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Preparation and Improved Quality Production of Flour and the Made Biscuits from Purple Sweet Potato

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Abstract

Among varieties of flesh color, purple-fleshed sweet potatoes have been increasingly paid attention to the basis of the nutritional aspects as they are excellent sources of powerful natural antioxidants of which, provide various health beneficial effects. Then as a consequence, a successful combination of purple sweet potato flour with wheat flour for biscuits production would be nutritionally advantageous. In this study, purple Sweet potato flour of variety HL491 was incorporated with wheat flour in ratio of 10%, 20%, 30%, 40% and 50%. The physico-chemical analysis and sensory evaluation were done to know the acceptability of developed biscuits. On the basis of nutritional value, biscuits containing 40% and 50% sweet potato flour had significantly higher ash, fiber and total flavonoid content than those the control samples. At the same time, the sensory evaluation brought the scores of biscuits containing 40% and 50% sweet potato flour which were significantly higher than those of the control biscuits in all attributes, respectively. The obtained results of this study have indicated that the developed biscuits were not only improved in terms of nutritional value and health benefits, but also had high potential of being accepted by consumers.

Keywords: Purple sweet potato flour, sweet potato biscuits, physicochemical analysis, sensory evaluation, nutritional values, functional foods

Introduction

The sweet potato (Ipomoea batatas (L.) Lam.) is a starchy, sweet-tasting root vegetable that belongs to the Convolvulaceae family. The statistical data of the United Nation's Food and Agriculture Organization (FAO) shows that sweet potato is the fifth and the seventh most important food crop in the developing countries and the world. More than 130 million tons of sweet potato are produced annually of which over 95% of the crop is produced in Asia developing countries. The sweet potato has become well established with a large potential for, and to be used as a staple food in developing nations due to its short maturity time, ability to grow under diverse climatic conditions and relatively poor soils [1]. Viet Nam has a long history of sweet potato cultivation, mostly by small- scaled farmer, and so, it has been recognized as the sixth most producer of this kind of crop with the yield was of 1.4 MT in 2014. Fresh roots are bulky and highly perishable, hence, the need to fully utilize the indigenous crops should be considered. One of good ways to minimize post-harvest losses is through processing sweet potato's tubers into flour, making them become more stable intermediate product to increase the utilization of the abundant fresh crops [2]. Sweet potato flour can be added to natural sweetness, color, and flavor to food products and used as starting material for production of noodles, bread, biscuits, snacks, alcohol beverages, etc. [3]. Further research on the potential of incorporating the sweet potato flour to develop as well as to improve processed food products has already been taken. Orange, yellow, white flesh sweet potatoes and the derived flour were the common subjects of those studies have also been done so far [4-6] .

According to Aniedu and AgugoTrejo-Gonzáleand Oluwalana et al, [7,8] a substitutional level of 10-15% sweet potato in bread making was the most acceptable based on the sensory properties. The higher proportion of sweet potato flour can be incorporated in the formulation of cake,and at a ratio of 30% the physicochemical properties and nutritional values of the product have been improved [9].

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The study on the suitability of making noodles from wheat-sweet potato composite flour [10] showed that a replacement of 25% of sweet potato flour with good textural and sensory quality could be used for the development of variety and enhanced nutritious noodles. Other experiments were also conducted to study the effects of incorporating sweet potato flour to wheat flour in producing biscuits. They have been focused on increasing the nutritional value and developing biscuits with good taste, texture and appearance, which resemble as closely as possible to the wheat flour based [11]. The most acceptable level of substitutional sweet potato flour was up to 40- 50%. However, the results showed that the customer preference score of wheat- based biscuits was significantly higher than the score of products made from the wheat- sweet potato flour [12].

Over the past few years, the confectionery industry in Vietnam has had a high and stable growth rate. The average annual revenue growth rate of the confectionary industry in 2006-2014 was 25%, It has been forecasted that from 2015 to 2019 the growth rate will be around 8-9%, at least (Agrofood Research Report, EU- Vietnam Business Network, STINFO 12-2015).

Biscuits have been one of the oldest baked goods and consumed extensively all over the world by all age groups. The popularity of biscuits comes from their attributes such as high palatable, dense nutrients, quickly released energy and available in convenient sizes as well as in various forms. In addition, the biscuits formulation can be modified easily to meet the nutritional demands of the target consumers (Ashaye, Olanipekun et al. 2015). Since biscuits are dried to low moisture content, and this can ensure their longshelf life storage, and especially free from microbial spoilage (Okaka 2005). Being faster in the growth of the biscuits manufacturing, there is a huge scope of research on diversification of this baked product in Vietnam (Agrofood Research Report, EU- Vietnam Business Network, STINFO 12- 2015).

The attention on functional foods consumption by World nutritional bodies due to different health problems has increased significantly (Chinma et al., 2012). Functional foods and beverages are natural products enriched or balanced with biologically active components which offer the high potential of enhanced health or reduced risk of disease (Hafez 2014). Specifically, minerals, vitamins, fatty acids, dietary fiber, phytochemicals and antioxidants or probiotics are enriched components that are commonly added to these food products for specific purposes. With the all mentioned information above, purple sweet potatoes, of which containing abundant nutrients, minerals, and polyphenols can be used as an excellent functional food material [13].

Carbohydrates, the main nutritional material in sweet potato, have a low glycemic index wich indicates the low digestibility of the starch while providing the quick energy to human cells' need without the negative side effects that accompany other energy-dense foods, such as wheat, rice, and corn (Ashley Tudor, 2012).

The tuber of sweet potato contains no saturated fats or cholesterol and is a rich source of dietary fiber. Substantial quantities of beta-carotene (a pro-vitamin A carotenoid), vitamin B complex (thiamin, riboflavin, and niacin) vitamin C, and vitamin E along with moderate amount of essential minerals and trace elements including iron, potassium, calcium, zinc, sodium and magnesium are required by the body to function properly (Krochmal-Marczak, Sawicka et al. 2014). Studies [14-17] have shown thatsweet potatoes are excellent sources of flavonoid compounds and phenolic compounds, which are powerful natural antioxidants and can serve as useful indicators for the antioxidant activities of sweet potatoes. Some of the best known are flavonoids include quercetin, kaempferol, catechins, and anthocyanidins. Flavonoids have received considerable attention because of their beneficial effects as antioxidants in the prevention of human diseases such as cancer and cardio vascular diseases, and some pathological disorders of gastric and duodenal ulcers, allergies, vascular fragility, and viral and bacterial infections [18,19].

There are varieties of flesh color of sweet potatoes, ranging from pure white through cream, yellow, orange and claret, to a very deep purple (Diop and Calverley 1998). Among varieties of flesh color, purple-fleshed sweet potatoes have attracted lots of attention in the basis of nutrition as they are excellent sources of phytochemical [20]. The darkish color of purple sweet potato is contributed by phenolic pigment called anthocyanins. Anthocyanins are members of the flavonoid group of phytochemicals which have the outstanding antioxidant activity as well as anti-inflammatory properties, particularly when passing through our digestive tract [21,22]. In food processing, anthocyanins can be used as natural colorants due to their high heat and light stability [23]. However, the provided information has shown that less is known about the flour derived from the purple sweet potato cultivar and its application in processed food products, especially in Vietnam. As the sixth most producer of sweet potato in the world, it is very important to maximize the utilization of the tuber as a source of natural food material to increase its consumption.

