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Full Length Research

Comparative studies on sensory attributes of Fresh Composite Puree (FCP), Spray-Dried Composite Powder (SDP) and Freeze-Dried Composite Powder (FDP) produced from some local varieties of mango, orange and watermelon species

J. A. Ankeli[1]*, O. G. Igbum[2] and F. G. Okibe[3]

[1]Department of Food Science & Technology, University of Mkar, Mkar, Gboko, Benue State, Nigeria.
[2]Department of Chemistry, Faculty of Science, Centre for Food Technology & Research (CEFTER), Benue State University, Makurdi, Benue State, Nigeria.
[3]Department of Chemistry, Faculty of Science, Federal University of Health Sciences, Otukpo, Benue State, Nigeria.

*Corresponding author. Email: jackankeli@umm.edu.ng; Tel: +234 7030089254.

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ABSTRACT: This research investigated the sensory evaluation of fresh puree freeze-dried powder (FCP), spray-dried powder (SDP), and freeze-dried powder (FDP) of mango, orange, and watermelon composite puree samples. The study assessed the appearance, aroma, taste, texture, consistency, and overall acceptability of the three products using a panel of evaluators. Results showed that the freeze-dried sample (FDP) had the highest appearance rating (7.44), while the spray-dried sample (SDP) scored the highest in terms of overall acceptability (7.72). Statistically, there was a significant difference ($p < 0.05$) across samples for appearance and consistency, while other sensory attributes showed no significant variation. Spray-dried samples consistently performed well across most sensory parameters, with aroma rated at 7.20 and taste at 7.24. The findings suggest that spray-dried and freeze-dried samples have sensory profiles comparable to fresh samples, making them suitable for commercial production while addressing post-harvest losses in the agricultural value chain.

Keywords: Maltodextrin, mango, orange, watermelon.

INTRODUCTION

Fruits and vegetables provide health benefits due to their high nutritional content and health-promoting effects (Bao *et al.*, 2016, Chen *et al.*, 2016; Chen *et al*., 2015; Xu *et al.*, 2017). Tropical fruits such as mango, orange, and watermelon are highly valued for their rich nutritional content, vibrant colours, and unique flavours. These fruits are essential sources of vitamins, minerals, antioxidants, and dietary fibre, which contribute significantly to human health. Mangoes, for instance, are abundant in vitamin A and beta-carotene, oranges are rich in vitamin C and flavonoids, while watermelons are known for their high water content and lycopene, a powerful antioxidant. High perishability is the main problem challenging fruit and vegetable production. Despite their nutritional benefits, these fruits are highly perishable, leading to significant post-harvest losses, particularly in tropical and subtropical regions like Benue State, Nigeria. This challenge negatively impacts food security, income generation, and the overall sustainability of agricultural practices in such regions.

Postharvest spoilage causes fast degradation of quality resulting in large wastage (Bassetto *et al.,* 2005). To mitigate these losses and extend the shelf life of these fruits, a variety of drying techniques are available for use on the industrial scale. According to Chopda and Barrett (2001), the most successful methods for fruit juice powder production are freeze drying, foam mat drying and spray drying. Among these effective drying methods are spray-drying and freeze-drying. Spray drying is widely used in the food industry due to its cost-effectiveness and efficiency. It involves atomizing the fruit puree into a fine mist, which is then dried rapidly using hot air. However, this process can lead to a partial loss of volatile compounds and heat-sensitive nutrients, potentially affecting the sensory attributes of the final product.

Eventhough spray drying has a short drying contact time, it involves relatively high drying temperatures, typically 150-220°C inlet air temperature and 50-80°C outlet air temperature (Phisut, 2012), which can damage sensitive compounds, i.e. lycopene, carotene, anthocyanins, vitamin C, colours and flavours (Bao *et al.*, 2016; Chen *et al.,* 2016; Kong and Ismail, 2011; Patil *et al.*, 2014).

