Mal J Nutr 30(3): 349-359, 2024

Physicochemical characteristics of *sawo belanda* (*Pouteria Campechiana*) flour with blanching process and drying techniques

Zaida[1], Hajar Fauziyah Zulfa[1], Rossi Indarto[1], Elazmanawati Lembong[1] & Mohd Nizam Lani[2]

[1]*Department of Food Industry Technology; Faculty of Agricultural Industry Technology, Universitas Padjadjaran, Indonesia;* [2]*Faculty of Fisheries and Food Science, Universiti Malaysia Terengganu, Malaysia*

ABSTRACT

Introduction: *Sawo belanda* fruit (*Pouteria campechiana*), a tropical fruit abundantly found in Southeast Asia, is highly productive and particularly thrives in the warm climates of Malaysia and Indonesia. However, the high fruit output of *sawo belanda* contrasts with its limited consumption in Indonesia. The process of converting *sawo belanda* into flour can significantly enhance its lifetime. The application of blanching methods and proper drying techniques can be a solution to avoid damage to the characteristics of the flour. This study aimed to determine the physicochemical characteristics of *sawo belanda* flour that has been treated with blanching and drying techniques. **Methods:** The parameters observed were moisture content (%), hygroscopicity (%), colour, antioxidant content (ppm), and carotenoid content (µg/g) with blanching and various drying techniques. **Results:** Microwave blanching and food dehydrator technique (C1) produced the best characteristics: moisture content of 7.82%, hygroscopicity of 8.04%, colour values of L* 84.0, a* 8.22, and b* 50.5, as well as functional characteristics including antioxidant content of 142 ppm and carotenoid content of 92.4 µg/g. **Conclusion:** *Sawo belanda* with C1 treatment had a significant impact on the water content, hygroscopicity, colour, antioxidant and total carotenoid contents of *sawo belanda* flour. The antioxidant content and incredibly high carotenoid content grant the *sawo belanda* flour an additional functional value when added to food ingredients.

Keywords: antioxidant, blanching, drying, *sawo belanda*

INTRODUCTION

Sawo belanda fruit (*Pouteria campechiana*), a tropical fruit that is abundantly found in Southeast Asia, particularly thrives in the warm climates of Malaysia and Indonesia. *Sawo belanda* fruit has a high productivity level in Indonesia (>60 tons/ha). One tree can yield up to 136 to 250 kg of *sawo belanda* fruit a year, with an average fruit weight of 175 g (Atapattu, Sanjeewani & Senaratna, 2015). *Sawo belanda* contains functional compounds that function as a source of natural antioxidants. Other than that, *sawo belanda* fruit also contains carotenoids belonging to the xantophylls group. Other nutritional content of the *sawo belanda* fruit includes carbohydrates, vitamin C, niacin, riboflavin, thiamine, starch, fibre,

*Corresponding author: Zaida
Department of Food Industry Technology, Faculty of Agricultural Industry, Universitas Padjadjaran Sumedang, Indonesia
Tel: (+62)85-722977997; Fax: (022) 842 88898; E-mail: zaida@unpad.ac.id
doi: https://doi.org/10.31246/mjn-2022-0138

and minerals such as iron, calcium, and phosphorus (Awang-Kanak & Abu Bakar, 2018). However, the utilisation of processed *sawo belanda* fruit is limited despite its substantial production. The flesh of the *sawo belanda* fruit is currently consumed fresh, processed into syrup, or used as an ice cream topping (Sunilla & Murungan, 2017). The fruit can be preserved for a longer period of time by converting it into flour, which lowers moisture content and prevents microbiological growth. In addition, it is easy to pack, facilitates the distribution process and storage, and becomes a raw material for food with high nutritional content, which includes carotenoids, natural antioxidants, vitamins A and C, and minerals like potassium (Awang-Kanak & Abu Bakar 2018). The flour may retain some of these nutritional benefits, providing a potential source of antioxidants, carotenoids, vitamins and minerals when used in food ingredients. Moreover, it uses regional food, lessening its environmental impact and aiding regional farmers and producers (Issaoui *et al.*, 2021).

Processing fruit into flour generally causes problems during drying, while browning causes damage to its colour, taste, texture, and flavour. One of the preventions can be achieved by using the blanching process, which has the main objective of inactivating enzymes, especially polyphenol oxidase enzymes, responsible for the quality characteristics of foodstuffs. The effectiveness of the blanching process can be determined based on the method and temperature applied to the food product. In addition, the blanching method can affect the physical, chemical, and bioactive components of the fruit (Daulay, 2017).