Though, numerous studies on the evaluation and utilization of sweet potato flour have been conducted as mentioned above, there is no information about how to prepare and improve the quality of flour and the made biscuits from purple sweet potato. So, it is scientifically and economically important to know whether the made flour from purple sweet potato can be used for the production of high quality biscuits with improved nutritional values. Also, consequence of various proportion of purple sweet potato (gluten free flour) to wheat flour in biscuits formation needs to be determined in order to make high quality final biscuits products. In summary, this study has been conducted to determine the suitable process for preparation and possibly improved quality production of flour and the made biscuits from the Purple Sweet Potato.

Materials and Methods

Research object and location

20kg purple sweet potatoes of variety HL 491 without any bruises were procured from a local market in Ho Chi Minh City.

Figure 1. Purple sweet potatoes of variety HL 491 used in this study

Other major ingredients needed to prepare biscuits such as wheat flour, sugar, baking powder, and butter were obtained from Nhat Huong Company, Ho Chi Minh City, Vietnam. Chemicals used in sample analysis such as hydrochloric acid, potassium chloride, methanol, hexane, etc were purchased from local agents in Vietnam.

The experimental studies were carried out in laboratories of Food technology department of International University – Vietnam National University in Ho Chi Minh City.

Preparation of purple sweet potato flour

The purple sweet potatoes were washed, trimmed and pealed to make them free from soil, rotting or insect damage. They were cut into 3cm thickness cubes before being steamed for 15 minutes. Sweet potato cubes were mashed, spread evenly on different trays, and then dried at 65°C for 24h. The dry samples were milled into flour using the laboratory grinder and passed through 250 μm sieve to obtain uniform sized flour. The flour was then packed in sealed plastic bag and stored at ambient temperature till further used.

Preparation of Wheat- Sweet potato biscuits

The Wheat- Sweet potato flour composites were prepared at different ratios (of 100:0; 90:10; 80:20; 70:30; 60:40; and 50:50) with other ingredients were weighed accurately as the formulations shown in Table 1. Shortening and sugar were creamed in a mixer before the homogenized mixture of dried ingredients was added. Smooth dough was formed and rolled to a 3-5mm sheeted size with the help of a rolling pin.A round cutter of 4cm diameter was used to create a uniform shape for all biscuits. Then, they were transferred to a lightly greased baking tray and baked at 165oC for 13 minutes in a preheated oven.

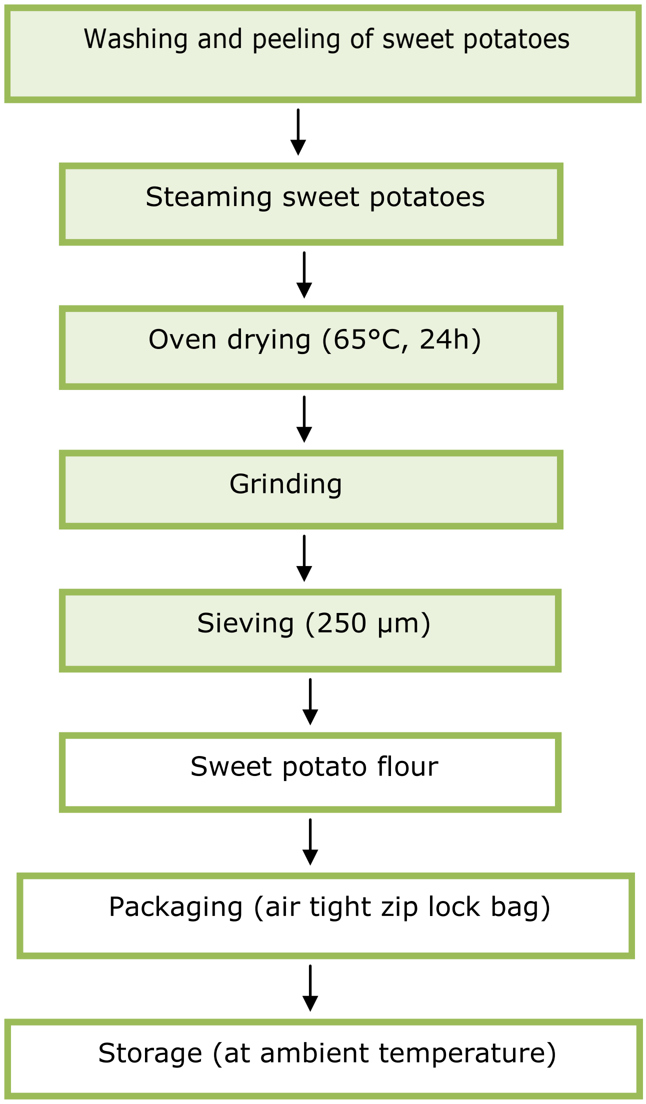

Figure 2: Flow chart for the preparation of sweet potato flour

After baking, all biscuits were allowed to cool completely (about 30 minutes) and stored in air tight containers for 12 hours before further analysis.

As shown in the all well prepared tables, A is symbol marked biscuits produced from 100% wheat flour. Similarly B is marked biscuits produced from 90% wheat and 10% sweet potato flour, C is marked biscuits produced from 80% wheat and 20% sweet potato flour, D is marked biscuits produced from 70% wheat and 30% sweet potato flour, E is marked biscuits produced from 60% wheat and 50% sweet potato flour, and F is marked biscuits produced from 60% wheat and 50% sweet potato flour.

A = 100: 0 ratio of wheat- sweet potato flour in biscuits
B = 90: 10 ratio of wheat- sweet potato flour in biscuits
C = 80: 20 ratio of wheat- sweet potato flour in biscuits
D = 70: 30 ratio of wheat- sweet potato flour in biscuits
E = 60: 40 ratio of wheat- sweet potato flour in biscuits
F = 50: 50 ratio of wheat- sweet potato flour in biscuits

Ingredients	Samples (g)					
	A	B	C	D	E	F
Wheat flour	100	90	80	70	60	50
Sweet potato flour	0	10	20	30	40	50
Powdered sugar	15	15	15	15	15	15
Butter	40	40	40	40	40	40
Baking powder	1.5	1.5	1.5	1.5	1.5	1.5
Salt	0.5	0.5	0.5	0.5	0.5	0.5

Table1. Ingredients used in the preparation of biscuits

Preparation of composite flour (wheat flour: sweet potato flour) at different ratios

