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PHYSICOCHEMICAL PROPERTIES OF FLOUR AND STARCH OF PURPLE WATER YAM (*Dioscorea alata*) TUBER AND THE DIFFERENCE ON SENSORY ACCEPTANCE OF THE COOKIES PRODUCED

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ABSTRACT

Purple water yam tubers (PWYTs) or Dioscorea alata are edible tubers containing bioactive compounds that are beneficial to human health. Its high carbohydrate content can be used to make flour or starch to increase its shelf life and food diversification. However, this food is unpopular among several communities in Indonesia, particularly for the juveniles due to limited processing knowledge. Therefore, this study aims to characterize the physicochemical properties of purple water yam flour (PWYTF) and starch (PWYTS) in order to assess consumers' acceptability toward gluten-free cookies. The PWYTF was prepared by drying peeled tubers, which was subsequently grounded. Meanwhile, the PWYTS was prepared by homogenizing the peeled tubers with water, the sediment from supernatant was dried. The chemical properties, such as moisture, ash, fiber, protein, and lipid, were determined using the Indonesian national standard procedures for flour. The physical properties, namely pH, bulk density (BD), water/oil absorption capacity (W/OAC), water/oil binding capacity (W/OBC), swelling power (SP) and solubility (Sol) were evaluated. The PWYTF and the PWYTS were used to make gluten-free cookies, with their physical properties and consumer's acceptability evaluated using semi-trained panelists. Yields of both the PWYTF and the PWYTS were 36.10% and 26.63%, respectively. The chemical compositions of the PWYTF and the PWYTS were significantly different ($p<0.05$) for carbohydrate (80.34 and 80.78 %), crude protein (0.78 and 0.81%), and crude fiber (2.0 and 1.9%) except for the ash content (2.6 and 0.5%), lipid (0.3 and 0.1%), and moisture (13.77 and 15.70%). Furthermore, their physical properties were also significantly different ($p<0.05$) for pH (6.62 and 5.84), BD (0.46 and 0.68 g/mL), WAC (2.07 and 0.46 g/g), WBC (1.07 and 0.49 g/g), SP, and Sol except OAC (1.63 and 1.49 g/g) and OBC (0.63 and 0.49 g/g). The cookies made from the PWYTS were appreciated with the highest hardness and rated from panelists. Therefore, the PWYTS can be used in place of a commercial wheat flour to make cookies..

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INTRODUCTION

Yam is the common name for edible tubers in the genus *Dioscorea* family. It is commonly found in the tropic and sub-tropic regions such as Africa, Asia, and Pacific countries (Zhu, 2015). One of the yams cultivated in Indonesia is uwi/water yam (*Dioscorea alata*). Varieties of water yam known in Indonesia are purple water yam (*Dioscorea alata* L. *var. Purpurea (Roxb)* M. Pouch), yellow water yam *(Dioscorea alata* L.), and white water yam (Rosida, Purnawati, & Susiloningsih, 2018, Wuryantoro, Puspitawati, Fitriyani, & Soni, 2019).

Several studies have been carried out to determine the nutritional value of water yam, such as moisture, ash, protein, fat, fiber, carbohydrate contents, minerals, and vitamins (Table 1b, Rosida et al., 2015; Hafsari, 2014; Baah et al., 2009; Obadina et al., 2014; Harijono et al., 2013; Awoyale et al., 2016; Alata et al., 2013; Rugchati, 2012; Nadia et al., 2015; Udensi et al., 2008; Fang et al., 2011; Riley et al., 2006; Winarti & Saputro, 2013). Water yam also contains high resistant starch and inulin, which acts as prebiotic (Winarti & Saputro, 2013; Rosida et al., 2018; Winarti & Saputro, 2013). Water yam cultivars also contain polyphenol (anthocyanin), dioscorin, diosgenin (steroid), vitamin, inulin, and carotenoid (Nadia et al., 2015; Harijono et al., 2013). Anthocyanin and carotenoid are responsible for the purple color in purple tubers. Dioscorin shows an immunomodulatory activity and antihypertension (Liu et al., 2007; Iu et al., 2009). Diosgenin can control cholesterol levels, anti-tumor activity (Roman, Thewles & Coleman, 1995; Shah & Lele, 2012). Meanwhile, starch and flour processing from fresh tuber affect its components such as proximate compositions, inulin, diosgenin, and dioscotin (Harijono et al., 2013).

