

FUNCTIONAL PROPERTIES OF PURPLE YAM (*Dioscorea alata*) FLOUR

Jittra Singthong*

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Abstract

Purple yam (*Dioscorea alata*) is one of the important staple foods of many tropical countries because of its rich carbohydrate and anthocyanin contents. The purpose of this study was to establish the composition and functional properties of purple yam flour. The results have indicated that the moisture, ash, crude fiber, protein, lipid, carbohydrate, and amylose contents were 9.52, 3.02, 2.23, 8.74, 0.01, 76.52, and 25.85%, respectively. The water and oil absorption capacity, swelling power, emulsion stability, and foaming stability of purple yam flour were greater than wheat flours (cake, all purpose, and bread flours). The peak viscosity of purple yam flour was higher than wheat flours. In contrast, the setback of purple yam flour was lower. The gelatinization temperature and enthalpy of the purple yam flour were 80.91°C and 10.43 J/g, respectively. The antioxidant activity and total phenolic content of purple yam flour were evaluated using the DPPH assay and the Folin-Ciocalteu method. It was found that purple yam flour showed a total phenolic content of 220 mg gallic acid/100 g flour. In addition, purple yam flour displayed an antioxidant activity determined by the DPPH assay at a value of 640 mg/100 g flour, compared with vitamin C. The amount of anthocyanin content of purple yam flour was 16 mg cyanidin-3-glycoside/ 100 g flour. The purple yam flour was used as a substitute for wheat flour (0, 20, 40, 60, 80, and 100%) and the other ingredients were kept constant for all formulae. The increase in purple yam flour resulted in a decrease in the loaf volume, specific volume, and softness. From sensory evaluation, adding not more than 40% of purple yam flour showed liking scores in all attributes (appearance, color, odor, taste, texture, and overall) which were similar to the control.

Keywords: Purple yam, purple yam flour, functional properties, cake

Department of Agro-Industry, Faculty of Agriculture, Ubon Ratchathani University, Warinchamrap, Ubon Ratchathani, 34190 Thailand. E-mail: jittra.w@ubu.ac.th

* Corresponding author

Introduction

Yams are an important source of carbohydrate for many people in many tropical countries (Hsu *et al.*, 2004; Falade *et al.*, 2007). The edible tubers of yams have nutritionally beneficial components such as a resistant starch and mucilage. Resistant starch has been attributed with slow digestion in the lower part of the human gastrointestinal tract which results in the slow liberation and absorption of glucose and aids in the reduction of the risk of obesity, diabetes, and other related diseases (Liu *et al.*, 2003). Some yams are used as medication to prevent diarrhea and diabetes in oriental countries (Hsu *et al.*, 2004). Yam consumption reduces blood sugar and lipid contents, and inhibits microbial activity. Also, yams do not contain any gluten, which is an important factor when considering a carbohydrate source and may aid in a reduction in the incidence of celiac disease or other allergic reactions (Aprianita *et al.*, 2009). *Dioscorea alata*, known as purple yam and many other names including greater yam and water yam, belongs to the genus *Dioscorea* of the family *Dioscoreaceae* and is bright lavender in color.

Flours and starches are an important ingredient for the food industry. As new food products are developed, starches or flours with specific properties are necessary to impart functionally desirable attributes (Alves *et al.*, 1999; Mali *et al.*, 2002). Starch gelatinization refers to the disruption of the molecular order within starch granules when they are heated in the presence of water. Evidence for the loss of an organized structure includes irreversible granule swelling, loss of birefringence, and crystallization (Freitas *et al.*, 2004). The thermal and pasting properties are the most important functional properties for the evaluation and estimation of process design, unit operation, and quality of final starch-based products. Pasting behavior is usually studied by observing changes in the viscosity of a starch system based on rheological principles. From the pasting curve, several parameters can be reported that indicate the extent of disintegration, and whether there is retrogradation (Huang *et al.*, 2006).

There are bioactive compounds in many plants which are important such as phenolic compounds, chlorophyll, and anthocyanin (Bae and Suh, 2007). Anthocyanins belong to the group of flavonoids and are becoming increasingly important not only as food colorants, but also as antioxidants. Anthocyanins are reported to have potential effects in reducing the risk of cardiovascular diseases and cancers by antioxidant, anti-inflammatory, and chemoprotective properties (Bae and Suh, 2007; Du *et al.*, 2008).

