EFFECT OF GERMINATION ON THE PROXIMATE COMPOSITION, FUNCTIONAL AND PASTING PROPERTIES OF FLOURS FROM RED AND BROWN VARIETIES OF PIGEON PEA (*Cajanus cajan)*SEEDS.

ABSTRACT

This study was designed to evaluate the effect of germination on the proximate composition, functional and pasting properties of red and brown pigeon pea flours. The red and brown pigeon pea seeds were cleaned and germinated for 48, 72 and 96 h, respectively and processed into flours, while the flours produced from the ungerminated red and brown pigeon pea seeds served as control samples. The flours obtained were analyzed for proximate, functional and pasting properties using standard methods. The proximate composition of the samples showed that the flours produced from the red pigeon pea seeds had a range of 6.24 – 9.34% moisture, 10.37 – 20.95% crude protein, 1.21 – 1.12% fat, 2.32 – 3.32% ash, 3.14 – 4.23% crude fibre, 76.75-61.07% carbohydrate, and 329.29 – 338.10KJ/100g energy, while that of the brown pigeon pea flours had a range of 6.44-9.77% moisture, 10.47-23.69% crude protein, 1.23-1.13% fat, 2.42-3.13% ash, 3.18-4.31% crude fibre, 76.26-57.99% carbohydrate and 358.18-336.83KJ/100g energy. The functional properties of the red pigeon pea flours revealed that the bulk density, water absorption capacity, oil absorption capacity, swelling capacity, gelation capacity and foam capacity ranged from 0.58-022 ml/g, 1.36-1.58 %, 1.40-1.61 %, 2.13-2.38 ml/g, 8.24-11.13 ml/g and 12.28-12.01 %, while that of the brown variety ranged from 0.63-0.36 ml/g, 1.47-1.69 %, 1.46-1.67 %, 1.67-2.46 ml/g, 8.88-11.41 ml/g and 13.33-13.06 %, respectively. The pasting properties of the red pigeon pea flours also showed that the peak viscosity, trough viscosity, breakdown viscosity, set back viscosity, final viscosity, peak time and pasting temperature ranged from 37.16-66.78 RVU, 58.35-40.18 RVU, 31.81-54.87 RVU, 92.95-62.76 RVU, 120.23-105.83 RVU, 7.34-6.79 min and 92.71-69.79^{o}C, while that of the brown variety ranged from 43.04-74.55 RVU, 67.34-50.24 RVU, 45.22-62.79 RVU, 98.98-67.03 RVU, 133.00-115.17 RVU, 7.99-7.07 min and 99.21-80.11^{o}C, respectively. The study, however, revealed that the flours produced from both the red and brown pigeon pea seeds could be generally used both as nutrient dense and functional ingredients in the preparation of a wide range of foods especially in areas where sources of animal protein are quite expensive or where there is acute shortage of protein.

Keywords: Pigeon pea seeds, varieties, proximate composition, germination, functional properties, pasting properties.

INTRODUCTION

Legumes are nutritious foods which serve as good substitutes for animal protein. The term legume is applied broadly to cover all plants of pea and bean family which are botanically referred to as *Leguminosae* or *Fabaceae* (Akubor, 2017). Legumes are known to be the third largest family among the flowering plants and they consist of approximately 650 genera and 20,000 species (Adebowale and Maliki, 2011).

Pigeon pea is one of the legumes that is commonly referred to as 'otili' in the south-west of Nigeria, where the seeds are boiled and eaten by the rural populace. It is also called '*fio-fio*' in the Igbo speaking areas of Nigeria. Though it is a perennial legume, it is cultivated at subsistence level in Nigeria with different varieties in existence. Pigeon pea is mainly consumed in Africa, India and the Caribbean. It is one of the important pulses in India where it contributes about 20% to the total production of all pulses.

Pigeon pea seeds are made up of 85% cotyledons, 14% seed coat and about 10% embryo which contains a variety of dietary nutrients (Faris and Singh, 1990). It also contains 20-22% protein, 1.2%fat, 65% carbohydrate and 3.8% ash (FAO, 2010). It equally contains crude fibre, magnesium, manganese and copper (Faris and Singh, 1990).

Germination refers to a series of changes in morphology, physiology and biochemistry. It is characterized by the growth of the embryo in the grain and is manifested by the growth of rootlets and increase in the length of the shoot (acrospire), which will inturnlead to the modification of the contents of the endosperm. These changes are likely to affect the nutritional content, anti-nutritional and functional properties of sprouted flour produced.

Germination is one of the most common and effective processes for improving the quality of legumes and germinated legumes are widely consumed all over the world. The process is influenced by the varietal differences and external factors such as soaking and germination time (Ridge, 1991). During germination, some of the food reserve materials are degraded and used for respiration and synthesis of new cell constituents of the developing embryo, thereby causing significant changes in the biochemical, nutritional, functional and sensory characteristics of the legumes. Steve (2012) and Valdez Aquino*et al.* (2015) also noted that germination is a process that is not expensive butis technologically effective in improving the nutritional quality of beans.