Some people in Indonesia consume water yam boiled, steamed, and fried. It probably causes water yam is still categorized as unpopular food in Indonesia. This is due to the inadequate diversification of the food and poor knowledge of the health benefits. The act of processing water yam to cookies commonly practiced in Indonesia increases its utilization. Cookies are some of the most popular food products in the world, consumed by young and older adults. Therefore, diversification of purple water yam products is needed to increase its utilization and cultivation. The application of water yam flour to obtain gluten-free cookies can be used as an alternative by patients who have celiac disease. Besides, they also improve gut health due to inulin, which plays a prebiotic role. In this study, purple water yam was made into flour and starch to produce functional and free-gluten cookies, which evaluated consumers' acceptability.

METHODS

Sampling

Fresh purple water yam tubers (PWYTs) were collected from a farm located at Jl. Sultan Agung, Desa Rasau Jaya, District of Kubu Raya, Province of West Kalimantan on February 12^{th}, 2018.

Flour preparation

The fresh PWYTs were peeled and sliced to approximately 2-5 cm^2 without washing and dried under sunlight for 6-8 hours i.e., from 9 am to 3 pm. Subsequently, the dried PWYTs were ground using a blender (National Omega) and sieved with 100 mesh sizes. The yield percentage of PWYT flour (PWYTF) was calculated as follow:

$$Yield\,\% = \frac{Flour\ or\ starch\ weight\ (g)}{Fresh\ tuber\ weight\ (g)} x100\%$$

Starch preparation

The fresh PWYTs were peeled, washed, cut diced, and homogenized with water using a blender. Meanwhile, the slurry was squeezed with fine cotton. These steps were continuously carried out until a clear filtrate is obtained, combined and incubated overnight to gain clear supernatant and sediment. In addition, the residue was dried under the sun for 6-8 hours, and sieved with 100 mesh sized. The outcome is called a PWYTS, with the yield percentage calculated using the formula for flour preparation.

Chemical analysis

The moisture, ash, and fiber contents were analyzed using the Indonesian national standard (SNI) 01-3751-2009 method (SNI, 2009). Crude lipid content was determined using *Extraction Unit* E-816 (*Buchi*) and the manufacturing procedure. The solvent used to extract lipid from the sample was *petroleum benzene*, while the protein content (Nx6.25) was determined using

Automated Kjeldahl Analysis from KjelMaster K-375 (Buchi). The procedure used for this analysis was recommended by the manufacturer. The carbohydrate content calculated as follows:

Carbohydrate percentage = 100% - (protein + lipid + ash+ water)x100%.

Physical Analysis

Bulk density (BD)

A 7 g of the sample was poured in a 50 mL graduated cylinder and gently tapped until flat. The sample volume was recorded, with BD calculated as the sample weight per volume (g/mL).

pH

A 1 g of sample was added to 4 mL of aquadest and mixed using a magnetic stirrer for 5 mins, with the pH meter used to measure the pH value.

Water absorption capacity (WAC) and water-binding capacity (WBC)

WAC was determined using Bashir et al. (2017) procedure. A 3 g of sample was resuspended with mL of aquadest and shaken using an orbital shaker (Kyntel KS501) at 100 RPM for 30 min and at room temperature. The suspension was then centrifuged at 3000 RPM for 30 min, then the supernatant was removed, and the wet pellet was weighed. WAC and WBC were expressed as follows:

$$WAC\ (g/g) = \frac{wet\ pellet\ weight(g)}{dry\ sample\ weight(g)}$$

$$WBC\ \left(\frac{g}{g}\right) = \frac{wet\ pellet\ weight - dry\ sample\ weight}{dry\ sample\ weight}$$

Oil absorption capacity (OAC) and oil binding capacity (OBC)

OAC was carried out in accordance with Bashir et al. (2017) procedure. A 0.5 g of sample was added with 6 mL of palm oil (Bimoli merk) and mixed using a magnetic stirrer for 1 min. The sample was allowed to stand for 30 mins then centrifuged at 3000 RPM for 15 mins. The supernatant was decanted, and the wet pellet was weighed. OAC and OBC were calculated as follows:

$$OAC = \frac{wet\ sample\ weight\ (g)}{dry\ sample\ weight(g)}$$

$$OBC\ \left(\frac{g}{g}\right) = \frac{wet\ pellet\ weight - dry\ sample\ weight}{dry\ sample\ weight}$$

Swelling power (SP) and solubility (Sol)