The aim of this research was to establish the physicochemical and functional properties of flour from purple yam in Thailand, investigate possible applications in cake production, and study the changes occurring in cake, as well as to determine consumer acceptance. It is expected that it will provide useful information that has a potential to make a new source of flour in food applications, especially in the development of value added products from flour depending on knowledge of the functional properties.

Materials and Method

Sample Preparation

Purple yam (*Dioscorea alata*) was obtained from a local farmer in Ubon Ratchathani province, Thailand. It was washed, manually peeled, and cut into rectangular slices having a thickness of 1 mm using a slicer (No. 530123, Berkel Sales & Service, Inc., Houston, TX, USA). The purple yam slices were dipped in 0.075% potassium metabisulfite solution to exhibit the browning reaction. The purple yam samples were transferred into the oven dryer at 45°C for 2 h to remove the moisture. Purple yam flour was milled and ground through a 100-mesh sieve to produce the whole flour (Figure 1). The flour was packed in a vacuum bag until required for further analyses.

Commercial wheat flours were obtained from United Flour Mill Public Co., Ltd., Thailand. The protein contents of the company's White

Swan bread flour, Kite all purpose flour, and Royal Fan cake flour were 13.5-14.0, 10.5-11.0, and 8.0-8.3%, respectively.

Physicochemical Composition

The moisture, ash, protein, lipid, crude fiber, and carbohydrate contents of the purple yam flour were determined according to the method of AOAC (2000). The amylose content was analysed by using the amylose-iodine complex following the method of Juliano (1971).

The color changes in the samples were determined with a Hunter Lab Color Flex Spectrophotometer EZ Model 45/0 (Hunter Associates Laboratory, Inc., Reston, VA, USA) in L^* , a^* , b^* color parameters.

The total anthocyanin content was measured using the method of Giusti and Wrolstad (2005). Anthocyanin was extracted with acidified methanol (methanol and 1 M HCl, 85:15, v/v) with a solvent to sample ratio of 1:10. Absorbance was measured after centrifugation at 525 nm against a reagent blank. Cyanidin 3-glucoside-chloride was used as a standard pigment, and the total antioxidant capacity was expressed as mg cyanidin 3-glucoside equivalent per 100 g flour.

The total soluble phenolic constituents of purple yam flour was determined using the Folin-Ciocalteu reagent with gallic acid as standard. Twenty μL of solution of purple yam flour was added into a 1.5 mL cuvette, to which

1.58 mL of water and 100 μL Folin-Ciocalteu reagent was added. The sample was thoroughly mixed and incubated for 5 min at room temperature. Following incubation, 300 μL of the Na_2CO_3 (2% w/v) solution was added and the mixture was allowed to stand at room temperature for 2 h. Absorbance was measured at 765 nm. The results were expressed as gallic acid equivalents (GA) (Oonsivilai *et al.*, 2007).

The antioxidant activity was evaluated in accordance with the 1,1-diphenyl-2-picrylhydrazyl (DPPH) method. The free radical scavenging activity was determined using the stable DPPH radical according to the procedure described by Brand-Williams *et al.* (1995) with slight modification. Briefly, 50 μL of purple yam flour solution was added to 950 μL DPPH methanolic solution. The reaction mixture was covered and left in the dark at room temperature. After 15 min, the absorption was measured at 515 nm. Ascorbic acid was used as the standard control.

Functional Properties

The water and oil absorption capacity, emulsion properties (emulsifying activity and stability), and foaming properties (foam capacity and stability) were determined using a method of Bhat and Sridhar (2008) with slight modification. The swelling power and solubility index were evaluated according to the method of Wang *et al.* (2010).

