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To cite this article: M Mohamad Nor *et al* 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **756** 012070

IOP Conf. Series: Earth and Environmental Science **756** (2021) 012070 doi:10.1088/1755-1315/756/1/012070

Comparative studies of physicochemical properties of sweet potato (*Ipomoea batatas*) cookies from different variations of sweet potato

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Abstract. Sweet potato possesses superb nutritional values and it grows easily in a hot and humid climate. In Malaysia, sweet potatoes are commonly used in making traditional snacks and sweet desserts despite that sweet potato has greater potential for utilization in other new food products. This study was conducted to formulate cookies with partial substitution of wheat flour with orange-flesh (*VitAto*) or purple-fleshed (*Anggun*) sweet potatoes. The cookies were prepared from the formulation blend of sweet potato and wheat flour in the substitution levels of 20% and 40%, respectively. The proximate composition and physicochemical properties of the formulated cookies were studied. The proximate analysis results depicted that, compared to the control cookies, sweet potato incorporated cookies had higher moisture, ash, and carbohydrates contents but lower crude protein and crude fat. The cookies incorporated with sweet potato presented a significantly greater spread ratio and diameter than the control. The results of texture profile analysis indicated that partial substitution of sweet potato for wheat flour significantly decreased the hardness of cookies though it had zero effect on the attribute of springiness. These findings revealed that the sweet potato has positive potential uses in the development of cookies or other bakery products with enhanced nutritional quality.

1. Introduction

Sweet potato (*Ipomoea batatas*) is a root crop that belongs to Convolvulaceae or the morning glory family. Sweet potatoes are originated from Latin America and grow annually in temperate, tropical, and subtropical climates. It is well adapted to different environments but has to undergo about 90 to 150 days of growth before harvesting [1]. Sweet potatoes grow well in sandy loam soil with temperature ranges between 21ºC and 29ºC [2]. Sweet potato ranks seventh of the world's most important food crops after wheat, rice, maize, potato, barley, and cassava [3]. The total harvested sweet potato area in Malaysia was about 2441 ha [4] and produced mainly in the states of Perak, Kelantan, and Terengganu [5].

Sweet potatoes are a very good source of not only carbohydrates but also vitamins A, vitamin B5, vitamin B6, vitamin C, vitamin E, zinc, iron, potassium, magnesium, calcium, carbohydrates, protein, carotenoid, and dietary fiber [6]. They have been regarded as an "anti-diabetic" food that can be used in diet therapy of diabetes mellitus to control blood sugars level [7]. The nutritional value, physical and chemical compositions of sweet potato may vary in different varieties of sweet potato. The common varieties of sweet potatoes found in Malaysia are purple and orange-fleshed sweet potatoes. The predominant pigments in the purple-fleshed sweet potato (PFSP), also known as *Anggun*, are anthocyanins. The orange-fleshed sweet potato (OFSP) aka *VitAto* is richer in carotenoid which makes it a strong antioxidant.

Recently, there has been a rising demand for healthy or functional foods such as fruits and vegetables-based snacks due to the upsurge of awareness among consumers towards healthy eating habits [8]. Meanwhile, the industry is working hard to formulate feature goods that are cheaper, readily accessible and that should have functional and sensory properties that are satisfactory [9]. Moreover, based on data from Mintel NPD [10], there has been 130 percent of the growth in the global launch of sweet potato cookies between 2011 and 2013. Most production activities were from Japan (45%), followed by Argentina (17%) and the United States (7%) [10]. Furthermore, between 2015 to 2018, the global launch of foods and beverages (F&B) using sweet potato as ingredients increased by 21 percent of compound annual growth (CAGR) [11].

This study was conducted to (i) produce PFSP, and OFSP based cookies by using different formulation ratios against wheat flour, and (ii) compare the effects of sweet potato varieties on the physicochemical, and texture profile analysis of the resultant cookies.

2. Materials and Methods

2.1. Sample collection

223.13 g of fresh OFSP and 186.65 g of fresh PFSP were purchased from Malaysian Agricultural Research and Development Institute (MARDI), Bachok, Kelantan, Malaysia.

2.2. Cookies preparation

Cookies were prepared according to the method of Srivastava, Genitha, and Yadav [12] with slight modification. Mashed sweet potatoes (MSP) and other ingredients (Table 1) were mixed thoroughly until a consistent dough was formed. After 30 minutes, the dough was rolled out to a thickness of about 0.3 cm and cut. The baking trays were greased and the cookies were baked in a preheated oven at 180 ºC for 15 minutes. The baked cookies were cooled at room temperature for 5 minutes and packed.

