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Effect of Flour Composition (Arrowroot, Lesser Yam and Potato) on its Nutritional and Functional Properties

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Abstract

In the present study, arrowroot, lesser yam and potato flours were prepared by drying these tuber slices at 60°C in the convective hot air dryer. The flours particle sizes were ≥ 27.28 μ. These flours were mixed in the proportion (%) of arrow root: lesser yam: potato as 100:0:0 (T1), 0:100:0 (T2), 0:0:100 (T3), 0:50:50 (T4), 10:40:50 (T5), 20:30:50 (T6), 30:20:50 (T7), 40:10:50 (T8) and 50:0:50 (T9) respectively. The various treatments had protein, fat, fiber, ash, moisture content and carbohydrates in the range of 2.27-5.36%, 0.23-0.98%, 0.48-3.86%, 1.91- 4.14%, 5.81-8.56% and 79.81-86.66%. The functional properties of the flour combinations were water absorption capacity, oil absorption capacity, bulk density, flour dispersibility and yellowness index was 1.36-2.46ml/g, 0.63-1.56ml/g, 2.41-4.31g/cm^3, 24.33-41.33% and 21.81-32.16 respectively. The effect of incorporation of lesser yam or arrowroot flour significantly affected (≤ 0.01) the nutritional and functional properties of the flour blends.

Key words: Arrowroot flour, lesser yam flour, potato flour, nutritional properties, functional properties, particle size analysis.

Introduction

Tropical root and tuber crops are considered as the third important crop after cereals and grain legumes. They contribute 6% of the average daily calorific intake of human beings. The tropical roots and tuber crops are of utmost importance for the world food security. The popular tuber crops includes sweet potato *(Ipomoea batatas)*, cassava (*Manihot esculenta*), taro (*Colocasia esculenta*), yam (*Dioscorea sp.*), elephant foot yam (*Amorphophallus paeoniifolius*), yam bean (*Pachyrrhizus erosus*), arrowroot (*Maranta arundinaceae*) constitute cheap source of food and energy particularly suitable for the poor section of human population and also they are capable enough to withstand biotic and abiotic stresses (Lenka et al., 2012).

Tubers and roots are important source of carbohydrates and are used as staple foods in tropical and sub tropical countries. They are major source of energy in developing countries (Lebot, 2009; Liu et al., 2006). These crops also have nutritionally beneficial components, such as resistant starch and mucilage. Resistant starch has been attributed with slow digestion in the lower parts 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., 2006). Mucilage extracted from various tubers and roots has been reported to possess angiotensin converting enzyme inhibitory (Lee et al., 2003) and antioxidative activities (Nagai et al., 2006). Tubers and roots does not contain any gluten, which is an important factor when considering a carbohydrate source. Using tubers as a source of carbohydrate instead of gluten containing carbohydrates, may aid in the reduction in the incidence of celiac disease or other allergic reactions (Rekha and Padmaja, 2002).

Arrowroot (*Maranta arundinacea*) is a straight herbaceous plant belonging to *Marantaceae* family, commonly known as 'West Indian Arrowroot' (Pandey, 2007). It is a low perennial herbaceous plant with thick, fleshy and creeping roots and long white fibers and is a good source of flour. Fig. 1(a) shows the arrowroot tuber. Arrowroot starch has a high digestibility and wide food applications such as convalescent foods, weaning food and biscuits. In addition to this, the starch also can be used as a thickener for sauces and gravies or used for making clear glazes for fruit piece. This tuber has been used as a traditional healthy diet in many Asian countries, including Indonesia due to the presence of a soluble dietary fiber *glucomannan*. This fibre has been claimed to prevent some diseases such as diabetes, obesity, hyperlipidemia, and cardiovascular diseases (Aprianita, 2010). It can be also be substituted for corn starch. Arrowroot starch is one of the purest forms of carbohydrates and has cooling effects on the body. It is a soft food that can be given to infants as well as pregnant women. It creates a healthy balance in the stomach and cures diarrhea. The most important health benefit of arrowroot powder is that it cures urinary infection in adults as well as children. Arrowroot starch is commercially underexploited tuber starch having potential digestive and medicinal properties and has been subjected to extrusion cooking for preparing extrudates using a twin screw food extruder (Anonymous, 2014).

Lesser yam (*Dioscorea*) belongs to the family of *Dioscoreaceae*. Yams are second to cassava as the most important tropical root crop. Fig. 1(b) shows the lesser yam tuber. Yams are a staple crop in many parts of Africa and Southeast Asia. Yams are mainly grown for consumption and are marketed as fresh produce in all the growing regions. Common methods of preparation includes boiling, baking or frying. Boiled and baked yams can be eaten with vegetable sauce or palm oil. The yams are first sliced and soaked in salt water for several hours before further processing for consumption. Yam tubers are also processed into several food products such as the yam flour, which are used in many parts of the tropics. Industrial processing and utilization of yam includes starch, poultry and livestock feed, and production of yam flour (Opara, 2003). Yam tubers are boiled with arums, mushrooms, cooked with vegetables and mixed with rice.

Potato (*Solanum tuberosum*) used for making several food products including snacks. It consists of 63-83% moisture, 13-30% carbohydrate, 0.7-4.6% protein and 0.44% ash (Puttongsiri et al., 2012). Fig. 1(c) shows the potato tuber. It is a nutritious food containing all the essential dietary constituents. Like cereals, carbohydrates are the major constituents of potato. Besides, it contains essential nutrients such as proteins and minerals like calcium, phosphorus and iron, and vitamins (B1, B2, B6 and C).

