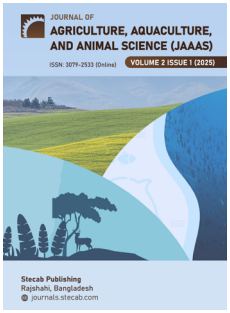

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Research Article

Comparative Effects of Drying Methods on Physicochemical Properties of Puree Blends of Some Indigenous Varieties of Watermelon (*Citrullus lanatus*), Orange (*Citrus sinensis*) and Mango (*Mangifera indica*) Fruits

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About Article

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ABSTRACT

This study evaluates the comparative effects of freeze-drying and spray-drying methods on the physicochemical properties of composite fruit puree powders produced from local varieties of watermelon (*Citrullus lanatus*), orange (*Citrus sinensis*), and mango (*Mangifera indica*) in Benue State, Nigeria. Composite formulations were developed by blending fruit purees in ratios of 50% watermelon, 30% orange, and 20% mango. Freeze-drying and spray-drying methods were employed to produce powders, which were subsequently analyzed for proximate composition, sensory attributes, and physicochemical properties. Freeze-dried powders retained higher vitamin C content (21.4 mg/100 g) compared to spray-dried powders (16.3 mg/100 g). Moisture content was significantly lower in freeze-dried powders (2.5%) than spray-dried powders (4.3%), while sensory evaluation showed no significant differences in overall acceptability ($p>0.05$). These findings suggest that freeze-drying is superior for nutrient preservation, whereas spray-drying is more energy-efficient. The results provide valuable insights for optimizing fruit powder production in agrarian settings.

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1. INTRODUCTION

Post-harvest losses in fruits are a critical challenge in Benue State, Nigeria, where agriculture is a dominant economic activity. The perishable nature of fruits like watermelon, orange, and mango exacerbates this issue, leading to significant economic losses and reduced availability of nutritious food products. Conventional preservation methods often fail to retain the quality and nutritional value of fruits, necessitating innovative approaches to extend shelf life while maintaining quality.

Developing effective drying technologies for fruit preservation is vital for minimizing post-harvest losses. Freeze-drying and spray-drying are two widely used methods for producing stable fruit powders, but their comparative effects on nutrient retention and physicochemical properties are poorly understood in local contexts. This study focuses on optimizing these drying methods for composite fruit purees from locally available fruits in Benue State, thereby contributing to sustainable food processing solutions. Such an approach aligns with global trends toward reducing food waste and improving food security (FAO, 2022).

The objectives of the study therefore, are to:

i. evaluate the proximate composition of composite fruit puree powders produced by freeze-drying and spray-drying methods.

ii. assess the sensory attributes and overall acceptability of the powders.

iii. compare the nutrient retention and physicochemical properties between freeze-dried and spray-dried powders.

1.1. Scope of the study

This research focuses on three fruit varieties (watermelon, orange, and mango) sourced from Benue State. The study examines the effects of two drying techniques on the powders' physicochemical properties, sensory attributes, and proximate composition. The findings are relevant for small-scale food processors and researchers in food technology.

1.2. Significance of the study

This research addresses critical gaps in the post-harvest management of fruits in Benue State, offering evidence-based insights for selecting appropriate drying technologies. The findings will guide local food processors in producing high-quality fruit powders, enhancing value addition, and supporting economic growth. Previous studies, such as Camacho *et al.* (2023) and Jeyanth *et al.* (2020), provide foundational methodologies for comparing drying techniques but lack focus on composite purees from these specific fruit varieties.

2. LITERATURE REVIEW

2.1. Watermelon

Watermelon (Citrulluslanatus) is a member of the Cucurbitaceae family. The fruitis popularly consumed especially during hot weather and the summer season. The fruit contains high amounts of vitamins, minerals and phytochemicals especially lycopene which is a type of carotenoid that is responsible for the red flesh color (Liu *et al.*, 2010). In addition to lycopene, watermelon is the cucurbit crop that contains the highest concentration of L-citrulline (citrulline). Citrulline is a non-proteinaceous, non-essential, physiologically active amino acid with relevance in mammalian metabolism (Jennings & Hallal, 2024). It is an intermediate metabolite that has sparked much human health research in the past forty years. This spike in citrulline-human health interest in concert with a consumer desire for functional foods has pointed scientists to watermelons as a natural source of citrulline (Jennings & Hallal, 2024). According to Jennings and Hallal (2024), regular intake of citrulline for at least 7 days improved aerobic performance by increasing the body's production of nitric oxide, which helps expand blood vessels so that the heart doesn't need to work as hard to pump blood through the body. Both citrulline and arginine play important role in the synthesis of nitric oxide, which helps lower blood pressure by dilating and relaxing your blood vessels. Nitric oxide is a gas molecule that causes the tiny muscles around blood vessels to relax and dilate resulting in a reduction in blood pressure. Arginine is also important for many organs such as lungs, kidneys, liver, and immune and reproductive systems and has been shown to facilitate wound healing.

2.2. Orange

is a citrus fruit consumed in high quantities all over the world in the natural and peeled forms and as a juice, puree or other forms. Orange is a low cost fruit which contains many nutrients including vitamin C, A and B, minerals (calcium, phosphorus, potassium), dietary fiber and many phytochemicals, including flavonoids, amino acids, triterpenes, phenolic acids and carotenoids (Melèndez-Martínez *et al.*, 2008; Roussos, 2011). The vitamin C content in oranges helps the body absorb iron. Iron enables the body to use oxygen better, and a lack of iron can cause fatigue. Getting enough iron is especially important for premenopausal people who lose iron through their period (Radlowski & Johnson, 2018). The flavonoids in citrus help prevent cancer cells from growing and spreading. For example, flavonoids help regulate, or program cell death(apoptosis). Apoptosis is a process the body uses to kill off abnormal cells before they multiply and grow out of control (Wang *et al.*, 2021). As an excellent source of the antioxidant vitamin C, oranges may help combat the formation of free radicals that cause cancer (Mateescu *et al.*, 2022).

Maintaining a low sodium intake is essential to lowering blood pressure. However, increasing potassium intake may be just as important for reducing a person's risk of high blood pressure, as it can help support the relaxation and opening of blood vessels. According to the Office of Dietary Supplements (ODS, 2024), increasing potassium intake can reduce the risk. Trusted Source of high blood pressure and stroke. Oranges are a good source of fiber and potassium, both of which can support heart health. A medium orange weighing 131 grams (g) contributes 3.14 g of fiber, which is nearly 10% of an adult's daily fiber requirement. Several studies have found that fiber can improve some factors that contribute to diabetes development and progression. According to Sass (2024), weight control is also important for reducing the risk of diabetes, as obesity and overweight can contribute to the development of type 2 diabetes. The body processes fiber more slowly than other nutrients, so it can help a person feel fuller for longer and reduce their urge to eat

snacks throughout the day.