Table 1. Cookie formulation.

Type of Cookies	Mashed sweet potato (MSP) (g)	Wheat flour (WF) (g)	Baking powder (g)	Sugar (g)	Salt (g)	Melted butter (g)	Formulation (MSP: WF)
OFSP cookies	0.0	100.0	2.0	50.0	0.5	20.0	Control (0:100)
	20.0	80.0	2.0	50.0	0.5	20.0	F1 (11.6:46.4)
	40.0	60.0	2.0	50.0	0.5	20.0	F2 (23.2:34.8)
PFSP cookies	0.0	100.0	2.0	50.0	0.5	20.0	Control (0: 100)
	20.0	80.0	2.0	50.0	0.5	20.0	F3 (11.6:46.4)
	40.0	60.0	2.0	50.0	0.5	20.0	F4 (23.2:34.8)

2.3. Physical Analysis

Cookies were selected randomly for analyzing their physical properties: diameter, thickness, weight, spread ratio, and density. The diameter, *d*, and thickness of cookies, *t* was determined using Vernier caliper. The weight of the cookie, *g* was measured using an analytical balance. The spread ratio of the cookie was obtained by dividing the average value of diameter, *D* with its average value of thickness, *T*. The density of the cookie, ρ was determined by dividing the weight of the cookie, *g* by the volume of the cookie, *V*. The volume of the cookie was calculated using equation (1).

$$\text{Volume (cm}^3\text{)}, V = \frac{D^2 \pi T}{4} \qquad (1)$$

Here; *D* indicates the average value of the diameter of the cookie whereas *T* represents the average value of the thickness of the cookie.

2.4. Colour measurement

The color of cookies was measured using a Konica Minolta Chroma meter (model CR-400, Osaka Japan). The color of cookie surfaces was determined by the CIE $L^*a^*b^*$ color space. Here, L^* is the lightness factor ranging from black (L=0) and white (L=100), a^* denotes the hue on the red (+*a*) to the green (-*a*) axis, and b^* represents the hue on the yellow (+*b*) to blue (-*b*) axis.

2.5. Proximate analysis

The proximate analysis of cookies was determined by a standard method of AOAC [13]. The oven-drying [8], Kjeldahl method [14], Soxhlet extraction [13], and dry ashing [15] were used to analyze the moisture, crude protein, crude fat, and ash content, respectively. Carbohydrate content was calculated by difference.

2.6. Texture analysis

Texture analysis was performed using a Brookfield CT3 Texture Analyzer with a TA-MTP fixture, and load cell of 10 kg. The stainless-steel cylindrical probe-type TA39 was used to penetrate the cookie sample at a pretest speed of 2mm/s, test speed of 0.5 mm/s, and return speed of 0.5 mm/s. The textural characteristics like hardness, springiness, cohesiveness, and chewiness were determined.

2.7. Statistical analysis

All analyses, presented as mean ± standard deviation (SD) of triplicate measurements were subjected to one-way ANOVA, and Tukey's test at 95% confidence level using the IBM SPSS (Version 21.0).

3. Results and Discussion

3.1. Cookies yield

For the total yield of formulated cookies from the partial substitution of sweet potato for wheat flour, it was predictable that the OFSP cookies had a higher yield over the PFSP cookies as the former's recorded a higher raw material weight than the latter (Table 2).

Table 2. The yield of cookies made with different substitution levels of sweet potato.

Variety of sweet potatoes	Weight of raw sweet potato (g)	Weight of mashed sweet potato (g)	Total weight of cookies (g)
OFSP aka *VitAto*	223.13	200.07	≈ 882.64
PFSP aka *Anggun*	186.65	161.47	≈ 707.58

3.2. Physical analysis of cookies

From Table 3, there were significant differences (p<0.0.5) between sweet potato cookies (all but F1) with 100% wheat flour cookies (control) in terms of thickness, weight, and spread ratio. The diameter and density of the resultant cookies, however, were unaffected.

Table 3. Physical characteristics of cookies with different substitution levels of sweet potato.