The blanching process can speed up drying by making the cell membranes permeable to water movement (Muchtadi, Sugiyono & Ayustaningwarno, 2013). Using sunlight-based traditional methods, the *sawo belanda* successfully produces fruit flour (Paragados, 2014). However, this technique has its drawbacks, such as being easily contaminated with microbes, less hygienic, and easily infested by insects or dirty dust. The quality of *sawo belanda* flour can also be effectively preserved through modern techniques such as freeze-drying and using a food dehydrator, which help maintain its nutritional value and flavour. These methods contrast with traditional sun drying, which, while cost-effective, can lead to variable quality and loss of some sensitive nutrients due to prolonged exposure to environmental conditions.

The application of blanching methods and proper drying techniques can be a solution to avoid damage to the characteristics of flour. Research by Efendi, Surawan & Winarto (2015) stated that the blanching effect and drying method significantly affected the physicochemical characteristics of orange sweet potatoes. The difference in drying techniques also reportedly affected the characteristics of potato starch (Buzera *et al.*, 2022) and mangoes (Gulzar *et al.*, 2018). Notably, good flour characteristics will increase consumer acceptance of flour. According to El Khatib & Muhieddine (2020), flour has the best characteristics when it produces carotenoid stability, has low water content, does not change significantly in colour, and when added to food, will increase its nutrition. There are numerous studies on the characteristics of fruit flour; however, there is rarely any information or research that examines the *sawo belanda*. Hence, the purpose of this study was to determine the physicochemical characteristics of *sawo belanda* flour that has been treated with blanching and drying techniques in order to obtain the characteristics of the best quality flour.

MATERIALS AND METHODS

Materials

The main ingredient used in this research was *sawo belanda* fruit at maturity stage four condition [16 weeks after pollination (WAP) (11.3°Brix)], obtained from Sumedang city, West Java, Indonesia. The materials used in the chemical analysis included distilled water, 96% methanol, sodium hydroxide (NaOH) solution, 1,1-Diphenyl-2-picrylhydrazyl (DPPH) solution, acetone, and petroleum ether (30-60. The treatments were without blanching and food dehydrator technique (A1), without blanching and freeze-drying technique (B1), microwave blanching and food dehydrator technique (C1), microwave blanching and freeze-drying (D1), hot water blanching and food dehydrator (E1), and hot water blanching and freeze-drying (F1).

Water content analysis

The water content analysis was conducted according to AOAC (2005). It was performed by drying the porcelain dish to be used at a temperature of 105°C for 1 hour (h), cooled in a desiccator for 30 minutes (min), then measured until the weight remained (A). After that, a sample of ±2 g (B) was measured in a cup. Then, it was dried for 5 h at a temperature of 100 – 105°C in an oven or until a constant weight was reached. After cooling in a desiccator for 30 min, the sample cup was measured again until the weight remained the same (C). The following formula was employed to determine water content:

$$Water\ content\ (\%) = \frac{B - (C - A)}{B} \times 100\%$$

Hygroscopicity analysis

Hygroscopicity analysis was conducted according to Ribeiro, da Costa & Afonso (2019) with some modifications. It was performed by weighing 2 g of sample into a constant cup and then placing the sample in a desiccator that had been conditioned, containing a saturated sodium chloride (NaCl) solution with a relative humidity (RH) of 75±2% at room temperature. Furthermore, every 60 min, the sample weight increased and was recorded until the weight was constant. Consequently, a graph between time was created, and the sample weight and slope value obtained were calculated.

Colour analysis

Colour analysis was conducted according to Mardiah *et al.* (2020) with some modifications. Colour measurements were performed using the Minolta CR-400 Chroma Meter and the values of L*, a*, and b* were obtained. The L* value corresponded to the degree of brightness, which ranged from 0 (black) to 100 (white). The brightness of the product was indicated by an increase in the L* value. The a* value indicated reddish and greenish. A tendency toward red was indicated by a positive a* value (0-100). A negative a* value [0-(-80)] indicates green. Meanwhile, the b* value indicated the level of yellowness and bluish colours. A negative b* value 0-(-70) suggested a tendency for blue colour, whereas a positive b* value (0-70) exhibited an inclination toward yellow colour.

The Minolta CR-400 Chroma Meter was first turned on by pressing the “ON” button and then pressing the calibration button. The sensor was attached to a standard colour plate to calibrate the chroma meter. The “capture” button was pressed. Correspondingly, the samples of various treatments were placed in transparent or clear containers. The sensor was affixed to the sample and the “capture” button was pressed. Hunter values L*, a*, and b* were listed as parameters.