Germination also increases the nutrient content, digestibility and availability of free amino acids, dietary fibre and bioactive components of lupine seeds (*Lapinusangustifoluis* L). Germination equally increases the water absorption capacity of seeds as well as the protein solubility of minced bean. It also increases the capacity of millet flour to bind oil but decreases its water absorption capacity.In addition, germination has been reported to increase the protein and crude fibre contents of legume products.

Functional properties refer to the intrinsic physicochemical characteristics which may affect the behaviour of food systems during processing, storage and consumption such as solubility, foamability, gelation and emulsification properties (Giami and Bekebain, 1992).

Functional properties constitute the major criteria for the adoption and acceptability of protein in food systems. Functional properties include bulk density, protein solubility, water and oil absorption capacities, emulsifying and foaming properties. Although pigeon pea is known to be a rich source of many substances, the effect of germination on the nutrient composition, functional and pasting properties of red and brown pigeon pea flours have not been widely reported in the recent times. For proper utilization and acceptability of the legume flour, it is desirable to study its rheological properties, since they play important role in the physical behaviour of food or its ingredients during preparation, production and processing (Adebowale and Lawal, 2004).

Pasting properties constitute valuable aspects of the rheological characteristics of starch. They are relevant in determining thebehaviourof starch in food systems. Some important pasting properties are peak, trough, setback, breakdown and final viscosities, in addition to other parameters which include peak time and pasting temperature. The complex nature of food composition often makes the measurement and interpretation of rheological properties difficult. To be able to successfully introduce a new supplement in any food item, it is necessary to know whether it possess suitable functional and pasting properties for food applications and consumer acceptability. The aim of this study therefore was to determine the effect of germination on the proximate, functional and pasting profiles of the flours produced from red and brown varieties of pigeon pea seeds.

MATERIALS AND METHODS

Procurement of Raw Materials

Mature red and brown varieties of pigeon pea (*Cajanus cajan*) seeds used for this study were purchased from Ogbete Main Market, Enugu, Enugu State, Nigeria. The choice of location for the purchase was informed by the availability of fresh and wholesome red and brown varieties of pigeon pea seeds in the market.

Pre-Preparation of the Seed Samples

The seeds were sorted manually to remove the stones, damaged and immature seeds after which the seeds were divided into four (4) equal lots of 500g in each case. The first lot of each variety was processed raw, while the other lots were subjected to germination treatment at different steeping and holding times, respectively.

Preparation of Raw Pigeon Pea Flour

The raw pigeon pea flour was prepared according to the method described by Ugwu and Oranye (2006) with slight modifications. Five hundred grams (500g) of each variety of sorted pigeon pea seeds were sterilized with 1.5% sodium hypochlorite solution followed by soaking in 75% ethanol for 20 min. The seeds were rinsed thoroughly with tap water, spread on trays and dried in a hot air oven (Model DHG 9101 ISA) at $60^{o}C$ for 8 h with occasional stirring of the seeds at intervals of 30 min to ensure uniform drying. The dried seeds weredehulled by cracking them in the attrition mill followed by winnowing to remove the hulls. Thereafter, the dried and dehulled seeds were milled into flour using the attrition mill and sieved through a 500 micron mesh sieve. The flour produced was packaged in an airtight plastic container, labelled and kept in a refrigerator until needed for further use.

Preparation of Malted Pigeon Pea Flour Samples

The malted pigeon pea flour was prepared according to the method described by the method of Ugwu and Oranye (2006) with slight modifications. Five hundred grams (500g) of each variety of sorted pigeon pea seeds were sterilized with 1.5% Sodium hypochlorite solution followed by soaking in 75% ethanol for 20 min. The seeds were rinsed thoroughly with tap water and steeped for 6 h in tap water at room temperature (30±2°C). The hydrated seeds were spread evenly on wet jute bags and allowed to germinate for 48 h. The seeds were sprinkled with water at intervals of 6 h to hasten sprouting. The ungerminated seeds were discarded. The sprouted seeds were collected and then dried in a hot air oven (Model DHG 9101 ISA) at 60°C for 6 h. The dried seeds were dehulled manually by rubbing them in between palms to remove the hulls along with the rootlets. The dehulled seeds were milled into flour usingthe attrition mill and sieved through a 500 micron mesh sieve. The flour produced was packaged in an airtight plasticcontainer, labelled and kept in a refrigerator until needed for further use. The same procedure was followed in the preparation of other samples of malted pigeon flours in each case except that steeping and germination treatments were carried out at intervals of 8 h for 72 h and 10 h for 96 h, respectively for both thethird and fourth lots of red and brown varieties of pigeon pea seeds.

Proximate Analysis

The moisture, crude protein, ash, fat and crude fibre contents of the samples were determined on dry weight basis according to the standard analytical methods of AOAC (2010). The carbohydrate was calculated by difference. % Carbohydrate = 100 - % (Moisture + Crude Protein + Fat + Ash + Crude Fibre). The energy content was calculated by multiplying the percentage values of protein, fat and carbohydrate by the Atwater factors of 4, 9 and 4, respectively (AOAC, 2010). All determinations were carried out in triplicate samples.