Sample	Physical characteristics				
	Diameter (mm)	Thickness (mm)	Weight (g)	Spread ratio	Density (g/cm^3)

Control	51.91 ± 1.28^{a}	9.81 ± 0.35^{b}	12.51 ± 0.21^{c}	5.29 ± 0.10^{d}	0.60 ± 0.04^{e}
F1	53.76 ± 1.32^{a}	9.30 ± 0.24^{b}	12.28 ± 0.15^{bc}	5.78 ± 0.08^{cd}	0.59 ± 0.03^{e}
F2	53.63 ± 1.08^{a}	8.25 ± 0.32^{a}	11.89 ± 0.18^{ab}	6.50 ± 0.21^{b}	0.64 ± 0.04^{e}
F3	52.22 ± 1.66^{a}	8.50 ± 0.15^{a}	11.75 ± 0.20^{a}	6.14 ± 0.09^{bc}	0.65 ± 0.04^{e}
F4	53.43 ± 1.87^{a}	7.94 ± 0.29^{a}	11.42 ± 0.24^{a}	7.01 ± 0.19^{a}	0.59 ± 0.04^{e}

*Superscript in the same column which is not followed by the same letter were significantly different at $p < 0.05$.

The diameter of cookies ranged from 51.91 mm to 53.76 mm. The control cookies made with 100% wheat flour had a smaller diameter followed by OFSP cookies and PFSP cookies. The obtained results showed a similar trend with those of Chinm and Gernah [16], who found that the diameter value is significantly affected by the amount of protein gluten in wheat flour. Protein gluten formed a gliadin-glutenin cross-linking network when baking and this network restricted the expansion of cookie dough. The results also indicated that the substitution of sweet potato in cookie formulation resulted in a larger diameter of cookies. It, therefore, implies that the viscosity of cookie dough is reduced if one uses the partial substitution of sweet potato for wheat flour.

The incorporation of sweet potato to cookie formulation significantly decreased the thickness of the resultant cookies. As observed, the PFSP cookies have a higher water holding capacity than OFSP cookies, and 100% wheat flour cookies. The property of high-water holding capacity of OFSP enables it to absorb more water molecules and decrease the dough viscosity. A low dough viscosity inflates the spreading rate of cookies during baking which resulted in cookies with low thickness. Besides, it is suggested that the temperature and the action of baking powder (chemical leavening agents) are key factors to the changes in cookie thickness [17]. Adding chemical leavening agents lead to the increment in cookie thickness during dough heating by releasing carbon dioxide.

The substitution of sweet potato for wheat flour in cookie formulation significantly decreased the weight of cookies. The greater weight of 100% wheat flour cookies may be due to the oil retention capacity of the wheat flour [18]. There were insignificant differences (p>0.05) in cookie density for all cookie formulations. As per Pereira, Correia, and Guiné [19], density decides the porosity structure of cookies whereby a low density causes cookies to have more porous structures.

The spread ratio of resultant cookies ranged from 5.29 mm to 7.01 mm. Lee and Abdul Latif [20] confirmed that the viscosity of cookie dough influences the spread rate of cookies. Cookies spread fast during baking when the viscosity of dough decreases. The viscosity of cookie dough is dependent on the protein gluten content. Gliadin-glutenin cross-linking network became stronger due to the high water-retaining capacity of the protein gluten, which led to an increment in dough viscosity and thereby lower the spread ratio of the control cookies as compared to the sweet potato incorporated cookies. Furthermore, Suriya et al. [21] described that the presence of a large amount of water in sweet potato accelerates the rate of dissolving for sugar and it then causes the cookies to spread faster. Cookies with a faster spread rate also may be resulted from the melting of fat components in the cookie dough.

3.3. Colour analysis of cookies

Colour is an important driver in determining the acceptable level of consumers towards a certain food product in terms of preferences and perception.

Table 4. The $L*$, $a*$, and $b*$ values of cookies with different substitution levels of sweet potato.

Samples	Colour analysis		
	$L*$	$a*$	$b*$
Control	52.90 ± 0.50^{a}	5.50 ± 0.32^{d}	19.53 ± 0.29^{b}
F1	52.10 ± 0.98^{a}	8.09 ± 0.18^{c}	24.57 ± 0.13^{c}
F2	49.62 ± 1.16^{d}	9.28 ± 0.31^{b}	24.93 ± 0.54^{c}

F3	40.02 ± 0.49^{c}	12.85 ± 0.48^{a}	11.79 ± 0.69^{a}
F4	32.86 ± 0.31^{b}	13.50 ± 0.35^{a}	10.56 ± 0.79^{a}

*Superscript in the same column which is not followed by the same letter are significantly different at $p < 0.05$.

Based on Table 4, the L^* value of 52.10 and 49.62 were found in OFSP cookies for F1 and F2 whereas the corresponding value of PFSP cookies for F3 and F4 were 40.02 and 32.86, respectively. According to Jan, Saxena, and Singh [22], color changes in lightness could be attributed to the presence of sugar, phenolic compounds, and protein content in cookie formulation that responsible for browning reaction. The darker color of both OFSP and PFSP cookies concerning a higher percentage of incorporation of sweet potato could be attributed to the brown pigment produced. The browning reaction is associated with the Maillard reaction, caramelization, and dextrinization of sugar [22]. Maillard browning decreases with the rising level of wheat flour because sugar and protein contents have been diluted when interacting with amino acids.