Freeze-drying, on the other hand, is regarded as the most efficient in nutrients preservation in powdered products, but its industrial-scale application is hampered by the high expenditures of the instrumentation and high energy consumption, as well as by a low throughput (Hsu *et al.,* 2003, Ratti, 2001). It is a more advanced technique that involves freezing the fruit puree and subsequently removing the moisture under low pressure through sublimation. This method is known to preserve the colour, flavour, and nutritional content of the fruits better than spray-drying, albeit at a higher operational cost and energy consumption.

Fruit juice powders have many benefits and economic potentials over their liquid counterparts such as reduced volume or weight, reduced packaging, easier handling and transportation, and much longer shelf life. Besides, their physical state provides a stable, natural, and easily dosable ingredient, which generally finds usage in many foods and pharmaceutical products such as flavouring and colouring agents (Shrestha *et al*., 2007). However, the dehydration of fruit juices is not a simple task. The low Glass transition temperature (*T*g) of the main juice components (low molecular weight sugars and organic acids) as well as their high hygroscopicity, low melting point, and high water solubility result in the highly sticky product when spray dried without a carrier agent due to their stickiness behaviour and low glass transition temperature, which leads to wall deposition problems and drying difficulties (Bhandari *et al.,* 1997). Therefore, carrier agents are one of the most important factors in spray drying. Carrier agents increase the Tg and yield percentage and reduce the stickiness and hygroscopicity of powdered product. Furthermore, the addition of a carrier agent to the liquid feed increases the drying yield and reduces the moisture content of the spray-dried product (Abadio *et al*., 2007). In literature, different kinds of carrier agents have been described, such as maltodextrin in amla juice, watermelon juice and gac fruit (Kha *et al.*, 2010; Mishra *et al.*, 2014; Quek *et al*., 2007); maltodextrin, gum arabic and micro-crystalline cellulose in black mulberry juice (Fazaeli *et al*., 2012); waxy starch, maltodextrin, and gum arabic in pomegranate juice (Yousefi *et al.*, 2011), maltodextrin, gum arabic and tapioca starch in black carrot (Murali *et al.,* 2015), maltodextrin, gum arabic and whey protein concentrate in tamarind pulp (Bhusari *et al*., 2014) and b-Cyclodextrin, gum arabic and maltodextrin in sage (Şahin-Nadeem *et al.,* 2013). The most frequently used carrier agents in spray drying of fruit and vegetable juices are maltodextrins (Tg ¼ 100-243°C) and gum arabic (Tg ¼ 126°C) owing to their high molecular weight, high glass transition temperature (Tg) and good solubility and low viscosity (Quek *et al.*, 2007; Schutyser *et al*., 2012).

The sensory attributes of dried fruit products, including appearance, aroma, taste, texture, and consistency, play a critical role in consumer acceptability. The successful commercialization of these dried products largely depends on maintaining sensory attributes that are comparable to fresh fruits. Previous studies have indicated that optimizing processing conditions during drying can significantly influence the quality and acceptability of the final product (Petikirige *et al*., 2022).

Recently, the demand on vegetable and fruit powders has considerably increased due to multiple benefits of the application of these products in varieties of food formulations. Hence, it is important to know how the spray drying technique and its processing factors influence the powder properties and how to optimize the suitable ranges of processing factors. Processing these fruits into stable forms such as spray-dried and freeze-dried powders offers a practical solution to extend their shelf life and reduce wastage (Esteve *et al*., 2005; Walkling-Ribeiro *et al.*, 2009).

In this study, the sensory attributes of fresh composite puree (FCP), spray-dried composite powder (SDP), and freeze-dried composite powder (FDP) made from a blend of mango, orange, and watermelon were evaluated. The objective was to assess the impact of these drying methods on sensory characteristics and to determine the most suitable drying technique for producing high-quality, shelf-stable fruit powders that retain consumer appeal. Additionally, this research aims to contribute to the development of value-added products from locally available fruits, thereby reducing post-harvest losses and enhancing the economic potential of fruit processing in Nigeria.

