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Impact of Spay-dried Banana Powder Incorporation and Incubation Duration on Sensory Attributes of Yoghurt

[1]Adepoju A. L., [2]Adeyanju J. A., [3]Abioye A. O.

[1]Department of Food Engineering, University of Ilorin, Ilorin.
[2]Department of Food Engineering Ladoke Akintola University of Technology, Ogbomoso, Oyo State, Nigeria,

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Corresponding Author:
adepoju.al@unilorin.edu.ng;
+2347065139079

ABSTRACT

Banana is a widely consumed fruit known for its natural sweetness, rich aroma, and functional properties. Incorporating banana-derived ingredients into dairy products like yoghurt can enhance sensory quality while offering potential health benefits. This study investigates the effect of spray-dried banana powder incorporation (0%, 20%, 25%, 30%) and incubation time (4h, 6h) on the sensory attributes of yoghurt, including appearance, aroma, taste, texture, and overall acceptability. Sensory evaluation, conducted using semi-trained panelists, revealed that banana powder significantly enhanced all sensory parameters compared to control samples (0% banana). The best-rated formulations, A2 (20% banana, 6h) and C2 (30% banana, 6h), exhibited improved flavour balance, a creamy texture, and high overall acceptability. In contrast, yoghurts without banana powder (D1, D2) had the lowest scores, likely due to their higher acidity and lack of fruit-based sweetness. A longer incubation time (6h) further improved taste and aroma retention, possibly due to increased fermentation-derived volatile compounds. Additionally, banana powder contributed to enhanced thickness and viscosity due to its fiber and pectin content, improving texture. These findings suggest that banana powder at 20–30% with a 6-hour incubation period enhances yoghurt's sensory quality, making it a promising functional ingredient for dairy products.

INTRODUCTION

The rising consumer demand for functional foods that are enriched with components that offer health benefits beyond their essential nutritional value is increasingly becoming popular in the food sector. This is because functional foods possess beneficial ingredients that include probiotics, prebiotics, vitamins, minerals, and nutrients derived from the food itself. Various types of functional foods exist and fermented foods, especially yoghurt, play an important role as they commonly serve as carriers of probiotics (Suriwong *et al.*, 2025).

Yoghurt is a popular fermented dairy product valued for its sensory appeal and health benefits, including improved digestion and enhanced immune function (Kabir *et al.*, 2021). The growing consumer demand for novel yoghurt products has spurred interest in incorporating fruit powders and other natural plant extracts to enrich the flavour, nutritional value, and functional properties (Asiimwe *et al.*, 2021; Postolache *et al.*, 2023). Among various fruits, bananas are particularly appealing due to their natural sweetness, inviting aroma, and high levels of bioactive compounds, such as vitamins, minerals, and antioxidants (Chowdhury *et al.*, 2024; Roy *et al.*, 2015).

However, fresh bananas are highly perishable, making the use of spray-dried banana powder an attractive alternative that offers extended shelf life and consistent quality (Lee *et al.*, 2023; Salih *et al.*, 2017). Spray drying, a widely used method for

converting fruit pulps into stable powders, preserves essential nutrients and enhances product versatility (Akbarbaglu *et al.*, 2021). This process converts banana pulp/juice into a fine, moisture-free powder, making it easier to incorporate into yoghurt retains key volatile compounds responsible for its characteristic fruity aroma, thereby enhancing the overall sensory experience of yoghurt (Kabeer *et al.*, 2023). Prior studies have shown the addition of banana to yoghurt in different forms such as fresh and dried banana chunks (Tariq *et al.*, 2023), banana pulp (Roy *et al.*, 2015), banana peel extract (Kabir *et al.*, 2021) and banana juice (Chowdhury *et al.*, 2024). However, the specific effects of incorporating spray-dried banana powder, varying its levels of incorporation and incubation times on yoghurt's sensory profile remain underexplored.

The fermentation process, crucial in yoghurt production, can significantly affect sensory attributes by altering texture, flavour, and aroma compounds through microbial metabolism (Moyo, 2024; Souza *et al.*, 2024).

Incubation time, in particular, influences the extent of fermentation and acid production, affecting the yoghurt's final consistency and taste. The interaction between fermentation time and added fruit powders/pulps can either enhance or diminish desirable sensory qualities, making it essential to identify optimal processing conditions (Kamber and Harmankaya, 2019). Despite the recognized benefits of fruit powder incorporation, there is a need for further exploration of the combined effect of banana powder concentration and fermentation time on yoghurt's sensory characteristics.