Antioxidant activity

Analysis of antioxidant activity was

conducted according to Leu *et al.* (2006) with some modifications. The antioxidant activity was extracted from the *sawo belanda* flour samples (25 g) and mixed with 500 ml of 70% ethanol. The samples were extracted using ultrasonic assisted extraction (UAE) at an amplitude of 60% for 45 min. Utilising a vortex, 2 mL of methanol was combined with 0.5 mL of DPPH stock solution (160 ppm) to make a blank. The preparation of the DPPH solution was conducted in conditions that were not exposed to light. Next, the sample solution (400 ppm) was prepared by mixing the sample, DPPH solution (160 ppm), and methanol in different volumes with a final total volume of 2.5 mL. After that, each blank sample was placed in a cuvette and covered with cling wrap. A spectrophotometer was applied to measure the sample's absorbance at a wavelength of 517 nm. The control used in this test was a DPPH solution without a sample. The percentage of inhibition by DPPH radicals was applied to express DPPH radical scavenging activity. The percentage of inhibition was calculated using the equation,

$$\% \ inhibition = \frac{(A - B)}{A} \times 100\%$$

A = Absorbance standard/control (without adding sample);
B = Absorbance with addition of sample.

Total carotenoids

Analysis of total carotenoids was conducted according to de Carvalho *et al.* (2012) modified in some ways. A sample of 1 g was added to 20 mL of acetone and then extracted, and the results were filtered. The filtrate was quantitatively collected into a separating funnel that already had 30 mL of petroleum ether in it. Subsequently, 100 mL of distilled water was slowly added and then the mixture was shaken slowly (not too strongly). Occasionally, the spout of the separating funnel was opened to release the gas phase that was formed. After two phases were formed, the clear phase or aqueous phase was discarded. The addition of 100 mL of distilled water was repeated three to four times and then the aqueous phase was discarded again. The petroleum ether phase was put into a 50 mL flask and then calibrated. Consequently, the absorbance was read on a spectrophotometer at a wavelength of 450 nm. Total carotenoids was obtained with the formula,

$$Total\ carotenoids\ (\mu g/g) = \frac{A \times V(ml) \times 10^4}{A^{1\%}_{1cm} \times W\ Sample(g)}$$

A = Absorbance;
V = Total extract volume;
$A^{1\%}_{1cm}$ = 2,592 (Coefficient β carotene in petroleum ether).

Statistical analysis

Statistical analysis was performed using the IBM SPSS for Windows version 26.0 (IBM Corporation, Armonk, New York, USA). Descriptive statistics were used to identify the average of each treatment as mean±standard deviation (*SD*). The obtained data were analysed by one-way analysis of variance (ANOVA) with Duncan's multiple range tests (DMRT) to determine the significance between samples. In all cases, $p<0.05$ was regarded as statistically significant.

RESULTS

Water content

The amount of water in flour affects its shelf life considerably. The results of the study of *sawo belanda* flour's moisture content are provided in Table 1.

Blanching treatment and drying technique significantly affected the moisture content of *sawo belanda* flour ($p<0.05$). The water content of *sawo belanda* flour ranged from 6.97% to 9.14%. Notably, treatments D1 and C1 that used microwave blanching

Table 1. Moisture content and hygroscopicity of *sawo belanda* flour

Treatment	*Water content (%)*	*Hygroscopicity (%)*
A1	9.14±0.01^{f}	7.04±0.30^{b}
B1	8.43±0.03^{d}	12.69±1.05^{c}
C1	7.82±0.05^{b}	8.04±0.00^{b}
D1	6.97±0.08^{a}	15.31±0.32^{d}
E1	8.86±0.05^{e}	4.42±0.17^{a}
F1	8.30±0.04^{c}	13.81±1.05^{d}

Values are expressed as mean±*SD.*
Similar letter notation means that there is no significant difference in Duncan's test with a 95% confidence level (α=0.05).

had a lower water content than hot water blanching and non-blanching treatments. However, all samples of *sawo belanda* flour had significantly different results. The water content of treatments B1, D1, and F1, which used a freeze-drying as drying method had a lower water content compared to a food dehydrator.

Hygroscopicity

Flour or powder has hygroscopic properties, so it can be damaged when water vapour is absorbed from the environment (Juarez-Enriquez *et al.,* 2017). The results of the hygroscopicity of *sawo belanda* flour are summarised in Table 1.