Several nutritional disorders due to deficiency of vitamin A, vitamin C and calcium could be easily alleviated by consumption of root and tuber crops like cassava, sweet potato, yam and aroids, as they are rich in vitamins and minerals. The orange and yellow fleshed sweet potato roots and green tops are good source of vitamin A, which can prevent night blindness and malnutrition prevalent. Besides, sweet potato is rich in anti- oxidant, nutrients like β-carotene, ascorbic acid (vitamin C), tocoferol (vitamin E), which can prevent coronary disorder and cancer (Lenka et al., 2012).

Functional properties are the fundamental physico-chemical properties that reflect the complex interaction

(a) (b) (c)

Fig.1. Tuber crops (a) Arrowroot; (b) Lesser yam; (c) Potato

between the composition, structure, molecular conformation and physico-chemical properties of food components, together with the nature of environment in which these are associated and measured (Kinsella, 1976; Kaur and Singh, 2006; Siddiq et al., 2009). The functional properties i.e. bulk density, water absorption capacity, oil absorption capacity are the intrinsic physicochemical characteristics of the flour which may affect the behavior of food systems during storage (Shobha *et al.*, 2014). Water absorption capacity of the flour is an important functional characteristic in the development of ready to eat food from cereal grains and high water absorption capacity may assure product cohesiveness (Shobha et al., 2007). Bulk density of the flour is a function of the particle size and low bulk density is an advantage when used as a weaning food (Ukwuru, 2003).

Bulk density is very important in determining the packaging requirement, material handling and application in wet processing in the food industry (Karuna *et al.*, 1996). The oil absorption capacity of the flour is a critical assessment of flavor retention and increases the palatability of foods (Shobha *et al.*, 2007). Oil absorption index is important since oil acts as flavor retainer and increase the mouth feel of foods, improvement of palatability and extension of shelf life particularly in bakery or meat products where fat absorptions are desired (Aremu *et al.*, 2007). Color is one of the important physical parameters often used by the manufacturers and consumers to qualitatively assess the eminence of food products (Kaur et al., 2014).

Drying is a complex operation involving transient transfer of heat and mass along with several rate processes such as physical or chemical transformation, which in turn may cause changes in product quality as well as the mechanisms of heat and mass transfer. Drying studies are reported for yam, potato and carrot, sweet potato, tigernut etc. (Dagde et al., 2014; Jimoh et al., 2009; Kafilat, 2010; Oladele and Aina, 2007; Srikiatden and Roberts, 2008; Seidu et al., 2012)

Material and Methods

The experiments were conducted in NAIP Lab of Department of Agricultural Process Engineering, College of Agricultural Engineering and Technology Dapoli. Raw materials such as arrowroot and lesser yam tubers required for flour preparation were procured from university farm, Dr. B.S.K.K.V. Dapoli. Potato required for experimentation was procured from Dapoli market.

Production of tuber crops based flour

Arrowroot flour

Arrowroot tubers were washed with clean water, and the outer layer was peeled and sliced (5-6 mm thick). The drying was carried out in a tray dryer (Make: M/s Rotex Industries, Pune) having a capacity 60 kg. The size of the tray was 54 cm× 50 cm × 2 cm. The temperature of the drying was 60±1°C for 7-8 h upto 8-9 % MC (db). The weight loss during drying was measured by three number of perforated trays placed at three different locations in tray dryer i.e. top, middle and lower side of the dryer. The slices taken out from the dryer were allowed to cool at ambient temperature and milled upto 42.76μ size particles. Fig.2 shows the flow chart of preparation of arrowroot flour.

Arrowroot

Washing
↓
Removal of surface moisture
↓
Peel material → Peeling of arrowroot
↓
Slicing (5-6 mm thick)
↓
Drying
(Convective hot air, Temp 60±1°C for 7-8 hrs)
↓
Dried slices (MC=8-9% db)
↓
Size reduction (Pulverizer)
(Avg. particle size 42.76μ)
↓
Arrowroot flour

Fig.2. Flow chart for preparation of arrowroot flour

Lesser yam flour

The lesser yams were washed and peeled and root heads were removed from the tuber. This peeled yam tubers were boiled in hot water up to 45 min to increase the moisture content from 76.21 to 78.34% (wb). After boiling, the boiled yam tubers were cut into slices (3-4 mm thick). These slices were placed into the convective dryer as discussed in the above section and dried at temperature 60±1°C for 6-9 hrs upto 9-10 % MC (db) and then slices were taken out from the dryer and allowed to cool at ambient temperature and milled using pulverizer up to an average particle size of 40.00μ to make flour (Adegunwa et al., 2011). Fig. 3 shows the flow chart of preparation of lesser yam flour.

Lesser yam
↓
Washing
↓
Peeling of lesser yam →Peel and root heads
↓
Boiling (45 min)
↓
Slicing (3-4 mm thick)
↓
Drying
(Convective hot air, Temp 60±1°C for 6-9 hrs)
↓
Dried slices (MC=9-10% db)
↓
Size reduction (Pulverizer)
(Avg. particle size 40.00μ)
↓
Lesser yam flour

Fig.3. Flow chart for preparation of lesser yam flour

Potato flour

Fig. 4 shows the flow chart of preparation of the potato flour (Darvishi et al., 2013). Potatoes were washed, peeled, sliced (2-4mm thick) and put to boiled water containing sodium meta-bi-sulphite solution (0.1% w/w) for 5 min. The blanched slices were dried from 76.22 to 79.06% (wb) to 6-7 % MC (db). The dried slices were cooled and ground to a particle size of 27.28μ (Darvishi et al., 2013).