PFSP cookies were darker in color compared to that of OFSP cookies as there was an improvement in redness (a^*) value, and reduction in both lightness (L^*) and yellowness (b^*) values. The higher in a^* value of PFSP cookies may be due to the presence of phenolic compounds in PFSP. Liao et al. [23] stated that PFSP has a high content of anthocyanin responsible for the purple and red color of sweet potato. OFSP cookies showed the highest yellowness (b^*) among all cookies. The highest in b^* value of OFSP cookies could be due to the accumulation of carotenoid pigments containing in OFSP. Carotenoid pigment such as β-carotene contributes to the yellow and orange color found in many fruits and vegetables. According to Provesi, Dias, and Amante [24], the stability of carotenoids might be affected by the presence of metal, light intensity, and storage temperature.

3.4. Proximate compositions of cookies

As shown in Table 5, there was a significant difference ($p < 0.05$) in moisture and crude protein contents between the means of sweet potato and non-sweet potato formulated cookies. Of note, when comparing to the control sample, not all cookie samples integrated with the sweet potatoes displayed a statistically significant difference in crude fat and carbohydrate contents. Ash content of cookies, on the other hand, was unaffected by the incorporation of sweet potato in cookie formulation.

Table 5. Proximate compositions of cookies with different substitution levels of sweet potato.

Samples	Proximate composition				
	Moisture	Crude protein	Crude fat	Ash	Carbohydrates
Control	5.52 ± 0.44^{d}	6.25 ± 0.18^{c}	34.16 ± 1.17^{c}	1.33 ± 0.17^{a}	52.74 ± 1.92^{b}
F1	6.78 ± 0.37^{bc}	5.56 ± 0.11^{b}	32.18 ± 0.97^{bc}	1.53 ± 0.39^{a}	53.95 ± 0.33^{b}
F2	7.80 ± 0.28^{a}	4.65 ± 0.13^{a}	29.64 ± 1.46^{ab}	1.72 ± 0.20^{a}	56.20 ± 1.35^{ab}
F3	6.67 ± 0.29^{c}	5.36 ± 0.13^{b}	31.37 ± 2.07^{bc}	1.37 ± 0.10^{a}	55.23 ± 1.65^{b}
F4	7.64 ± 0.22^{ab}	4.60 ± 0.03^{a}	26.45 ± 1.50^{a}	1.70 ± 0.07^{a}	59.60 ± 1.31^{a}

*Superscript in the same column which is not followed by the same letter are significantly different at $p < 0.05$.

The highest moisture content was observed in OFSP cookies. Increasing moisture content following the increment in sweet potato substitution level may be attributed to the sweet potato's high water holding capacity that could retain more water in the formulated cookies. According to Kaur, Singh, and Kaur [25], the moisture content is important for product storage life, packaging, and transportation cost. Cookies with low moisture content are fewer perishables and more shelf-stable if they are kept properly.

Crude protein content reduced when the percentage of sweet potato in cookie formulation increased. According to Musa and Lawal [26], the decrease of crude protein content may be associated with the effect of heat and temperature applied to the cookies during baking. Higher extend of heat and temperature could denature the protein and thereby leading to the loss of nutrients. The crude fat content of the sweet potato incorporated cookies was revealed to be significantly lower than in the 100% wheat flour cookies. The decreased crude fat content may be attributed to the lower fat content in sweet potato than wheat flour. Furthermore, the high oil retention capacity of wheat flour had resulted in the highest crude fat content of 34.16% in cookies made from 100% wheat flour. According to Musa and Lawal [26], low crude fat content can prevent rancidity of fats. Cookies with high-fat content are more susceptible to rancidity and particularly unacceptable by the consumer due to the development of unpleasant smells from the rancid fats.

There was an insignificant difference ($p > 0.05$) in ash content for all samples. According to Bhat and Sridhar (as cited in [27]), ash content reflecting the presence of mineral content in food products. The ash content of sweet potatoes is dependent on the mineral content in the soil. As noticed, the ash content of cookies increased if a higher amount of sweet potato was incorporated into the cookie formulation.