The results revealed that drying and blanching techniques significantly affected the hygroscopicity of *sawo belanda* flour (p<0.05). *Sawo belanda* flour with treatment D1 exhibited the highest hygroscopicity (15.31±0.32%). GEA Niro Research Laboratory (2024) classified the levels of hygroscopicity: hygroscopicity value <10% as a non-hygroscopic material; hygroscopicity value of 10.1%-15% as a slightly hygroscopic material; hygroscopicity value of 15.1%-20% as a hygroscopic material; hygroscopicity value 20.1-25% as a very hygroscopic material; and hygroscopicity value >25% as a extremely hygroscopic material. Treatments E1, C1, and A1 were included as non-hygroscopic materials. Treatments F1 and B1 were included as slightly hygroscopic materials, while treatment D1 was included as hygroscopic materials. The Duncan's test results on *sawo belanda* flour revealed that B1 had significantly different hygroscopicity from D1 and F1. However, treatment D1 had significantly different hygroscopicity from C1.

Colour

The colour of the *sawo belanda* flour was indicated by the values of L*, a*, b*, and ΔE. The colour characteristics of the *sawo belanda* flour are presented in Table 2. The results revealed that colour (L*, a*, and b*) was significantly affected by the blanching and drying methods of *sawo belanda* flour (p<0.05). The a* value is a value that indicates a reddish colour. The negative will be green, and positive will be red, marked as having a value range of [0-(-80)] green and (0-100) red. Meanwhile, the b* value indicates the degree of yellowness when it is positive, and if it is negative, it indicates a bluish colour represented by the range [0-(-70)] will be blue and (0-70) will be yellow. Based on Table 3, freeze-dried *sawo belanda* flour had L* values ranging from 81.48±0.02 to 86.75±0.21, a* values ranging from 6.09±0.15 to 9.58±0.02, and b* values ranging from 37.38±2.04 to 48.64±0.04.

The Duncan's test results for all treatments of *sawo belanda* flour

Table 2. The colour characteristics of *sawo belanda* flour

Treatment	*L**	*a**	*b**	ΔE
A1	80.64±0.40^{b}	12.31±0.92^{d}	53.30±3.63^{c}	-
B1	86.38±0.23^{e}	7.37±0.03^{b}	40.28±2.09^{a}	-
C1	84.01±0.02^{d}	8.22±0.00^{b}	50.50±4.39^{bc}	6.63±0.58 ^{b}
D1	86.75±0.21^{f}	6.09±0.15^{a}	37.38±2.04^{a}	3.20±1.82 ^{a}
E1	78.79±0.03^{a}	8.96±0.00^{c}	50.15±0.10^{bc}	5.37±2.81^{ab}
F1	81.48±0.02^{c}	9.58±0.02^{c}	48.64±0.04^{b}	10.00±1.60^{c}

Values are expressed as mean±*SD.*
Similar letter notation means that there is no significant difference in Duncan's test with a 95% confidence level (α=0.05).

had significantly different L* values. Treatment E1 exhibited the most flour colour changes. Treatments A1, C1, and E1 had significantly different L* values. Microwave blanching exhibited the brightest colours. Notably, treatment F1 had a significantly different L* value from treatment E1. Furthermore, drying using freeze-drying exhibited a much higher or lighter L* value than drying using a food dehydrator. A Positive a* value indicated a red colour from *sawo belanda* flour. The a* values in the D1 and A1 treatments were significantly different from all treatments. This suggested that the blanching treatment and drying technique affected the a* value of *sawo belanda* flour. However, treatments A1, C1, and E1 demonstrated no significant differences in b* values. High b* values can be caused by high carotenoids content. Treatment C1 or microwave blanching, followed by drying in a food dehydrator resulted in L*84.01±0.02, a* 8.22±0.00, and b* 50.50±4.39, producing a brighter L* value and a fairly high b* value.

Antioxidant activity

The results on antioxidant activity in *sawo belanda* flour are provided in Table 3. The study's results indicated that the antioxidant content of *sawo belanda* flour was significantly impacted by blanching and drying techniques (p<0.05). Treatment B1 had antioxidants that were not significantly different from D1 and F1. Notably, freeze-drying could maintain the antioxidant content of *sawo belanda* flour. Treatment E1 had antioxidants that were significantly different from all treatments, with the highest IC50 of 855.47±93.40 ppm. Treatment D1 of *sawo belanda* flour with microwave blanching, followed by freeze-drying had a high antioxidant