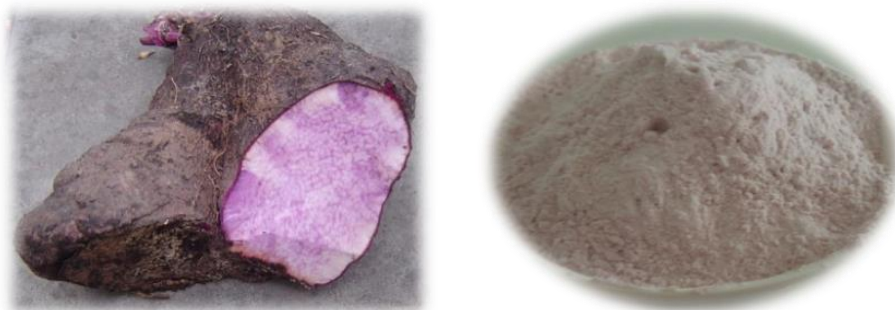


Figure 1. Purple yam and flour

The pasting properties were measured using a rapid visco analyzer (RVA-4D, Newport Scientific, Inc., Jessup, MD, USA) following the method described by Sandhu and Singh (2007). Flour (3 g, 14 g/100 g moisture basis) was weighted directly in a rapid visco analyzer canister and distilled water was added to obtain a sample weight of 28 g. The sample was held at 50°C for 1 min, heated to 95°C in 7.5 min, and then held at 95°C for 5 min. Afterwards, it was cooled to 50°C in 7.5 min, and then held at 50°C for 2 min. The rotating speed was maintained at 160 rpm during the process. The parameters including peak viscosity, final viscosity, breakdown, and setback were recorded. Three replicates of the sample were carried out.

The thermal properties were determined using a differential scanning calorimeter (DSC1/400W, Mettler Toledo, Greifensee, Switzerland) (Sandhu and Singh, 2007). Flour (3 mg) and distilled water were loaded into an aluminum pan and hermetically sealed. The sample pan was allowed to stand for 1 h at room temperature in order to attain an even distribution of water before heating with the calorimeter. An empty aluminum pan was used

as reference and the calorimeter was calibrated with indium. The scanning temperature range was 20-120°C at a heating rate of 10°C/min. The onset (T_o), peak (T_p), and conclusion (T_c) temperatures and the enthalpy (ΔH) of gelatinization of the starch were calculated automatically.

Preparation of Cake

Ingredients for making the control cake and purple yam flour-added cake were wheat flour, egg, butter, margarine, salt, sugar, baking powder, skim milk, and water. Purple yam flour was used as a substitute for wheat flour (0, 20, 40, 60, 80, and 100%) and the other ingredients were kept constant for all formulae.

For the cake preparation, the procedures included flour and baking powder being mixed together (mixture 1), whereas butter, margarine, sugar, salt, skim milk, and egg were mixed together until a foam was obtained. Then, the foam was mixed with mixture 1 with the addition of water. The resulting batter was transferred to a 1 lb. rectangular bowl and the bowl was put into an oven set at 180°C for 30-35 min or until the surface turned yellow.

Table 1. Physicochemical properties of purple yam flour

Parameter	Purple yam flour
Proximate analysis (%)	
Moisture	9.52±0.11
Ash	3.02±0.09
Crude fiber	2.23±0.13
Protein	8.74±0.19
Lipid	0.01±0.01
Carbohydrate	76.52±0.24
Amylose (%)	25.85±0.15
Color (Hunter Lab)	
L*	80.45±0.03
a*	3.32±0.02
b*	3.45±0.04
Phenolic (mg gallic acid/100 g)	220±0.01
DPPH (mg vitamin C/100 g)	640±0.01
Anthocyanin (mg Cyn-3-Glu/100 g)	16±0.01

Note: Means ± SD, each value in the table is the mean of 3 replications and 5 replications for color.

The product was taken out from the oven and the bowl was left to cool before further analysis.

Analytical Methods of Cake

The weight, volume, and specific volume of the cake were determined by the method of Shittu *et al.* (2009). The color of the cake was determined using the spectrophotometer. The texture of the cake was evaluated in terms of texture profile analysis with a texture analyzer (texture analyzer model LR5K, Lloyd Instruments Ltd, Segensworth, UK) with a cylindrical probe (diameter 1 cm) and test speed of 60 mm/min.