Oranges also contain choline and zeaxanthin (Sass, 2024). As reported by this author, choline is an important nutrient in oranges that helps with sleep, muscle movement, learning, and memory. Choline also aids the transmission of nerve impulses, assists in the absorption of fat, and reduces chronic inflammation. Zeaxanthin is a type of carotenoid antioxidant that can reduce inflammation. According to Sass (2024), it can positively benefit heart, liver, skin, and eye health.

2.3. Mangoes

Mango (*Mangiferaindica L.*) is one of the choicest fruits in the world (Joshi *et al*., 2013). social and economic impact are most relevant in developing and emerging countries, where mango is a high-valued component in diet, rich in vitamins and minerals (Ribeiro *et al*., 2007).

Fresh mango contains vitamin C and folate in significant amounts of the Daily Value as 44% and 11%, respectively. Mango is an excellent source of bioactive compounds such as carotenoids (provitamin A), vitamin C and phenolics, dietary fibre (Lemmens *et al*., 2013; Pott *et al*., 2003; Rincon & Kerr, 2010; Sogi *et al*., 2012), essential to human nutrition and health. Moreover, mango is known to contain other vitamins, carbohydrates and minerals such as calcium, iron and potassium, and to be low in calories and fat.

2.4. Drying methods for 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.

2.4.1. Spray drying

Spray drying is an excellent common method for preserving heat and oxygen-sensitive fruits (Shi *et al*., 2018). The method entails atomizing the solution in hot air to produce a powder product in a short amount of time. It provides a large surface area in the form of fine liquid droplets through atomization in the drying chamber, which leads to the production of regularly and spherically shaped powder particles (Fazaeli *et al*., 2012; Turchiuli *et al*., 2011).

It is the most economic technique maintaining quality by rapid dehydration.

Aside from preserving colour and aroma, dried powders offer significant cost savings over liquids, such as in lowering the weight, minimizing packaging, and ensuring longer shelf life (Tuyen *et al*., 2010).

2.4.2. Freeze drying

Freeze drying is another approach well used in industry. It is about a dehydration process that removes water through ice sublimation from the frozen products. It 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). According to Dincer (2000), the main advantages of freeze-drying over other traditional methods of food preservation (such as conventional drying and spray drying) are the preservation of morphological, biochemical, and immunological properties; high levels of viability and activity; lower temperatures and shear conditions than other drying methods; high recovery of volatiles; preservation of structure, surface area, and stoichiometric ratios; high yield; and long shelf life. Equipment for freeze-drying is very expensive and might not be economical for some goods. However, according to Jude *et al.* (2023), the equipment requires a lot of space and operates for a long period to freeze-dry foods with the attendant high energy costs. Again, not all foods can be freeze dried while some may require additives. The process preserves the natural fresh fruit colour, texture, flavour, nutritional content, taste, physical characteristics, chemical compound, and biological activity with just minor alteration (Nawirska *et al*., 2009).

2.5. Drying aids

Different drying aids such maltodextrims, gum Arabic, modified starches and proteins are used in spray drying to minimize the stickiness problem (Caliskan & Drim, 2013; Sahinadeem, 2013; Rascon *et al*, 2011).

2.5.1. Maltodextrin

To minimize the stickiness problem during spray-drying, high molecular weight drying aids are added to the feed material before atomization, so as to increase its glass transition temperature (Cabral *et al*., 2004; Shreshtha *et al*., 2007; Santhalakshmy *et al*., 2015). These drying aids not only overcome the stickiness problem and reduce powder hygrosopicity but also protect sensitive components of food material including phenolics, vitamins and caroteinoids (Ferrari *et al*., 2012).

3. METHODOLOGY

3.1. Materials

3.1.1. Sources of raw materials and preliminary handling

The mango, orange varieties (20kg each) and ten (10) fruits each were procured from the Gboko local market in Gboko Benue State Nigeria, while five (5) fruits of the 'Sugar Baby' variety of watermelon were sourced from the Makurdi Railway mark*et al*so 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 proccesing and analysis.

3.2. Methods

3.2.1. Sample Preparation

The fruits were washed and their average weights taken and recorded. They were peeled and the weights of the peels measured and also recorded. The remaining processes to produce the puree prior to drying were according to the following flow charts (Figures 1 to 4).

Each puree type, depending on its stickiness and viscosity were mixed with 15%, 20%, 25%, and 30% (w/w) commercial maltodextrin for water melon, orange, and mango puree (the ratio of puree solids to the carrier being 1:1.38; 1:1.95; 1:2.60; 1:3.35) respectively with Dextrose Equivalent (DE) 20–30. The purees were formulated into smoothies. With the selected

addition of maltodextrin, the most acceptable smoothie was subjected to the spray and freeze drying techniques.

3.2.2. Fruit puree production process

The general flow chart for fruit puree production is shown in Figure 1 using the method described by Mateescu *et al.* (2022). The analyses of the nutrients were carried on the purées 30 min after production. Watermelon, orange and mango puree production are similar to the production process as shown in flow charts in Figures 2, 3 and 4 respectively.

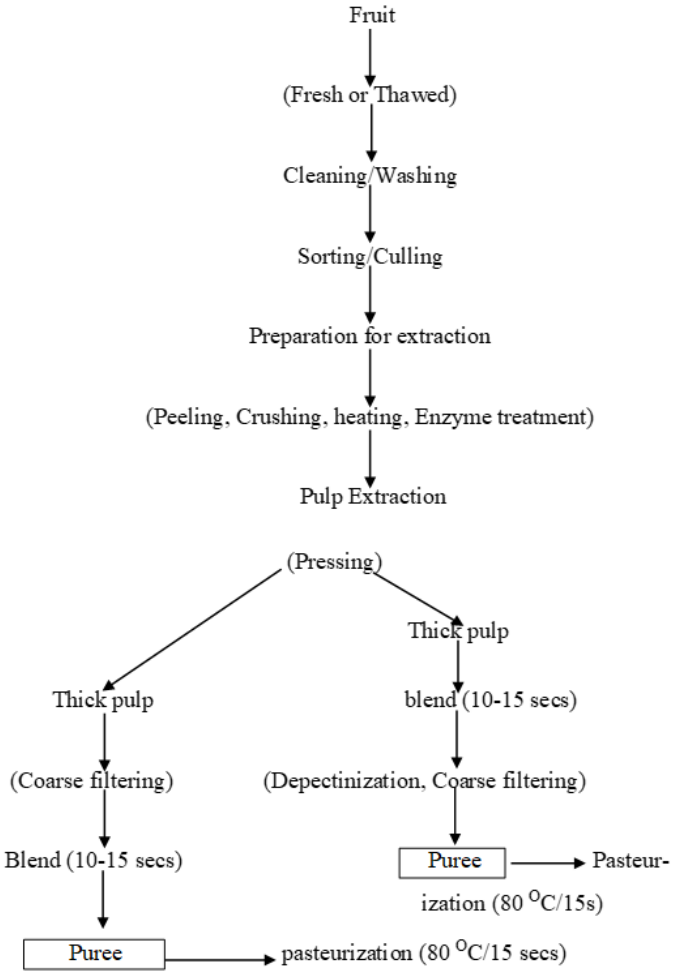

Figure 1. General flow for fruit puree production
Source: Mateescu et al. (2022)