Potato
↓
Washing
↓
Peeling of potato → Peel material
↓
Slicing (2-4 mm thick)
↓
Boiling
(hot water + 0.1 w/w sodium Metabisulphate solution)
(Boiling = 5-7 min)
↓
Drying
(Convective hot air, Temp 60±1°C for 8-9 hrs)
Dried slices (MC=6-7% db)
↓
Size reduction (Pulverizer)
(Avg. particle size 27.28μ)
↓
Potato flour

Fig.4. Flow chart for preparation of potato flour

Arrowroot, lesser yam and potato flour combinations

Individual flours of arrowroot (T1), lesser yam (T2) or potato (T3) or their blends (T4-T9) were studied for their nutritional and functional characteristics. Three replicates were maintained for each experiment. The arrowroot: lesser yam: potato were mixed at the ratio of 100:00:00, 00:100:00, 00:00:100, 00:50:50, 10:40:50, 20:30:50, 30:20:50, 40:10:50 and 50:00:50 respectively.

Particle size analysis of tuber crop flours

The particle size distribution of various flours or their blends was studied using Image analysis system by using KOZO KXP 300 digital microscope with cold light source LED ring (Make: China). Small quantity of samples from various treatments (T1-T9) were taken on the glass slide with sample was exposed to the microscope. The images of the particles obtained by Kozo stereo zoom microscope was compared with the scale by using image analysis software Biovis IP, 2000 with 3 MPS camera. The software directly gives the particle size distribution within 1 to 2.5; 2.6 to 5; 5.1 to 10; 10.1 to 30; and 30 microns and above. The software also gives the average particle size (μ) of the flour samples. The average particle size of the flour was determined at ambient temperature 22±1°C for all treatment of flour combinations.

Nutritional properties

The initial moisture content of flour samples (T1-T9) was determined by using hot air oven method (AOAC, 2010). Crude protein content of flour samples was determined by Microkjeldahl method (Ranganna, 1986), with slight modifications. Approximately 0.25 g flour was mixed with 15 ml H_2SO_4 and pre-digested for 14 h (overnight). After digestion, 5 ml H_2O_2 was added to make the samples colourless. This was then used for titration. Fat content of individual flours and blends was determined by Soxhlet fat extraction system (AOAC, 2010) using Soxhlet apparatus (M/s Elico, Hyderabad). The crude fibre content of the flour samples was determined in the fat free sample by the acid and alkali digestion method (Ranganna (1986). Ash content of flour samples was determined using muffle furnace at 650°C for 4-5 h till constant weight was achieved. Carbohydrate content of flour samples was determined by subtracting the total of protein, fibre, ash and fat from the total dry matter (Vengaiah et al., 2013). The carbohydrate was calculated by using the following formula (1)

Carbohydrates = 100 - (protein + fat + fibre + ash + moisture content) ...(1)

Functional properties

Water absorption capacity (WAC) (ml/g)

The water absorption capacity of flours was determined by the method adopted by Chandra and Samsher, 2013. One gram of sample was mixed with 10 ml of distilled water in centrifuge tube and allowed to stand at ambient temperature (30 ± 2°C) for 1h, the mixture was centrifuged by using centrifuge (Make: M/s Remi Electrotecnik limited, Thane, India; Model: R- 8C BL) for 30 min at 2000 rpm. The sediments were weighed after complete removal of the supernatant. The average value of WAC is reported. The WAC was calculated by using the following formula (2)

$$WAC = \frac{W_2 - W_1}{W_0} X\,100 \quad \ldots(2)$$

where:

W_0 - the weight of the sample, g;
W_1 - the weight of centrifuge tube plus sample, g; and
W_2 - the weight of centrifuge tube plus the sediments, g.

Oil absorption capacity (OAC) (ml/g)

The oil absorption capacity of the flour was determined by the method of Shad et al., 2012. One gram of sample was mixed with 10 ml of refined soybean oil and was kept at ambient temperature for 30 min and centrifuged for 30 min at 2000 rpm. Oil absorption capacity was expressed as percent oil bound per gram of the sample. The sediments were weighed after the complete removal of supernatant oil. The average value of OAC is reported. The OAC was calculated by using following formula (3)

$$OAC = \frac{W_2 - W_1}{W_0} X\,100 \quad \ldots(3)$$

Where:

W_0 - the weight of the sample, g;
W_1 - the weight of tube plus sample, g; and
W_2 - the weight of the tube plus the sediments, g.

Bulk density (g/cm^3)

The bulk density of flour was determined according to the method described by Vengaiah et al. (2013). A graduated measuring cylinder of 5 ml was weighed and flour sample filled in to it by constant tapping until there was no further change in volume. The cylinder with the flour sample was weighed and the difference in weight was determined. The average value of bulk density is reported. The bulk density was calculated by using following formula (9);

$$\text{Bulk density}\left(\frac{g}{cm^3}\right) = \frac{\text{Wt. of cylinder after filling sample, g - Wt. of empty cylinder, g}}{\text{Volume of sample after tapping, cm}^3} \quad \ldots(1)$$

Flour dispersibilty (%)

The dispersibility of flour samples and their blends was determined according to the method of Airani (2007). Ten gram of flour sample was taken in 100 ml measuring cylinder. Distilled water was added to make the volume of 100 ml and the mixture was stirred vigorously and allowed to settle for three hours. The volume of settled particles at the bottom of the mixture was subtracted from 100 and the difference was reported as percentage dispersibility. The average value of flour dispersibility was reported.