This study aims to investigate the combined effect of spray-dried banana powder incorporation (0, 20, 25, and 30%) and incubation time (4 and 6h) on the sensory attributes of yoghurt. By understanding how these variables affect consumer-perceived quality, this research seeks to formulate functional yoghurt and evaluate its sensory acceptance. The findings will contribute to the growing field of functional foods, aligning with consumer preferences for natural and nutritious ingredients.

MATERIALS AND METHODS

Materials

Powdered milk (Lactorich), sugar, and starter culture were procured from the Mandate ultramodern market and Habib Yoghurt in the Ilorin metropolis, Kwara State, Nigeria. Fully ripe banana fruits (*Musa acuminate var. red dacca*) used for the spray-dried banana powder were obtained from a popular agricultural produce market located in Ganmo, Ilorin in Kwara State, Nigeria. Maltodextrin (carrier agent) and pectinase enzyme used were of food grade and obtained from Special Ingredients Ltd, Foxwood Industrial Park, Chesterfield, S41 9RN, United Kingdom, and North Mountain Supply, Mildred, PA, USA respectively.

Methods

Preparation of Spray-Dried Banana Powder

Fresh red bananas **(***Musa acuminata***)** were washed, peeled, and homogenized using a manual food chopper to obtain banana pulp. The pulp was then enzyme-liquefied with 0.5% w/w pectinase enzyme at ambient temperature for 2 h to extract the juice. The banana juice was afterward spray-dried using a laboratory spray dryer (Xiamen Ollital, China) at an inlet temperature of 165.4°C, feed flow rate of 28 rpm, and 25% concentration of maltodextrin. The resulting banana powder was stored in an airtight container at room temperature until use.

Experimental Design

The experiment was structured using an adapted Taguchi L8 Orthogonal Array (OA) allowing efficient evaluation of two factors at multiple levels: spray-dried banana powder concentration,

SBPC (0, 20, 25, and 30%), and incubation duration, ID (4 and 6h) on sensory attributes of yoghurt. The experimental design is shown in Table 1.

Table 1: Adapted Taguchi L8 Orthogonal Array Design for Spray-dried Banana Incorporated Yoghurt Formulation

Run	Sample code	SBPC (%)	ID (Hours)
1	**A1**	**20**	**4**
2	**A2**	**20**	**6**
3	**B1**	**25**	**4**
4	**B2**	**25**	**6**
5	**C1**	**30**	**4**
6	**C2**	**30**	**6**
7	**D1**	**0**	**4**
8	**D2**	**0**	**6**

Preparation of Spray-dried Banana Powder Incorporated Yoghurt

Stirred-type yoghurts with eight different formulations according to the experimental design in Table 1 were prepared using the methods of (Mencia, 2018) and (Zahid *et al.*, 2022) with modifications. All utensils, equipment, and containers were thoroughly washed before use. The ingredient formulation is presented in Table 2. The powdered milk (Lactorich) was reconstituted to 14% w/v with distilled water (about 40 ºC) and stirred vigorously to ensure efficient dissolution. The reconstituted liquid milk was pasteurized at 90 ºC for 10 minutes (Gavril Rațu *et al.*, 2024). Sugar (2.5% of reconstituted milk) was added in the process of pasteurization. The mix was cooled to a fermentation temperature of 43 ºC in a water bath while it was stirred slowly with a wooden spatula. The different percentages of spray-dried banana powder (20, 25, and 30% of the powdered milk weight) and the starter culture (3% of reconstituted milk) were added and the mixture was agitated gently until properly dissolved. Inoculated yoghurt mix was placed in sterilized containers and incubated at 43 ºC for 4 and 6 hours until pH 4.5 was reached (Gavril Rațu *et al.*, 2024; Suriwong *et al.*, 2025). The percentage of the banana powder incorporation and choice of the incubation duration of the yoghurt were selected based on previous studies (Abdalla and Ahmed, 2019; Chowdhury *et al.*, 2024; Leeward *et al.*, 2023; Mbaeyi-Nwaoha and Iwezor-Godwin, 2015; Pravitha and Chandran, 2022; Roy *et al.*, 2015). The yoghurts were placed in a refrigerator and stored overnight at 4 ºC before the sensory evaluation.