Evaluation of Functional Properties

The water andoil absorption capacities were determined on dry weight basis according to the methods of AOAC (2010). The foam andswelling capacities were determined according to the methods described by Onwuka (2005). The bulk density was determined according to the method described byIwe*et al.,* (2016). Thegelation capacity was determined according to the method described by Butt and Batool (2010).All determinations were carried out in triplicate samples.

Evaluation of Pasting Properties

The pasting characteristics of the samples were determinedusing Rapid Visco Analyser (RVA) (Model 4500,Perten Instrument, Sweden) according to the method of AOAC (2010). Two grams (2g) of each sample was weighed into a dried empty canister and then 25mL of distilled water was dispensed into the canister containing the sample. The slurry was thoroughly mixed ineach case and each canister was fitted into the Rapid ViscoAnalyzer.The slurry was individually heated from 50^{o}C to 95^{o}C with a holding time of 2 min followed by cooling to 50^{o}C with 2 minholding time. The rate of heating and cooling was maintained at aconstant rate of 11.25^{o}C per min.The peak, trough, breakdown, final and setback viscosities as well as the peak time and pasting temperature of each sample were read from the pasting profile with the aid of a thermocyline for windows software that was connected to a computer.

Statistical Analysis

The data generated were subjected to one-way analysis of variance (ANOVA) using Statistical Package for Social Sciences (SPSS, Version 20) software. Significant means were separated using Turkey's least significant difference (LSD) test at $p<0.05$.

RESULTS AND DISCUSSION

Proximate Composition of Raw and Germinated Red and Brown Pigeon Pea Flours

The proximate composition of raw and germinated red and brown pigeon pea flour samples are presented in Table 1.

The moisture content of the samples ranged from 6.24 to 9.34% for the red variety and 6.44 to 9.77% for the brown variety, while that of the raw samples ranged from 6.24 to 6.44% with the red raw flour sample having the least moisture content (6.24%). The samples steeped for 10 h and germinated for 96 h had the highest moisture contents of 9.34% and 9.77%, respectively for the red and brown pigeon pea flours. The increase could be attributed to the absorption of large quantity of water by the seeds due to prolonged soaking in water during processing. The moisture content (6.24-9.34% and 6.44-9.77%) obtained for both samples were lower than the recommended moisture content limit of 14% that is compartible for the proper storage of legume flours (Nwosu *et al*., 2013). High moisture content of flour samples have been reported to accelerate enzymatic and microbial activities which in turn lead to loss of nutrients and inferior sensory characteristics of such products (Butt *et al*., 2004). Therefore, the lower the moisture content of a food material, the higher its shelf stability.Nsa and Ukachukwu (2009) reported that high moisture content generally affects the storage stability of legume and other flour products. The result obtained in this study indicate that the processed pigeon pea flours would have good keeping qualities with proper packaging and storage.

The crude protein content of the flour samples was significantly ($p<0.05$) higher in the germinated pigeon pea flours and ranged from 10.37 to 20.95% for the red variety, while that of the brown variety ranged from 10.47 to 23.69% compared to the raw samples which ranged from 10.37 to 10.47%. This development is in consonance with the findings of Duenas *et al*. (2009)

who reported that germination has the ability to increase the protein content and availability of free amino acids of lupine seeds. Hamad and Field (1997) also reported significant improvement in the protein content of sorghum and other grains during malting. Dietary proteins are needed for the synthesis of new cells, enzymes and hormones required for the development of the body. Specific proteins help in blood clotting, fluid balance as well as in hormone and enzyme production (Okaka*et al*., 2006).

The fat content of the flours ranged from 1.21 to 1.12% for the red variety and 1.23 to 1.13% for the brown variety. The fat content of the samples were generally reduced by steeping and germination treatments compared to the raw samples. The decrease in fat content could be due to increase in the activities of lipase enzymes which were activated during malting (Akubor and Chukwu, 1999). Fat is important in human diets because it is a high energy-yielding nutrient. Fat provides body backup fuel and acts as an insulator to the body during cold. It also provides satiety, delicious flavours and aroma during food preparation and processing.

The ash content of the flour samples ranged from 2.32 to 3.32% for the red variety, while that of the brown variety ranged from 2.42 to 3.13%. The ash contents of the flours processed from both varieties increased significantly ($p<0.05$) by steeping and germination treatments. Mbaeyi and Onweluzo (2010) reported a decrease in ash content of sprouted sorghum flour and suggested that the reduction could be due to the removal of vegetative part of the seeds during drying and milling which led to decrease in ash content.

The crude fibre content of the samples ranged from 3.14 to 4.31% with the brown variety steeped for 10 h and germinated for 96 h having the highest value (4.31%). The crude fibre content of the germinated pigeon pea flours increased with increase in steeping and germination period. This increase may be attributed to the synthesis of more cell wall materials during germination which in turn support the development of fibrous materials in the seeds (Akubor *et al*., 2000). Fibre plays a significant role in the digestion and absorption of foods through the promotion of increased excretion of bile acids, sterols and fats which have been implicated in the etiology of certain ailments in humans (Okaka*et al*., 2006).