Yellowness index (YI)

The colour of individual flours and their blends was measured using colour flow meter under Hunter Lab calorimeter (Make: Hunter Associate Laborotary, USA; Model: Colourflex 45/0). The colour measuring device was calibrated with standard white and black tile. The flour was taken into a glass sample holder of the color meter. The sample holder was kept on the aperture of the colour measuring device in such a way that light should not pass through it. 20 g sample was placed in the sample glass holder. The test was conducted for each treatment. The L, a and b values of the sample was determined. It represents the colour in L*, a* and b* value. Degree of lightness or darkness of the samples was represented by "L*" value, redness to greenness by "a*" value and yellowness to blueness by "b*" value on hunter scale. Yellowness index (YI) of L, a and b values was determined (Pankaj et al., 2012). The yellowness index was calculated by using the following formula (5)

$$YI = \frac{142.87b^*}{L^*} \quad \ldots(5)$$

Results and Discussion

Drying characteristics of tuber crops slices

Fig.5 shows moisture content % (db) w. r. t. time (min) of tuber crops i.e. arrowroot, lesser yam and potato slices dried by tray drying at 60°C. The arrowroot tuber crop slices were dried from an initial moisture content of 124.42% (db) to 7.61% (db). The lesser yam tuber crop slices were dried from an initial moisture content of 361.71% (db) to 9.56% (db). The potato tuber crop slices were dried from an initial moisture content of 243.85% (db) to 6.10% (db). It took around 8.25 h, 7.75 h and 9.25 h for drying of arrowroot, lesser yam and potato respectively by tray drying at 60°C. As drying time increases moisture content decreased for all the three tuber crops slices.

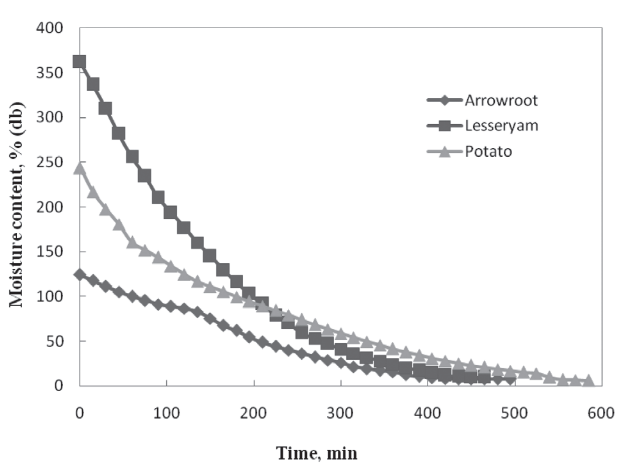

Fig. 5. Moisture content % (db) versus Time (min) of tuber crops drying

Fig. 6 shows the drying rate (kg of water removed/kg of dry matter/h) w.r.t. moisture content % (db) of arrowroot, lesser yam and potato dried by tray drying at 60°C. The drying rate decreased from 0.43 to 0.001, 2.52 to 0.006 and 1.79 to 0.02 kg of water removed/kg of dry matter/h for arrowroot, lesser yam and potato respectively. The lesser yam drying rate was highest because of the mucilage, acting as a barrier to water loss during drying.

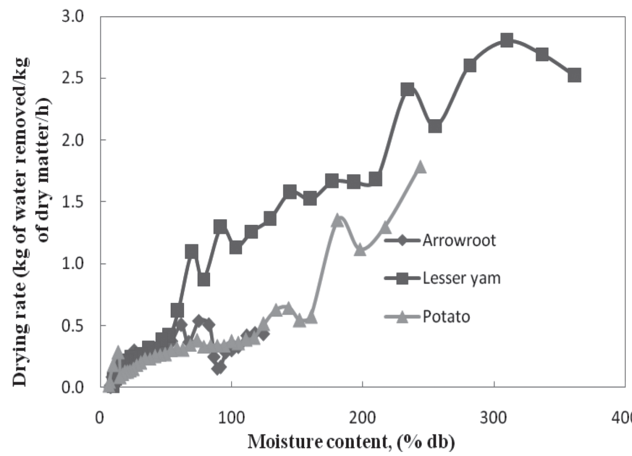

Fig. 6. Drying rate (kg of water removed/kg of dry matter/h) versus Moisture content % (db) of tuber crops slices drying (arrowroot, lesser yam and potato)

Particle size distribution and average particle size of flours (T1 to T9)

Figure 7 shows the images of flours and their blends using image analyzer. The images were obtained using KOZO KXP 300 digital microscope with cold light source LED ring. These images were analysed using the software Biovis IP. The particle size distribution of these flour samples were 1 microns to 30 microns and above were determined. Table 1 gives the particle size distribution and average size of the individual flours and their blends. Highest average particle size was for T6 followed by T9, while the lowest particle size was for T3 and T5.

