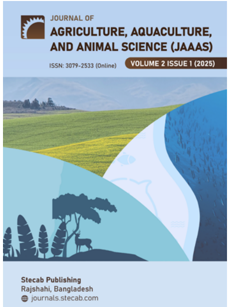

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Effect of Selected Drying Methods on Color of Fruit Composite Produced from *Sugar Baby* Watermelon, *Washington* Orange and *Julie* Mango Varieties

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About Article

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ABSTRACT

This study investigates the effect of selected drying methods on the color attributes of fruit composite purees produced from Sugar Baby watermelon, Washington orange, and Julie mango varieties. A composite puree was formulated from varying proportions of the three fruits (20% mango, 50% orange, and 30% watermelon), based on preliminary sensory evaluations, which identified it as the most acceptable combination. The purees were processed using two drying methods freeze-drying and spray-drying and color measurements were taken before and after drying. The Hunter color scale parameters (L*, a*, b*, c*, Hue angle, and ΔE) were used to evaluate color changes. Results showed that the freeze-dried fruit powder (FDFP) exhibited minimal color changes (ΔE = 1.57), while the spray-dried fruit powder (SDFP) had more noticeable color changes (ΔE = 6.23). The differences in color were attributed to the variation in drying temperatures, with spray-drying leading to more intense yellow hues and darker tones compared to freeze-drying. These findings suggest that drying method influences the color retention of fruit purees, with freeze-drying better preserving the original color of the composite puree. The study provides valuable insights for the optimization of drying methods for the preservation of fruit puree quality.

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1. INTRODUCTION

1.1. Statement of the problem

The drying process significantly influences the color, flavor, and overall quality of fruit products. As fruit composite purees are gaining popularity for their convenience and nutritional benefits, understanding how drying methods affect their color is crucial for developing high-quality, visually appealing products. The challenge lies in maintaining the natural color of the fruit purees while effectively preserving them for storage and transport.

1.2. Objectives

This study aims to evaluate the impact of freeze-drying and spray-drying on the color of composite fruit purees made from Sugar Baby watermelon, Washington orange, and Julie mango varieties. Specifically, the objectives are to:

i. Compare the color differences between fresh and dried fruit purees using the Hunter color scale.

ii. Analyze how the drying process (freeze-drying vs. spray-drying) affects the lightness, Chroma, hue, and overall visual appeal of the fruit powders.

iii. Identify the preferred drying method based on sensory evaluation and color preservation

The influence of drying on fruit products has been studied by various researchers (Mamadou *et al.*, 2018; Labaky *et al.*, 2020). Previous work has shown that drying methods such as freeze-drying and spray-drying yield differing effects on the final product's sensory attributes, including color (Obasi *et al.*, 2017). These studies indicate that freeze-drying typically preserves the color and flavor of fruits better than spray-drying due to the lower processing temperatures involved (Li *et al.*, 2023). This paper builds on this foundation, focusing on composite fruit purees and their color retention during drying.

2. LITERATURE REVIEW

Fundamental investigations on the stability of fruit powders produced using emerging novel drying technologies are crucial for assessing the shelf life of dehydrated products and for selecting appropriate packaging and storage conditions needed to preserve quality. Spray drying and freeze drying are such technologies that have been proven to produce high-quality food powders from different raw materials (Caprino *et al.*, 2010; Krokida *et al.*, 2001). Development of alternative products, such as mango powder, watermelon powder, and orange powder, are gaining popularity as ingredients for other food products, including health drinks, baby foods, sauces, marinades, confections, yoghurt, ice cream, nutrition bars, baked goods, and cereals (Rajkumar *et al.*, 2007), as well as in the pharmaceutical and cosmetic industries (FAO, 2007).