Sensory Evaluation of Spray-dried Banana Powder Incorporated Yoghurt

The sensory evaluation of yoghurt with and without the spray-dried banana powder was performed according to the method of Postolache *et al.* (2023) with modifications. Ten (10) semi-trained panelists were used for the evaluation based on literature for descriptive sensory analysis (Drake *et al.*, 2023; Khalil *et al.*, 2022; Drake, 2007). The panelists consisting of the staff and students of the Food Engineering Department, University of Ilorin, with regular yoghurt consumption (more than once a month) between 16 and 50 years old were randomly selected. They were informed of the study's overall objective and the necessary procedures for handling personal data. The fortified yoghurt samples were assessed by the panelists on a 9-point hedonic scale for appearance, aroma, taste, texture, and overall acceptability (1 = extremely dislike; 9 = extremely like). The sensory evaluation space was maintained in a suitable environment with the temperature in the booths at around ambient (25 ºC). Duly labeled yoghurt samples of about 30 ml were presented in transparent cups for evaluation and panelists were provided with unsalted crackers and water to clean

the palate between samples (Mencia, 2018; Ribeiro *et al.*, 2019).

Statistical analysis

The observed results were transformed and reported as signal-to-noise ratio (S/N ratio) according to Taguchi's principles. The S/N ratio for the larger-the-better characteristic was chosen for the sensory properties (Equation 1) since a high value of these properties was expected.

$$S/N = -10 \times \log_{10} MSD \quad (1)$$

Where MSD is the Mean Squared Deviation and is calculated using Equation 2 as follows:

$$MSD = \frac{1}{n}\sum \frac{1}{y^2} \quad (2)$$

where n and y represent several observations and sensory scores respectively.

The desirable value (mean) for the output characteristic is known as 'signal' while the undesirable value (standard deviation) for the output characteristic is called 'noise'. Therefore, the Taguchi method uses the signal-to-noise ratio to measure the quality characteristic deviating from the desired value (Kongpichitchoke *et al.*, 2021; Sangeetha *et al.*, 2023)

RESULTS AND DISCUSSIONS

The sensory evaluation of the spray-dried banana incorporated yoghurt **at a varying concentration** (0, 20, 25, and 30%) **and incubation duration (4 and 6 h) are presented in Table 2.** For appearance, the highest scores were recorded for **A2 (8.0) and C2 (7.6),** indicating a visually appealing yoghurt with well-integrated banana powder while the lowest score **(D2 = 6.8)** suggests that yoghurt without banana powder lacks the characteristic colour enhancement. Research has shown that incorporating **fruit powders** into yoghurt **enhances colour intensity and visual appeal**, leading to higher consumer acceptance as colour is one of the major quality parameters that influence yoghurt attractiveness and consumer acceptability (Zahid *et al.*, 2022).

Run	Sample code	SBPC (%)	ID (h)	Appearance	Aroma	Taste	Texture	Overall Acceptability
1	A1	20	4	7.5	6.8	6.3	6.6	7
2	A2	20	6	8	7	7.1	7.2	7.6
3	B1	25	4	7.4	6.7	6.8	6.7	6.8
4	B2	25	6	7.3	7	6.8	6.7	7.1
5	C1	30	4	7.3	6.3	6	6.9	6.5
6	C2	30	6	7.6	6.7	7.4	7.2	7.6
7	D1	0	4	7.3	6.1	5.8	6.9	6.3
8	D2	0	6	6.8	5.8	4.9	6.8	5.6

Table 2: Sensory Evaluation of Spray-Dried Banana-Incorporated Yogurt

B2 (7.0) and A2 (7.0) had the highest aroma scores, while D2 (5.8) was the lowest. The presence of banana powder contributed to a more appealing fruity aroma, whereas yoghurt without banana powder (D1, D2) had lower scores. Due to the lack of aromatic volatiles. Studies confirmed that spray drying retains key volatile compounds, specifically esters such as isoamyl acetate, isoamyl butyrate,