The sensory evaluation of the cake was conducted by 40 panelists, who were students and staff members in the Department of Agro-Industry, Ubon-Ratchathani University. Randomly coded samples were served to panelists individually. Six sensory attributes were evaluated (appearance, color, odor, taste, texture, and overall acceptability) using a 9-point hedonic scale for each trait, where 9 = excellent and 1 = extremely poor.

For the scanning electron microscopy, samples were coated with gold using a sputter coater, model SPI-MODULE™ Sputter Coat, and examined with a JSM-5410LV scanning microscope (JEOL Ltd., Tokyo, Japan).

Data Analysis

All experiments and analytical measurements were run in triplicate. The means of each parameter were analyzed by analysis of variance. Differences between treatments at the 5% ($p \leq 0.05$) level were considered significant.

Results and Discussion

Physicochemical Characteristic of Purple Yam Flour

The chemical compositions of the purple yam flour are shown in Table 1. The amounts of moisture, ash, crude fiber, protein, lipid, and carbohydrate contents were 9.52, 3.02, 2.23, 8.74, 0.01, and 76.52%, respectively. The

carbohydrate was composed mainly of flour, while the high protein content emphasised the value as a vital source of nutrients. The quantity of ash assumes importance, as it determines the nutritionally important minerals. The amylose content of the purple yam flour was 25.85%. The amylose content in the yam flour was different to that reported by other authors: 29% (McPherson and Jane, 1999), 27% (Hoover and Vasanathan, 1994), 28.5% (Gunaratne and Hoover, 2001), and 30% by Mali *et al.* (2002). These differences might be explained by the different growing conditions and amylose determination (Wang *et al.*, 2010). The amylose content is an important factor of the functional properties. The swelling behavior is primarily a property of its amylopectin, but amylose acts as both a diluent and an inhibitor to the swelling (Wang *et al.*, 2010). The results showed that the purple yam flour was a slightly purple color or bright lavender color because of the anthocyanin content in purple yam (Figure 1). The total phenolic content in the purple yam flour, as determined by the Folin-Ciocalteu reagent, was 220 mg gallic acid equivalent/100 g flour. The total anthocyanin content, examined by spectrophotometric assay was 16 mg cyanidin 3-glucoside/100 g purple yam flour. Similar results were found in sweet potato flours (Huang *et al.*, 2006) and colored maize flours (Lopez-Martinez *et al.*, 2009). The phenolic contents ranged from 4.79-80.78 mg GA/100 g flour for sweet potato flour and 215.8-3400.1 mg GA/100 g flour for colored maize flour. Anthocyanin contents ranged from 0.36-54.59 mg Cyn-3-Glu/100 g flour and 1.54-850.9 mg Cyn-3-Glu/100 g flour for sweet potato flour and colored maize flour, respectively. The antioxidant components were different in the flours of the sweet potato and colored maize varieties. Furthermore, anthocyanin and phenolic were the major compounds for DPPH radical-scavengers in the purple yam flour. Purple yam flour has high carbohydrate, protein, total phenolic compounds, DPPH radical scavenging activity, and anthocyanin contents.

Functional Properties of Purple Yam Flour

Gelatinization is an energy absorbing process that can be followed by differential scanning calorimetry (Whistler and BeMiller, 1997). It showed a single symmetrical endotherm during gelatinization. The onset, peak, and conclusion temperatures of gelatinization (T_o , T_p , T_c) and the enthalpy of gelatinization of the purple yam flour were 78.16°C, 80.91°C, 84.48°C, and 10.43 J/g, respectively. The flour from purple yam with an obtained high amylose content gelatinized at a high temperature (Huijbrechts *et al.*, 2008). The same phenomenon was found for the gelatinization temperature in potato and tapioca starches (Liu *et al.*, 2003; Freitas *et al.*, 2004), as the gelatinization temperature reflects the degree of orderly arrangement of the molecules in the starch granules (Huang *et al.*, 2006). In the case of wheat flour, the gelatinization was a lower endothermic event and a spread gelatinization process. The purple yam flour had a better resolved process. The gelatinization enthalpy of the purple yam flour was similar to that of tapioca starch (10.66 J/g) and higher than wheat flours (5.45 J/g). The melting thermodynamic properties of starches were directly correlated to their amylose content (Matveev *et al.*, 2001). The characteristics of the crystalline structure of starch granules have been analyzed using X-ray

diffraction (Zobel *et al.*, 1988). Most root and tuber starches exhibit a typical B-type X-ray pattern whereas an A-type X-ray pattern is exhibited in cereal starches (Blanshard, 1987; Huang *et al.*, 2006).