2.1. Importance of color in dried fruit products

Color is a crucial quality attribute influencing consumer acceptance of dried fruit products. Various drying methods impact color retention in fruit composites made from Sugar Baby watermelon, Washington orange, and Julie mango varieties. Optimizing processing techniques is essential to maintaining the visual appeal and nutritional quality of dried fruit products. The choice of drying methods, conditions, and pre-treatments plays a vital role in preserving color quality in dried fruit composites (Nguyen *et al.*, 2012; Krokida *et al.*, 2001). Techniques like freeze drying and osmotic pre-treatment help minimize color degradation, enhancing product appeal and marketability (Saga *et al.*, 2010). Considering preharvest and postharvest conditions further optimizes color retention, ensuring high-quality dried fruit products (Diop *et al.*, 2021).

2.2. Effect of drying methods on color retention

Different drying methods influence the color parameters of dried fruits, including lightness (L*), redness (a*), and yellowness (b*) (Krokida *et al.*, 2001).

2.3. Conventional drying methods

Air, vacuum, and microwave drying often result in extensive browning, leading to decreased L* values and increased a* and b* values. High temperatures and prolonged drying times accelerate browning reactions, affecting the final color (Singh *et al.*, 2013).

2.4. Freeze drying and hybrid techniques

Freeze drying is known for better color preservation, with minimal changes in L*, a*, and b* values (Ciurzyńska & Lenart, 2011). Infrared and hot air drying combinations have been found to result in lower overall color differences compared to conventional drying techniques (Zang, 2023).

2.5. Influence of drying temperature and time

Higher drying temperatures and longer durations cause decreased lightness and increased redness, indicating browning reactions (Karam *et al.*, 2016). Drying at 80°C has been found to be optimal, as it shortens drying time and minimizes color degradation compared to lower temperatures with longer drying durations (Petikirige, 2022).

2.5.1. Impact of pre-treatments on color retention

Certain pre-treatments help mitigate color changes during drying. Osmotic pre-treatment before drying has been shown to reduce browning and preserve the natural color of mango slices (Saga *et al.*, 2010). Freeze drying and fluidized bed drying outperform solar and spray drying methods in maintaining color quality (Petikirige, 2022).

2.5.2 Factors affecting color changes during drying

Color alterations during drying occur due to changes in surface properties, pigment degradation, and chemical reactions (Krokida *et al.*, 2001). Convective and microwave drying lead to significant color differences between fresh and dried products (Petikirige *et al.*, 2022).

2.5.3. Influence of preharvest and postharvest factors

Factors such as fruit maturity and ripening temperature affect color parameters like hue and chroma during drying (Diop *et al.*, 2021). Fruits at advanced maturity or ripened at higher temperatures may show greater hue changes but better color purity retention (Kassa *et al.*, 2016).

3. METHODOLOGY

3.1. Materials

3.1.1. Sources of raw materials and preliminary handling

The mango (*Julie*) and orange (*Washington*) varieties, 20kg of ten fruits each were procured from the Gboko local market in Gboko Benue State, Nigeria. Watermelon, five fruits of the Sugar baby variety were sourced from the Makurdi Railway market in Benue State. All fruits were transported in polyethylene bags to the Joseph Tarka Federal University of Agriculture, Makurdi, Nigeria, for identification. Upon arrival, the fruits were refrigerated for further processing and analysis.

3.2. Methods

3.2.1. Sample preparation

Each fruit was washed, peeled, and weighed, with the peels also weighed and recorded. The purees were formulated by blending each fruit and adding varying concentrations (15%, 20%, 25%, and 30%) of maltodextrin. The purees were then processed into smoothies before being subjected to spray and freeze drying. Figures 1 to 3 provide the general flow charts of the puree production process.

3.2.2. Fruit puree production process

The preparation of watermelon, orange, and mango purees was based on previous methodologies (Mamadou *et al.*, 2018; Obasi *et al.*, 2017; Labaky *et al.*, 2020) with slight modifications for local conditions. All purees were pasteurized, stored, and prepared for composite formulation.

3.2.3. Composite Fruit Puree Formulation

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

The composite purees were prepared as shown in Table 1, with varying proportions of watermelon, orange, and mango. The puree formulation labeled 618 (50% watermelon, 30% orange, 20% mango) was the most preferred in preliminary sensory evaluations and used for drying processes.

3.3. Fruit powder production

3.3.1. Sensory evaluation

3.3.1.1. 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.