SP and Sol were carried out following a modified procedure described by Leach et al. (1960) and Anderson, Conway & Peplinski (1970). A 0.1 g of sample was added with 10 mL of aquadest, mixed with a magnetic stirrer for 30 min. Then, the suspension was heated at different temperature of 65 °C, 75 °C, 85 °C, and 95 °C for an hour. After it was cooled, the suspension was centrifuged at 1.731 x g for 15 minutes. Then the supernatant was carefully removed from the pellet into a new container, dried using an oven at 110 °C, and weighed until constant. Furthermore, the pellet was air-dried for 10 min to remove excess supernatant. The Sol percentage and the SP were calculated as follows:

$$Sol\ (\%) = \frac{dry\ supernatant\ weight\ (g)}{dry\ sample\ weight\ (g)} x\ 100$$

$$SP\ \left(\frac{g}{g}\right) = \frac{wet\ pellet\ weight(g)}{dry\ sample\ weight\ (g) - dry\ supernatant\ (g)}$$

Preparation and evaluation of the cookies

Cookies made from the PWYTF, the PWYTS and the commercial wheat flour (CWF, Segitiga Biru merk), were a positive control. The recipe for these cookies consisted of margarine (200 g, blue band), flour (150 g), granulated sugar (42 g), and a whole egg. Margarine and fine granulated sugar were stirred using a hand mixer for 3-7 min before the flour was added and blended until a smooth dough was obtained. The smooth dough was rolled out into a thin sheet and molded using a specific mold. Finally, the cookies were baked at 180 °C until they turned light golden brown.

Physical properties of the cookies

The physical properties of the cookies were evaluated for the hardness of each using a *texture analyzer* TA-XT plus.

Sensory evaluation of cookies

The cookies were assessed for consumer's acceptability using 30 semi-trained panelists. The criteria used to evaluate 'consumers' acceptability were taste, performance, color, aroma, and texture. Furthermore, the cookie preference was measured using a nine-point hedonic rating scale, with the data analyzed using the Analytical Hierarchy Process (AHP) model.

Statistical Analysis

The experiments were performed using a completely randomized design for physicochemical properties between the flour weight and starch. Results were presented as mean ± SD (standard deviation). All of the experiment was conducted three times. Furthermore, the differences among the means were counted by paired-samples T-test with a 95% significance level ($p < 0.05$) using the IBM SPSS statistics 23 software.

RESULTS AND DISCUSSION

Preparation of the PWYTF and the PWYTS

The color of the fresh PWYTs (FWYTs) obtained from an anthocyanin pigment is purple (Figure 1). Drying the PWYTs under the sun during the flour preparation process changed the color from purple to cream (Figure 1). This change in color was probably caused by the thermally unstable anthocyanin (Jiang et al., 2019). The dried PWYTs (DPWYTs) were grounded, which generated the peach color of flour and called PWYTF with a pleasant smell and a rough texture.

The PWYTS was prepared by homogenizing PWYTs in water to obtain a purple slurry suspension, due to the release of anthocyanins from starch granules. The anthocyanins were water-soluble pigments (Khoo, 2017). As a result, the sediment is white and odorless and is called the PWYTS (Figure 1).

The yields (wet sample basis) of PWYTF and the PWYTS were categorized low at 36.10%±1.00 and 26.63%±0.83, respectively. This is caused the PWYTs contain high water content, with the average PWYTS yield relatively higher than the starch yield reported by Jayakody et al., at 11.52% (Jayakody & Hoover, 2007; Zhu, 2015). However, the starch yield value was affected by the purity level of the starch.

Chemical compositions of the PWYTF and the PWYTS

The PWYTF and the PWYTS in this study contain high carbohydrate content, which is the general character of flour and starch. Furthermore, they were categorized as high moisture and low protein content, which was different than some references (Table 1). *Dioscorea* sp. generally contains low protein content, which is suitable to make cookies, cake, and pie crusts (Awoyale et al., 2016). Ash, lipid, and fiber of the PWYTS were significantly lower ($p<0.05$) than those of the PWYTF and different from the references. The ash content can be used to describe the number of minerals in the foodstuff. It can also be used to assess the purity of the starch besides microscopic examination (Jayakody & Hoover, 2007). The low ash content of the starch indicates its high purity value. Furthermore, the ash content of the PWYTS was within the range reported for most water yam tuber starch. The crude lipid and the ash content significantly decreased during starch extraction from the PWYT compared to the PWYTF.