MATERIALS AND METHODS

Sample collection

Mango and orange fruits of the same varieties were procured from the Gboko local market in Gboko Benue

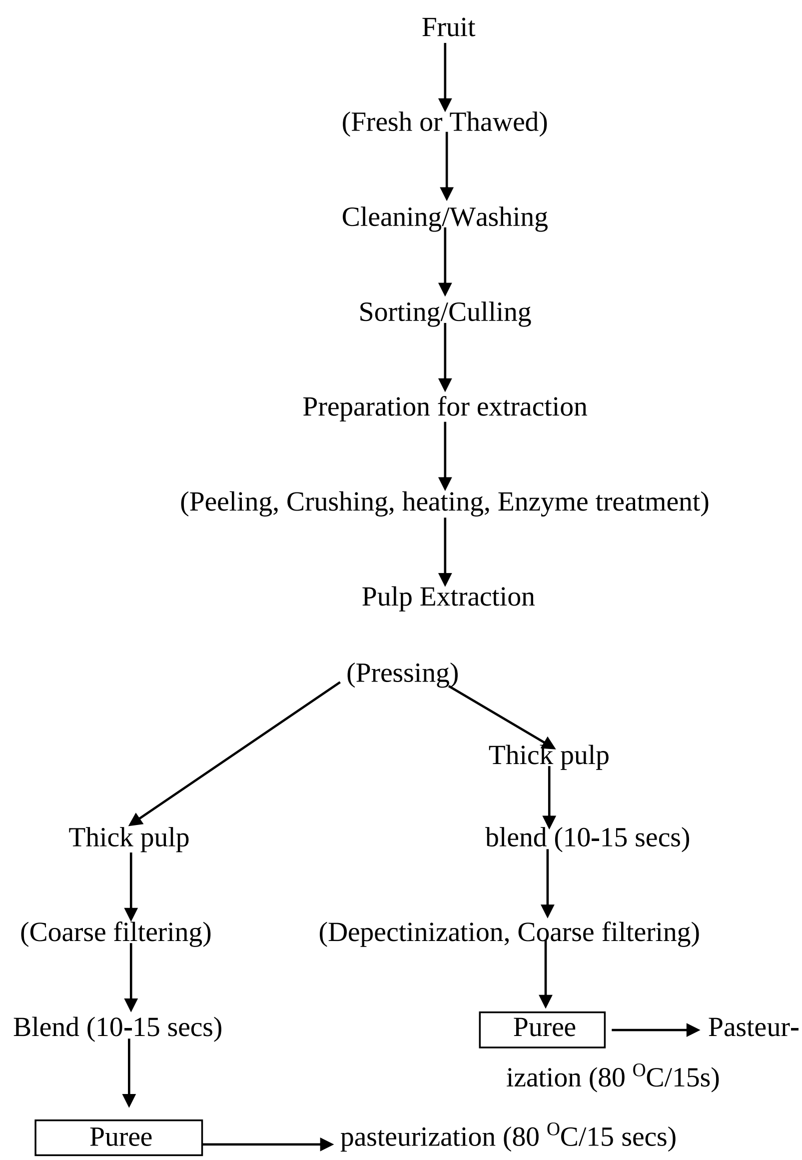

Figure 1. General flow for fruit puree production (Source: Mateescu *et al.,* 2022).

State Nigeria, while watermelon fruits (Sugar Baby) variety were sourced from the Makurdi Railway market also in Benue State, Nigeria. All fruit varieties were transported in polyethylene bags to the Joseph Tarka Federal University of Agriculture, Makurdi, Nigeria for proper identification. They were then refrigerated in preparation for further processing and analyses.

Sample preparation

The fruits were washed, and their average weights were taken and recorded. The fruits were peeled, and the weights of the peels were taken. The remaining processes to produce the puree prior to drying were shown in the flow charts (Figures 1 to 4).