3.2.3. Watermelon fruits puree production

The flow chart for the production of watermelon puree is shown in Figure 2 using the method described by Mamadou *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 (Kenwood Electricals, UK) at speed number 3 for 15s into smooth pastes which were pasteurized at 70 oC for 15s in 250 ml glass beakers with aluminum foil coverings. After cooling, the watermelon purees were kept in a refrigerator prior to use for composite purees formulation.

3.2.4. Orange fruits puree production

Orange fruits puree was produced with slight modification 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 the removal of the seeds, the slices were blended into a smooth paste using the house hold electric blender. The orange puree

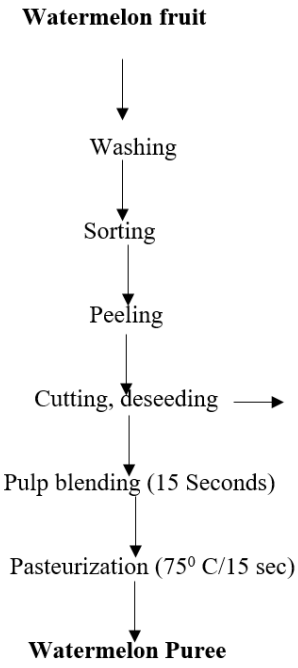

Figure 2. Flow chart for watermelon fruits puree production
Source: Mamadou et al. (2018)

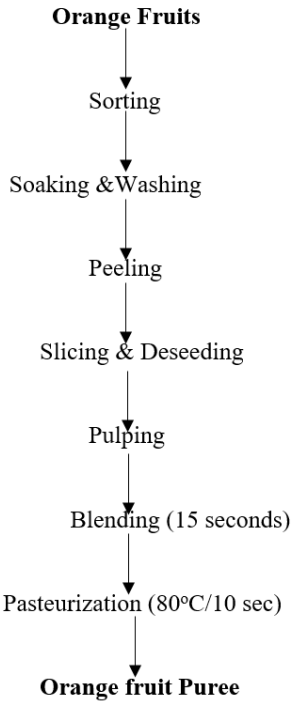

Figure 3. Flow chart for production of orange fruits puree
Source: Obasi et al. (2017)

was then pasteurized at 70ºC for 15s 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.

3.2.5. Mango fruits puree production

The production of the mango fruit 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 98ºC for 5min. 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 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.

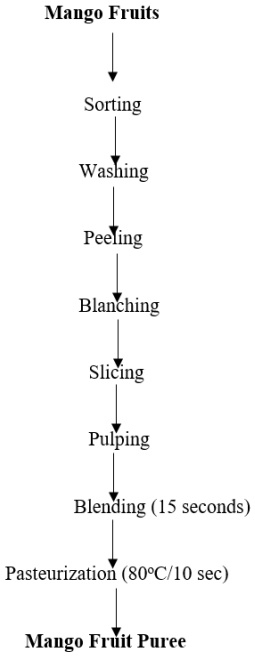

Figure 4. Flow chart for mango puree production
Source: Labaky et al. (2020)

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 min in closed plastic containers. The analyses of the nutrients were carried out on the purées 30 min after the crush.

3.2.5. 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-digit 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.

Table 1. Composite purees 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

3.2.6. 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:

i. 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: LabconcoFreeZone 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 fruits puree was poured into 250g 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 2min and the powder packaged in air tight aluminum pouches which were then stored on dry shelves in glass desiccators containing activated silica.

ii. 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 at 10 rpm (10 rpm ~ 30 ml/min) to achieve an inlet and outlet temperatures of 200°C and 120°C, respectively. The dryer was run at this condition for about 10 min prior to the introduction of the feed. The feed puree was passed through the spray-dryer chamber (500 mm x 21 mm) with the aid of 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 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 flavor, color, and aroma compounds (Fegus *et al.*, 2014).

3.2.7. Sensory evaluation

i. 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 & Heymann, 2010). The samples were presented in 200ml disposable identical cups that did not influence taste perception (neutral color and odor-free). Consistent portions of 50 mL per sample was used (Lawless & Heymann, 2010).

The sensory evaluation of the fresh composite purees was carried out using 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.

ii. Evaluation: The sensory evaluation of the fresh samples were carried out four hours after formulation while sensory evaluation 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 panelists were thoroughly briefed on how to use the sensory evaluation forms and terminologies of sensory attributes. All samples were presented before the panelists 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 process. 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 Ihekoronyeand and Ngoddy (1985).

iii. 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 $p<0.05$ (Ihekoronye & Ngoddy, 1985).

3.2.8. Chemical Analyses

3.2.8.1. Proximate analysis

The moisture, crude protein, crude fibre, fat, ash, and total carbohydrate contents and also the energy values of the working composite fruits puree and the fruit powders were determined according to the AOAC (2012) official methods.

i. Moisture content: Two grams of sample (in triplicate) were weighed into an empty, dry, and clean crucible of a known weight. The crucible containing the sample was placed in an oven at 105° C for 24 hrs. After that, the crucible was removed and placed in a desiccator containing dry silica gel and weighed three times at 10 minutes intervals and the weights were calculated as averages. This was repeated twice and the moisture content calculated as a percentage according to the following equation:

% Moisture = $((W_1-W_2)/W_0) \times 100$

Where:

W_1 is the weight of crucible and sample before drying,

W_2 is weight of the crucible and sample after drying, and

W_0 is the original weight of Sample.