ethyl butanoate, and hexyl acetate, which are responsible for banana's fruity aroma and longer incubation time (6h) played a role in enhancing their production, boosting aroma perception (Wang *et al.*, 2011; Saha *et al.*, 2018). In this study, it was observed that a moderate banana content (20%) combined with extended incubation (6h) helped to retain a more natural banana aroma. A similar observation was reported by (Chowdhury *et al.*, 2024). C2 (7.4) and A2 (7.1) scored highest, indicating that higher banana incorporation (30%) with extended fermentation (6h) enhances taste. The lowest taste score (D2 = 4.9) suggests that yoghurt without banana powder is perceived as more acidic and less palatable. Banana naturally contains fructose and glucose, which can counteract yoghurt acidity, improving taste perception (Deshmukh *et al.*, 2017). Studies on fruit-fortified yoghurt confirmed that higher fruit concentrations enhance sweetness perception, leading to higher consumer preference (Asiimwe *et al.*, 2021). A conclusion drawn from this study as regards the taste of the banana-incorporated yoghurt is that, for optimal taste, a higher banana concentration (30%) with 6-hour fermentation created a well-balanced sweet-acidic profile.

For texture, samples A2 and C2 (7.2) had the best scores, confirming that banana powder improves yoghurt consistency. The lowest texture score was obtained in sample D2 (6.8) with 0% banana powder, and this may be due to a lack of fruit fibers contributing to viscosity. Banana contains pectin and dietary fiber, which contribute to thicker and creamier yoghurt textures. A certain study confirmed that fiber content in fruit is associated with increasing viscosity and consequently improves the textural properties of fruit yoghurts (Roy *et al.*, 2015). In addition, the spray drying process used to produce the banana powder preserved fiber integrity that helped to improve the mouthfeel of the yoghurt without additional stabilizers and artificial thickeners.

For the overall acceptability, samples A2 (7.6) and C2 (7.6) were rated highest, confirming that a balance between banana content and fermentation time optimizes sensory appeal. Sample D2 with 0% banana powder had the lowest acceptability (5.6), indicating that banana incorporation significantly improves yoghurt desirability. Consumer studies show that fruit-fortified yoghurts with optimal sweetness and texture score higher in overall acceptance. The prebiotic potential of banana powder also enhanced consumer perception of yoghurt as a functional food. Similar results have been obtained for various yoghurt fortified with fruits and fruit by-products (Jany *et al.*, 2024; Taha *et al.*, 2024; Costa *et al.*, 2023; Nilufa Yeasmin *et al.*, 2023)

Various authors obtained similar results. For instance, Pravitha and Chandran (2022) reported that the sensory scores of yoghurt incorporated with 20% banana fruit pulp (robusta banana) were found to be higher than the plain yoghurt (control) with a mean score of overall acceptability of 8.3 while that of the control is 6.8. In another study on the sensory properties of pawpaw-flavored yoghurt, the authors reported that yoghurts incorporated with 5, 10 and 15% of pawpaw puree registered slightly higher scores compared to the one without the fruit puree (Njoya *et al.*, 2017). However, Suriwong *et al.* (2025) reported a contrary observation for yoghurt fortified with cocoa powder. The authors noted that the addition of more than 1 % (w/w) cocoa powder resulted in the lower sensory acceptance of the yoghurt, except colour. This was attributed to the unfamiliarity of adding cocoa powder to yoghurt. In addition, Safdari *et al.* (2021) reported a decrease in the overall acceptability of yoghurt when banana fiber and peel were increasingly added.

In another study on yoghurt incorporated with

unripe false horn plantain, the authors observed that the overall acceptability score for the yoghurt products decreased as the addition of the unripe plantain flour increased, with the 2% UPF-enriched yoghurt having the next highest mean overall acceptability score after the control. This implied that the panelists preferred the control yoghurt without the flour addition (Leeward *et al.*, 2023). This is in contrast to the findings of this study where panelists preferred the banana powder incorporated yoghurt to the control.

Signal-to-Noise (S/N) Ratio Calculation Showing Factor Effects on Sensory Attributes

In this section, the signal-to-noise (S/N) ratio was computed to help quantify the effect of each factor on sensory attributes while minimizing variability.

Effect of Spray-dried Banana Powder Concentration, SBPC (%) on Sensory Attributes

The S/N ratios showing the effect of SBPC on the sensory properties were calculated and revealed that higher values indicate better consistency and improved sensory performance (Figure 1). It was noted that SBPC of 20% had the highest overall acceptability (7.30), indicating the best balance of the sensory properties.