The carbohydrate content of the samples was significantly ($p<0.05$) lower in the germinated flour samples compared to the control samples. The carbohydrate content ranged from 76.75 to

61.07% for the red variety, while that of the brown variety ranged from 57.99 to 76.26%. Similar decrease in carbohydrate content has been reported by Akubor and Chukwu (1999) for germinated millet flour. The decrease in carbohydrate content could be due to the reduction in alpha amylase activity which tends to break down complex carbohydrates into simpler and more absorbable sugars by the growing seedlings during the early stage of germination.

The energy content of the samples ranged from 329.29 to 353.22KJ/100g for the red variety and 336.83 to 358.18KJ/100g for the brown variety. The raw flour sample produced from the brown variety had the highest energy content of 358.18KJ/100g compared to the red variety which had the energy value of 329.29KJ/100g. The result showed that the energy content of the samples was generally higher than the energy value of 325.46 KJ/100g reported by Adebowale *et al*. (2011) for fermented pigeon pea flour. The decrease in energy content of the samples could be attributed to the decrease in both the fat and carbohydrate contents of the samples. Generally, the steeping and germination of red and brown varieties of pigeon pea seeds for 10 and 96 h, respectively greatly improved the protein, ash and crude fibre contents of the flour samples, while their fat, carbohydrate and energy contents were drastically reduced. The decrease in both carbohydrate and fat contents of the germinated pigeon pea flours has some beneficial effects when these flours are intended for use in the formulation of food products for people suffering from diabetes mellitus, cardiovascular diseases and hyper-cholesterolemia.

Table 1. Proximate composition (%) of raw and germinated red and brown pigeon pea flours

Parameters	A 1 h (0 h)	B 6 h (48 h)	C 8 h (72 h)	D 10 h (96 h)	E 1 h (0 h)	F 6 h (48 h)	G 8 h (72 h)	H 10 h (96 h)
	Samples							
Moisture	$6.24^{g}\pm0.01$	$7.24^{g}\pm0.01$	$8.11^{d}\pm0.01$	$9.34^{b}\pm0.01$	$6.44^{f}\pm0.01$	$7.32^{e}\pm0.01$	$8.55^{c}\pm0.01$	$9.77^{a}\pm0.01$
Crude Protein	$10.37^{g}\pm0.01$	$14.51^{f}\pm0.01$	$17.64^{c}\pm0.01$	$20.95^{b}\pm0.05$	$10.47^{e}\pm0.01$	$15.10^{d}\pm0.01$	$17.77^{c}\pm0.01$	$23.69^{a}\pm0.01$
Fat	$1.21^{b}\pm0.01$	$1.18^{c}\pm0.01$	$1.15^{c}\pm0.00$	$1.12^{d}\pm0.01$	$1.23^{a}\pm0.01$	$1.20^{b}\pm0.00$	$1.17^{c}\pm0.01$	$1.13^{d}\pm0.01$
Ash	$2.32^{f}\pm0.02$	$2.41^{e}\pm0.01$	$2.77^{c}\pm0.01$	$3.32^{a}\pm0.01$	$2.42^{e}\pm0.01$	$2.56^{d}\pm0.01$	$2.72^{c}\pm0.02$	$3.13^{b}\pm0.01$
Crude fibre	$3.14^{g}\pm0.02$	$3.53^{f}\pm0.01$	$3.88^{d}\pm0.01$	$4.23^{b}\pm0.01$	$3.18^{g}\pm0.01$	$3.64^{e}\pm0.01$	$3.95^{c}\pm0.01$	$4.31^{a}\pm0.01$
Carbohydrate	$76.75^{a}\pm0.05$	$71.16^{b}\pm0.02$	$66.47^{d}\pm0.01$	$61.07^{f}\pm0.01$	$76.26^{b}\pm0.02$	$70.20^{c}\pm0.02$	$65.87^{e}\pm0.02$	$57.99^{g}\pm0.06$
Energy (KJ/100g)	$359.29^{g}\pm0.01$	$353.22^{b}\pm0.12$	$346.76^{d}\pm0.01$	$338.10^{d}\pm0.09$	$358.18^{a}\pm0.05$	$351.96^{c}\pm0.11$	$345.005^{e}\pm0.12$	$336.83^{f}\pm0.07$

Values are mean ± SD of triplicate determinations. Means within the same row with the same superscripts are not significantly different ($p<0.05$)

A-Red (raw) pigeon pea flour without steepingand germination treatment**,**B-Red pigeon pea flour steeped for 6h and germinated for 48 h**,**C-Red pigeon pea flour steeped for 8h and germinated for 72 h**,**D-Red pigeon pea flour steeped for 10 h and germinated for 96 h**,**E- Brown (raw) pigeon pea flour without steeping and germination treatment,F-Brown pigeon pea flour steeped for 6 h and germinated for 48 h,G-Brown pigeon pea flour steeped for 8 h and germinated for 72 h,H-Brown pigeon pea flour steeped for 10h and germinated for 96 h.

Functional Properties of Raw and Germinated Red and Brown Pigeon pea Flours

The functional properties of raw and germinated pigeon pea flour samples are presented in Table 2.