The results from the rapid visco analyzer of the purple yam and wheat flours are summarized in Table 2. The peak and final viscosity of the purple yam flour was higher than the wheat flours. The peak viscosity of the purple yam flour is an important characteristic to distinguish a given starch from the other flours. Purple yam flour has a lower breakdown which indicates its paste stability. The lower setback in the purple yam flour indicates its lower tendency to retrograde. The viscosity increased with increasing the temperature of all flours, which has been attributed to the removal of water from the exuded amylose by the granules on the swelling of starches (Singh *et al.*, 2008). Some researchers have shown the same tendency for the peak viscosity to be present in sweet potato starch and potato starch (Noda *et al.*, 1995; Liu *et al.*, 2003). The pasting properties indicate that the viscosity remains stable in the cooking processes, and the viscosity of the purple yam flour is stable in the cooling processes. Purple yam flour requires a high temperature to ensure complete gelatinization and pasting, which is potentially

Table 2. Functional properties of purple yam and wheat flours

Functional properties	Purple yam	Cake	Bread	All purpose
Pasting properties				
Peak viscosity (cP)	3945.67±66.88 ^a	1940.33±14.19 ^b	1843.00±7.55 ^c	1787.67±11.93 ^c
Final viscosity (cP)	4613.67±64.24 ^a	2421.67±41.07 ^b	2124.00±9.64 ^d	2265.67±9.02 ^c
Breakdown	64.33±4.16 ^d	536.00±48.49 ^c	756.00±16.52 ^a	661.67±30.24 ^b
Setback	732.33±4.73 ^c	1017.33±75.88 ^b	1037.00±7.55 ^b	1139.67±9.87 ^a
Swelling power (g/g)	11.95±0.49 ^a	9.46±0.27 ^b	9.16±0.33 ^b	8.38±0.32 ^c
Solubility index (%)	7.13±0.13 ^a	7.16±0.39 ^a	5.26±0.09 ^b	4.87±0.23 ^b
WAC (ml/g)	4.57±0.08 ^a	2.22±0.07 ^b	2.02±0.06 ^c	2.07±0.05 ^c
OAC (ml/g)	1.88±0.22 ^a	1.59±0.02 ^b	1.70±0.01 ^{ab}	1.63±0.02 ^b

Note: ^{a,b,c,d} Values with different letters in the same row are significantly different ($p \leq 0.05$).

useful in products in which delayed pasting is desired (Torre-Gutiérrez *et al.*, 2008).

The swelling power and solubility index of the purple yam and wheat flours are presented in Table 2. The swelling power of the purple yam flour was higher than the wheat flours. Starch granules become increasingly susceptible to shear disintegration as they swell. Starch with a lower amylose content swells more than that with a higher amylose content; amylopectin contributes to the swelling of starch granules and pasting, while amylose and lipids inhibit the swelling (Singh *et al.*, 2008). The starch granules with low total amylose content being less rigid swell freely when heated, and the swelling power of starch depends on the water holding capacity of the starch molecules by hydrogen bonding (Adebooye and Singh, 2008). The solubility index of the purple yam flour was 7.13%. The solubility is associated with the hydrophilicity and ease of disruption of the starch granules; the solubility index was low due to the high amylose content and low gelatinization temperature (Huijbrechts *et al.*, 2008). The solubility index of the purple yam flours would provide better aqueous flour dispersion in food applications, as well as higher water absorption and retention (Torre-Gutiérrez *et al.*, 2008).