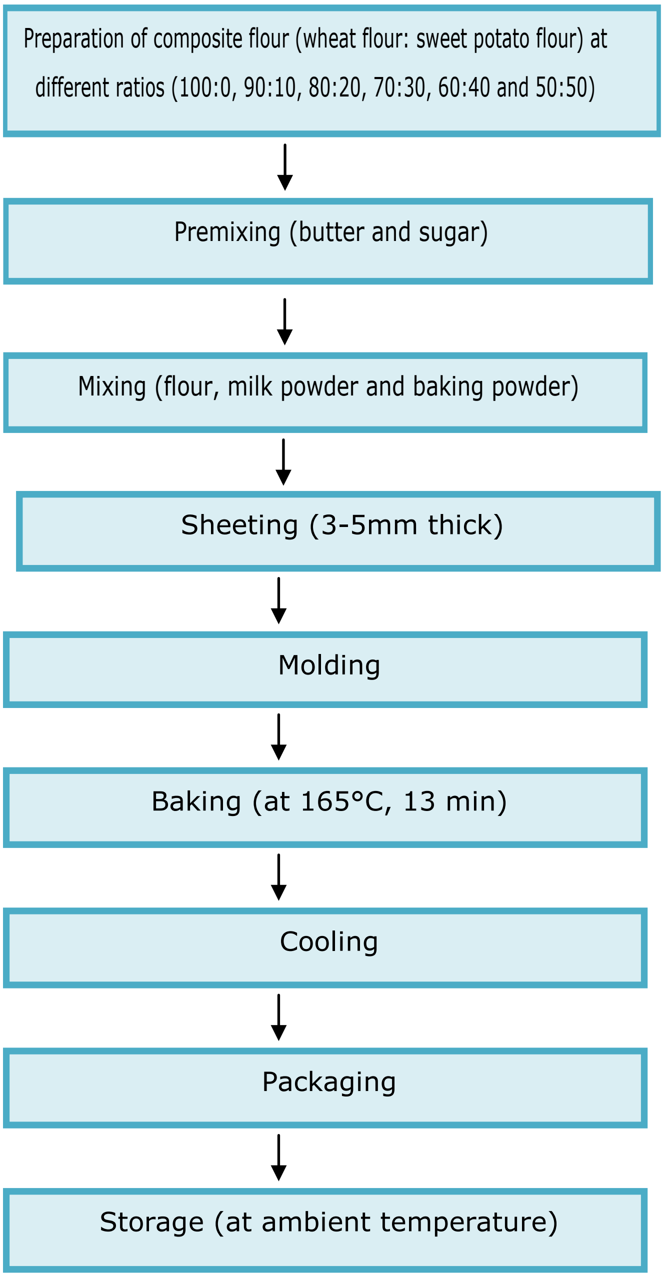

Figure 3. Flow chart for the preparation of biscuits

Proximate analysis of sweet potato flour

The proximate analysis of the composite flours and biscuits moisture, protein, ash, fiber and fat content were determined to the methods described by A.O.A.C (2012). Total carbohydrates were calculated by difference (AOAC, 1990).

Moisture content: The flour sample (3g) was taken in a pre-weighed porcelain crucible, was dried to constant weight at 105°C for 14 hours. Loss in weight was taken as the moisture content of the sample (AOAC, 2012).
% Moisture = Weight loss (g) x 100 / sample weight (g)

Ash content

The crucibles containing 5g of sample was charred on a heater before kept in the muffle furnace at 550oC for 4 hours until only white matters can be seen. Then, the crucible with ash content was then cooled in a desiccator and weighed accurately to a constant weight (AOAC, 2012).

Fat

Fat content was determined by extracting 3g of sample with hexane using soxhlet apparatus for 6 hours. The residual hexane was removed from the extracted sample by evaporation. The extracted fat was then dried and weighed (AOAC, 2012).

Protein

Protein content was analyzed by using the Kjeldahl method according to the AOAC methods (2012). 1g of sample was placed in a digestion tube; 0.2g $CuSO_4$, 1g K_2SO_4, and 20ml concentrated H_2SO_4 were added to the tube with sweet potato flour. The sample was let digested on digestion block until white fumes can be seen and continue heated for about 60 – 90 minutes until cleared with no charred material remaining. Tube was placed in the distillation apparatus and 50ml NaOH 32% was added. The ammonia in the sample was steam- distilled for 5 minutes into a receiving flash containing 4% boric acid. The sample was titrated with H_2SO_4 0.1N solution. The protein was calculated by the equation: %Nitrogen x

Crude fiber

Crude fiber was determined following the approved AOAC method 962.09. Crude fiber is loss on ignition of dried residue remaining after digestion of sample with 1.25% H_2SO_4 and 1.25% NaOH solutions under specific conditions. 2g of each sample was extracted with ether or petroleum ether and transferred to beakers of ceramic fiber mixture. Two beakers of ceramic fiber mixture for each sample were prepared as follows: 1.5 g dry weight of sample was added to each 100 ml beaker, then 60-75 ml 0.255N H_2SO_4 was added to each beaker and allowed to soak. Beakers were placed on digestion apparatus with pre-adjusted hot plate and boiled exactly 30 minutes. Contents of beaker were filtered through Buchner funnel (pre-coated with ceramic fiber if extremely fine materials are being analyzed).

Beaker was rinsed with 50-75 ml boiling H2O and washed through Buchner funnel. Residue was removed before 200 ml 1.25% NaOH was added and boiled exactly 30 minutes. Contents was filtered and then washed with 25 ml boiling 1.25% H2SO4, 50 ml H2O and 25 ml alcohol. Residue was transfer to ashing dish, dried for 2 hours at 130± 2o C. Then, it was cooled in desiccator and weighed. Residue was ignited 30 minutes at 600 ± 15oC and cooled in desiccator before being reweighed.

% Crude fiber in ground sample = C = (Loss in weight on ignition loss in weight of ceramic fiber blank) x 100- weight sample

Carbohydrate

Total carbohydrate was determined by the difference[24]

% Carbohydrate = 100 – % (protein+ fat + ash+ fiber + moisture)

Functional properties analysis of the flour samples

Bulk density: Bulk density was determined following the method described by Eleazu and Ironua (2013) and Onabanjo and Dickson (2014). A (10ml) graduated cylinder, previously tarred, was gently filled with 5g of sample. The bottom of the cylinder was gently tapped on a laboratory bench several times until there was to a constant. The bulk density of the sample (g/ml) was calculated as weight of the sample per unit volume of sample.

Water Absorption Capacity (WAC): The WAC of the sample was determined using the method as described by Eleazu and Ironua (2013) and Onabanjo and Dickson (2014) with minor modification. A measured quantity (1g) of the sample was dispersed in 10 ml of distilled water in a conical graduated centrifuge tube. The sample was thoroughly mixed for 30 seconds and allowed to stand at room temperature for 30 minutes before being centrifuged at 4000 rpm for another 20 minutes. The volume of the supernatant was measured directly from the graduated centrifuge tube. The amount of the absorbed water was multiplied by the density of water (1 g/ml) and results were expressed as g/100 g.

Oil Absorption Capacity (OAC): Oil absorption capacity of the flour was determined using the method as described by (Adepeju, Gbadamosi et al. 2011) and (Eleazu and Ironua 2013). One gram of sample was mixed with 10ml of pure canola oil for 60 seconds. The mixture was set to stand for 10 minutes at room temperature, centrifuged at 4000rpm for 30 minutes and the oil that separated was carefully decanted. The tubes were allowed to drain at an angle of 45° for 10 minutes and then weighed. Oil absorption was expressed as percentage increase of the sample weight.