Carbohydrate contents were significantly affected by increasing the level of substitution of sweet potato, says F4 sample. An increase in carbohydrate content with increasing substitution level of sweet potato may be attributed to the fact that the sweet potato is one of the best food sources of carbohydrates. As stated by Jemziya and Mahendran [28], a high percentage of carbohydrate content is a desired characteristic that contributes to the texture of cookies. The texture of cookies is enhanced when the starch granules in cookie dough forming a gel.

3.5. Texture profile analysis of cookies

According to Table 6, the substitution of sweet potato for wheat flour significantly affected the hardness, cohesiveness, and chewiness of cookies as compared with the control cookies made with 100% wheat flour. However, the springiness of cookies was unaffected with the incorporation of sweet potato in cookie formulation.

For the hardness value, the results showed that there is a wide range of variability between 1089.67 g to 3551.00 g. Hardness depicts the required force needed to compress the cookies. The incorporation of sweet potato decreased the hardness characteristics of cookies. The decrease in hardness in sweet potato incorporated cookies has been related to the higher moisture content introduced into the cookie dough. Control cookies exhibited the highest value of hardness may be associated with the denser matrix formation resulted from the starch crystallization and high level of protein in wheat flour.

Table 6. Textural properties of cookies formulated with different substitution levels of sweet potato.

Samples	Textural properties			
	Hardness (g)	Cohesiveness	Springiness (cm)	Chewiness (mJ)
Control	3551.00 ± 205.17^{c}	0.20 ± 0.02^{b}	0.24 ± 0.01^{a}	17.00 ± 0.56^{b}
F1	2129.33 ± 348.95^{ab}	0.18 ± 0.06^{b}	0.24 ± 0.05^{a}	8.90 ± 4.59^{a}
F2	1089.67 ± 130.85^{b}	0.37 ± 0.04^{a}	0.25 ± 0.02^{a}	9.47 ± 0.49^{a}
F3	3172.00 ± 794.98^{ac}	0.17 ± 0.02^{b}	0.25 ± 0.04^{a}	12.67 ± 1.07^{ab}
F4	1273.33 ± 161.72^{b}	0.32 ± 0.03^{a}	0.24 ± 0.03^{a}	9.37 ± 1.12^{a}

*Superscript in the same column which is not followed by the same letter are significantly different at $p < 0.05$.

The cohesiveness of cookies measures the strength of internal bonds of cookie molecules and the tendency of the cookies to hold together when subjected to compression. The cohesiveness value of cookies ranged from 0.17 to 0.37. Cookies with a 40% substitution level of sweet potato (F2 and F4) had a higher cohesiveness value, which significantly differed from the control cookies. High cohesiveness value indicates the maximum degree to which the cookies can be deformed before it shatters into pieces [14]. Springiness measures the degree to which the deformed cookies bounce back to their initial state. The incorporation of sweet potato at levels of 20% and 40% did not significantly affect the springiness of cookies as compared with the control cookies. However, Jauharah, Rosli, and Robert [29] reported that the springiness of food products tends to decline gradually upon storage due to the decreased amount of moisture introduced in the food products.

Regarding the chewiness value, the results showed that the chewiness value of control cookies was significantly different from the cookies from F1, F2, and F4. Based on the results, control cookies have the highest value of chewiness followed by PFSP cookies, and OFSP cookies. A higher value in chewiness may result in greater energy needed to chew the control cookies before swallowing.

4. Conclusion

Sweet potato cookies were successfully developed from the mixing blend of sweet potato and wheat flour. It was found that substitution of sweet potato for wheat flour significantly enhanced proximate composition, physical, and textural attributes of formulated cookies. Cookies prepared by the incorporation of sweet potato into wheat flour presented higher ash, carbohydrate, and moisture contents as compared to those formulated from 100% wheat flour. The incorporation of sweet potato to wheat flour increased the diameter and spread ratio of cookies but a decrease in weight was observed. For control cookies, the results demonstrated significant differences in color and hardness of cookies with increasing levels of sweet potato incorporation. The foregoing results of physicochemical and texture profile analysis of this study revealed that cookies containing 40% sweet potato which are F2 and F4 have the best overall nutritional quality. Therefore, it can be concluded that sweet potato could be a potential raw ingredient for the development of cookies or other functional food products with improved nutritional values. The utilization and emphasizing of nutritional advantage of sweet potato in the food industry by developing more nutritious food products are recommended.

Acknowledgment

This research work was supported by an external grant (R/ABIDA0700/01565A/002/2019/00697) from the Ministry of Agriculture and Food Industry (MAFI) and the authors would like to thank the lab technicians of the Faculty of Agro-Based Industry, University Malaysia Kelantan for their fruitful assistants and guidance on the research.

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