slightly lower taste score may be due to the unfamiliar flavour profile associated with watermelon rind incorporation. However, the respondents still had a positive acceptance of the product. The comparatively lower taste score may be associated with the intrinsic characteristics of watermelon rind as a fruit by-product. Previous studies have reported that fruit by-products generally contain substantial amounts of dietary fibre and bioactive compounds, which may influence flavour perception, mouthfeel, and overall sensory acceptance when incorporated into food formulations (Lau et al., 2021; Nirmal et al., 2023; Liu et al., 2023). These characteristics may have contributed to the slightly lower taste ratings observed compared with colour and overall acceptability. Similar sensory challenges were identified by Zhang et al. (2021), who reported that watermelon rind inclusion in beverages affected flavour preferences despite its nutritional benefits. The findings suggest that further optimisation of seasoning composition, sweetness, acidity, or spice levels may improve flavour acceptance in future product development. Enhancing taste formulation may further increase consumer preference and commercial viability. Previous studies on watermelon rind confectionery products similarly reported that flavour optimisation remains one of the primary challenges in achieving maximum consumer acceptance despite favourable nutritional characteristics (Rezagholidade-Shirvan et al., 2023).

3.1.5 Overall Acceptability

Overall acceptability recorded the highest mean score ($M = 4.58$, $SD = 0.56$), indicating that respondents generally liked the watermelon rind-based dipping sauce. The high overall acceptance demonstrates the successful integration of watermelon rind into a palatable and marketable food product. This finding supports the potential of agricultural waste valorisation in food innovation. The low standard deviation further suggests consistency in consumer responses, indicating that the product was widely accepted among respondents. The positive acceptance of the dipping sauce is consistent with previous studies demonstrating that watermelon rind can be successfully transformed into acceptable food products such as candies, chips, juices, and bakery items (Rezagholidade-Shirvan et al., 2023). Therefore, this study extends existing literature by introducing condiment-based applications for watermelon rind utilisation.

3.1.6 Comparison with Previous Studies

The findings of this study are consistent with previous research on the utilisation of watermelon rind and other fruit by-products in food product development. The overall acceptability score of 4.58 indicates that consumers responded positively to the watermelon rind-based dipping sauce despite the use of an unconventional food ingredient. Similar

findings were reported by Rezagholizade-Shirvan et al. (2023), who found that watermelon rind chips achieved favourable sensory acceptance among consumers when appropriate formulations were applied. Their study demonstrated that watermelon rind can be successfully incorporated into value-added food products without negatively affecting consumer perception. The present findings are also in agreement with the study conducted by Zhang et al. (2021), who evaluated beverages containing watermelon rind. Although the inclusion of watermelon rind altered the sensory profile of the beverage, the researchers reported acceptable levels of consumer acceptance and highlighted the nutritional benefits associated with rind utilisation. Likewise, the current study found that all sensory attributes achieved mean scores above 4.00, indicating a generally positive perception of the product. Furthermore, the results support the findings of Jothilakshmi et al. (2026), who developed watermelon rind-based tutti frutti products as part of a zero-waste food processing initiative. Their study reported favourable sensory scores for colour, aroma, and overall acceptability, suggesting that watermelon rind possesses considerable potential for food product innovation. Similar trends were observed in the present study, where colour ($M = 4.55$) and overall acceptability ($M = 4.58$) were among the highest-rated attributes.

The findings are also consistent with broader studies on food waste valorisation. Zhu (2022) reported that food by-products can be effectively transformed into marketable food products when appropriate processing methods are employed. Similarly, Yafetto (2022) emphasised that consumer acceptance remains a key factor in the successful commercialisation of food products developed from agricultural waste. The high acceptance scores obtained in the present study indicate that watermelon rind-based dipping sauce has potential to overcome common consumer concerns regarding waste-derived food ingredients. Overall, the results demonstrate that the sensory performance of the watermelon rind-based dipping sauce is comparable to other watermelon rind-derived products reported in the literature. This finding strengthens the potential of watermelon rind as a sustainable raw material for innovative food product development and supports ongoing efforts toward food waste reduction and circular economy practices.

3.2 Discussion on Sustainable Food Waste Valorisation

The findings of this study highlight the importance of food waste valorisation in promoting sustainable food systems. Watermelon rind is commonly discarded despite containing beneficial nutrients and functional compounds. The successful development and acceptance of watermelon rind-based dipping sauce demonstrate that food waste materials can be transformed into innovative and commercially viable food products. Sustainable food innovation is increasingly important due to rising environmental concerns and food insecurity challenges. Agricultural by-products represent untapped resources that may contribute to waste reduction and circular economy practices. The utilisation of watermelon rind in dipping sauce production supports sustainable development by reducing organic waste generation while simultaneously creating value-added products. Recent reviews have emphasised that the conversion of fruit and vegetable waste into value-added food products contributes directly to circular economy objectives by extending resource utilisation and reducing environmental burdens associated with food disposal (Răpă et al., 2024).

The study also contributes to consumer acceptance literature regarding food products developed from agricultural waste materials. Consumer perception remains a major barrier in the commercialisation of sustainable food products because consumers may associate waste-derived ingredients with poor quality or safety concerns. However, the high sensory acceptance scores obtained in this study suggest that proper product formulation can positively influence consumer perceptions. Moreover, the incorporation of watermelon rind into dipping sauce formulations may offer nutritional benefits due to the presence of dietary fibre and antioxidants. Previous studies have identified watermelon rind as a rich source of citrulline and phytochemicals associated with health-promoting properties (Capossio et al., 2022). Therefore, future studies may investigate the nutritional composition and functional properties of watermelon rind-based dipping sauce in greater detail. From an industrial perspective, watermelon rind-based products may provide economic opportunities for small-scale food entrepreneurs and food processing industries. The use of low-cost food waste materials may reduce production costs while supporting environmentally sustainable business practices. Nevertheless, several limitations should be acknowledged. The study involved a relatively small sample size of 31 respondents, which may limit generalisability. In addition, the study focused primarily on sensory evaluation without examining shelf life, microbial safety, nutritional analysis, or physicochemical characteristics. Future research should include larger respondent samples and advanced analytical methods such as texture profile analysis, nutritional composition assessment, and shelf-life evaluation.

4. CONCLUSION

This study developed a watermelon rind-based dipping sauce and conducted a preliminary sensory evaluation involving 31 respondents. The sensory evaluation indicated favourable responses across the evaluated attributes, with all mean scores exceeding 4.00 on a five-point hedonic scale. Among the evaluated attributes, overall acceptability and colour obtained the highest mean scores, while taste recorded the lowest score. The findings suggest that watermelon rind can be incorporated into a dipping sauce formulation with acceptable sensory characteristics under the conditions evaluated in this study. However, the results should be interpreted cautiously due to the limited sample size and the use of convenience sampling. In addition, the study did not include comparative sensory testing against commercial products, physicochemical analysis, shelf-life assessment, or economic evaluation. Future research should

involve larger and more diverse consumer samples, comparative product testing, nutritional and physicochemical analyses, and shelf-life studies to provide a more comprehensive evaluation of the product's feasibility and potential applications.

ACKNOWLEDGMENT

The authors would like to express appreciation to all respondents who participated in the sensory evaluation process and to the institution that supported the implementation of this research.

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