The water and oil absorption capacity of the purple yam and wheat flours are presented in Table 2. The water and oil absorption of the purple yam flour (4.57 g/g) was higher than

the wheat flours (2.02-2.22 g/g) which suggests that the purple yam flour was more hydrophilic (Sirivongpaisal, 2008). Water absorption characteristics represent the ability of a product to associate with water under conditions where water is limiting. The oil absorption capacity of flour is also important as it improves the mouth feel and retains the flavor (Kaur and Singh, 2005). The oil absorption capacities of the flours were not significant. Difference protein structures and hydrophilic carbohydrates might be responsible for variations in the water absorption characteristics of the flours. Some researchers have shown different results for the water absorption characteristic and oil absorption capacity of flours. Water absorption characteristic values are reported for chickpea (1.33-1.47 g/g), field pea flour (1.24-1.25 g/g), and pigeon pea flour (1.37-1.39 g/g) by Kaur and Singh (2005) and Kaur *et al.* (2007), respectively. Oil absorption capacity values of 1.05-1.24 g/g for chickpea flour (Kaur and Singh, 2005), 1.06-1.17 g/g for field pea flour, and 0.96-0.98 g/g for pigeon pea flour (Kaur *et al.*, 2007) have been reported. Differences in the water and oil absorption capacities of protein may be related to the high levels of charge/polar and non-charge/non-polar groups, thus increasing the hydrophilic and hydrophobic groups of proteins (Chandi and Sogi, 2007). The water absorption characteristic and oil absorption capacity of purple yam flour indicate the ability of protein to absorb and retain water or oil. It may help to improve binding of the structure, flavor retention,

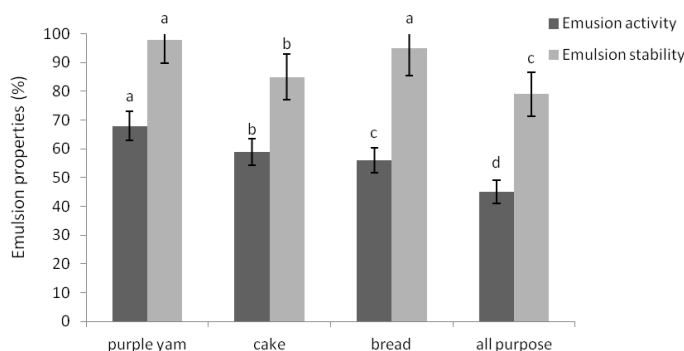


Figure 2. Emulsion properties of purple yam and wheat flours

improve mouthfeel, and reduce moisture and fat losses of extended meat products and baked products (Kaur *et al.*, 2007, Bhat and Sridhar, 2008).

The emulsion activity (EA) and emulsion stability (ES) of the flours are shown in Figure 2. The EA is defined as the ability of a flour to emulsify oil (Kaur *et al.*, 2007). The EA and ES of the purple yam flour were higher than the wheat flours. The efficiency of emulsification by flour varies with the type, concentration, and solubility of protein (Akubor, 2000). Purple yam flour may be most useful as an additive for the stabilization of fat emulsion in the production of sausages, soups, mayonnaises, salad dressings, and bakery products.

The formation of foam requires that proteins should solubilize in the aqueous phase and rapidly unfold to form a cohesive layer of protein around a gas/air droplet (Chandi and Sogi, 2007). The foaming capacity (FC) and foaming stability (FS) of the flours are shown in Figure 3. The FC and FS of the purple yam flour were lower than the wheat flours, but the FS decreases when the time increases. The foam produced by the purple yam flour was relatively thick with a low foam volume but high foam stabilities. An increase in protein concentration facilitated an enhanced protein-protein interaction at the air-water interface and this promoted formation of a highly viscoelastic multiplayer film that offers resistance to a coalescence of bubbles (Adebowale and Lawal,

2003). Foam stability is important since the usefulness of whipping agents depends on their ability to maintain the whipped state as long as possible (Kaur and Singh, 2005). However, the purple yam flour had a more stable foam than the wheat flours after 120 min of storage (Figure 3). The foaming properties of the purple yam flour may be improved by additions of sodium chloride as it enhances the ionic strength of water and solubilized protein (Bhat and Sridhar 2008).

Application of Purple Yam Flour in Cake

The results concerning the physicochemical and functional properties of the purple yam flour indicate the possibility of developing various applications for this flour in food processing. Purple yam flour enhanced the ability to absorb water and oil. It also has high viscosity and viscosity stability when the temperature changes and good emulsion properties and stability. Purple yam flour may be most useful as additives for the stabilization of fat emulsion in the production of meats, soups, salad dressings, and bakery products.