ii. Crude protein: For the test composite puree and each of the powders, 0.2g of sample was placed in 10 mL Kjeldahl digestion flask; then 0.4g of kjeldahl catalyst tablets and 3. 5 mL of concentrated sulfuric acid were added. The flask was heated in an electrical heater for 2 hours. The samples were cooled and diluted with distilled water and placed in the distillation apparatus. Twenty mls of 50% sodium, hydroxide (NaOH) was added and the distillation took place for 10 minutes. The evolve dammonia received in 10 mL of 2% boric acid contained in a 100ml conical flask was titrated against 0.02M HCl using a universal indicator (bromocresol green and methyl red in alcohol). The protein content was calculated as a percentage according to the following equation:

Protein Content (%) = (Titre (less blank) x Molarity x 0.014 x 100 x 6.25) / W_0

Where: W_0 is the original weight of Sample.

iii. Crude fibre: Five grams of the sample was digested with tri-chloroacetic acid by refluxing for 40 minutes followed by filtration. The residue was washed with boiling distilled water and then with acetone. The washed residue was dry-heated at 150°C in oven and the dried residue was scraped into porcelain crucible, weighed and placed in a muffle furnace for ashing for 2 h. After cooling in desicators, the crucibles and contents were weighed. Crude fibre was calculated as a percentage as follows:

Crude fibre (%) $=((W_1-W_2)/W_0) \times 100$

Where:

W_1 is the weight of crucible + ash,

W_2 is the weight of crucible+ residue, and

W_0 is the initial weight of sample.

iv. Ash: Two grams of the sample was weighed into a clean ashing dish with a known weight. The ashing dish containing the sample was ignited in a muffle furnace at 550°C for 3 hours. The ashing dish was removed, cooled in a dessicator and weight again. The ash content of the sample was calculated as a percentage according to the following equation.

Ash content (%) = $((W_1-W_2)\times100)/W_0$

Where:

W_1 is the weight of empty ashing dish (before ignition),

W_2 is the weight of the ashing dish containing the ash (after

ignition), and
W_0 is the original weight of the sample.

v. Fat: For each fruit powder and the original test composite puree, an extraction thimble was weighed empty, filled with sample up to half and weighed again. The mouth of the extraction thimble was plugged with cotton wool to prevent sample from spilling. The thimble containing the sample was then placed over petroleum ether. The extractor containing thimble and sample was then fitted into the quick fit flask and connected to the reflux condenser. The flask was heated on the heating mantle and the extraction carried out for 16 hours after which the petroleum spirit was evaporated. The weight of flask and oil were determined after heating in boiling water to remove all traces of the solvent followed by drying over calcium chloride. Fat content was determined as a percentage according to the following equation:
Crude fat content (%) = ((D-C)/(B-A)) x 100
Where: A is the weight (g) of thimble, B is weight (g) of the thimble + sample, (B - A) is the weight (g) of sample, C is weight (g) of empty quick fit flask, D is weight (g) of quick fit flask + oil and D-C = Weight (g) of oil.

vi. Total carbohydrates: Total carbohydrates were determined by difference as follows:
100 - (% protein + % fat + % crude fibre + % moisture + % ash)
3.2.5.1.6 Determination of energy values
The energy values of the samples was estimated by calculation using Atwater's Conversion factor (4 x % protein + 9 x % fat + 4 x %carbohydrate) expressed in kcal/100g as reported by Onyeike *et al.*, (2003).

3.2.9. Vitamins determination

The vitamins composition of the test composite puree and fruit powders were determined according to the methods described by Hassan and Hassan (2008) as follows:
Vitamin A precursor (Beta-carotene): The β-carotene in each of the samples (i.e. test composite puree, freeze dried fruit powder, and spray dried fruit powder respectively) was extracted by dissolving 1g of each in 50ml of methanol followed by incubation for 2 h under dark at room temperature for complete extraction. The mixture was then mixed with 5ml of hexane and transferred into a separator funnel. The upper non aqueous layer was separated through the funnel and the volume made up to 10ml with hexane and then passed through the sodium sulphonate layer in a filter funnel in order to remove any moisture from the layer. The absorbance of the layer was subsequently measured at 436mm using hexane as a blank (Ranganna, 1999). The (3-carotene was calculated using the formula:
β-carotene (mg/100g) = (Absorbance (46mm) x V x D x 100 x 100) / (W x Y)
where: V is the total volume of extract, D is the dilution factor, W is the weight of sample, Y is the percentage dry matter content of the sample
The β-carotene contents were expressed as retinol equivalents (RE) by multiplying each value by a factor of 0.167 (FAO/WHO, 2005).

3.2.9.1. Ascorbic acid (Vitamin C)

Vitamin C contents of the samples were determined according to the titrimetric official method described by AOAC Official Method 967.21(2012) using 2-6-dichlorophenol indophenol (DCPIP). By this procedure, 2g of each powder or the test composite puree was mixed with 100 ml of 0.1Mmetaphosphoric acid and 10mLs of each solution titrated with DCPIP. The end point of titration was determined by the change of colour to pink. Ascorbic acid content was expressed as mg Ascorbic acid/100 g sample s follows:
Ascorbic Acid (mg/100g) = (Volume of DCPIP x Titration Factor x Dilution Factor) / Sample Weight
Where: Volume of DCPIP (mL) is the volume of DCPIP used to titrate the sample, Titration Factor (mg/mL) is the amount of ascorbic acid equivalent to 1 mL of DCPIP (usually provided with the DCPIP reagent), Dilution Factor is the Dilution of the sample (if any) while Sample Weight (g) is the weight of the sample taken for analysis

Standard Calculation: Ascorbic Acid (mg/100g) = (V x TF x DF) / (SW x 100)
Where: V is the volume of DCPIP (mL), TF is Titration Factor (mg/mL), DF is the Dilution Factor and SW is the sample weight (g)

3.2.9.2. Tocopherol

Saponification and extraction of tocopherols was performed according to Gornas *et al.* (2014). Essentially, 0.2 g of each powder or the test composite puree was dissolved firstly in 2.5 mL of absolute ethanol followed by the addition of 0.05 g of pyrogallol, and then 0.25 mL of aqueous potassium hydroxide (600 g/L) in capped pyrex glass test tubes. The test tubes were capped tightly immediately and mixed (10 sec) by gentle swirling and then incubated at 80°C for 25 min. After incubation, the samples were rapidly cooled in an ice-water bath for 5 min, and 2.5 mL of sodium chloride (10 g/L) added to each and mixed for 5sec. Tocopherol content of each was extracted by mixing with 2.5 mL of n-hexane:ethyl acetate (9 :1 v/v) and shaken for 15s.The organic layer was separated by centrifugation (1000 ×g, at 4oC, 5 min) and transferred to a round-bottom flask. Residual to chopherol were reextracted twice following the protocol above. The combined extracts for each sample were dried by evaporation using a vacuum rotary evaporator. The dried extracts were dissolved in 0.5 ml methanol and filtrated through a syringe filter (0.22 µm) into vials. Samples were injected directly after preparation into the RP-LC and SFC system.
RP-LC (Reversed-Phase Liquid Chromatography), a type of liquid chromatography that separates compounds based on their hydrophobicity and SFC (Supercritical Fluid Chromatography), a type of chromatography that uses a supercritical fluid (e.g., CO_2) as the mobile phase were used to define and describe the conditions for the estimation of tocopherol as detailed above:
Conditions for estimation of the tocopherol by RP-LC
Column: C18 reversed-phase column (250 x 4.6 mm, 5 µm), Mobile phase: Methanol: Water (95:5, v/v), Flow rate: 1mL/min, Injection volume: 20 µL, Detection: Fluorescence UV (280 nm), Temperature: 25°C
Conditions for estimation of tocopherol by SFC