Depending on its stickiness and viscosity, each puree type was mixed with 15%, 20%, 25% and 30% (w/w) commercial maltodextrin for watermelon, orange and mango puree. The ratio of puree solids to carrier was 1:1.38; 1:1.95; 1:2.60; and 1:3.35, respectively with Dextrose Equivalent (DE) 20 – 30. The purees were formulated into smoothies with a selected addition of maltodextrin. The most acceptable smoothie was subjected to the spray and freeze-drying techniques.

Fruit puree production process

The general flowchart for fruit puree production is shown in Figure 1 using a method described by Mateescu *et al.* (2022) while mango puree production is shown in flow

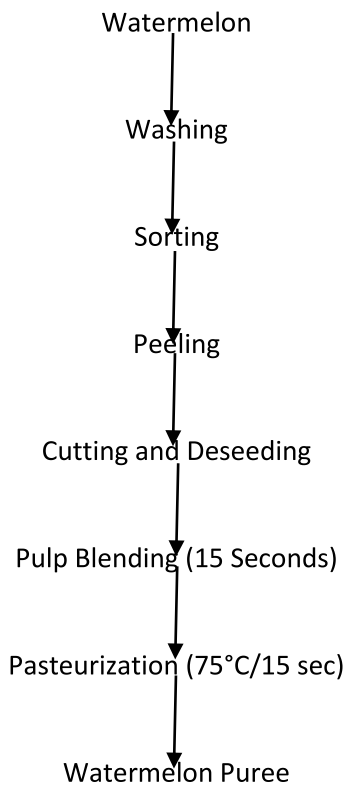

Figure 2. Flow chart for watermelon fruits puree production (Source: Mamadou *et al.*, 2018).

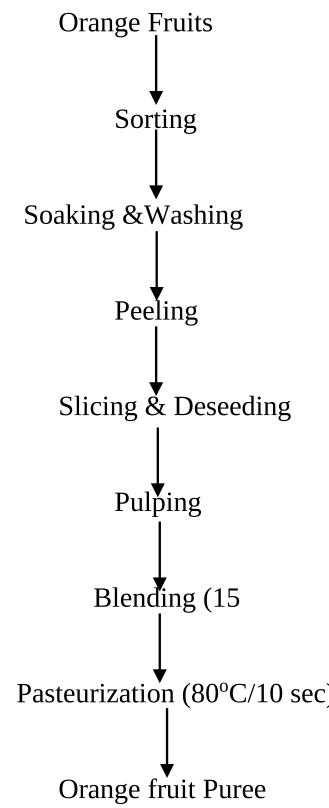

Figure 3. Flow chart for production of orange fruits puree (Source: Obasi *et al*., 2017).

chart in Figure 4. The purée of blanched mango pieces was obtained by crushing blanched mango in the presence of 0.2 M citric acid buffer (pH 5.2) blanched at 90°C for 4 minutes in closed plastic containers. The analyses of the nutrients were carried on the purées 30 minutes after crushing. The production process of orange and watermelon puree were similar to that of mango, as shown in Figures 2 and 3.

Watermelon fruit puree production

The flow chart for the production of watermelon puree is shown in Figure 2 using the method described by Sadji *et al.* (2018). After washing and sorting, the fruits were peeled manually using stainless steel knives followed by slicing, removal of the seeds followed by blending of pulps in a household electric blender (model KE-2268)) at speed number 3 for 15 seconds into smooth pastes which were pasteurised at 70°C for 15 seconds in 250 ml glass beakers with aluminium foil coverings. After cooling, the watermelon purees were kept in a refrigerator prior to use for composite puree formulation.