The purple water yam in this study was cultivated in peat soil with a low C/N ratio, thereby leading to the low protein content of both the PWYTF and the PWYTS. The variation of chemical composition among reported water yam tuber flour and starch was caused by different flour or starch processes. For example, preparing *D. alata* flour using parboiled and soaked tuber (Obadina et al., 2014) or cooked (Hsu et al., 2003). Some processing in starch extraction were carried out using 0.75% sodium metabisulfite solution, 10% toluene, 80% ethanol and 0.1% NaOH (Rugchati, 2012), 0.05 M NaOH solution (Farhat et al., 1999). Furthermore, 1 M NaCl was used in the homogenization of tuber (Riley et al., 2006; Nadia et al., 2013). Besides, different cultivars, tuber size, soil, location, maturity at harvest, and particle size generally cause different chemical compositions of food commodities. Water yam flour, and starch are produced using different strategies, and this tends to affect chemical and physical properties (Table 1,Table 2). In this study, the PWYTF was prepared by drying tuber under the sun. The fat content of PWYTF and PWYTS in this study was very low and insignificantly different from others (Table 1). However, the carbohydrate content was approximately 80% and categorized high.

Physical properties of the PWYTF and the PWYTS

The physical properties of the PWYTF and the PWYTS were focused on BD, pH, WAC, WBC, OAC, OBC, SP, and solubility (Table 2). These properties are related to the chemical properties to describe the interactions which occur in food. The interactions of components in food during preparation, cooking, and sensory evaluation, such as appearance, texture, structure, and tastes, are called functional properties (Godswill et al., 2019). Protein plays a pivotal role in the interaction of food products (Mattil, 1971). The other components that influenced the functional properties are carbohydrates, fats, oils, moisture, fiber, ash, food additives, and ingredients (patulin) (Godswill et al., 2019). Furthermore, the functional properties are responsible for the overall quality, sensory perception, and manufacture of products (Taylor et al., 2014).

BD is important to predict the relative volume of the packaging. The PWYTS had significantly higher BD than the PWYTF due to the increased moisture content (Table 2a). The BD value was affected by particle size, moisture content, surface properties, the solid density of the material, and starch content (Chandra et al., 2015; Godswill et al., 2019). The high BD value of the PWYTS can be used as a thickener in food preparation.

Figure 1 FPWYTs: The fresh purple water yam tubers. PWYTs: The dried purple water yam tubers. PWYTF: The purple water yam tuber flour. PWYTS: The purple water yam tuber starch.

Table 1 Chemical compositions of water yam flour and starch

a. This study

Sample	Percentage of					
	Carbohydrate	Ash	Lipid	Moisture	Protein	Fiber
FPWYTF	80.34±0.27[a]	2.69±0.02[a]	0.37±0.02[a]	13.77±0.04[a]	0.78 ±0.13[a]	2.05±0.30[a]
PWYTS	80.78±0.27[a]	0.54±0.05[b]	0.19±0.01[b]	15.70±0.13[b]	0.81±0.16[a]	1.99±0.19[a]

Mean±SD of three replicates. Mean value with the different superscripts within a column are significantly different(P>0.05). n=3. PWYTF: Theurple water yam tuber flour. PWYTS: The purple water yam tuber starch.

b. Previous study

Sample	Percentage of						References
	Carbohydrate	Ash	Lipid	Moisture	Protein	Fiber	
Purple WYT flour	ND	3.62±0.07	0.49±0.02	4.40±1.01	8.33±0.02	5.73±0.12	(Harijono et al., 2013)
Blanching purple WYT flour	ND	2.36±0.05	0.42±0.01	5.24±1.51	6.84±0.07	4.44±0.24	(Harijono et al., 2013)
WYT flour	78.12-83.76	1.33-3.75	0.01-0.77	6.81-11.26	4.48-9.85	ND	(Nadia et al., 2015)
WYT starch	81.6-87.6	2.25-3.15	0.75-1.10	5.26-7.57	5.69-8.31	0.75-1.13	Udensi et al., 2008
WYT starch, mun jao dieng	ND	0.6	0.02	ND	0.6	0.12	Rugchati, 2012
WYT starch, mun lead	ND	0.29	0.29	ND	0.42	0.01	Rugchati, 2012
WYT starch	53.70	2.04	0.32	ND	ND	ND	Fang et al., 2011)
WYT starch	ND	0.17-032	0.28-0.30	8.25-8.75	ND	ND	Jayakody & Hoover, 2007