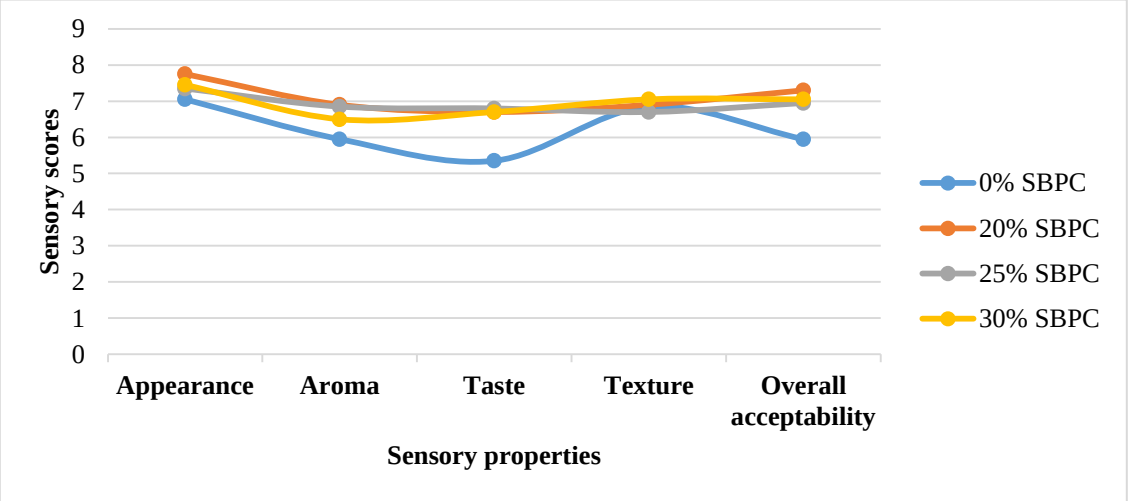

Figure 1: S/N ratios showing the effect of SBPC (%) on the sensory properties.

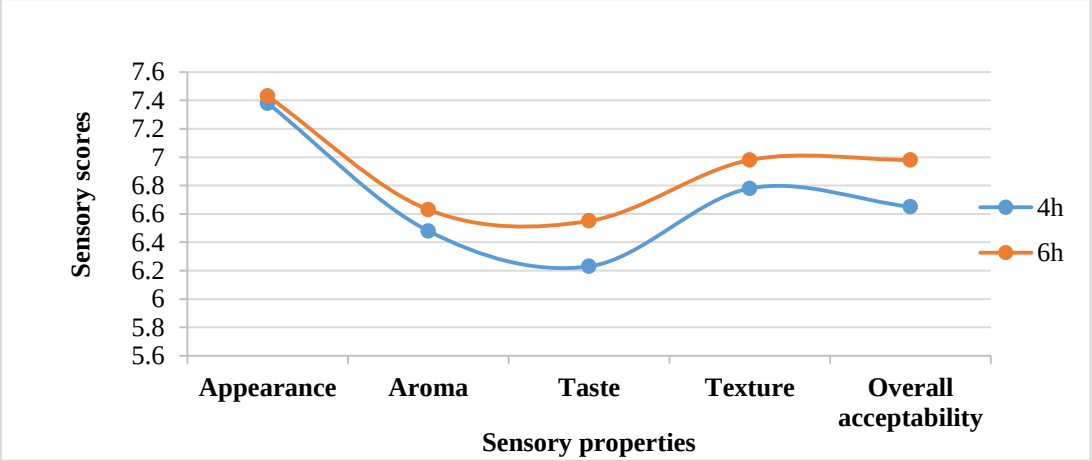

Figure 2: The effect of ID (h) on the sensory properties.

Effect of Incubation Duration, ID (h) on Sensory Attributes

The effect of ID on sensory attributes as shown from the calculation of S/N ratios is presented in Figure 2. It was noted that the incubation duration

of 6 h improved aroma, taste, texture, and overall acceptability while shorter incubation time (4 h) resulted in slightly lower sensory scores.

CONCLUSION

This study demonstrated that incorporating spray-dried banana powder (20–30%) into yoghurt, especially with a 6-hour incubation period, significantly enhances sensory attributes such as taste, texture, odour, and overall acceptability. The best-rated formulations (A2 and C2) exhibited a well-balanced flavour, creamy texture, and improved overall acceptability as rated by the panellists. Yoghurts without banana powder received lower scores, highlighting the positive impact of fruit-based sweetness and reduced acidity. These findings suggested that banana powder is a valuable functional ingredient for improving yoghurt sensory quality and is therefore recommended for inclusion in the production of functional yoghurt. Future research should explore its nutritional and probiotic benefits for enhanced health and commercial applications.

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