The bulk density of the processed samples ranged between 0.22 to 0.48 ml/g for the red variety and 0.36 to 0.58ml/g for the brown variety, while that of the raw samples ranged from 0.58 to 0.63 ml/g with the brown variety having the highest value (0.63 ml/g). The reduction in the bulk density observed in all the germinated samples could be due to solubilization of starch polymers during processing as a result of steeping and germination treatments (Uche *et al*., 2014). The observation is in agreement with the report of Arukwe*et al*. (2017) who stated that germination causesthe decrease in bulk density of foods. The bulk density is important in determining the packaging requirement and material handling in food processing and preparation (Malomo*et al*., 2012).

The water absorption capacity of the processed samples ranged between 1.44 to 1.58% for the red variety and 1.54 to 1.69% for the brown variety, whereas the water absorption capacity of the raw samples ranged from 1.36 to 1.47% with the brown variety having the highest value (1.47%). The increase in the water absorption capacity observed in all the germinated samples could be due to ability of the protein present in both varieties of the seed to absorb and retain water during processing as a result of steeping and germination treatments. The water absorption capacity of the samples was significantly ($p<0.05$) higher in samples steeped for 10 h and germinated for 96h compared to those steeped for 6 h and 8 h and germinated for 48h and 72 h, respectively for red and brown varieties of pigeon pea seeds. The observation is in agreement with the findings of Leonel*et al*. (2009) who observed that germination increased the water absorption capacity of the flours. The high water absorption capacity of both the processed red and brown pigeon pea flours suggest that they can be used as thickeners in the preparation of liquid and semi liquid foods because of their ability to absorb and retain water due to increase in hydrophilicity of the seed proteins (Osundahunsi*et al*., 2003; Fasasi *et al*., 2007). The flours will also have higher flavour retention capacity and better mouthfeel than the flours made from the raw samples.

The oil absorption capacity of the processed samples ranged between 1.48 to 1.61% for the red variety and 1.46 to 1.67% for the brown variety, while that of the raw samples ranged from

1.40to 1.46% for brown and red varieties. The increase in oil absorption capacity of the germinated samples could be attributed to the presence of more hydrophobic proteins than the non – polar amino acid side chains which have superior binding effects to oil during processing as a result of steeping and germination treatments (Onimawo and Akubor, 2005). The oil absorption capacity was significantly ($p<0.05$) higher in samples steeped for 10 h and germinated for 96h compared to those steeped for 6 and 8 h and germinated for 48 h and 72 h, respectively for the red and brown pigeon pea flours. The result is in agreement with the report of Falmata*et al*. (2014) who reportedsignificant increase in oil absorption capacity of cereal and legume flours as a result of sprouting. The oil absorption capacity of the flour is known to be of great importance in enhancing the sensory characteristics such as flavour and mouthfeel of the foods. Flours with excellent oil absorption capacity may be useful in the preparation of pastries and doughnuts. The flours could be used also as flavour retainers in food formulations.

The swelling capacity of the processed samples ranged between 2.22 to 2.38ml/g for the red variety and 2.21 to 2.46ml/g for the brown variety, while that of raw samples ranged from 1.67 – 2.13ml/g with the brown variety having the highest value (2.13ml/g). The increase in the swelling capacity of the germinated pigeon pea flours might be due to modifications of the starch granules during sprouting which resulted in higher water uptake by the granules. The result is in agreement with the report of Falmata*et al*. (2014) who stated that sprouting of legumes and cereals resulted in increase in the swelling capacities of their flours. The high swelling capacity of the flour is anindication of their suitability for use as disintegrants in the pharmaceutical industry (Omojola*et al*., 2004). Flours with good swelling capacity are primarily used for thickening of soups, sauces, and gravies.

The gelation capacity of the processed samples ranged between 9.12 to 11.13ml/g for the red variety and 9.37 to 11.41ml/g for the brown variety, while that of the raw samples ranged from 8.24 – 8.88ml/g with the red and brown varieties having the least (8.24ml/g) and highest (8.88ml/g) values, respectively. The variation in gelation capacity of germinated pigeon pea flours could be associated with the relative ratios of different constituents such as protein, carbohydrate and fat that made up the seeds(Akubor *et al*., 2000). Flours with good gelation capacity could be useful in the preparation of puddings and snacks especially where thickening and gelling are needed.

The foam capacity of the processed samples ranged between 12.01 to 12.19% for the red variety and 13.06 to 13.25% for the brown variety, whereas the foam capacity of the raw samples ranged from 12.28 to 13.33% with the brown variety having the highest value (13.33%). The foam capacity of the flour samples was found to decrease as the time of steeping and germination treatments increased during processing. Akubor and Obiegbunam (1999) reported that germination reduced thefoam capacity of millet flour but slightly increased its foam stability. Foams are used to improve the texture, consistency and appearance of foods. Flours with good foam capacity may be useful in the preparation of bakery products.

Generally, steeping and germination greatly enhanced the functional properties of the pigeon pea flours with the exception of bulk density and foam capacity. This implies that the flours can be used in food systems like bread, cake and biscuit products. The ability of the flours to absorb water and oil may help to enhance the sensory qualities of bakery products and pastries such as flavour and mouthfeel.