Proximate analysis of developed biscuits

Moisture, fiber, ash, and fat content of prepared biscuits were determined by the same methods used for sweet potato flour analysis.

Assay of flavonoids of developed biscuits

Extract preparation

Total phenolics were extracted from the samples by the described method[25] with slight modification. After baking, biscuits were allowed to cool at room temperature and milled into biscuit powder. For each sample, two replicates were prepared. Briefly, flour samples (2g) were mixed with 16 ml of methanol containing 1% HCl for 24 hours at 24 °C. The procedure was repeated twice. The methanol extracts were centrifuged at 8000 rpm for 20 minutes and the resulting supernatants were pooled and stored at 4°C.

Total flavonoid content (TFC)

TFC was determined by a colorimetric method with a minor modification (Li, Ma et al. 2015). Aliquots (0.5ml) of diluted extracts or standard solutions were transferred into 15ml polypropylene conical tubes containing 2ml double distilled H2O and 0.15ml of 5% NaNO2. After 5 minutes, 0.15ml of 10% AlCl3•6H2O solution was added, and the mixture was allowed to stand for another 5 minutes, after which 1ml of 1 mol/l NaOH was added. The solution was mixed and allowed to stand for 15 minutes. Absorbance was measured at 415 nm. TFC was calculated from a standard quercetin curve and expressed as quercertin equivalents (μg QE g−1 dry weight).

Physical properties measurements of biscuits

The width was measured by placing 6 biscuits edge-to-edge to get the average value in millimeters. The thickness was measured by stacking 6 biscuits on top of each other to get the average value in millimeters. Width divided by the thickness gave the spread factor. Digital weighing scale was used to determine the weight (in grams) of biscuits. Volume of biscuits was defined as the area multiplied by thickness. After calculating volume, density was obtained by ratio of weight of volume [26, 27].

Sensory evaluation

The consumer acceptance of six different samples of biscuits was evaluated by fifty judges comprising undergraduate students of International University without training. The sensory evaluation test was conductedin the air-conditioned laboratory, which provided a quiet and comfortable environment. The biscuits were served on white disposable plastic trays and tap water was provided for rinsing. Samples were coded with different symbols and the sample order was randomized. Consumers were asked to evaluate the color, taste, flavor, texture and overall acceptability of the biscuits using a 5-point hedonic scale.

Statistical analysis

Data was subjected to analysis of variance using the “Statistical Package for Social Sciences” (SPSS) version 19.0. Results were presented as means ± standard deviations of triplicate experiments. Significant difference was established at $p \leq 0.05$.

Results and Discussion

Proximate analysis of sweet potato flour

The results of analysis proximate attributes of sweet potato flour derived from the cultivar HL 491 are presented in Table 2.

Components (%)	Value*
Moisture (d.w.b)	7.14 ± 0.09
Ash	1.98 ± 0.74
Fat	0.44 ± 0.19
Protein	2.48 ± 0.20
Crude fiber	2.1 ± 0.00
Total carbohydrate	85.80 ± 0.61

Table2. Proximate values of purple sweet potato flour

*Values in the table represent the means ± standard deviations (n = 3 replicates) DWB = dry weight basis

As shown in the Table 2, the moisture content of the flour (dry weight basis) was 7.14 ± 0.09%. Reportedly, moisture content of sweet potato flour is considered a quality characteristic where storage is concerned since high moisture content in the processed flour can accelerate chemical or microbiological deterioration [28].

Data collected from numerous researches on sweet potato flour have shown that the moisture content of the flour is in the range of 2.50–13.2% (Van Hal 2000, ERIC 2012, Singh, Riar et al. 2013, Olatunde, Henshaw et al. 2015). A value of 12.5% has been considered as critical moisture content of flour within a locality at ambient temperature of 27–29°C while a value of 10% has been recommended for long term storage [28]. Also,from the Table 2, the ash content of the flour was 1.98± 0.74%, of which the collected value in this study was in a highly acceptable range if compared to the work done by Singh, Riar et al. 2013, and by Olatunde, Henshaw et al. 2015. According to Do Nascimento, Lopes et al. (2015),the ash content of the analyzed food represents the mineral content of the food material, hence it has long been identified to containing calcium, phosphorus, magnesium, sodium, potassium, iron, zinc and copper as they are the main mineral constituents in sweet potato roots. The minerals such as iron, copper, zinc and manganese are essentially important roles in biological systems [29].

Differentiated with other roots and tubers, purple sweet potato is known as low fat content foo. The fat content of the studied purple sweet potato flour was considerably low, valued of 0.44 ± 0.19% which was similar data collected by Olatunde, Henshaw et al.2015 when the fat content of ten cultivars of sweet potatoes ranged from 0.04 to 1.45%. It can easily be seen that the protein content of the flour was 2.48 ± 0.2%. Though sweet potato is a low source of food protein, its protein in both fresh and flour form has been reported to be of good biological value. It is therefore, highly possible to serve as a fairly important protein source among low-income consumers in developing countries whose diets contain protein derived mostly from foods of vegetable origin [30].

The study of Olatunde, Henshaw et al. 2015 revealed that the fiber content of ten different kinds of sweet potato flours ranged from 0.08 to 5.54% and the result obtained from the sweet potato flour in this study was within that range, of 2.1%. It has been well known that Dietary fiber serves as a useful tool in the control of oxidative processes in food products and as functional food ingredient (Eleazu and Ironua 2013). In addition, dietary fiber decreases the absorption of cholesterol from the gut in addition to delaying the digestion and conversion of starch to simple sugars, an important factor in the management of diabetes [31]. Scientifically and practically, it is very necessary to determine and know the carbohydrate content of the studied food materials. As shown in the Table 2, data on the total carbohydrate content was of 85.80 ± 0.61%. In sweet potato flour, carbohydrates account for the bulk of the flour and hence serve as a good energy source (Olatunde, Henshaw et al. 2015). In a special addition, it is worthy mentioning that the carbohydrates contents in of purple sweet potato have a rather low glycemic index while providing the quick energy to human cells' need without the negative side effects that accompany other energy-dense foods, such as wheat, rice, and corn (Ashley Tudor, 2012).

Functional properties of composite flour

Functional properties of foods are those properties that determine the applications and use of food material during processing, storage and preparation because they affect the general quality of foods as well as their acceptability. The important functional properties that are usually assayed include: water absorption capacity, bulk density, oil absorption capacity, viscosity, foam stability, etc.[2]. The results of functional properties of purple sweet potato flour and the composite flour samples are as presented in Table 3 and 4.