Production of orange fruit puree

Orange fruits puree was produced with slight modifications as described for orange juice production by Obasi *et al*. (2017). Essentially, as shown in Figure 3, the fruits were sorted, washed, peeled and sliced using stainless steel knives. After removal of the seeds, the slices were blended into a smooth paste using the house hold electric blender (model KE-2268). The orange puree was then pasteurized at 70°C for 15 seconds in 250 ml glass beakers with aluminum foil covers. The pasteurized orange puree was rapidly cooled in an ice bath and promptly stored in a refrigerator prior to use for mixed purees formulation.

Production of mango fruits puree

The production of the mango fruits puree was by the method of Labaky *et al*. (2020) as provided in Figure 4. The mango fruits were sorted, washed and blanched by immersion in a boiling hot water bath maintained at 98°C for 5 minutes. The blanched mango fruits were then cooled in running tap water, peeled using stainless steel knives and the fleshy mesocarp sliced to obtain pieces which were blended in the Kenwood mixer (model KMM770) in the presence of 0.2 M citric acid buffer (pH 5.2) into a smooth slurry. The slurry was then stored in the freezer compartment of a household refrigerator prior to use for composite purees formulation. The purée of blanched

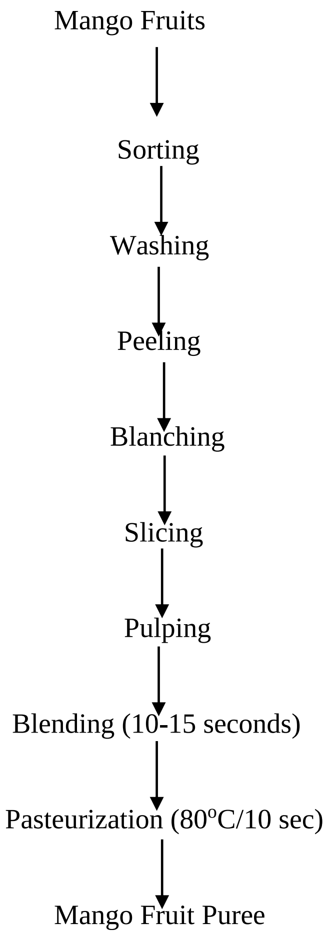

Figure 4. Flow chart for mango puree production (Source: Labaky *et al*., 2020).

mango pieces was obtained by crushing blanched mango in the presence of 0.2 M citric acid buffer (pH 5.2) blanched at 90°C for 4 minutes in closed plastic containers. The analyses of the nutrients were carried on the purées 30 minutes after crush.

Composite fruit purees formulation

The composite fruit purees compositions are shown in Table 1. In order to minimize bias, the formulations were each coded using 3-digits random numbers. Each puree type was treated with commercial maltodextrin as a carrier agent respectively to obtain a dextrose equivalent (DE) of 30 for each group. The composite purees together with the maltodextrins were each blended into smoothies and subjected to preliminary sensory evaluation which indicated that the composite puree sample comprising 50% watermelon, 30% orange and 20% mango composite puree (code: 618) was the most acceptable smoothie and hence was used for the spray and freeze-drying experiments respectively.

Production of reconstituted powders (fruit powders production)

The most organoleptically accepted composite fruits puree containing 50% watermelon, 30% orange and 20% mango was subjected to freeze drying and spray drying respectively as follows:

Freeze drying operations

Freeze drying of the composite fruits puree was as described by Camacho *et al.* (2023) using a pilot scale freeze dryer (model: Labconco Free Zone Triad, Freeze Dry System, Freeze Dry Ltd., Warwickshire, UK). The freeze-drying machine (with a Capacity of 18 litres of ice condensing capacity.) was preheated to 50 °C with an initial pressure of 0.030 mbar according to the manufacturer's instructions. The mixed fruit puree was poured into 250 g capacity freezer bags, sealed and placed on freezer trays prior to loading and in the freeze-drying chamber of the freeze dryer. The initial freezing was done to −45 °C while during drying the temperature was increased up to 60 °C. A vacuum of 100 mmHg was maintained during freeze-drying. The process was regularly monitored to ensure proper drying. The freeze-dried composite fruit puree powder containing 2–3 % moisture was allowed to cool to room temperature. The freeze-dried puffy material was then blended in a household Kenwood dry mixer for 2 minutes and the powder was packaged in air-tight aluminium pouches which were then stored on dry shelves in glass desiccators containing activated silica.