Column: C18 packed column (150 x 4.6 mm, 5 µm), Mobile phase: CO_2: EtOH (95:5 v/v), Flow rate: 2mL/min, Pressure: 200 bar, Temperature: 30°C and Detection: UV (280nm)

Tocopherol Estimation Conditions

Sample preparation: tocopherol was extracted from samples using hexane, Standard preparation: α and β-tocopherol standards were used, Calibration curve: the peak area was plotted vs concentration for each tocopherol isomer, Sample analysis: 20 µL of the sample extract was injected and the peak areas measured.

Estimation:

Caliberation curve equation is y = ax + b

Where: y = peak area (Integrated area under the chromatographic peak), x = concentration of tocopherol standard(mg/ml), a = slope, b = intercept

Tocopherol quantification equation

Tocopherol (mg/g) =

(Peak area X slope X correction factor (accounts for mobile phase composition))/Injection volume x sample weight

Tocopherol content calculation

Tocopherol content (mg/100g) = (Tocopherol amount / sample weight) X 100

3.2.10. Minerals determination

The selected mineral elements were analyzed using the method described by Fashakin *et al.* (1991). For each of the fruit powders and the test composite puree, 0.5g sample was as held in a muffle furnace and the resultant ash was mixed with 10 ml each of conc. NHO3andconc. HCL respectively in digestion flasks. Each mixture was digested for 10 min followed by filtration through Wattman #1 filter paper. Each filtrate was made up to 50ml with distilled water. Calcium, sodium, iron, potassium, and magnesium was measured using an atomic absorption spectrophotometer (Perkin Elmer Analyst 400, USA).

Experimental Conditions (AAS)

Instrument: Perkin-Elmer 503, Wavelength: Element-specific (e.g., Ca: 422.7 nm, Mg: 285.2 nm), Lamp current: 15 mA, Slit width: 1 nm, Flame type: Air-acetylene, Fuel flow: 5 L/min, Oxidant flow: 10 L/min.

Operational Temperature

Flame temperature: 2000-3000°C, Furnace temperature (for graphite furnace AAS): 100-3000°C.

Quantification Equation (AAS)

C = (A / S) x DF

Where: C is the Concentration of mineral element (mg/L or µg/mL), A = Absorbance reading, S = Slope of calibration curve (L/mg or mL/µg), DF = Dilution factor.

Quantification Equation (ICP-AES)

C = (I / S) x DF

Where is C = Concentration of mineral element (mg/L or µg/mL), S = Slope of calibration curve (L/mg), DF = Dilution factor.

Caliberation Curve Equation

y = mx + b

Where: y is Absorbance (AAS) or Emission intensity (ICP-AES), x is Concentration of mineral element standard (mg/L or µg/mL), m is Slope (S), b is the Intercept, and DF accounts for sample dilution.

3.2.11. Amino acids Determination

The amino acids were determined by the method described by Liu *et al.* (2022) using High-Performance Liquid Chromatography (HPLC).

Briefly, the amino acids were separated using reverse-phase HPLC with C18 column and mobile phase (acetonitrile: water, 80:20). The amino acids were detected using fluorescence detection (excitation: 340 nm, emission: 450 nm).

3.2.11.1. L-Citrulline & L-Arginine determination

Extraction and Quantification

L-Citrulline and L-Arginine extraction and quantification were as described by Jayaprakasha *et al.* (2011).

Extraction

Frozen puree samples thawed at room temperature and the powdered samples were weighed as 0.2 g +/− 0.01 g aliquots. Phosphoric acid (1.2 mL, 0.03 M) was added to samples before vortexing for 1 min. Samples were sonicated (30 min), left at room temperature (10 min), and then centrifuged for 20 min at 4 °C, 5700× g; (Eppendorf, Model 5417R). A mL aliquot of supernatant was filtered (17 mm nylon syringe filter, F2513-2, Thermo Scientific) into amber HPLC vials and held at −80 °C until HPLC analysis.

Quantification by HPLC

L-Citrulline and L-Arginine concentrations were determined using the method of Jayaprakasha *et al.* (2011) with modifications. Filtered samples (5 µL) were injected onto a High-Performance Liquid Chromatograph (Hitachi Elite LaChrom) equipped with a photodiode array detector and autosampler. A Gemini 3u C18, 110 A, 250 × 4.6 mm. 00G-4439-EO column and guard column (C18 4 × 2.0; AJO-4286, Security Guard Cartridge), (Phenomenex, CA, USA) held at 25 °C and a mobile phase of 15 mM phosphoric acid, 0.5 mL/min was used for peak separation. External standards of arginine and citrulline (Sigma) were used to verify and quantify these amino acid peaks.

3.2.12. Physical Properties

Bulk Density

Bulk densities of the freeze dried (FD) and spray dried (SD) fruit powders samples were determined as described by Onwuka (2018). Essentially, 50g of each powder was poured into a 100 ml capacity glass measuring cylinder followed by gentle tapping to a constant volume. Bulk density of each was then calculated as follows:

Bulk Density (g/ml) =(wt of sample)/(volume of sample after tapping (ml))

Specific Gravity (SG)

Specific gravities of the fruit samples were determined using density bottles. Each sample was poured into a 50ml density bottle and weighed. The mass of each less weight of the density bottle was divided by the volume of the density bottle to get the density. The specific gravity was then calculated as the density of the sample relative to the density of the water at the same temperature as follows:

$X_1 = (W_2\text{-}W_1\ (g))/Vml$

Where: W_2 is weight of sample + density bottle, Wi is weight of density bottle, V is volume of the density bottle (50ml), Specific gravity = X_1/ X_2 and X_2 = Density of water (0.998 g/mL).