Sample	Bulk density (g/cm3)	Water absorption Capacity (g/g)	Oil absorption capacity (g/g)
A	0.69 ± 0.04a	1.74 ± 0.06a	2.23 ± 0.04a
B	0.70 ± 0.04a	1.84 ± 0.05a	2.21 ± 0.01ab
C	0.72 ± 0.01a	1.89 ± 0.01a	2.18 ± 0.01ab
D	0.73 ± 0.03a	2.18 ± 0.04b	2.17 ± 0.02ab
E	0.75 ± 0.02a	2.39 ± 0.02c	2.15 ± 0.01ab
F	0.77 ± 0.00a	2.66 ± 0.08d	2.13 ± 0.03b

Table 3. Effect of incorporating sweet potato flour on the functional properties of the composite flours
*Values in the table represent the means ± standard deviations (n = 3 replicates)
The values denoted by different letters in the same column are significantly different
($p \leq 0.05$)

Physical property	Value*
Bulk density (g/cm3)	0.94 ± 0.04
Water absorption capacity (g/g)	2.76 ± 0.11
Oil absorption capacity (g/g)	2.12 ± 0.03

Table 4. Functional properties of purple sweet potato flour
*Values in the table represent the means ± standard deviations (n = 3 replicates)
The values denoted by different letters in the same column are significantly different
($p \leq 0.05$)

Bulk density

Value of bulk density for wheat flour (sample A) was 0.69 g/cm3 while purple sweet potato flour recorded of 0.94 g/cm3. As can be seen from table 4, when more and even more purple sweet potato flour was incorporated into wheat flour, the bulk density of composite flour was decreased. The values of the mentioned samples ranged between 0.69 to 0.77 g/cm3, with sample was F recorded as of the highest value and the lowest one was of sample A. The values of bulk density among studied samples were insignificantly different ($p>0.05$) Scientifically and economically, bulk density is generally affected by the particle size and density of the flour, and so, it is a really important approach to determining the packaging requirement, material handling and application in wet processing in the food industry (Adeleke and Odedeji 2010, Onabanjo and Dickson 2014). Hence, the higher the particle size, the lower the bulk density. Consequently, increase in bulk density is desirable because it offers greater packaging advantage, as a greater quantity may be packed within a constant volume [2].

Water Absorption Capacity (WAC)

From the Table 4, the water absorption capacity (WAC) of the flour composites were more or less argumentative. Though the results were similar among sample B and C, there were significant differences ($p<0.05$) in the WAC of remaining flours when comparedto the control sample A. The result ranged between 174 to 266% for all samples, with sample Frecorded the highest value and the lowest was sample A. This suggested that when more purple sweet potato flour was added to wheat flour, the WAC of the blended samples was increased. A similar trend also observed by Singh, Riar et al. (2013) [32].

Water absorption capacity has been a method for measuring the ability of flour to absorb water and swell for improved consistency in food. It is a desirable property in food systems to improve yield, consistency and contribute to the food body as reported byOsundahunsi, Fagbemi et al. (2003), and Eleazu and Ironua (2013). According to Chandra, Singh et al. (2015), the increase in the WAC has always been associated with increase in the amylose leaching and solubility, and loss of starch crystalline structure. This leads to the weakened dough, decreases its stability and extensibility. However, wheat-purple sweet potato flour composites displayed acceptable binding properties during preparation, which may suggest that the combination of wheat- purple sweet potato flour can be use in making biscuits [33].

Oil Absorption Capacity (OAC)

Data shown in the Table 3 may suggest that the flour derived from this purple sweet potato variety had considerable oil absorption capacity- OAC (212%). Among all flour samples, the OAC ranged between 213 to 223% in which the highest recorded value was of sample A and the lowest one was of the sample F. The OAC of flour composites slightly decreased as more and more purple sweet potato flour was incorporated, which indicated diluting effect of sweet potato flour on OAC of wheat flour (Adeleke and Odedeji 2010). The values of OAC were significantly different ($p<0.05$) between sample A and F. The mechanism of fat absorption is attributed mainly to the physical entrapment of oil and the binding of fat to a polar chain of protein. Non-polar amino acid side chains can form hydrophobic interaction with hydrocarbon chains of lipids [34,35]. Therefore, the low protein content in purple sweet potato flour wasthe possible reason for the decrease in the OAC of composite flours when increasing the level of substitution.

Physical properties of developed biscuits

The results obtained from the physical measurements of biscuits made from wheat flour and composite flour with varying levels of purple sweet potato flour are shown in Table 5. The spread ratio is considered as one of the most important quality parameters of biscuits because it correlates with texture, grain fineness, bite and overall mouth feel of the biscuits (Jothi, Hashem et al. 2014). Figure 2 shows that the higher level of composite flour significantly increased the spread ratio of the final product ($p<0.05$). The highest value was of sample F (7.98), while the lowest value belonged to sample A (7.12). An increase in sweet potato flour content significantly increased the spread ratio of the biscuits, which was directly related to their thickness, whereas the diameter was generally not affected. The significant difference in term of spread ratio among samples was due to the low protein content of purple the sweet potato flour. Reportedly [36], a decrease in spread with increased protein in the cookies was noticed. The study of Aziah, Noor et al. (2012)and Miller, Hoseney et al. (1997) revealed that the amount of protein in the flour affects the formation of continuous gluten web which increases the viscosity and stops the flow of the dough. As a result, the biscuits made from composite flour had higher spread ratio of than that of the wheat biscuits.

The volume of biscuits were ranged from 6.58 to 7.56 cm3, with the highest value was seen in sample A and the lowest value was of sample F. The higher the replacement of purple sweet potato flour, the lower the volume of the biscuits. This is possibly due to the fibers present in the sweet potato flour which might interfere in the structure of the matrix, diminishing the gas retention capacity in the dough as reported by Ostermann-Porcel, Quiroga-Panelo et al. (2017).

Smpl	Width (cm)	Thickness (cm)	Spread ratio	Weight(g)	Volume (cm^3)	Density (g/cm^3)
A	4.09 ± 0.06^a	0.58 ± 0.01^a	7.12 ± 0.04^a	6.62 ± 0.03^a	7.56 ± 0.37^a	0.88 ± 0.05^a
B	4.08 ± 0.08^a	0.56 ± 0.01^{ab}	7.30 ± 0.01^b	6.45 ± 0.07^b	7.28 ± 0.45^a	0.89 ± 0.04^a
C	4.06 ± 0.08^a	0.54 ± 0.01^{abc}	7.49 ± 0.01^c	6.31 ± 0.03^{bc}	7.01 ± 0.44^a	0.91 ± 0.05^a
D	4.06 ± 0.08^a	0.53 ± 0.01^{bc}	7.67 ± 0.07^d	6.13 ± 0.04^d	6.84 ± 0.35^a	0.90 ± 0.04^a
E	4.07 ± 0.09^a	0.52 ± 0.01^{bc}	7.78 ± 0.06^d	6.16 ± 0.01^{cd}	6.79 ± 0.42^a	0.91 ± 0.06^a
F	4.06 ± 0.08^a	0.51 ± 0.01^c	7.98 ± 0.02^e	6.07 ± 0.03^d	6.58 ± 0.42^a	0.93 ± 0.06^a

Table 5. Physical properties of developed biscuits
*Values in the table represent the means ± standard deviations (n = 3 replicates).
The values denoted by different letters in the same column are significantly different ($p \leq 0.05$)