Table 3. Antioxidant activity and total carotenoids in *sawo belanda* flour

Treatment	*IC50 (ppm)*	*Total carotene (µg/g)*
A1	166.20±0.09^{ab}	88.92±0.22^{d}
B1	161.39±0.13^{ab}	70.50±2.23^{b}
C1	142.74±15.40^{ab}	92.39±0.92^{e}
D1	109.58±0.24^{a}	72.04±0.40^{b}
E1	855.47±93.40^{c}	36.26±0.21^{a}
F1	184.08±9.24^{b}	81.11±0.14^{c}

Values are expressed as mean±*SD.*
Similar letter notation means that there is no significant difference in Duncan's test with a 95% confidence level (α=0.05).

content of 109.58±0.24. The smaller the IC50 value, the higher the antioxidant value. According to Molyneux (2004), the classification of antioxidant power based on IC50 values are: IC50 (<50 ppm) very strong, IC50 (50 –100 ppm) strong, IC50 (100 –150 ppm) moderate, IC50 (150 – 200 ppm) weak, and IC50 (>200 ppm) very weak. Therefore, all treatments on *sawo belanda* flour produced moderate antioxidant activities, except treatment E1 with an antioxidant activity of 855.47±93.40 ppm, which was very weak.

Total carotenoids

The results on total carotenoids content of *sawo belanda* flour in this study are provided in Table 3. According to this research, the total carotenoids of *sawo belanda* flour was significantly affected by blanching and drying techniques (p<0.05). Treatment A1 was significantly different from C1 and E1. Treatment C1 demonstrated significantly different total carotenoids from D1. In addition, treatment C1 had higher total carotenoids. Meanwhile, treatment E1 demonstrated significantly different total carotenoids from other treatments. Treatment C1 with 92.39±0.92 µg/g indicated that microwave blanching and food dehydrator drying could minimise damage to the bioactive components of *sawo belanda* flour and maintain its quality.

DISCUSSION

In this research, the characteristics of *sawo belanda* flour were identified and assessed after different treatments. The findings indicated that the overall water content of *sawo belanda* flour ranged from 6.97% to 9.14%. This is similar to previous research, which stated that *sawo belanda* flour has a water content of 8% to 10% (Pertiwi, Nurhalimah & Aminullah, 2020). Treatment D1 exhibited the lowest water content. This result is attributed to microwave blanching, which accelerates molecular absorption and drying due to its rapid heating. Additionally, blanching increases the permeability of cell membranes, leading to wider pores in the material. These wider pores facilitate faster water evaporation, resulting in reduced moisture content.

The loss of water content can also be caused by freeze-drying, converting moisture into ice and transforming it into water vapour directly, by passing the liquid phase, causing the water content of *sawo belanda* flour to be lower. Similar studies have proven that yam flour experienced high water loss and lower moisture content when freeze-dried compared to other drying methods (Shams *et al.,* 2022). The lower water content in food will inhibit the growth of microorganisms, thereby extending the shelf life of the material. Furthermore, moisture content also impacts food attributes such as aroma, flavour, and microbial proliferation.

Another characteristic that was identified was hygroscopicity. *Sawo belanda* flour with treatment D1 indicated the highest hygroscopicity (15.31±0.32%) due to its low water content. As drier materials absorb water more quickly, higher hygroscopicity levels result (Rozi, 2013). Treatment B1 had significantly different hygroscopicity from D1 and F1. According to Slamet's (2010) research, blanched pumpkin demonstrated greater hygroscopicity (93%) than unblanched pumpkin (62.8%). Treatment D1 demonstrated greater hygroscopicity due to the fact that *sawo belanda* flour that was freeze-dried had less water than flour that was dehydrated by a food dehydrator. A substance becomes more hygroscopic as it is dried. Thus, the cavities left by evaporated water molecules enable the

material to absorb moisture from its surroundings more readily.

The colour values of freeze-dried *sawo belanda* flour varied, with L* values ranging from 81.48±0.02 to 86.75±0.21, a* values from 6.09±0.15 to 9.58±0.02, and b* values from 37.38±2.04 to 48.64±0.04. Previous research suggested that freeze-dried *sawo belanda* flour has similar colour values of L* at 81.8, a* at 12.6, and b* at 66.2. However, differences in species, locality, and the time of harvesting the sawo fruit can all affect colour values (Anjo *et al.,* 2021).

All treatments of *sawo belanda* flour had significantly different L* values. This is due to the blanching process and differences in drying techniques, which can affect the brightness of *sawo belanda* flour. Treatments A1, C1, and E1 had significantly different L* values. Microwave blanching exhibited the brightest colours. This is because it uses a power of 600–700W for 30 seconds to effectively preserve the flour's colour by preventing degradation. This technique also inactivates polyphenol oxidase (PPO) compounds, known to cause browning. Similar research with sweet potatoes revealed that inhibiting these browning enzymes helps maintain the flour's brightness (Belkacemi, 2022).