Arrowroot flour had 11% of particles in the size range 10.1-30 μ, while 89% were in 30 μ or above. Nevertheless, in the case of lesser yam and potato flours, 33 and 39% were in the range of 10.1-30 μ respectively, while those in the range of 30 μ or above were 51 and 50% respectively. Although the retention of particles with size 10.1-30 μ was similar (27-28%) for T4 and T5, there was much less retention of particles $>30\ \mu$ in T5 compared to T4.When the level of arrowroot flour in the

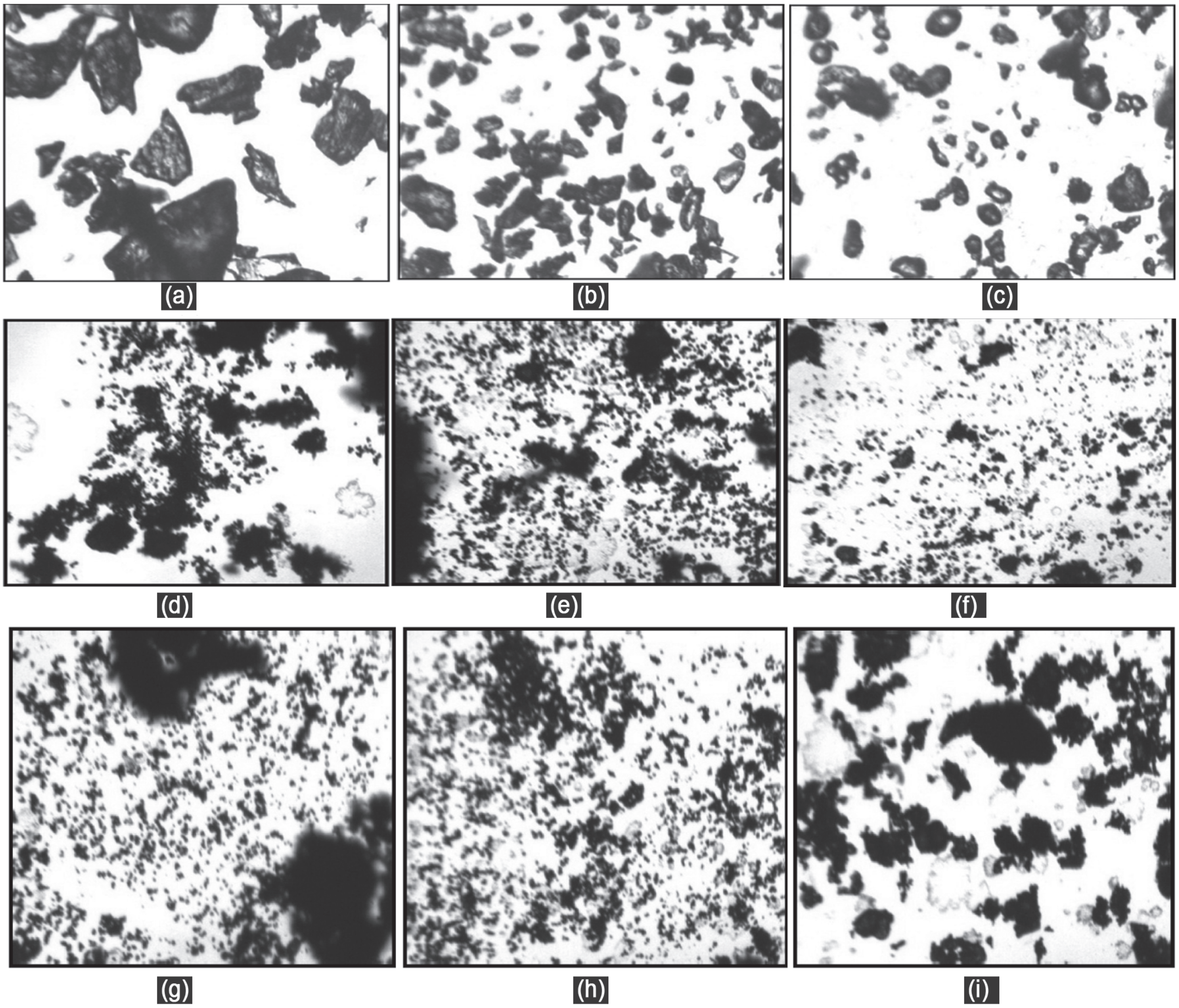

Fig.7. Particle size distribution (T1 to T9) at 60 °C (a) Treatment T1; (b) Treatment T2; (c) Treatment T3; (d) Treatment T4; (e) Treatment T5; (f) Treatment T6; (g) Treatment T7; (h) Treatment T8; (i) Treatment T9.

blend was raised to 40-50%, 70-75% of particles were in the range of 30 μ or above.

Nutritional properties

Table 2. gives the nutritional characteristics of flours and their blends.

Moisture content (MC)

Moisture content is ranges between 5.81± 2.05% to 8.56±2.99 (db). Treatment T2 displaying the highest MC (8.56±2.99% (db)) compared with treatment T1 which content low MC (5.81± 2.05% (db)). The low moisture content of flours makes them easy to store at room temperature and less prone to fungal and microorganism infections making them amenable for utilization (Nuwamanya et al., 2011). Moisture content is also an index of storage stability of the flour (Vengaiah et al., 2013). Table 3 (a.) shows the ANOVA for change in MC from T1-T9 and MC was found to be significant at $p \leq 0.01$ for all treatments.