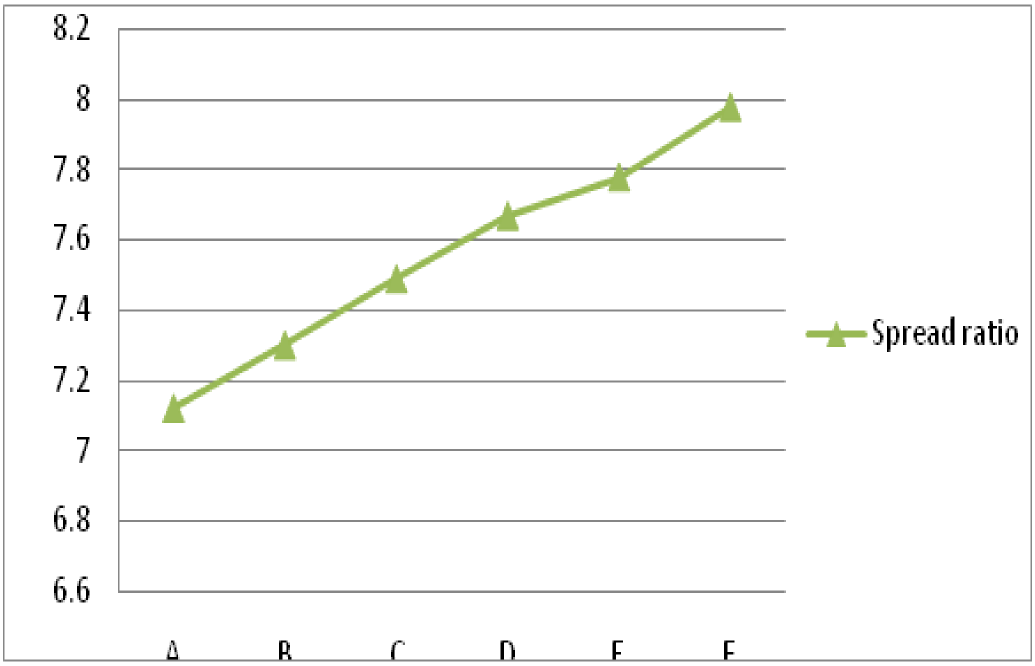

Figure 4. Effect of incorporating different levels of sweet potato flour on the spread ratio of biscuits.

The volume of sweet potato biscuits decreased linearly whereas, density increased in the similar manner. However, the differences of two attributes among samples were insignificant ($p<0.05$). Mean densities of biscuits ranged from 0.88 to 0.93 g/cm3, with the highest value was of sample F and the lowest value was of sample A. Density was the best index of sensory texture of biscuits. Lower density means greater crispiness and higher textural value (Dogan 2006). As reported by Manohar and Rao (2002), there was a positive correlation between dough firmness and density. The weight of the experimental biscuits was between 6.07 and 6.62g with the highest value was of sample A and the lowest was found in sample F. The results differed significantly among samples ($p<0.05$). As can be seen, the higher level purple sweet potato flour incorporated, the more weight loss of the biscuits. The purple sweet potato flour had higher water absorption capacity than the wheat flour, hence, this resulted in the higher initial moisture content of the dough and the higher loss of water during baking of the biscuits [37].

Proximate values of developed biscuits

Table 6 shows the effect of the incorporation of sweet potato flour to the physic-chemical composition of developed biscuits. It indicated that there was a gradual decrease of moisture content of biscuits from sample A to sample F (from 5.96% to 4.89%). As shown in the previous parts, the water absorption capacity of wheat flour was 1.74 g/g lower than that of sweet potato flour, namely 2.76g/g. Therefore, the biscuits contained more purple sweet potato flour had higher affinity for water which was informed by their lower moisture content [33]. The difference in moisture between the control sample A and other treated samples was significant when more than 30% purple sweet potato flour was incorporated in the biscuit formulation ($p<0.05$). The concentration of fat in the biscuits ranged between 24.29% and 26.69%, with the highest concentration of fat was seen in biscuits sample A. Though there was a slight variation in the fat content in different types of biscuits, it was statistically similar ($p>0.05$).

The result showedthat the fat concentration was decreased when the quantity of purple sweet potato flour increased. This was probably due to the lower fat retention ability of purple sweet potato flour when comparing with that of wheat flour during baking process. Higher fat retention may improve the mouth feel and retains the flavor of the biscuits (Baljeet, Ritika et al. 2010). The result was in agreement with the works of other researchers [12,33].

Sample	Moisture (%)	Fat (%)	Ash (%)	Fiber (%)
A	5.96 ± 0.01[a]	26.69 ± 0.87[a]	0.92 ± 0.18[a]	0.33 ± 0.04[a]
B	5.93 ± 0.01[a]	26.51 ± 0.86[a]	1.04 ± 0.13[ab]	0.42 ± 0.03[ab]
C	5.81 ± 0.07[a]	26.36 ± 0.87[a]	1.07 ± 0.18[ab]	0.52 ± 0.02[bc]
D	5.52 ± 0.06[b]	26.25 ± 0.94[a]	1.22 ± 0.02[ab]	0.61 ± 0.01[c]
E	5.52 ± 0.03[b]	25.69 ± 1.22[a]	1.41 ± 0.03[b]	0.72 ± 0.03[d]
F	4.89 ± 0.01[c]	24.29 ± 1.46[a]	1.50 ± 0.02[b]	0.91 ± 0.01[e]

Table 6. Proximate values of developed biscuits
*Values in the table represent the means ± standard deviations (n = 3 replicates).
The values denoted by different letters in the same column are significantly different
($p \leq 0.05$)

As shown in figure 3, the ash content of samples was improved when there was higher level of purple sweet potato flour in biscuits formulation. The clear effect could be seen when more than 40% purple sweet potato flour was used in making biscuits. Hence, the highest ash content was of sample F (1.50%), followed by sample E (1.41%) and they were significantly higher ($p < 0.05$) when comparing with that of the control sample A (0.92%). These results were in consistent with those reported by other researchers(Srivastava, Genitha et al. 2013, Onabanjo and Dickson 2014). The ash content of food material could be used as an index of mineral constituents of the food because ash is the inorganic residue remaining after the water and organic matter have been removed by heating in the presence of an oxidizing agent [33].

The value of crude fiber content of biscuits also increased significantly ($p < 0.05$) when more purple sweet potato flour was added to wheat flour in biscuits production. The highest value of crude fiber was found in sample F (0.91%) having 50% purple sweet potato flour substitution and the lowest were seen in sample A (0.33%). This suggested that purple sweet potato flour had more crude fiber than wheat flour. The result was in agreement with the observation of Onabanjo and Dickson in 2014 [12,7].

People who consume generous amounts of dietary fiber have health protective effect compared to those who have minimal fiber intake. Increasing the intake of high fiber foods or fiber supplements improves serum lipoprotein values, lowers blood pressure, improves blood glucose control for diabetic individuals, aids weight loss, and improves regularity[38]. With the mounting evidence of the overall health benefits of fiber, efforts should have been made to incorporate fiber intake goals in nutrition therapy for metabolic conditions as well as in nutrition guidelines for health promotion (Anderson, Smith et al. 1994).