Spray drying operations

Spray drying of the composite fruits puree containing 50% watermelon, 30% orange and 20% mango was as described by Jeyanth *et al.* (2020) using a pilot plant spray-dryer (Simon Dryers Ltd, Cheshire, England.) with a co-current air flow. The speed of the blower was set at 2400 rpm for all the drying. Distilled water was pumped into the dryer at a set flow rate of 10 rpm (10 rpm ~ 30 ml/min) to achieve inlet and outlet temperatures of 200 and 120°C, respectively. The dryer was run at this condition for about 10 minutes prior to the introduction of the feed. The feed puree was passed through the spray-dryer chamber (500 mm x 21 mm) with a centrifugal pump. The speed of rotation of the pump controls the feed flow rate, which passes from the atomizer nozzle with an inner diameter of 0.5 mm. The inner temperature and feed rate were maintained at 160°C and 400 ml/h, respectively. After the spray-drying operation, the powder obtained was collected in a pre-weighed insulated glass bottle connected at the end of the cyclone collector and packed in aluminum pouches which were stored at 25°C in a desicator containing activated silica gel prior to prompt use for

Table 1. Composite puree formulation.

Sample code	Puree composition (%)		
	Watermelon	Orange	Mango
573	30	50	20
618	50	30	20
335	20	50	30
804	50	20	30
732	20	30	50
408	30	20	50

analyses. The powders were produced 24 hours prior to the sensory evaluation and stored in air-tight sealed polyethylene containers, at low temperatures (20°C), and away from light and moisture to prevent degradation of flavour, colour, and aroma compounds (Fegus *et al*., 2014).

Sensory evaluation

Reconstituted solvent

Distilled water was used to reconstitute the fruit powders. Tap or distilled water is typically used to mimic natural consumption (Fang and Bhandari, 2011). The water temperature was maintained between 20°C during reconstitution to ensure that the dissolved particles did not alter the sensory properties, such as sweetness or flavour intensity, due to temperature variation (Fang and Bhandari, 2011). The appropriate reconstitution ratio was determined based on a typical reconstitution ratio of 1:10 (powder to water), meaning 10 grams of fruit powder was reconstituted in 100 mL of water, depending on the powder's moisture content and concentration of flavour components (Santos *et al*., 2014). Using a stirring rod, the mixture was stirred gently but thoroughly to ensure uniform dispersion and solubilization of the fruit powder in the liquid. The reconstituted solution was allowed to rest for a standardised time of 10 minutes, to ensure full hydration of the powder and to allow volatile compounds to stabilize in the solution (Chirife *et al.*, 2020). This step also ensures uniform sensory properties across all samples.

Sample labelling

The samples were labelled with random 3-digit codes to ensure blind testing and avoid bias during the sensory evaluation process. The reconstituted fruit samples were served at room temperature (~20°C), as temperature fluctuations can influence the perception of taste and aroma (Lawless and Heymann, 2010). The samples were presented in 200 ml disposable identical cups that did not influence taste perception (neutral colour and odour-free). Consistent portions of 50 mL per sample were used (Lawless and Heymann, 2010). The sensory evaluation of the fresh composite purees was carried out using a trained sensory panel consisting of staff and students of the University of Mkar. The panel consisted of 50 members including male and female members of the University of Mkar, Mkar. All evaluation sessions were held in the Food Chemistry Laboratory of the Food Science and Technology.