Protein

Protein content ranged from 2.27 (T3) -5.36% (T1), indicating that arrowroot flour had the highest crude protein and potato flour had the least. Increasing the arrowroot flour addition increased protein in T4 –T9. Tuber flours in the present study had higher protein than reported for cassava flour (0.5-2% fresh weight basis; fwb), sweet potato flour (1-3% fwb) and yam flour (2-4% fwb) (Lebot, 2009). Table 3(b.) shows the ANOVA

Table 1. Particle size distribution of treatment combination (T1toT9) flours in percentage

Treat-ments	No. of particles falling										Average particle size (μ)
	0-2.5 microns		2.6-5.0 microns		5.1-10 microns		10.1-30 microns		30 microns and above		
	Retained no.	%	Retained no.	%	Retained no.	%	Retained no.	%	Retained no.	%	
T1	0	0	0	0	0	0	3	11	24	89	42.76
T2	3	7.6	1	2.5	2	5.1	13	33.33	20	51.28	40
T3	1	2.6	1	2.6	2	5.2	15	39.47	19	50	27.28
T4	1	7.1	0	0	0	0	4	28.57	9	64.28	38.36
T5	2	18.18	1	9.09	0	0	3	27.27	5	45.45	27.4
T6	2	10	0	0	1	5	4	20	13	65	46.13
T7	0	0	3	9.09	2	6.06	7	23.33	21	70	43.04
T8	1	3.57	1	3.57	1	3.57	4	14.28	21	75	40.05
T9	3	14.28	0	0	0	0	4	19.04	14	66.66	45.7

Table 2. Nutritional properties for treatment combination of flours

Sr. No.	Constituents	T1	T2	T3	T4	T5	T6	T7	T8	T9
1	Moisture [% (db)]	5.81± 2.05	8.56± 2.99	8.07± 0.65	6.89± 0.81	6.14± 0.29	7.84± 0.97	7.54± 0.59	6.15± 0.63	6.39± 0.65
2	Protein (%)	5.36± 0.27	2.62± 0.35	2.27± 0.46	3.38± 0.10	3.20± 0.83	3.85± 0.18	4.02± 0.18	3.44± 0.10	4.25± 0.27
3	Fat (%)	0.23± 0.03	0.61± 0.16	0.48± 0.02	0.98± 0.21	0.66± 0.13	0.70± 0.13	0.48± 0.03	0.53± 0.14	0.53± 0.06
4	Fiber (%)	3.86± 0.04	1.08± 0.01	0.48± 0.05	1.39± 0.07	1.39± 0.03	1.42± 0.14	1.42± 0.14	1.36± 0.10	1.27± 0.02
5	Ash (%)	4.14± 0.11	2.78± 0.18	3.92± 0.38	2.39± 0.43	1.91± 0.60	2.45± 0.23	2.51± 0.15	2.51± 0.11	2.93± 0.37
6	Carbohy-drate (%)	80.58± 2.11	84.33± 3.24	84.75± 0.40	79.81± 1.39	86.66± 0.56	83.71± 1.19	83.99± 0.58	86.00 ±0.45	84.60± 1.23

for change in protein at different flour combination treatments from T1 to T9. The increase in protein with decrease in lesser yam proportion in flour combination was significant at pd”0.01 for all types of flour combinations from T4 to T9.

Fat

Fat content ranged from 0.23 (T1) -0.98% (T4). The lesser yam proportion decreases in flour combinations from T4 to T9 with decrease in fat content of flour combinations. The lesser yam proportion decreases in flour combinations from T4 to T9 with decreases in fat content of flour combinations. Fat content value is relatively low when compared to pigeon pea flour (1.8%) (Okpala and Mammah, 2001) and wheat flour (3.1%) (Akubor and Badifu, 2004) and similar results reported by Sankaralingam et al., 1999. Similar observations reported in literature i.e.: 0.23% for arrowroot, 0.5% for potato and 0.5% for lesser yam (Wheatley et al., 1995; Bradbury and Holloway, 1988) and 0.18% for cassava, 0.70% for sweet potato, 0.71 for potato (Odebunmi et al., 2007). Table 3(c.) shows the ANOVA for change in fat content at different flour combination treatments from T1 to T9. The decrease in fat with decrease lesser yam proportion in flour combination was significant at $p \leq 0.01$ for treatment T4 to T9.

Fiber

Fiber content of flour composition ranges from 3.86 to 0.48%. Highest fiber content observed in treatment T1 (3.86± 0.04%) compared with treatment T3 (0.48±0.05%) which content lowest quantity of fiber in flour composition. Lesser yam proportion decreases from T4 to T8 there was increase in fiber content in flour composition was observed. The treatment T9 has no lesser yam. This value is comparable to value of 3.1% reported

Table 3. ANOVA for nutritional properties of flour combinations

Source of variations	SS	Df	MS	F	P-value
(a.) Moisture content (% db)					
Between Groups	98.465	8	12.308	7.208	2.61E-04
Within Groups	30.733	18	1.707		
Total	129.198	26			
(b.) Protein (%)					
Between Groups	20.187	8	2.523	18.235	3.75E-07
Within Groups	2.49	18	0.138		
Total	22.678	26			
(c.) Fat (%)					
Between Groups	0.997	8	0.124	8.691	7.84E-05
Within Groups	0.258	18	0.014		
Total	1.256	26			
(d.) Fiber (%)					
Between Groups	20.719	8	2.589	331.103	6.28E-18
Within Groups	0.14	18	0.007		
Total	20.86	26			
(e.) Ash (%)					
Between Groups	12.898	8	1.612	15.003	1.65E-06
Within Groups	1.934	18	0.107		
Total	14.832	26			
(f.) Carbohydrate (%)					
Between Groups	79.797	8	9.974	4.865	0.002
Within Groups	36.904	18	2.05		
Total	116.701	26			

*F critical was 2.510 for all the parameters

by Sankaralingam et al., (1999) for palmyrah. Similar observations reported in literature i.e. 4.4% for arrowroot, 0.5% for potato and 0.6% for yam, 1.0% for cassava, 1.0% for sweet potato (Wheatley et al., 1995; Bradbury and Holloway, 1988) and 1.38% for cassava, 0.9% for sweet potato, 0.77 for potato (Odebunmi et al., 2007). Fiber content is range between 1.43 to 1.27%. Table 3 (d.) shows the ANOVA for change in fibre content at different flour combination treatments from T1 to T9. The increase in fibre with decrease lesser yam proportion in flour combination was significant at $p \leq 0.01$ for treatment T4 to T8.