Table 2: Functional properties of raw and germinated red and brown pigeon pea flours

Parameters	A 1 h (0 h)	B 6 h (48 h)	C 8 h (72 h)	D 10 h (96 h)	E 1 h (0 h)	F 6 h (48 h)	G 8 h (72 h)	H 10 h (96 h)
Bulk Density (ml/g)	0.58^{b}±0.01	0.48^{c} ±0.01	0.33^{e}±0.01	0.22^{f}f±0.01	0.63^{a} ±0.01	0.58^{b} ±0.01	0.43^{d} ±0.01	0.36^{e}±0.01
Water Absorption Capacity (%)	1.36^{d} ±0.01	1.44^{c} ±0.01	1.51^{b} ±0.01	1.58^{a} ±0.01	1.47^{d} ±0.01	1.54^{c} ±0.01	1.61^{b} ±0.01	1.69^{a} ±0.01
Oil Absorption capacity (%)	1.40^{d} ±0.01	1.48^{c} ±0.01	1.55^{b} ±0.01	1.61^{a} ±0.01	1.46^{d} ±0.01	1.54^{c} ±0.01	1.61^{b} ±0.01	1.67^{a} ±0.01
Swelling capacity (ml/g)	2.13^{d} ±0.01	2.22^{c} ±0.01	2.29^{b} ±0.01	2.38^{a} ±0.01	1.67^{d} ±0.05	2.21^{c} ±0.01	2.38^{b} ±0.01	2.46^{a} ±0.01
Gelation capacity (ml/g)	8.24^{d} ±0.02	9.12^{c} ±0.02	10.07^{b} ±0.02	11.13^{a} ±0.01	8.88^{d} ±0.01	9.37^{c} ±0.02	10.77^{b} ±0.01	11.41^{a} ±0.01
Foam capacity (%)	12.28^{a} ±0.01	12.19^{b} ±0.01	12.08^{c} ±0.01	12.01^{d} ±0.01	13.33^{a} ±0.01	13.25^{b} ±0.01	13.18^{c} ±0.01	13.06^{d} ±0.01

Values are mean ± SD of triplicate determinations. Means within the same row with the same superscripts were not significantly different ($p<0.05$)

A-Red (raw) pigeon pea flour without steeping and germination treatment**,** B-Red pigeon pea flour steeped for 6 h and germinated for 48 h**,** C-Red pigeon pea flour steeped for 8 h and germinated for 72 h**,** D-Red pigeon pea flour steeped for 10 h and germinated for 96 h**,** E- Brown (raw) pigeon pea flour without steeping and germination treatment,F-Brown pigeon pea flour steeped for 6 h and germinated for 48 h,G-Brown pigeon pea flour steeped for 8 h and germinated for 72 h,H-Brown pigeon pea flour steeped for 10 h and germinated for 96 h.

Pasting Properties of Raw and Germinated Red and Brown Pigeon pea Flours

The pasting properties of raw and germinated pigeon pea flour samples are presented in Table 3. The peak viscosity of the processed samples ranged between 48.15 to 66.78RVU for the red variety and 56.74 to 74.55RVU for the brown variety, while the peak viscosity of the raw samples ranged from 37.16 to 43.04RVU with the brown variety having the highest value (43.04RVU). The samples steeped for 10 h and germinated for 96 h had the highest values of 66.78 RVU and 74.55 RVU, respectively for the red and brown pigeon pea flours. There were significant differences (p<0.05) in the peak viscosity of the flour samples. The increase in the peak viscosity of the germinated samples could be attributed to the increase in the activities of hydrolytic enzymes which degraded the starch molecules into simpler sugars during processing as a result of steeping and germination treatments(Arukwe*et al*., 2017). Germination has been reported to increase the peak viscosity of food materials (Uche *et al*., 2014).

The trough viscosity of the processed samples ranged between 40.18 to 52.76RVU for the red variety and 50.24 to 61.10RVU for the brown variety,whereas that of the raw samples ranged from 58.35 to 67.34RVU with the red pigeon pea flour having the least value (58.34RVU). There were significant differences (p<0.05) in the trough viscosity of the flour samples. The reduction in the trough viscosity of the germinated samples could be attributed to the production of flours with low retrogradation tendenciesfrom red and brown pigeon pea seeds coupled with the increase in the activities of hydrolytic enzymes as a result of steeping and germination treatments during processing (Uche *et al*; 2014). Trough is the minimum viscosity which measures the ability of paste to withstand breakdown during cooling (Bolarinwa *et al*., 2015).