Viscosity (cP)

Viscosity of the fruit samples were measured using a Brookfield viscometer DV-II+ Pro, USA (Wong *et al.*, 2015). 250mL of samples were added with spindle no.2 at 25oC and the reading measured at a speed of 150 rpm

Water Absorption Capacity (WHC)

WAC of the samples was determined using the method of Onwuka (2018). One gram of the sample was dispensed into a weighed centrifuge tube with 10ml of distilled water and mixed thoroughly. The mixture was allowed to stand for 1h prior to centrifugation at 3,500 rpm for 30 minutes. The excess water (unabsorbed) was decanted and the tube inverted over an absorbent paper to drain dry. The weight of water absorbed was determined by difference. The water absorption capacity was calculated as:

WAC (%) = (Volume of Water used-Volune of free water)/ (Weight of sample used) x 100

Oil Absorption Capacity (OAC)

Oil Absorption Capacity (OAC) of the fruit samples were determined using the method adapted from Que *et al.* (2008) with slight modifications.

One gram of the dried fruit powder was weighed into a clean, dry centrifuge tube and

10 milliliters of refined vegetable oil (soybean oil) was added to the tube containing the sample. The mixture was vortexed for 1 minute to ensure thorough mixing of the powder and oil and the mixture was allowed to stand at room temperature for 30 minutes to enable the powder to absorb the oil. The mixture was centrifuged at 4,000 rpm for 25 minutes to separate the oil-absorbed powder from the unabsorbed oil and the supernatant oil was carefully decanted without disturbing the sediment. And, the tube with the oil-absorbed powder residue were weighed and recorded

Calculation

The amount of oil absorbed was calculated by subtracting the initial weight of the powder from the weight of the oil-absorbed powder residue using the formula:

OAC (g oil/g sample) = (Weight of oil-absorbed powder - Initial weight of powder) / Initial weight of powder

3.2.13. Color determination

The Hunter color measurement of fresh and reconstituted puree powders were by the method described by Jaya and Das (2004) and also Nindo *et al.* (2003). By this procedure 250 g each of the freeze-dried and spray-dried powders respectively were reconstituted with distilled water to provide 6.143 kg water/ kg dry solids similar as the original composite puree. The reconstitution of each powder was carried out by mixing with water at 23 °C in a vortex mixer (Fisher Scientific mini Vortexer, USA) until the powder was completely dissolved. Then 10 ml each of the reconstituted purees and the original test composite puree (fresh composite) were poured into separate Petri dishes, slightly shaken to form a layer of 10 mm thickness and covered with transparent film (Saran TM Wrap, SC Johnson, Racine, WI).

The International Commission on Illumination (CIE) parameters L*, a* and b* were

measured with a Minolta Chroma CR-200 color meter (Minolta Co., Osaka, Japan). The colorimeter was calibrated with a standard white ceramic plate (L* = 95.97, a* = 0.13, b* =0.30) prior to reading.

The L*, a* and b*, H* and C* values for each puree were immediately measured; they were also used in determining the change in color after the spray and freeze-drying processes.

Hunter Lab Equation

$\Delta E=\sqrt{(\Delta l^{*2})+(\Delta a^{*2})+(\Delta b^{*2})}$

Where:

L* indicates lightness and ranges from 0 (black) to 100 (white), a* Represents the red/green axis (positive values = red, negative values = green and zero a* is neutral, no red or green bias.), b* represents the yellow/blue axis (positive values = yellow, while negative b* is blue and zero b* is neutral, no yellow or blue bias) c* Chroma, showing color saturation or intensity, and *b/a* ratio compares the yellow component (b*) to the red component (a*), giving an indication of the dominant color tone. Hue Angle describes the color of an object in terms of its position on the color wheel (e.g., red, green, blue, etc.). It is calculated from the a* and b* values, which represent color coordinates. Higher Hue Angles generally indicate a shift toward yellow-green, while lower values trend toward red hues. ΔE (Delta E) measures total color difference between the fresh puree and the dried purees. It quantifies the visual color change. A higher ΔE means a more noticeable color difference.

4. RESULTS AND DISCUSSION

4.1. Results

Table 2. Sensory attributes of the fresh mango-orange-water melon 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^{a}	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±0.971^{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. Proximate composition of fresh, freeze-dried & spray-dried puree mixture (composite) (%)

Product	Moisture	Ash	Protein	Crude fibre	Fat	Carbohydrate	Energy (Kcal)
Fresh Sample	83.45±1.243[a]	0.737±1.213[a]	0.960 ±1.428[a]	0.743±1.428[a]	0.503±1.530[c]	14.00±1.060[b]	64.37±1.357[a]
SDFP	2.83±1.060[b]	3.49±1.053[b]	0.31±1.206[b]	1.21±1.021[c]	1.11± 0.971[a]	6.15±1.115[a]	41.35±1.021[c]
FDFP	3.55±1.021[c]	4.39±1.063[b]	0.78 ±1.530[c]	2.89±1.288[bc]	2.76±1.037[ab]	5.51±1.208[a]	46.62±1.201

FDFP = freeze-dried fruit powder
SDFP = spray-dried powdered powder

Table 4. Vitamin composition of fresh,freeze-dried & spray-dried puree mixture (composite) (mg/100g)

Product	Vit.C	Vit. A	Vit. B1 (Thiamine)	Vit.B2 (Riboflavine)	Vit. B3 (Niacin)	Vit. B2 (Riboflavine)
Fresh Sample	23.42±1.481[a]	16.64 ±1.428[a]	0.637 ±1.115[a]	0.052 ±1.435[a]	5.203 ±1.084[a]	0.052 ±1.301[a]
SDFP	5.40±0.702[b]	0.01 ±0.770[b]	0.02 ±1.056[b]	0.02 ±0.770[b]	0.00±0.001[c]	0.021±1.201[b]
FDFP	5.60±1.067[b]	0.04 ±1.060[b]	0.06 ±0.770[b]	0.06 ±1.036[a]	0.21 ±1.201[b]	0.063 ±1.037[ab]

Average results from at least triplicate determinations

Values are mean ± standard deviation (SD) of triplicate determinations. Samples with different superscripts within the same column were significantly ($p<0.05$) different.

FDFP = freeze-dried fruit powder
SDFP = spray-dried powdered powder

Table 4. conts...