The amount of purple yam flour incorporated into a butter cake was a key factor examined in this study. All purple yam flour-added cakes had significantly lower loaf volume and firmer texture than the control cake (with no added purple yam flour) (Table 3). It suggests that added purple yam flour reduces the loaf volume by diluting the gluten content and

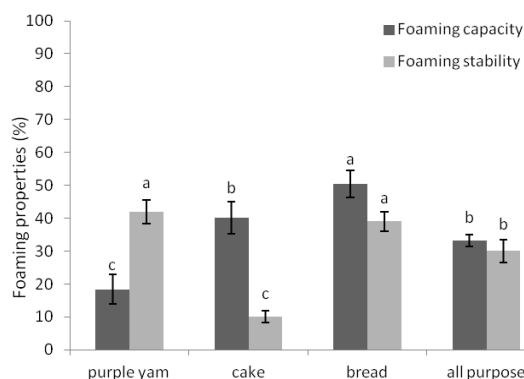


Figure 3. Foaming properties of purple yam and wheat flours

changing crumb structure, which in turn impairs CO₂ retention (Shittu *et al.*, 2009). Redness of the cake was directly related to the increased purple yam flour content (Table 3). In contrast, the lightness and yellowness of the cake reduced with an increased purple yam flour content (Figure 4). The anthocyanin and moisture contents of the cake were increased as the amount of added purple yam flour was increased.

The sensory evaluation results are shown in Table 4. Generally, all the samples were acceptable to the panelists. The hedonic scores of appearance, color, odor, taste, and overall acceptability for the 20% and 40% purple yam flour- added cake were not different from the control (with no added purple yam flour) but were significantly lower in scores for appearance and color. The hedonic scores of all attributes for the 60%, 80%, and 100% purple

Table 3. Effect of purple yam flour on physical properties of bread

Purple yam flour (%)	Loaf weight (g)	Loaf volume (ml)	Specific volume (ml/g)	Hardness (N)	Color L*	Color a*	Color b*
0	31.54±1.29 ^a	73.33±2.89 ^a	2.33±0.17 ^a	1.15±0.05 ^d	76.65±0.81 ^a	0.85±0.26 ^e	33.14±0.51 ^a
20	30.77±0.92 ^a	71.67±2.89 ^a	2.33±0.16 ^a	1.27±0.04 ^{cd}	69.36±1.08 ^b	1.81±0.14 ^d	20.58±0.42 ^b
40	30.75±1.19 ^a	68.33±2.88 ^{ab}	2.22±0.13 ^a	1.36±0.04 ^c	62.01±2.11 ^c	3.97±0.43 ^c	18.90±1.44 ^c
60	30.67±0.43 ^a	61.67±2.87 ^{bc}	2.01±0.11 ^{ab}	1.42±0.08 ^c	60.04±1.18 ^c	4.23±0.11 ^c	12.78±0.59 ^d
80	31.03±1.07 ^a	58.30±2.89 ^c	1.88±0.11 ^b	1.74±0.15 ^b	57.46±3.60 ^d	5.57±0.13 ^b	11.67±0.97 ^e
100	31.17±1.08 ^a	56.67±2.64 ^c	1.82±0.29 ^b	1.99±0.22 ^a	55.84±1.13 ^d	6.51±0.19 ^a	10.98±0.02 ^e

^{a,b,c,d,e} Values with different letters in the same column are significantly different ($p \leq 0.05$).

Means $\pm$ SD, each value in the table is the mean of 3 replications and 5 replications for texture and color.