The breakdown viscosity of the processed samples ranged between 39.30 to 54.87RVU for the red variety and 50.34 to 62.79RVU for the brown variety, while the breakdown viscosity of the raw samples ranged from 31.81 to 45.22RVU with the red pigeon pea flour having the least value (31.81RVU). The samples steeped for 10 h and germinated for 96 h had the highest values of 54.87 RVU and 62.79 RVU, respectively for the red and brown pigeon pea flours. There were significant differences (p<0.05) in the breakdown viscosities of the flour samples. The increase in the breakdown viscosity observed in the germinated samples could be attributed to treatment effects which resulted in the degradation of starch molecules into simpler sugars by the activities of enzymes during processing.The breakdown viscosity is essentially a measure of the degree of paste stability or starch granule disintegration during heating (Usman *et al.,* 2016). The ability of starch to withstand heating at high temperature and shear stress is an important factor in many processes. Elofosson*et al*. (1997) stated that the formation of gels by the proteins in foods results from a two-step process involving, first, the partial denaturation of individual proteins to allow more access to the reactive side groups within the protein molecules and secondly, the aggregation of these proteins by means of reactive side groups into a continuous three dimensional network structure that is capable of retaining significant amount of water and also exhibiting same structural rigidity. This phenomenon is of great importance in foods since it contributes significantly ($p<0.05$) to the textual and rheological properties of various food products.

The setback viscosity of the processed samples ranged between 62.76 to 85.21RVU for the red variety and 67.03 to 87.34RVU for the brown variety, whereas that of the raw samples ranged from 92.95 to 98.98RVU with the brown variety having the highest value (98.98 RVU). There were significant differences ($p<0.05$) in the setback viscosity of the flour samples. The reduction in the setback viscosity of the germinated samples could be attributed to the increase in the activities of hydrolytic enzymes which degraded the starch molecules into simpler sugars as a result of steeping and germination treatments during processing(Arukwe*et al*., 2017). The reduction in setback viscosity of the flour samples is an indication of low rate of retrogradation and syneresis tendency of the pastes prepared from the flours. Setback viscosity has been correlated with the texture of the food products (Machiyo*et al*., 2004).

The final viscosity of the processed samples ranged between 105.83 to 117.19 RVU for the red variety and 115.17 to 125.05RVU for the brown variety, while the final viscosity of the raw samples ranged from 120.23 to 133.00 RVU for the red and brown pigeon pea flours, respectively. There were significant differences ($p<0.05$) in the final viscosity of the flour samples. The reduction in the final viscosity of the germinated samples could be attributed to treatment effects during processing. The final viscosity is an indication of the stability of paste after cooking. Akubor (2017) stated that flours with low final viscosity values are more stable than flours with high final viscosity values. Therefore, the lower final viscosity values recorded by the germinated pigeon pea flours could be an added advantage in the preparation of a wide range of food products.

The peak time of the processed samples ranged between 6.79 to 7.21 min for the red variety and 7.07 to 7.76 min for the brown variety, whereas that of the raw samples ranged from 7.34 to 7.99 min with the brown variety having the highest value (7.99 min). There were significant differences ($p<0.05$) in the peak time of the flour samples. The reduction in the peak time of the germinated samples could be attributed to the increase in the activities of hydrolytic enzymes which degraded the starch molecules of red and brown pigeon pea seeds into simpler sugars during processing as a result of steeping and germination treatments (Arukwe*et al*., 2017).This showed that the samples steeped for 10 h and germinated for 96 h would require less time to form paste compared to the other samples steeped for 6 and 8 h and germinated for 48 and 72 h, respectively for the red and brown pigeon pea flours. The peak time is an indication of the actual time taken by a food product to attain its peak viscosity, and the lower the peak time, the faster the cooking time of such a food product (Usman *et al*., 2016).

The pasting temperature of the processed samples ranged between 69.79 to 88.33^{o}C for the red variety and 80.11 to 93.66^{o}C for the brown variety, while the pasting temperature of the raw samples ranged from 92.71 to 99.21^{o}C with the red variety having the least value (92.71^{o}C). There were significant differences ($p<0.05$) in the pasting temperature of the flour samples. The differences in the pasting temperature of the processed samples could be due to treatment effects which might have made the samples to exhibit different stages of gelatinization (New Port-Scientific, 1996). The pasting temperature provides an indication of the minimum temperature required to cook a given sample and this also has some implications on energy usage during cooking (Ragee and Abdel-Aal, 2006). This means that the germinated pigeon pea flour samples could cook faster and save more energy (fuel) than the raw samples during cooking.

Generally, the good pasting properties of the processed flours will be beneficial in the formulation of infant foods and in meat processing industry.

Table 3: Pasting properties of raw and germinated red and brown pigeon pea flours