Product	Vit. B5 (Panthothenic acid)	Vit. B6 (pyridoxine)	Vit. B9 (folic acid)	Vit.E (α-tocopherol)	Vit. K	Vit B12	(Cobalamin)
Fresh Sample	0.274 ±1.435[a]	4.15	0.531±1.357[a]	1.073	1.567±1.037[a]	0.000±0.100[a]	6.001±1.215[a]
SDFP	0.000 ±0.002[b]	5.16(µg)	2.430±1.541[b]	0.000	0.000 ±0.010[b]	5.253±1.115[a]	0.001±0.010[b]
FDFP	0.127±1.021[ab]	41.30(µg)	0.873±1.251[a]	4.23 (µg)	6.003 ±1.106[c]	17.851±1.315[a]	4.563±1.154[a]

Average results from at least triplicate determinations

Values are mean ± standard deviation (SD) of triplicate determinations. Samples with different superscripts within the same column were significantly ($p<0.05$) different.

FDFP = freeze-dried fruit powder
SDFP = spray-dried powdered powder

Table 5. Mineral Composition of Fresh,Freeze-dried & Spray-dried Puree Mixture (Composite) (mg/100g)

Product	Calcium	Iron	Phosphorus	Potassium	Sodium	Selenium (µg/100g)	Iodine	Magnesium
Fresh Sample	22.59±1.031[a]	0.89±0.751[a]	7.22±1.301[a]	92.13±1.213[a]	15.82±1.203[a]	0.42±1.143[a]	0.005±1.032[a]	6.97±1.043[a]
FDFP	21.89±1.021[a]	0.88±0.681[a]	6.92±1.301[a]	90.93±1.043[a]	14.89±1.233[a]	0.38±1.043[a]	0.003±1.043[a]	5.94±1.203[a]
SDFP	19.54±1.213[b]	0.53±0.531[b]	4.25±1.131[b]	62.16±1.013[b]	12.83±1.243[a]	0.16±1.203[a]	0.001±1.240[a]	3.93±1.240[a]

Average results from at least triplicate determinations
FDFP = Freeze-dried fruit powder
SDFP = Spray-dried fruit powder

Table 6. Amino acid (AA) Composition of Fresh, Freeze-dried & Spray-dried Puree Mixture (Composite) (mg/100g)

Amino acid	Glutamic acid	Phenyl Alanine	Tyrosine	Tryptophan	Threonine	Valine	L-Citrulline	Arginine
Fresh Sample	27.27±0.631^{a}	11.87±0.081^{b}	8.47±0.781^{b}	9.83±0.083^{a}	10.07±0.071^{b}	10.78±0.701^{b}	118.05±0.731^{a}	188.67±0.758^{b}
FDFP	30.20±0.681^{a}	40.87±0.181^{a}	38.47±0.701^{a}	39.83±0.081^{b}	40.07±0.069^{a}	41.78±0.780^{a}	250.01±0.783^{b}	181.14±0.785^{a}
SDFP	14.94±0.601^{b}	38.93±0.076^{a}	37.13±0.780^{a}	17.67±0.080^{c}	38.32±0.087^{a}	39.06±0.708^{a}	181.43±0.738^{c}	179.81±0.781^{a}

Average results from at least triplicate determinations
FDFP = Freeze-dried fruit powder
SDFP = Spray-dried fruit powder

Table 7. Chemical Composition of Fresh, Freeze-dried & Spray-dried Puree Mixture (Composite)

Puree	PH	Total soluble sugars (%)	Titratable Acidity (TTA) %	Reducing sugars (%)	Total soluble solids (oBrix)	Glycemic index (GI)	Glycemic load (GL)
Fresh sample	4.03^{b}±0.02	12.27^{a}±0.01	0.91^{b}±0.03	7.31^{a}±0.03	12.85^{a}±0.02	55.19^{b}±0.03	5.36^{a}±0.02
FDP	4.36^{a}±0.02	12.25^{b}±0.02	0.89^{c}±0.03	7.28^{c}±0.02	12.90^{c}±0.01	55.20^{a}±0.02	3.03^{c}±0.02
SDP	4.32^{c}±0.02	12.00^{c}±0.02	0.92^{a}±0.03	7.21^{b}±0.03	14.00^{b}±0.03	57.00^{c}±0.02	6.00^{b}±0.03

Values are mean ± standard deviation (SD) of triplicate determinations. Samples with different superscripts within the same column were significantly ($p<0.05$) different.
FDFP = Freeze-dried fruit powder
SDFP = Spray-dried fruit powder

Table 8. Hunter colour measurement of fresh and dried puree powders obtained from the different drying processes.

Drying method	L*	a*	b*	c*	Hue Angle	*b/a*	ΔE
Fresh sample	45.12 + 0.02^{a}	4.65 + 0.01^{c}	41.78 + 0.03^{a}	41.78 + 0. 03^{c}	83.61 + 0.01^{a}	8.93 + 0.01^{c}	-
FDFP	43.74 + 0.06^{c}	4.69 + 0.01^{b}	40.99 + 0.23^{a}	40.26 + 0.23^{b}	83. 47 + 0.04^{b}	8.73 + 0.06^{d}	1.57 + 0.03^{c}
SDFP	41.59 + 0.07^{e}	3.05 + 0.01^{e}	36.64 + 0.02^{c}	36.77 + 0.03^{a}	85.24 + 0.02^{d}	12.00 + 0.05^{a}	6.23 + 0.02^{b}

ΔE is calculated using the original puree as reference.
Superscript letters (e.g., a, b, c, etc.) in the table indicate whether values in a column are significantly different. Different letters mean the values are significantly different, while the same letters indicate no significant difference at $P < 0.05$.
FDFP = Feeze-Dried Fruit Powder
FDFP = Spray-Dried Fruit Powder

Table 9. Functional properties of fresh and dried puree powders obtained from the different drying processes

Puree	Bulk density g/cm^{3}	Specific gravity	Viscosity (cP)	Water holding capacity (%)	Oil holding capacity (%)
Fresh sample	1.11^{a}±0.02	1.13^{a}±0.02	3.84^{a}±0.04	83.74^{c}±0.03	27.01^{a}±0.02
FDFP	0.89^{c}±0.02	0.92^{c}±0.01	1.53^{c}±0.03	93.03^{a}±0.03	18.03^{c}±0.03
SDFP	0.93^{b}±0.02	1.05^{b}±0.02	2.04^{b}±0.02	84.49^{b}±0.39	23.01^{b}±0.02

Superscript letters (e.g., a, b, c) in the table indicate whether values in a column are significantly different. Different letters mean the values are significantly different, while the same letters indicate no significant difference at $P < 0.05$.
FDFP = Feeze-Dried Fruit Powder
FDFP = Spray-Dried Fruit Powder

4.2. Discussion

Sensory Attributes (Table 2)

The sensory evaluation of the composite puree samples revealed significant differences ($p<0.05$) in appearance, aroma, taste, and overall acceptability. Sample 618, which contained 20% mango, 30% orange, and 50% watermelon, exhibited the highest overall acceptability (7.72 ± 1.208). This aligns with studies by Tunde-Akintunde and Ogunlakin (2020), which suggested that a higher proportion of watermelon enhances sensory appeal due to its natural sweetness and juiciness and its balanced flavor profile and consistency. Conversely, sample 573 (20% mango, 50% orange, 30% watermelon) scored the lowest for taste (6.28 ± 1.021), suggesting that higher orange content may have contributed to increased acidity, reducing sweetness and flavor desirability. Previous studies confirm that consumer preferences for fruit blends are significantly influenced by their sweetness-to-acidity balance (Ferro *et al*., 2019).