WYT: water yam tuber. ND: Not determined

Table 2 Physical properties of water yam flour and starch

a. This study

Sample	BD, g/mL	pH	WAC, g/g	WBC, g/g	OAC (g/g)	OBC, g/g
The PWYTF	0.46±0.02[a]	6.62±0.31[a]	2.07±0.05[a]	1.07±0.01[a]	1.63±0.05[a]	0.63±0.04[a]
The PWYTS	0.68±0.02[b]	5.84±0.03[b]	0.46±0.05[b]	0.49±0.09[b]	1.49±0.09[a]	0.49±0.09[a]

Value: Mean±SD of three replicates. Mean value with the different superscripts within a column are significantly different (*P*>0.05). n=3; PWYTF: The purple water yam tuber flour. PWYTS: The purple water yam tuber starch.

b. Previous study

Sample	BD, g/mL	pH	WAC, g/g	WBC, g/g	OAC (g/g)	OBC, g/g	References
Parboiled WYT flour	ND	6.4	1.33±0.04	0.33±0.04	ND	ND	Obadina et al., 2014
Purple WYT flour	ND	ND	1.88±0.04	ND	1.11±0.07	ND	Harijono et al., 2013
Blanching purple WYT flour	ND	ND	1.64±0.07	ND	1.06±0.09	ND	Harijono et al., 2013
WYT starch	0.64-0.76	ND	2.90-3.20	ND	ND	ND	Udensi et al., 2008

WYT: Water yam tuber. ND: Not determined.

The pH of flour or starch plays an essential role in the storage life and taste of food. The pH also tends to affect taste perception, making it sour or bitter. The pH values of the PWYTF and the PWYTS were 6.62 and 5.84, respectively (Table 2a). However, these values were categorized as low pH, although the tastes were not sour for both. However, it might even allow microorganisms to grow.

WAC, WBC, OAC, and OBC play a pivotal role in the sensory perception of food products, such as the mouthfeel, texture, flavor, and moisture (Taylor et al., 2014; Köhn et al., 2015). WAC/WBC was defined as the quantity of the water/oil retained in hydrophilic substances, while W/OBC was the ability to absorb and entrap water/oil in a material. Therefore, the WAC is vital to food formulation, such as in improving dough handling and cohesiveness on bakery products such as bread, cake, and cookies (Kiin-Kabari et al., 2015; Boakye & Essuman, 2016). WAC and WBC described the hydration properties of the materials that can make food products more moist, dry, or brittle. The W/OAC and W/OBC of the PWYTF were significantly higher values than those of the PWYTS (Table 2a). The W/OAC value also depended on the presence of polar/nonpolar side chains that form hydrophilic/hydrophobic interactions between the amino acid and hydrophilic chains of protein/hydrocarbon chain of lipids, respectively. OAC and OBC tend to develop the mouthfeel in food preparation (Chandra, 2013). Different varieties of water yam and granule structure can cause different WAC values (Udensi et al., 2008; Jiang et al., 2013).

The swelling of the substances occurred due to the uptake of water, known as absorption. Solubility is defined as the ability of substances to dissolve in the liquid solvent. The high solubility of food can be described as the ease indigest(Godswill et al., 2019). SP and Sol can also be used to describe the gelatinization of the starch or flour granules (Zhu, 2015). SP and Sol of the PWYTF showed higher value than those of the PWYTS, but overall they had a similar pattern, which decreased from 65 °C to 75 °C and increased from 75 °C to 95 °C (Figure 2). When flour or starch is heated in excess water, it tends to break the hydrogen bonds of their crystalline structure thereby exposing the hydroxyl group of amylose and amylopectin to water (Eliasson, 2004; Moses & Olanrewaju, 2018).

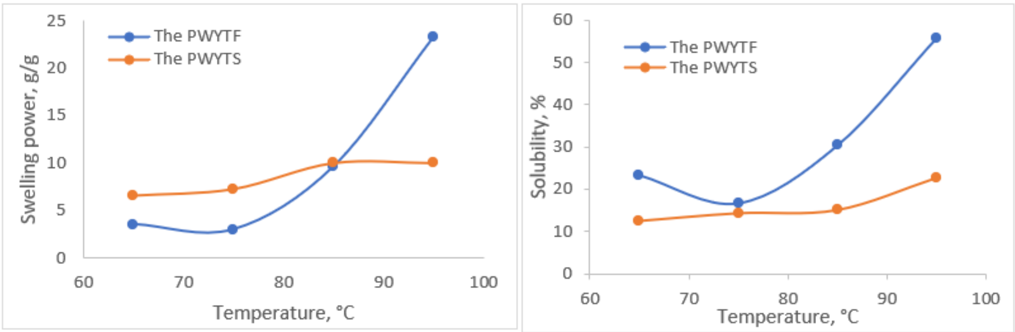

Figure 2 SP and Sol of the purple water yam tuber flour (the PWYTF) and starch (the PWYTS)