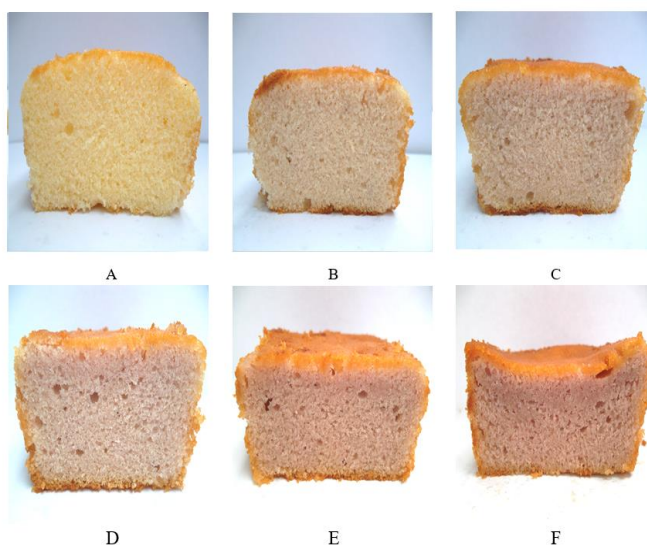


Figure 4. Butter cake from purple yam flour (A) 0% purple yam flour, (B) 20% purple yam flour, (C) 40% purple yam flour, (D) 60% purple yam flour, (E) 80% purple yam flour, (F) 100%purple yam flour

yam flour-added cakes were significantly lower when compared with the control. The darker color and unfamiliar taste to the panelists of some treated samples could be reasons for the lower hedonic scores when compared with the control cake. All the purple yam flour-added

cakes had a significantly firmer texture than the control cake. Despite this result, the panelists still preferred the lighter color and softer texture of the cakes containing purple yam flour. From the sensory result, it can be concluded that adding not more than 40% of purple yam flour is acceptable to consumers.

The scanning electron micrograph of the control and purple yam flour-added cakes were compared (Figure 5). The number of crumb cells was reduced by the addition of purple yam flour. The decreased number of cells in the purple yam flour-added cake is reflected in lower loaf volume and specific volume which in turn had a significantly negative impact on the crumb softness (Hu *et al.*, 2009).

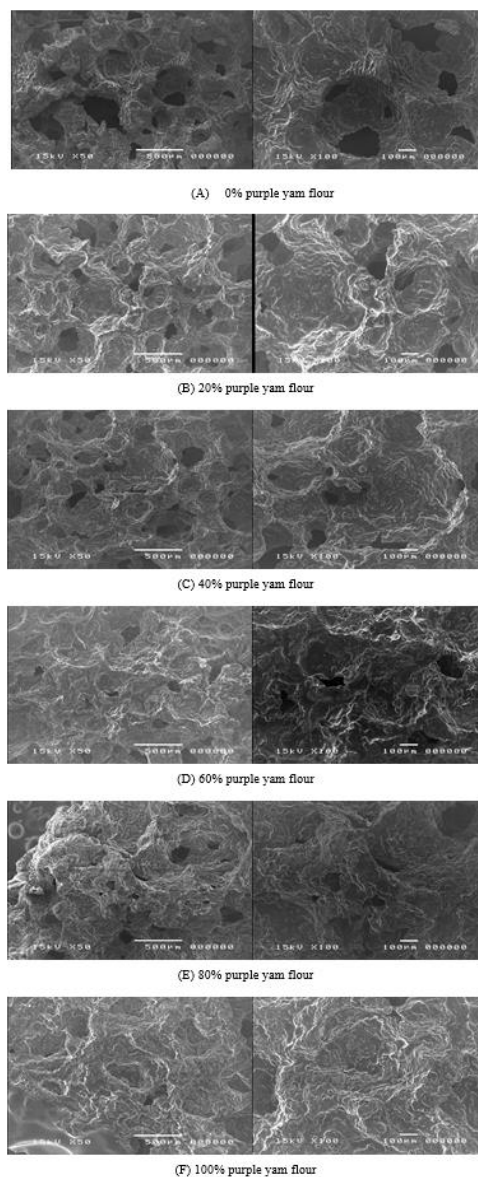


Figure 5. Structure of butter cake from purple yam flour

Conclusions

The present study reveals that purple yam flour consists of high protein and carbohydrate contents. The result of analysis of the antioxidant properties showed a high level of phenolic compound, DPPH radical scavenging activity, and anthocyanin content. The purple yam flour exhibited good functional properties, indicating the potential for addition to food systems, especially in bakery products, as nutrient supplements as well as functional agents. When incorporating not more than 40% purple yam flour in cake, the quality was improved and the cake was acceptable to consumers.

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