Freeze-drying resulted in a higher or brighter L* value compared to a food dehydrator. The L* value also decreased when using a food dehydrator, in accordance with studies suggesting that pumpkins dried at higher temperatures would have a lower L* value (Onwude *et al.,* 2017). Treatment C1 with microwave blanching, followed by food dehydrator drying had colour values of L* 84.01±0.02, a* 8.22±0.00, and b* 50.50±4.39, producing a brighter L* value and a fairly high b* value. The yellow colour discovered in *sawo belanda* flour indicated the presence of carotenoid components. Therefore, treatment C1 could maintain the colour of *sawo belanda* flour. Meanwhile, treatment E1 or hot water blanching, followed by drying in a food dehydrator had the most colour changes in flour or was the darkest. However, the use of high heat could damage the colour structure.

The antioxidant content of *sawo belanda* flour was significantly impacted by blanching and drying techniques ($p<0.05$). Blanching helps in releasing antioxidants from plant cells. Treatments D1 and C1 produced antioxidant results that were not significantly different. In contrast, treatments D1 and F1 produced significantly different antioxidant results, indicating that different drying techniques have varied impacts on antioxidant retention. This highlights the significance of the chosen processing method in maintaining the antioxidant properties of flour. Notably, microwave blanching retained antioxidants in *sawo belanda* flour.

Treatment B1 had antioxidants that were not significantly different from D1 and F1, which is described by the efficiency of freeze-drying in preserving antioxidants. Compared to a food dehydrator, freeze-drying preserves the better quality of material as it uses lower temperatures. In addition, freeze-drying uses a sublimation process with a slow phase to prevent changes in the structure of material and preserve its antioxidant activity. However, treatment E1 had an antioxidant content that was significantly different from all treatments, which had the highest IC50 of 855.47±93.40 ppm. A high IC50 value indicates a lack of antioxidant activity. Hot water with a high temperature can lead to structural changes that may potentially damage the antioxidant content of the material, as antioxidants are highly susceptible to heat. In contrast to E1, other treatments on *sawo belanda* flour were able to retain modest antioxidant levels, underscoring the importance of temperature in keeping these beneficial

chemicals. At the same time, microwave blanching demonstrated higher antioxidant activities than hot water blanching and unblanched treatments. This increase can occur due to the release of antioxidant compounds from within plant cells or the information and accumulation of melanoidin as a Maillard derivative with a high level of antioxidant activity. This is consistent with a study demonstrating that the antioxidant activity of fruit peels was increased after microwave blanching (Feumba *et al.,* 2020).

Total carotenoids content of *sawo belanda* flour was significantly affected by blanching and drying techniques. Blanching can prevent loss of carotenoids compared to fresh material without treatment. The method of drying affects the amount of carotenoids. Treatment A1 was significantly different from C1 and E1. *Sawo belanda* flour with blanching process exhibited higher total carotenoids compared to unblanched *sawo belanda* flour. This can be due to the loss of dissolved solids and moisture during the blanching process, which also includes a better extraction process. Research by Wardani *et al.* (2020) suggested that blanching improves the stability of carotenoids in foods. Treatment C1 demonstrated total carotenoids in *sawo belanda* flour to be significantly different from the other treatments. Meanwhile, microwave blanching provides higher total carotenoids, as evidenced by Başkaya Sezer & Demirdöven's (2015) research, which discovered that microwave blanching of carrots preserved more carotenoids than conventional blanching methods.

Treatment C1 had higher total carotenoids. Food dehydrators could maintain bioactive compounds or minimise the damage of carotenoids in *sawo belanda*. The temperature of the food dehydrator was not too high (50°C), thus preserving carotenoids in *sawo belanda* flour while avoiding damage. Treatment E1 produced significantly different total carotenoids from other treatments. Notably, blanching hot water with high temperatures could reduce and degrade carotene levels. This was demonstrated by the research of Wardani *et al.* (2020), which discovered that one of the factors that causes the degradation of carotenoids is the temperature at which high temperatures will cause the isomerisation process, leading to the formation of cis derivatives. In response to heat, oxygen, and light, carotenoids are highly susceptible to oxidation and deterioration. Treatment C1 with 92.39±0.92 µg/g indicated that microwave blanching and food dehydrator drying could minimise damage to the bioactive components of *sawo belanda* flour and thus maintain its quality. *Sawo belanda* flour can be categorised as an incredibly high carotene producer, according to the Britton and Khachik classification, which stated the carotene level as high when it is 5–20 µg/g or incredibly high when >20 µg/g (Britton & Khachik 2009). This indicates that the treatment was effective in maintaining the nutritional value of the flour.