3.3.1.2. Evaluation

The sensory evaluation of the fresh samples was carried out four hours after formulation while sensory evaluation of the dried products was 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 Ihekoronye and Ngoddy (1985).

The composite puree sample with the highest overall acceptability was subjected to both freeze-drying and spray-drying methods to produce fruit powders. The drying parameters followed established procedures by Camacho *et al.* (2023) for freeze-drying and Jeyanth *et al.* (2020) for spray-drying.

3.4. Color determination

The Hunter color measurement of fresh and reconstituted puree powders was 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

3.5. 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 analyzed 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).

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[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. Hunter color measurement of fresh and reconstituted puree powders obtained from the different drying processes.

Drying method	L*	a*	b*	c*	Hue Angle	*b/a*	ΔE
Fresh puree	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 a 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.

Where:

FDFP = Freeze Dried Fruit Powder

FDFP = Spray Dried Fruit Powder

Definitions:

Hue Angle: This 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): A measure of 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.

Hunter Color Measurement Components:

L*: Indicates lightness (0 = black, 100 = white).

a*: Represents the red/green axis (positive values = red, negative values = green).

b*: Represents the yellow/blue axis (positive values = yellow, negative values = blue).

c*: Chroma, showing color saturation or intensity.

b/a: This ratio compares the yellow component (b*) to the red component (a*), giving an indication of the dominant color tone.

The table presents the Hunter color measurements for reconstituted puree powders prepared using Freeze-Drying (FDFP) and Spray-Drying (SDFP), compared to the fresh puree. Fresh puree was the reference point with values for L*, a*, b*, etc., and a ΔE of 0.

Freeze-Dried Fruit Powder (FDFP) retained colors close to the fresh puree but showed minor changes, as indicated by its smaller ΔE value (1.57).

Spray-Dried Fruit Powder (SDFP) showed more significant color differences, with a higher ΔE (6.23), a lower L* value (darker), and a higher \(*b/a*\ ratio (more yellow relative to red).

From the analysis, color values such as L*, a*, b*, Chroma, and hue for the fresh samples and powders, it was observed that hue and chroma values were influenced by the temperature of drying of the fruit samples. The variation in drying temperature had an influence on the surface color of the samples. The redness value of the spray dried fruit powders was lower than that of the freeze-dried powder due to higher drying temperature (Song *et al.*, 2024). Spray dried fruit powders had the highest hue angle value but the lowest Chroma value with a dull color. The freeze drying process led to a very slight color change in the sample which gave a clear indication of the good quality of the samples.

4.2. Discussion

Significant Differences Among Sample Results:

The results from the sensory evaluation and color measurements revealed that the drying method significantly influenced the appearance, aroma, and taste of the fruit purees. Freeze-dried fruit powder (FDFP) exhibited only minor color changes (ΔE = 1.57), indicating that this method better preserved the original color of the fruit purees, especially in terms of lightness (L*) and hue angle. In contrast, spray-dried fruit powder (SDFP) showed more pronounced color changes (ΔE = 6.23), with a shift towards more yellow tones, as evidenced by the higher b* values and increased Chroma (c*). This observation aligns with findings by Song *et al.* (2024), who reported that higher temperatures in spray-drying tend to reduce the redness of fruit powders, as seen in the lower a* values. These findings are consistent with similar studies that have shown that freeze-drying better retains the color quality of fruits (Camacho *et al.*, 2023). In contrast, our study diverges slightly from others, such as Jeyanth *et al.* (2020), who found that spray-drying resulted in minimal color degradation. The discrepancy could be attributed to differences in the drying parameters (temperature, air flow) and the specific composition of the fruit purees used.

5. CONCLUSIONS

In conclusion, this study demonstrates that the drying method plays a crucial role in the color retention of fruit composite purees. Freeze-drying was found to better preserve the original color of the fruit purees, with minimal color deviation observed. Spray-drying, while efficient, resulted in more significant color changes, particularly a shift towards yellow tones. These findings suggest that for products where color retention is a key quality indicator, freeze-drying is the preferable method. However, further research into the cost-effectiveness and sensory characteristics of these drying methods would be beneficial for large-scale production.

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