Ash content

Ash content of flour composition ranges from 4.14± 0.11to 1.91±0.60%. Highest ash content was observed in treatment T1 (4.14± 0.11%) compared with treatment T5 (1.91±0.60%) which contain lowest amount of ash in flour composition. Lesser yam proportion decreases from treatment T4 to T9 with increases ash content in flour composition. Ash content of 2.8 to 3.3% (dry matter basis) has been reported for palmyrah tubers (Sankaralingam et al., 1999). The disparity may be due to varietal differences and the locality. Similar observations reported in literature i.e. 1.0-1.5% for potato and 0.5-1.0% for yam, 0.5-1.5% for cassva, 1.0% for sweet potato (Wheatley et al., 1995; Bradbury and Holloway, 1988) and 0.85% for cassava, 0.97% for sweet potato, 1.45% for potato (Odebunmi et al., 2007). Table 3 (e.) shows the ANOVA for change in ash content at different flour combination treatments from T1 to T9. The increase in ash content with decrease lesser yam proportion in flour combination was significant at $p \leq 0.01$ for treatment T4 to T8.

Carbohydrates

Table 2 shows the carbohydrate content of treatment combinations of flours from T1 to T9. The carbohydrate content varied among different flour combinations of flours. Carbohydrate content of flour composition ranges from 86.66±0.56 to 79.81±1.39%. Highest carbohydrate content observed in treatment T5 (86.66±0.56%) compared with treatment T4 (79.81±1.39%) which content lowest amount of carbohydrate in flour composition. There was no specific trend has been observed with the decrease of lesser yam proportion in the flours. Table 3 (f.) shows the ANOVA for change in carbohydrates content at different flour combination treatments from T1 to T9.

Functional properties of treatment composition of flours (T1toT9)

Table 4 shows the functional properties (i.e. water absorption capacity, oil absorption capacity, bulk density, flour dispersibility and colour) of treatment composition of flours (T1toT9).

Water absorption capacity (WAC)

Water absorption capacity describes flour-water association ability under limited water supply. Water absorption capacity ranges from 1.36 to 2.46 ml/g. Highest water absorption capacity observed in treatment T3 (2.46±0.25/g) compared with treatment T1 (1.36±0.06ml/g). The water absorption capacity for the palmyrah tuber flour was 18% (2.5 ml/g), 1.7 ml/g reported for African yam bean, 3 to 4 ml/g for tiger nut flour, (0.22- 0.64ml/g) was for the elephant foot yam starches (Sankaralingam et al., 1999; Eke and Akobundu, 1993; Oladele and Aina, 2007; Babu and Parimalavalli, 2012).

No specific trend was observed for the absorption capacity with decrease in lesser yam proportion. The water absorption capacity (WAC) increased from treatment T4 (2.10±0.20ml/g) to T6 (2.16±0.25ml/g) and further decreased for T7 (1.90±0.10ml/g) and increased from T8 (2.06±0.20ml/g) to T9 (1.86±0.15ml/g) as the percentage of lesser yam deceased in flour formulation from treatments T4 to T9. The result obtained shows that the flours used i.e. treatments T1 to T9 has a good ability to bind water. Table 5 (a.) shows the ANOVA for the water absorption capacity of different flour combination treatments from T1 to T9. The decrease in water absorption capacity with respect to the decrease lesser yam flour composition in treatments from T4 to T9 was significant at $p \leq 0.01$.

Oil absorption capacity (OAC)

Table 4 shows the oil absorption capacity (OAC) of treatment combination of flours. Oil absorption capacity ranges from 1.56±0.05to 0.63±0.25ml/g. Highest oil absorption capacity observed in treatment T4 and T6 (1.56±0.05ml/g) compared with treatment T3 (0.63±0.25ml/g) which has lowest value. No as such trend was observed when there is decrease in lesser yam proportion with reference to the oil absorption. This may be because of the particle size of the flour and the interaction of the flour with respect to the three different flours. The values of oil absorption capacities for palmyrah tuber was found to be 14% (1.7ml/g), 1.0 to 1.1ml/g for tiger nut flour, 1.2 to 1.4ml/g for raw winged bean, 1.06-1.40ml/g for cush-cush yam starches (Sankaralingam et al., 1999; Oladele and Aina, 2007; Narayana and Narasinga Rao, 1982; Eke and Akobundu, 1993 and Babu and Parimalavalli, 2012). As increase in arrowroot composition retains the oil absorption capacity. Oil absorption is an important property in food formulations because fats improve the flavor retention and mouth feel