Evaluation

The sensory evaluation of the fresh samples was carried out four hours after formulation while the sensory evaluations of the dried products were after one week of production. The samples were stored at 5°C and taken out three hours before serving. Appearance, aroma, taste, texture, consistency and overall acceptability were evaluated following a nine-point hedonic scale (9 = like extremely, 8 = like very much, 7 = like moderately, 6 = like slightly, 5 = neither like nor dislike, 4 = dislike slightly, 3 = dislike moderately, 2 = dislike very much, 1 = dislike extremely). The panellists were thoroughly briefed on how to use the sensory evaluation forms and terminologies of sensory attributes. All samples were presented before the panellists at room temperature under normal lighting conditions in 50 ml cups coded with random, 3-digit numbers to ensure blind testing and avoid bias during the sensory evaluation. Drinking water was provided for oral rinsing. The average values of the sensory scores (appearance, aroma, taste, texture, consistency and overall acceptability) were used in the analysis as described by Ihekoronye and Ngoddy (1985).

Statistical (data) analysis

All the experiments were conducted in triplicate samples and the data were the mean of the three replications. All data obtained were statistically analysed using the Analysis of Variance (ANOVA) using SPSS Version 20 and the Duncan Multiple range test to separate means with a significance level of $p<0.05$ (Ihekoronye and Ngoddy, 1985).

Table 2. Sensory attributes of the fresh mango-orange-watermelon composite puree samples.

Sample codes	Appearance	Aroma	Taste	Texture	Consistency	Overall acceptability
573	7.000±1.080[ab]	6.7200±1.243[a]	6.2800±1.021[c]	6.3200±1.435[a]	6.5200±1.530[b]	7.0800±1.115[a]
618*	7.7200±1.060[b]	7.2000±1.251[ab]	7.2000±1.040[ab]	7.1200±1.301[a]	7.3200±1.069[a]	7.7200±1.208[a]
335	6.8400±0.943[b]	7.0000±1.154[ab]	7.0800±1.222[ab]	6.4000±2.020[a]	7.0800±1.382[ab]	7.2000±1.208[a]
804	6.8800±1.201[b]	7.5200±0.770[b]	7.4800±1.084[a]	6.7600±1.984[a]	6.8800±1.268[ab]	7.5200±1.357[a]
732	7.2400±1.640[ab]	6.9600±1.206[ab]	6.9200±1.288[abc]	7.0400±1.428[a]	7.1200±0.781[ab]	7.6400±1.036[a]
408	7.4400±1.193[ab]	6.8400±1.374[ab]	6.6400±1.350[ab]	7.1200±o.971[a]	6.9200±1.037[ab]	7.1200±1.266[a]

Values are mean ± standard deviation (SD) of triplicate determinations. Samples with different superscripts within the same column were significantly ($p<0.05$) different. **Key:** 573 = 20% mango, 50% orange, 30% watermelon; *618 = 20% mango, 30% orange, 50% watermelon; 335 = 30% mango, 50% orange, 20% watermelon; 804 = 30% mango, 20% orange, 50% watermelon; 732 = 50% mango, 30% orange, 20% watermelon; 408 = 50% mango, 20% orange, 30% watermelon; *Most Acceptable (Overall Acceptability).

Table 3. Sensory attributes of the fresh (FCP), spray-dried (SDP) and freeze-dried (FDP) mango, orange and water melon composite puree samples.

Sample codes	Appearance	Aroma	Taste	Texture	Consistency	Overall acceptability
681	6.8800±1.160[ab]	7.2000±1.372[ab]	7.2400±1.278[ab]	7.1200±1.435[a]	7.3200±0.670[a]	7.7200±1.125[a]
618	6.8400±1.201[b]	7.0800±1.322[ab]	7.0800±1.330[ab]	6.4000±1.411[a]	7.0800±1.106[ab]	7.2000±1.128[a]
608	7.4400±1.183[ab]	6.7600±1.388[ab]	6.9200±1.288[abc]	7.0400±1.428[a]	7.1200±1.274[ab]	7.6400±1.266[a]

Values are mean ± standard deviation (SD) of triplicate determinations. Samples with different superscripts within the same column were significantly ($p<0.05$) different. **Key:** 681 = Spray- dried Composite powder (SDP); 608 = Freeze-dried Composite powder (FDP); 618 = Fresh Composite puree (FCP); All fresh and dried samples are composed of: 20% mango, 30% orange, 50% watermelon freeze-dried powder.