This research necessitates further exploration into the characteristics of *sawo belanda* flour. The discovery must be developed to ascertain more functional values of the *sawo belanda* flour in order to realise its full functional potential. The strength of this research was comprehending the characteristics of *sawo belanda* flour, obtaining more insights into *Pouteria campechiana* and acknowledging the capacity of appropriate blanching and drying methods to produce *sawo belanda* flour with a high functional value. Therefore, for future study, the application of *sawo belanda* flour in food ingredients should be considered.

CONCLUSION

Sawo belanda flour treated with treatment C1 (microwave blanching and food dehydrator drying technique) had a significant impact on the characteristics of water content, hygroscopicity, colour, antioxidants, and total carotenoids. Treatment C1 produced the best characteristics: moisture content of 7.82%, hygroscopicity of 8.04%, colour values of L* 84.01, a* 8.22, and b* 50.50, as well as functional characteristics including antioxidant content with an IC50 of 142 ppm and carotenoid content of 92.4 μg/g. Furthermore, the antioxidant content and incredibly high carotenoid content grant the *sawo belanda* flour an additional functional value when added to food ingredients.

Acknowledgement

The authors would like to thank the food chemistry laboratory, food processing engineering, and food processing laboratory of the Food Industry Technology Department.

Author's contributions

Zaida, principal investigator, conceptualised, prepared the draft of the manuscript and reviewed the manuscript; Zulfa HF, conducted the study, led the data collection, and reviewed the manuscript; Indarto R, designed the study, assisted in drafting and reviewed the manuscript; Lembong E, conducted data analysis and interpretation, and reviewed the manuscript; Lani MN, reviewed the manuscript and verified the data.

Conflict of interest

The authors declare no conflict of interest.

References

Anjo FA, Saraiva BR, Ogawa CYL, Vital ACP, Sato F & Matumoto-Pintro PT (2021). Phytochemical and technological characterization of canistel dehydrated pulp: A new potential food ingredient. *Res Soc Dev* 10(1):e16410111577.

AOAC (2005). *Official Methods of Analysis*. 18th Edition, Association of Official Analytical Chemists, Washington DC.

Atapattu NSBM, Sanjeewani KGS & Senaratna D (2015). Effects of dietary canistel (Pouteria campechiana) fruit meal on growth performance and carcass parameters of broiler chicken. *Trop Agr Res Extension* 16(2):34.

Awang-Kanak F & Abu Bakar MF (2018). Canistel Pouteria campechiana (Kunth) Baehni. In S Rodrigues, E de Oliveira Silva, ES de Brito (eds). *Exotic Fruits* (pp 107–111). Academic Press.

Başkaya Sezer D & Demirdöven A (2015). The effects of microwave blanching conditions on carrot slices: Optimization and comparison. *J Food Process Preserv* 39(6):2188–2196.

Belkacemi L (2022). Blanching effect on physicochemical and functional properties of flours processed from peeled and unpeeled white-fleshed sweet potato Algerian Cultivar. *Food Sci Technol (Brazil)* 42:1–10.

Britton G & Khachik F (2009). Carotenoids in Food. In Britton G, Pfander H, Liaaen-Jensen S (eds). *Carotenoids Volume 5: Nutrition and Health* (pp 45–66) Birkhäuser Basel, Basel.

Buzera A, Gikundi E, Orina I & Sila D (2022). Effect of pretreatments and drying methods on physical and microstructural properties of potato flour. *Foods* 11(4):507.

de Carvalho LMJ, Gomes PB, de Oliveira Godoy RL, Pacheco S, do Monte PHF, de Carvalho JLV, Nutti MR, Neves ACL, Vieira ACRA & Ramos SRR (2012). Total carotenoid content, α-carotene and β-carotene, of Landrace pumpkins (Cucurbita Moschata Duch): A preliminary study. *Food Res Int* 47(2):337–40.

Daulay IN (2017). Pengaruh metode dan lama blansing terhadap karakteristik fisik, kimia, dan fungsional tepung ubi jalar ungu (*Ipomea Batatas L*). Undergraduate Theses. Repositori Institusi Universitas Sumatra Utara.

Efendi Z, Surawan FED & Winarto (2015). Efek blanching dan metode pengeringan terhadap sifat fisikokimia tepung ubi jalar orange (*Ipomoea Batatas L.*) *J Agroindustri* 5(2):109–17.