Table 4. Functional properties for treatment combination of flours

Sr. No.	Constituents	T1	T2	T3	T4	T5	T6	T7	T8	T9
1	Water absorbtion capacity,ml/g	1.36± 0.06	2.00± 0.10	2.46± 0.25	2.10± 0.20	2.20± 0.10	2.16± 0.25	1.90± 0.10	2.06± 0.20	1.86± 0.15
2	Oil absorbtion capacity, ml/g	1.26± 0.25	0.90± 0.10	0.63± 0.25	1.56± 0.05	1.30± 0.10	1.56± 0.05	1.40± 0.20	1.33± 0.05	1.13± 0.15
3	Bulk density, g/cm^3	2.41± 0.00	4.31± 0.25	4.07± 0.25	3.92± 0.39	3.88± 0.48	3.65± 0.33	3.87± 0.21	3.87± 0.21	3.92± 0.55
4	Flour dispersibility, %	34.33± 0.58	24.33± 2.08	41.66± 0.57	39.33± 1.15	38.66± 1.15	39.33± 1.15	49.33± 2.30	41.00± 1.00	40.00± 2.00
5	Yellowness Index	21.81± 0.14	27.99± 0.77	32.16± 2.16	29.04± 0.97	27.29± 0.51	26.34± 0.79	25.90± 0.35	25.19± 0.28	23.97± 0.08

Table 5. ANOVA for functional properties of flour combinations

Source of Variation	SS	Df	MS	F	P-value
(a.) Water absorption capacity (ml/g)					
Between Groups	2.18	8	0.272	9.2	5.37E-05
Within Groups	0.533	18	0.029		
Total	2.714	26			
(b.) Oil absorption capacity (ml/g)					
Between Groups	2.24	8	0.28	11.454	1.18E-05
Within Groups	0.44	18	0.024		
Total	2.68	26			
(c.) Bulk density (g/cm^3)					
Between Groups	6.988	8	0.873	7.599	1.87E-04
Within Groups	2.069	18	0.114		
Total	9.057	26			
(d.) Flour dispersibility (%)					
Between Groups	1075.33	8	134.416	68.476	6.73E-12
Within Groups	35.333	18	1.962		
Total	1110.67	26			
(e.) Yellowness Index					
Between Groups	220.205	8	27.525	31.419	4.85E-09
Within Groups	15.769	18	0.876		
Total	235.974	26			

*F critical was 2.510 for all the parameters

of foods (Kinsella, 1976). The result obtained shows that arrowroot tuber flour is a high flavour retainer and may therefore find useful application in food systems and formulation. Table 5(b.) shows the ANOVA for the oil absorption capacity of different flour combination treatments from T1 to T9. The decrease in oil absorption capacity with respect to the decrease lesser yam flour composition in treatments from T4 to T9 was significant.

Bulk density (BD)

Bulk density ranges from 2.41 to 4.31 g/cm^3. Highest bulk density observed in treatment T2 (4.31g/cm^3) and lowest bulk density was observed in treatment T1 (2.41g/cm^3). Bulk density depends upon the particle size of the samples. Bulk density is a measure of heaviness of a flour sample. No specific trend have been observed in the bulk density of flours. The value of bulk density for palmyrah tuber was 0.7 g/cm^3, 0.6 g/cm^3 for tiger nut flour, 0.5 g/cm^{3}for African breadfruit kernel flour, 0.7 g/cm^{3}for wheat flour (Sankaralingam et al., 1999; Oladele and Aina (2007); Akubor and Badifu, 2004. It is important for determining packaging requirements, material handling and application in wet processing in the food industry. Since flours with high bulk densities are used as thickeners in food products, the lesser yam tuber flour studied could be used as a thickener. Table 5 (c.) shows the ANOVA for the bulk density of different flour combination treatments from T1 to T9. The bulk density decreases from T4 (3.92±0.39g/cm^3) to T6 (3.65±0.33g/cm^3) further increased from T7 (3.87±0.21g/cm^3) to T9 (3.92±0.55g/cm^3) as lesser yam proportion decreased from T4 to T9 was significant.

Flour dispersibility

The flour dispersibility of treatment combination of flours. Flour dispersibility ranges from 24.33 to 41.33 %. Highest flour dispersibility observed in treatment T7 (41.33) and lowest value of flour dispersibility was observed in treatment T2 (24.33). There is no as such particular trend have been observed in the flour dispersibility. The flour dispersibility increases from T4 (39.33±1.15%) to T7 (49.30±2.30%) further decreased from T8 (41.00±1.00%) to T9 (40.00±2.00%) as lesser yam proportion decreased from T4 to T9. Table 5 (d.) shows the ANOVA for the flour dispersibility of different flour combination treatments from T1 to T9 was significant at $p<0.01$.

Yellowness Index (YI)

Yellowness index ranges from 21.81 to 32.16. Highest yellowness index observed in treatment T3 (32.16) and lowest value of flour dispersibility was observed in treatment T1 (21.81). Table 5(e.) shows the ANOVA for the yellowness index of different flour combination treatments from T1 to T9. The decrease in yellowness index with respect to the decrease lesser yam flour composition in treatments from T4 to T9 was significant at $p<0.01$.

Conclusion

The level of incorporation of lesser yam significantly affected the nutritional (protein, fat, fiber, ash, moisture and carbohydrates) and functional (water absorption capacity, oil absorption capacity, bulk density, flour dispersibility and yellowness index) properties of flour combinations/blends.

The desirable properties of flour for use as thickener in semi-liquid foods and bakery products are high WAC and it was found that potato flour had high WAC and lesser yam flour incorporation also retained the high WAC. High bulk density provides packaging advantages and the study proves that lesser yam flour with the highest bulk density could have potential application in the preparation of high nutrient density weaning foods.

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