RESULTS AND DISCUSSION

Based on the results, which evaluated the sensory attributes (Table 2) of fresh (FCP), spray-dried (SDP), and freeze-dried (FDP) mango, orange, and watermelon composite puree samples, the statistical analysis indicated significant differences between these sample treatments in various sensory categories.

For appearance, FDP (Freeze-Dried) had the highest score (7.44), followed by SDP (6.88) and FCP (6.84) (Table 3). The significant difference between freeze-dried and the other two treatments ($p<0.05$) suggests that freeze-drying retained a more visually appealing appearance, potentially due to less moisture content and colour preservation due to the minimal heat treatment. According to Kapoor *et al.* (2021), the variation in drying temperature had its influence on the surface colour of samples. Freeze-drying often retains more natural color compared to other drying methods, making products more visually attractive to consumers.

For aroma, SDP (Spray-Dried) and FCP were not significantly different, scoring 7.20 and 7.08, respectively, while FDP (6.76) scored slightly lower (Table 3). Literature indicates that spray drying can retain volatile aroma compounds more effectively than freeze-drying due to Mailard reaction, which may explain the better aroma scores for the spray-dried sample (Quek *et al.*, 2007). This finding aligns with research by Chegini and Ghobadian (2005) and Petikirige *et al.* (2023), where spray-dried samples retained desirable aromas better than freeze-dried counterparts.

All treatments (SDP: 7.24, FCP: 7.08, FDP: 6.92) exhibited no statistically significant difference in taste (Table 3). According to Li *et al.* (2021), while different drying methods can impact taste due to the degradation of heat-sensitive compounds, this study shows minimal variation, possibly because the fruit mix balances out differences in drying impact. Previous studies confirm that consumer preferences for fruits blends are significantly influenced by their sweetness-to-acidity balance (Silva-Espinoza, 2018).

SDP (7.12) and FDP (7.04) showed higher texture scores compared to FCP (6.40), with a significant difference between fresh and dried samples ($p<0.05$) (Table 3). Freeze-dried and spray-dried products typically have improved textures because drying reduces moisture, enhancing crispness or smoothness. Takougnadi *et al*. (2020) noted that dried fruit powders often improve mouthfeel.

Both SDP (7.32) and FDP (7.12) were significantly superior to FCP (7.08), which may indicate that drying methods offer better product consistency in puree samples (Table 3). This is consistent with the findings of Bhat *et al.* (2018), who reported that bottled gourd sweetmeat heated by microwave tends to have a more uniform texture, aiding in consistency.

For overall acceptability, all samples had high overall acceptability scores, with SDP (7.72) being slightly higher, followed by FDP (7.64) and FCP (7.20). The small but significant difference in favour of spray-dried powder could be due to a better balance of all sensory attributes, particularly in aroma and texture (Table 3). According to recent studies by Petikirige *et al*. (2022), spray-dried fruit products often have better overall consumer acceptance due to their stable flavour, texture, and appearance.

Conclusion

The sensory evaluation of the mango, orange, and watermelon composite puree samples revealed that drying methods significantly impact the sensory characteristics of the final product. Spray-dried samples demonstrated high overall acceptability, suggesting that this method could be viable for commercial production, balancing both quality and cost-effectiveness. Freeze-dried samples, though slightly lower in overall acceptability, showed superior ratings for appearance, making them potentially more appealing for high-end markets. This research underscores the importance of selecting the appropriate drying method to maximize product quality and consumer acceptance, which can, in turn, help reduce post-harvest losses and enhance economic gains in agrarian regions.

CONFLICTS OF INTEREST

The authors declare that they have no conflict of interest.

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