Proximate Composition (Table 3)

4.2.1. Proximate Composition

The proximate analysis showed that drying processes significantly affected moisture, ash, protein, crude fiber, fat, carbohydrate content, and energy values:

4.2.2. Moisture Content

Freeze-dried (FDFP) and spray-dried (SDFP) samples had significantly lower moisture content (3.55% and 2.83%, respectively)

compared to the fresh puree (83.45%). The moisture content of the fresh puree was significantly higher (83.45 ± 1.243%) than in freeze-dried (FDFP) and spray-dried (SDFP) powders. Freeze-drying retained slightly more moisture than spray-drying, corroborating findings by Chiewchan *et al.* (2021), who reported that spray-drying is more effective at reducing moisture due to higher heat exposure. The lower moisture in FDFP (3.55 ± 1.021%) indicates better preservation potential compared to SDFP (2.83 ± 1.060%), consistent with findings in similar studies on fruit drying processes (Hassenberg *et al*., 2017).

4.2.3. Ash and Fibre Content

FDFP showed higher ash and crude fiber content than SDFP. This can be attributed to the minimal thermal degradation during freeze-drying, which preserves mineral and fiber integrity (Oyinloye & Yoon, 2020).

4.2.4. Energy and Carbohydrates

Fresh samples exhibited higher carbohydrate content (14.00%) compared to FDFP and SDFP (5.51% and 6.15%, respectively). The lower energy values in dried samples are likely due to water loss and possible nutrient degradation during processing. Carbohydrate and energy contents were higher in fresh samples due to retained natural sugars.

4.2.5. Protein

Spray-dried samples had significantly lower protein content (0.31 ± 1.206%) than FDFP, likely due to higher thermal degradation during spray drying.

4.2.6. Vitamin Composition (Table 4)

Vitamin retention varied significantly between drying methods.

4.2.7. Vitamin C

Fresh samples retained significantly higher vitamin levels, particularly vitamin C (23.42 ± 1.481 mg/100g), compared to FDFP (5.60 ± 1.067 mg/100g) and SDFP (5.40 ± 0.702 mg/100g). These findings align with earlier reports on vitamin retention during drying (Carvalho *et al*.,2019). Fresh puree contained the highest vitamin C (23.42 mg/100g). Freeze-dried samples retained more vitamin C (5.60 mg/100g) compared to spray-dried (5.40 mg/100g). Heat-sensitive Vitamin C was degraded during drying, with more loss in SDFP due to higher process temperatures. Similar results were reported by Lei *et al.* (2024), emphasizing the superior retention of heat-sensitive vitamins in freeze-drying.

4.2.8. Other Vitamins

Spray-drying led to significant losses in vitamin A and B-complex vitamins due to thermal degradation. Freeze-dried samples retained more of these vitamins due to the lower processing temperatures

4.2.9. Mineral Composition (Table 5)

Mineral content, including calcium, iron, and potassium, was generally stable across drying methods. However, the fresh puree had higher mineral contents compared to dried powders, with freeze-drying preserving more minerals than spray-drying. For instance, calcium and potassium were better retained in FDFP (22.59 mg and 92.13 mg, respectively) compared to SDFP (19.54 mg and 62.16 mg, respectively). This observation aligns with the findings of Mahalakshmi and Meghwa (2019). Similarly, FDFP exhibited slightly higher retention of selenium and magnesium, possibly due to gentler drying conditions. This supports prior studies indicating freeze drying's superiority in preserving mineral integrity (Sagar *et al*., 2020)

4.2.10. Amino Acid Composition (Table 6)

Freeze-dried samples retained higher levels of essential amino acids, such as glutamic acid (30.20 ± 0.681 mg/100g), compared to spray-dried samples. The reduction in amino acid levels in SDFP highlights the adverse effects of higher thermal processing, corroborating previous research on the impact of drying methods on protein quality (Yisa *et al*., 2022).

4.2.11. Chemical Composition (Table 7)

The fresh puree had a lower pH (4.03 ± 0.02) and higher total soluble sugars (12.27 ± 0.01%) than dried powders. Total soluble solids were slightly higher in SDFP (14.00 ± 0.03), indicating concentration effects during drying. The glycemic index (GI) of fresh samples was lower (55.19 ± 0.03) than SDFP, suggesting that drying methods influence carbohydrate bioavailability, consistent with findings in carbohydrate analysis studies that high drying temperatures decrease the swelling capacity of carbohydrates and increase their susceptibility to breakdown during hydrothermal processes (Daniel *et al*., 2016).

4.2.12. Color Attributes (Table 8)

The Hunter color analysis revealed significant differences between fresh and dried samples. FDFP retained better color attributes (L*, a*, b*) compared to SDFP. Spray-drying caused greater color degradation, likely due to thermal oxidation (Krokida *et al*., 2019). The color analysis revealed significant differences in lightness (L*), chroma (c*), and hue angle. Fresh puree showed the highest lightness (45.12 ± 0.02), while SDFP had a noticeable color shift (highest ΔE of 6.23 ± 0.02), indicating significant browning, possibly due to Maillard reactions during spray drying.

4.2.13. Functional Properties (Table 9)

Water-holding capacity was significantly higher in FDFP (93.03 ± 0.03%) compared to SDFP and fresh puree, indicating better rehydration potential. Bulk density was lower in FDFP (0.89 ± 0.02 g/cm³), consistent with its porous structure.

The results align with literature emphasizing the advantages of freeze drying over spray drying in nutrient preservation and functional properties (Liu *et al*., 2021). Additionally, the observed nutrient losses in SDFP highlight the importance of optimizing spray drying parameters to minimize thermal damage.

5. CONCLUSION

This study demonstrated that drying methods significantly impact the nutritional, functional, and sensory properties of mango-orange-watermelon composite purees. Freeze-drying retained more nutrients, minerals, and bioactive compounds, while spray-drying produced powders with higher bulk density and stability. These findings underscore the importance of selecting an appropriate drying technique based on the desired application and nutritional preservation. It also highlights the need to balance nutrient retention and process feasibility in developing dried fruit products.

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