Total Flavonoid Content of developed biscuits

Flavonoids are major coloring components of flowering plants and found in all plant foods (Clifford 2000). The levels of individual and total flavonoids in food are influenced by genetic factors such as species, environmental conditions such as light, ripeness, and post harvest treatments such as processing (Yao, Jiang et al. 2004). Besides their relevance in plants, flavonoids are important for human health because of their high pharmacological activities as radical scavengers [39]. More than 5000 different plant-derived flavonoids have been isolated from various plants (Cook and Samman 1996) They are classified into at least ten chemical groups. Flavanones, flavones, isoflavonoids, flavans (flavanols), anthocyanins, and flavonoids are particularly common in the diet [39,40].

The estimated values of total flavonoid content (TFC) in the studied biscuits are given in Table 7. As it can easily be seen, from the collected data, the increasing the level of purple sweet potato flour substitution in producing biscuits exhibited a significant level of TFC of the products compared to the control samples. The flavonoids contents (mg/g) in the different varieties of the sample extracts were calculated using the standard curve for quercetin with the equation $y = 0.0051x + 0.0491$, $R2 = 0.9989$. In the incorporated purple sweet potato biscuits, TFC ranged between 5.25 and 7.51 mg quercetin equivalent (QE)/g, whereas the value of the control sample was 4.8 mg QE/g. These concentrations were statistically different ($p < 0.05$) among the studied samples.

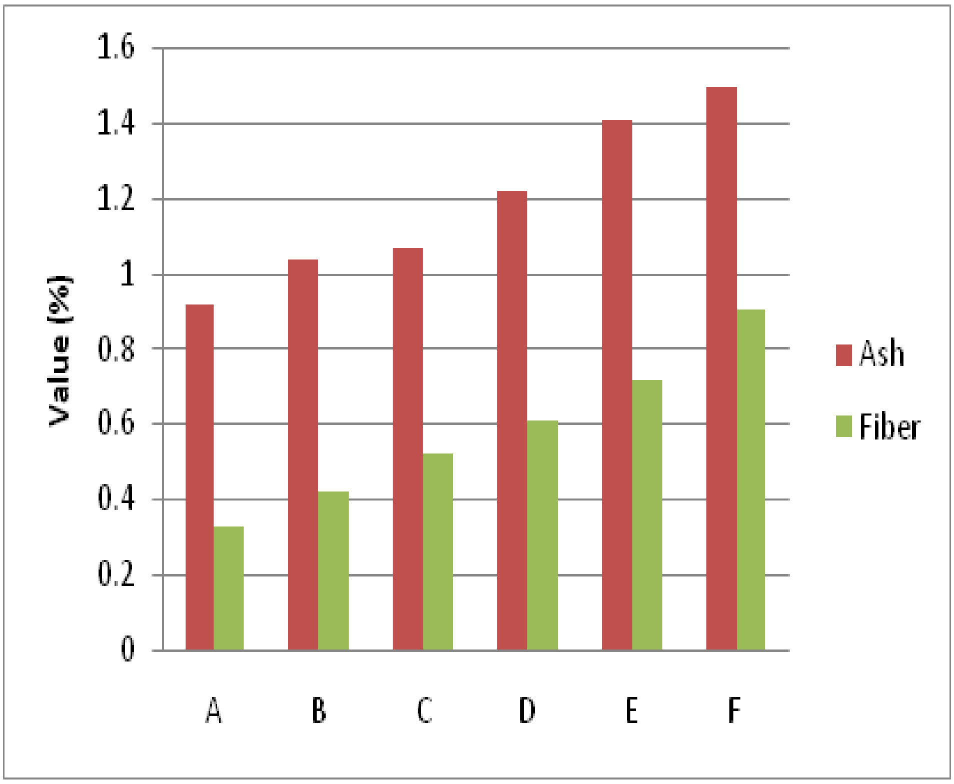

Figure 5. Effect of incorporating different ratio of sweet potato flour on the Ash and Fiber content of biscuits

Total Flavonoid Content of developed biscuits

Flavonoids are major coloring components of flowering plants and found in all plant foods (Clifford 2000). The levels of individual and total flavonoids in food are influenced by genetic factors such as species, environmental conditions such as light, ripeness, and post harvest treatments such as processing (Yao, Jiang et al. 2004). Besides their relevance in plants, flavonoids are important for human health because of their high pharmacological activities as radical scavengers [39]. More than 5000 different plant-derived flavonoids have been isolated from various plants (Cook and Samman 1996) They are classified into at least ten chemical groups. Flavanones, flavones, isoflavonoids, flavans (flavanols), anthocyanins, and flavonoids are particularly common in the diet [39,40]. The estimated values of total flavonoid content (TFC) in the studied biscuits are given in Table 7. As it can easily be seen, from the collected data, the increasing the level of purple sweet potato flour substitution in producing biscuits exhibited a significant level of TFC of the products compared to the control samples. The flavonoids contents (mg/g) in the different varieties of the sample extracts were calculated using the standard curve for quercetin with the equation $y = 0.0051x + 0.0491$, $R2 = 0.9989$. In the incorporated purple sweet potato biscuits, TFC ranged between 5.25 and 7.51 mg quercetin equivalent (QE)/g, whereas the value of the control sample was 4.8 mg QE/g. These concentrations were statistically different ($p < 0.05$) among the studied samples.

Sample	Flavonoids (mg QE/g)*
A	4.80 ± 0.02a
B	5.25 ± 0.01b
C	6.07 ± 0.09c
D	6.36 ± 0.08d
E	6.45 ± 0.02d
F	7.51 ± 0.04e

Table 7: Total Flavonoid Content of developed biscuits

QE = quercetin equivalence
*Values in the table represent the means ± standard deviations (n = 3 replicates).
The values denoted by different letters in the same column are significantly different ($p \leq 0.05$)

Purple sweet potato has increasingly been paid special interests and attention as a healthy food additive due to their high levels of anthocyanins (Montilla, Hillebrand et al. 2011). Anthocyanins are responsible for the intense colors of many vegetables and fruits such as red grapes, berries, red cabbages and purple sweet potato (McGhie and Walton 2007, Steed and Truong 2008). As one of the most abundant compounds among dietary polyphenols, anthocyanins are widely present in human diets in the forms of fresh fruits, vegetables, or beverages (Scalbert and Williamson 2000). The daily intake of anthocyanins in the human diet has been estimated at around 180-215mg/d in the USA, which is about 9-fold higher than that of other dietary flavonoids such as genistein, quercetin and apigenin (20-25mg/d) [41].

Anthocyanins have been increasingly important to the food industry as when used as natural alternatives to synthetic dyes, and so Anthocyanins have recently become widespread (Mateus and de Freitas 2008). Apart from their colorant features, many studies have associated anthocyanins with antioxidant, anti-inflammatory and anti-carcinogenic properties [43]. Notably, in a study on sweet potato storage roots, it has recently been reported that the relationship between anthocyanins content and radical-scavenging activity was really positively correlated [44].