Figure 3 The cookies prepared from. CWF: The commercial wheat flour. PWYTS: The purple water yam tuber starch. PWYTF: The purple water yam tuber flour

Physical properties of the cookies

The necessary physical characteristics of cookies are taste, crispness, and ease to eat (Chauhan et al., 2016). The crispness and hardness textures are essential parameters used to assess the cookie freshness and distinguish it from the other bakery products. The hardness of the cookies prepared from the CWF, PWYTS, and PWYTF are measured using a texture analyzer known as TA-XT plus. Furthermore, the cookies made from the PWYTS have the highest hardness value than others (Figure 4). It was caused by the low WAC/WBC value of the PWYTS, which causes imperfection of the gelatinization or pasting process during baking.

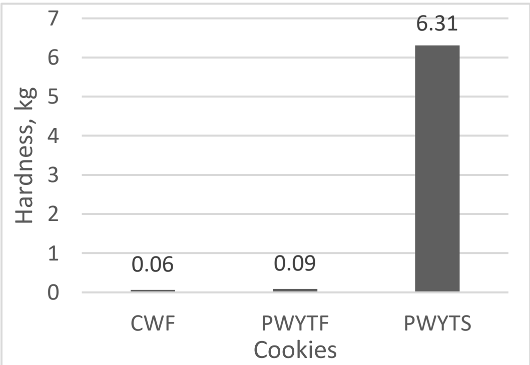

Figure 4 The cookies hardness measured using a texture analyzer TA-XT. The cookies made from the commercial wheat flour (CWF), the purple water yam tuber flour (PWYTF) and the purple water yam tuber starch (PWYTS).

Color can be used to assess product quality. The color is formed as a result of physical or chemical interactions that occur during the baking. The cookies prepared from the commercial wheat flour, the PWYTS, and the PWYTF showed different appearances and colors. This was peculiar with those made from the PWYTF, which contained anthocyanins (Figure 4).

Sensory Evaluation of the Cookies

The sensory evaluation of the cookies was determined using the AHP technique to analyze the consumer's acceptability. Some criteria used for the sensory evaluation are taste, aroma, appearance, color, mouth sensation, and texture attributes. However, out of these criteria, four were considered important by the bakery chefs, namely taste, aroma, appearance, and texture, in accordance with their dominancy from high to low. The cookies prepared from the PWYTS obtained the highest rating for three of four criteria, which were taste, appearance, and texture (Table 3). The texture rating indicated a similar trend with its hardness result (Figure 4). The cookies prepared from the PWYTF and CWF exhibited the second and the third-highest ratings, with a similar overall criteria score.

Table 3 Sensory evaluation of the cookies using the AHP technique

Cookies prepared from	Criteria score of				Overall criteria score
	Taste	Aroma	Appearance	Texture	
The CWF	0.3174	0.3431	0.2852	0.3071	0.3167
The PWYTS	0.3752	0.2857	0.4282	0.4191	0.3674
The PWYTF	0.3074	0.3712	0.2866	0.2738	0.3159
Dominant Criteria	0.3500	0.2860	0.1974	0.16665	

CWF: Commercial wheat flour. PWYTS: Purple water yam tuber starch. PWYTF: Purple water yam tuber flour.

CONCLUSION

In conclusion, the PWYTF and the PWYTS showed significant differences ($p<0.05$) in their chemical compositions and physical properties, particularly in carbohydrate (80.34 and 80.78 %), crude protein (0.78 and 0.81%), crude fiber (2.0 and 1.9%), pH (6.62 and 5.84), BD (0.46 and 0.68 g/mL), WAC (2.07 and 0.46 g/g), WBC (1.07 and 0.49 g/g), SP, and Sol. However, their ash content (2.6 and 0.5%), lipid (0.3 and 0.1%), moisture (13.77 and 15.70%), OAC (1.63 and 1.49 g/g) and OBC (0.63 and 0.49 g/g) contents were exempted. The cookies made from the PWYTF and the PWYTS also obtained different characteristics based on the physical properties and consumers' response. The best physical properties and the consumer's responses were obtained from the cookies made from the PWYTS. Therefore, it can be used as an alternative flour to make gluten-free cookies that can be consumed by celiac disease patients.

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