Feumba D, Romelle, Emmanuel PA, Ashwini RP, Quentin MT & Carl MMF (2020). Effect of Microwave Blanching on Antioxidant Activity, Phenolic Compounds and Browning Behaviour of Some Fruit Peelings. *Food Chemistry* 302:125308.

GEA Niro research Laboratory (2024). Method No. A 14 a Hygroscopicity. *GEA* Process Engineering. From https://www.gea.com/en/assets/170113/ [Retrieved October 29 2024].

Gulzar A, Ahmed M, Qadir MA, Shafiq MI, Ali S, Ahmad I & Mukhtar MF (2018). Effect of blanching techniques and treatments on nutritional quality of dried mango slices during storage. *P J Food and Nutr Sci* 68(1):5–13.

Issaoui M, Flamini G & Delgado A (2021). Sustainability opportunities for Mediterranean food products through new formulations based on carob flour (Ceratonia siliqua L.). *Sustainability* 13(14):8026. https://dx.doi.org/10.3390/SU13148026.

Juarez-Enriquez E, Olivas GI, Zamudio-Flores PB, Ortega-Rivas E, Perez-Vega S, & Sepulveda DR (2017). Effect of water content on the flowability of hygroscopic powders. *J Food Eng* 205:12–17. DOI:10.1016/j.jfoodeng.2017.02.024

el Khatib S & Muhieddine M (2020). Nutritional profile and medicinal properties of pumpkin fruit pulp. In LC Salanta (ed) *The Health Benefits of Foods - Current Knowledge and Further Development.* First Edition (pp 1-20). IntechOpen.

Leu SJ, Lin YP, Lin RD, Wen CL, Cheng KT, Hsu FL & Lee MH (2006). Phenolic constituents of Malus Doumeri Var. Formosana in the field of skin care. *Biol Pharm Bull* 29(4):740–745.

Mardiah M, Andini SF, Hafiani N, Fitrilia T & Widowati S (2020). Effect of drying method on physicochemical properties of pumpkin flour. *Int J Adv Sci Technol* 29(7):79–85.

Molyneux P (2004). The use of the stable free radical diphenylpicrylhydrazyl (DPPH) for estimating antioxidant activity. *Songklanakarin J Science Technol* 26(2):211-219.

Muchtadi TR, Sugiyono & Ayustaningwarno F (eds) (2013). *Ilmu Pengetahuan Bahan Pangan.* AlfaBeta, Bandung

Onwude D, Hashim N, Janius R, Nawi NM & Abdan K (2017). Colour change kinetics and total carotenoid content of pumpkin as affected by drying temperature. *Ital J Food Sci* 29(1):1–18.

Paragados DA (2014). Acceptability of Canistel (Lacuma Nervosa A.DC) fruit flour in making cookies. *Asia Pac J Multidiscip Res* 2:1-1.

Pertiwi SR, Nurhalimah S & Aminullah A (2020). Optimization on process of ripe Canistel (Pouteria Campechiana) fruit flour based on several quality characteristics. *Braz J Food Technol* 23:1–8.

Ribeiro LC, da Costa JMC & Afonso MRA (2019). Hygroscopic behavior of acerola powder obtained by spray-drying. *Acta Sci Technol* 41(1):35382.

Rozi AF (2013). Pengaruh suhu dan waktu pengeringan pada pembuatan serbuk perisa (flavor) alami udang (Penaeus Monodon) dari hasil samping industri udang beku. Universitas Brawijaya.

Shams R, Singh J, Dash KK & Dar AH (2022). Comparative study of freeze drying and cabinet drying of button mushroom. *Appl Food Res* 2(1):100084.

Slamet A (2010). Pengaruh perlakuan pendahuluan dan suhu pengeringan terhadap sifat fisik dan kandungan β carotene tepung waluh (*Cucurbita Moschata*). Jurnal AgriSains *1(2):38-45*. https://lppm.mercubuana-yogya.ac.id/wp-content/uploads/2013/12/Jurnal-AgriSains-Vol.-1-No.-2-2010.pdf [Retrieved November 7 2024]

Sunilla AV & Murungan K (2017). Nutritional composition of fruits from Pouteria Campechiana (kunth) Baenhi at different stages of development. *Trends Biosci* 10(20):4020-4026.

Wardani AD, Susanto E, Dewi EN & Purnamayati L (2020). Pengaruh perbedaan pre-treatment terhadap stabilitas karotenoid dan fenol pada ekstrak sargassum duplicatum selama penyimpanan. *J Pengolah Has Perikan Indones* 23(2):236–247.