In order to obtain any influence in a specific tissue or organ, these anthocyanins must be bioavailable as well as effectively absorbed from the gut into the circulation and transferred to the appropriate location within the body while still maintaining their bioactivity [45]. Most of the bioavailability studies are claiming the low bioavailability of anthocyanins [46,47]. One of the key factors affecting the bioavailability of anthocyanins is their transport through the gut epithelium. The Caco-2 cell line, a human intestinal epithelial cell model derived from a colon carcinoma, has been proven to be a good alternative to animal studies for predicting intestinal absorption of anthocyanins [48].

Despite of their low bioavailability, numerous studies have been reported cancer preventing effects of anthocyanins (Lim 2012). In vitro studies, it has been showed that anthocyanins or anthocyanidin rich extracts have exhibited growth inhibitory effects on a variety of cancer cells in lung[49], breast (El Babili, Bouajila et al. 2010), liver (Feng, Wang et al. 2009), and colon cancers [50]. Anthocyanins have also shown their effect on cell-cycle regulation. By interrupting the cell cycle at G1 and G2/M, they may induce apoptosis and inhibit cancer cell proliferation [51]. Delphinidin induced G2/M cell cycle arrest in human colon cancer cells [52]. In human breast cancer cells, bilberry extract did cause an increase in the fraction of cells at the G2/M phase of the cell cycle [63].

Sensory evaluation

Consumer acceptance, preference or hedonic (degree of liking) tests were used to determine the degree of consumer acceptance for a made product. Examples of acceptance tests are: the 9-Point Hedonic Scale, Labeled Affective Magnitude Scale (LAM), Line Scales, Just-About-Right scales (JAR) and Food Action Rating Scale (FACT) [54]. Among these tests, the hedonic scale is probably the most commonly used [55]. This scale is a category-type scale with an odd number (five to nine) categories ranging from "dislike extremely" to "like extremely." A neutral midpoint (neither like nor dislike) is included [56]. The panelists included in the test should be users of the product and there is no need for panel training. Optimally, a panel should consist of at least thirty people and much larger numbers are preferable [56]. This is necessary for the development and marketing of a new product, as no laboratory test can tell whether the public will accept a new product or not [57]. The result of acceptance of a food product usually indicates actual use of the product (purchase and eating). Moreover, preferences of individual consumers can be projected as vectors to suggest directions for product optimization

The mean scores of six samples in the five sensory attributes are presented in Table 8. The results revealed that the color of biscuits made from wheat- purple sweet potato composite flour was more preferable than that of the control sample. The highest score was of the sample D (3.72) having 30% of sweet potato flour, followed by sample E (3.66) with 40% sweet potato flour substitution while the score of control sample was the lowest, namely 2.82. This pattern happened similarly to the taste and flavor where sample D had the highest scores (3.96 for both sensory attributes), followed by sample E with 3.80 and 3.68 points and the lowest points was of sample A, 3.00 and 3.16, respectively. Though the results of texture evaluation varied among samples, ranged from 3.1 to 3.58, they were not statistically different ($p > 0.05$). The results of the evaluation also showed that biscuits made from the composite flours of wheat and sweet potato were more accepted than the control ones. The highest scores were of sample D and sample E (3.80), followed by sample F with the score of 3.72 and the last place was sample A with the score of 2.92. These results were contradicting with those reported by [33] and Srivastava, Genitha et al. 2013 [12] whereby the biscuits produced from wheat- purple sweet potato composite flour were scored lower than the 100% wheat biscuits in term of all sensory attributes.

Sample	Color	Taste	Flavor	Texture	Overall acceptance
A	2.82^{a}	3.00^{a}	3.16a	3.10^{a}	2.92^{a}
B	3.00^{ab}	3.48^{ab}	3.44^{ab}	3.58^{a}	3.38^{ab}
C	3.46^{bc}	3.64^{b}	3.62^{ab}	3.58^{a}	3.64^{b}
D	3.72^{c}	3.96^{b}	3.96^{b}	3.50^{a}	3.80^{b}
E	3.66^{c}	3.80^{b}	3.68^{ab}	3.54^{a}	3.80^{b}
F	$3.44b^{c}$	3.68^{b}	3.60^{ab}	3.40^{a}	3.72^{b}

Table 8. Sensory evaluation scores of developed biscuits in term of color, taste, flavor, texture and overall acceptability in 5 - point scale.

*Average of 50 evaluations. The values denoted by different letters in the same column are significantly different ($p \leq 0.05$)

Conclusions

In this study, the replacement potential of the wheat flour by sweet potato flour in biscuits to improve nutritional values and the development of new recipes to make good quality biscuits from the purple sweet potato were successfully and thoroughly investigated.

The chemical analysis of the wheat- sweet potato biscuits revealed that the fiber, ash and total flavonoids contents of the samples were significantly increased with at least 30% sweet potato flour by the selected substitutions. According to the sensory evaluation scores, the results of biscuits produced from wheat- sweet potato flour composites were significantly higher than that of 100% wheat biscuits in terms of all sensory attributes.

The made biscuits exhibited that the greatest acceptable sensory characteristics among consumer panel members were those containing 30% to 40% sweet potato flour, followed by the sample containing higher content (50%).

The obtained results of this study indicated that the developed biscuits were not only improved in terms of nutritional value and health benefits, but also highly accepted by various age of consumers

Fig A1. Sweet potato samples before drying

Fig A2 . Dried sweet potato samples

Figure A3. Developed biscuits. From top to bottom-B,C,D,E,F,A

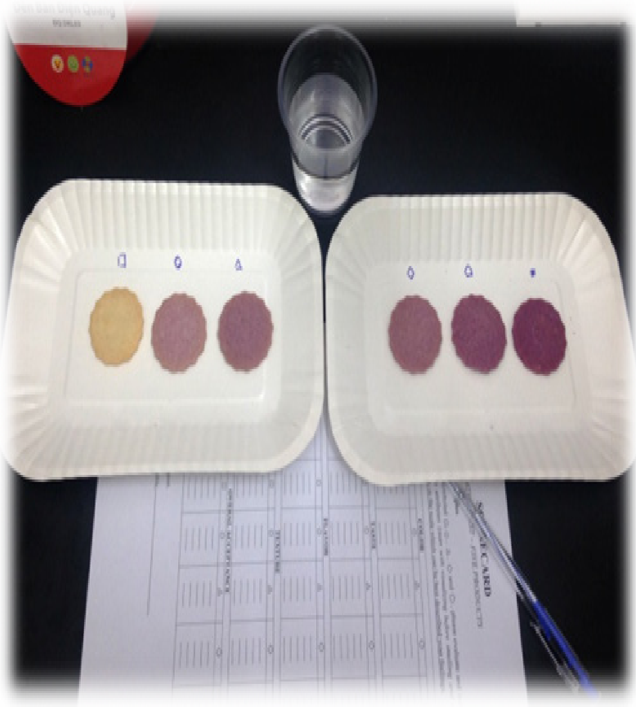

Figure A4. Preparation for sensory evaluation of the studied biscuits

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