	Samples							
Parameters	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**
	1 h (0 h)	**6 h (48 h)**	**8 h (72 h)**	**10 h (96 h)**	**1 h (0 h)**	**6 h (48 h)**	**8 h (72 h)**	**10 h (96 h)**
Peak viscosity (RVU)	37.16^{h}±0.38	48.15^{f} ±0.69	54.89^{d} ±0.72	66.78^{b} ±0.01	43.04^{g} ±0.70	56.74^{e} ±0.02	62.68^{c} ±0.01	74.55^{a} ±0.01
Trough viscosity (RVU)	58.35^{c} ±0.01	52.76^{e} ±0.01	46.85^{g} ±0.70	40.18^{h} ±0.01	67.34^{a} ±0.01	61.10^{b} ±0.47	56.33^{d} ±0.49	50.24^{f} ±0.01
Breakdown viscosity (RVU)	31.81^{h} ±0.66	39.30^{g} ±0.70	47.87^{e} ±0.01	54.87^{c} ±0.00	45.22^{f}±0.01	50.34^{d} ±0.01	57.19^{b} ±0.47	62.79^{a} ±0.47
Setback Viscosity (RVU)	92.95^{b} ±0.36	85.21^{d} ±0.93	73.17^{f} ±0.39	62.76^{h} ±0.60	98.98^{a} ±0.01	87.34^{c} ±0.62	78.81^{e} ±0.01	67.03^{g} ±0.24
Final viscosity (RVU)	120.23^{c} ±0.01	117.19^{e}±0.52	112.74^{g} ±0.57	105.83^{h} ±0.57	133.00^{a} ±0.57	125.05^{b} ±0.55	$119.4d^{c}$ ±0.61	115.17^{f} ±0.59
Peak time (min)	7.34^{c} ±0.01	7.21^{d} ±0.01	7.06^{e} ±0.01	6.79^{f} ±0.01	7.99^{a} ±0.01	7.76^{b} ±0.01	7.37^{c} ±0.01	7.07^{e} ±0.01
Pasting temperature (^{o}C)	92.71^{c} ±0.01	88.33^{d} ±0.63	77.59^{g} ±0.01	69.79^{h} ±0.01	99.21^{a} ±0.41	93.66^{b} ±0.01	86.93^{e} ±0.53	80.11^{f} ±0.01

Values are mean ± SD of triplicate determinations. Means within the same row with the same superscripts were not significantly different (p<0.05)
A-Red (raw) pigeon pea flour without steeping and germination treatment**,** B-Red pigeon pea flour steeped for 6 h and germinated for 48 h**,** C-Red pigeon pea flour steeped for 8 h and germinated for 72 h**,** D-Red pigeon pea flour steeped for 10 h and germinated for 96 h**,** E- Brown (raw) pigeon pea flour without steeping and germination treatment,F-Brown pigeon pea flour steeped for 6 h and germinated for 48 h,G-Brown pigeon pea flour steeped for 8 h and germinated for 72 h,H-Brown pigeon pea flour steeped for 10 h and germinated for 96 h.

CONCLUSION

This present study evaluated the effect of germination on the proximate composition,functional and pasting properties of red and brown pigeon pea flours. The proximate composition of the samples revealed that steeping and germination treatments relatively increased the protein, crude dietary fibre and ash contents of red and brown pigeon pea flours, while their carbohydrate, fat and energy contents decreased drastically.The functional properties of the samples showed that the water absorption, oil absorption, swelling and gelation capacities were enhanced by steeping and germination treatments during processing, while the bulk density and foam capacity of the samples decreased. The pasting properties revealed that the peak, breakdown and final viscosities increased significantly ($p<0.05$) with increase in the time of steeping and germination during processing, while their trough and setback viscosities as well as the peak time and pasting temperature decreased. However, the processed red and brown pigeon pea flours generally have good functional and pasting properties which suggest that they could be used in the preparation of baked products, supplementary foods and meat extenders. They could be also used as thickening agents in both liquid and semi-liquid foods.

REFERENCES

Adebowale, K.O. and Lawal, O.S. (2004). Comparative study of the functional properties of bambara groundnut (*Voanbzeiasubterranean*), jack bean (*Cavanaliaensiformis*) and mucuna bean (*Mucunapruriens*). *Food Research International*;37: 355-365.

Adebowale, O.J. and Maliki, K. (2011). Effect of fermentation period on the chemical composition and functional properties of pigeon pea (*Cajanus cajan*) seed flour. *International Food Research Journal*;*18(4):* 1329-1333.

Akubor P.I. and Chukwu, J.K (1999). Proximate composition and selected functional properties of fermented and unfermented African oil bean (*Pentaclethra macrophylla*) seed flour. *Plant Foods for Human Nutrition*. 54: 227-238.

Akubor, P. I. (2017). Effect of processing methods on the chemical composition and functional properties of pigeon pea seed. *Asian Journal of Advances in Agricultural Research;* 2(2): 1-8.

Akubor, P. I. and Obiegbunam, J. E. (1999). Functional properties of ungerminated and germinated milled flour. *Journal of Food Science and Technology*;36(3):241-243.

Akubor, P.I., Isolokwu, P.C., Ugane, O. and Onimawo, I.A. (2000). Proximate composition and functional properties of African bread fruit kernel and wheat flour blends. *Food Research International*;33:707- 712.

AOAC. (2010). *Official Methods of Analysis. 18thedn. Association of Official Analytical Chemists*. Washington D.C. USA. Pp. 214-225.

Arukwe, D.C., Nwanekezi, E.C. and Agomuo, J.K. (2017). Effects of combined processing methods on the functional and pasting properties of pigeon pea (*Cajanuscajan*) flour. *InternationalJournalof Science and Qualitative Analysis*. 3(3): 23-30.

Bolarinwa, I.F., Olaniyan, S.A., Adebayo, L.O. and Ademola, A.A. (2015) Malted sorghum-soy composite flour: preparation, chemical and physicochemical properties. *Journal of Food Processing and Technology*;6(8): 1-7.

Butt, M.S., Sharif, M., Nasir, M., Iftikhar, S. and Rehman, K. (2004). Preparation and quality evaluation of cookies containing sweet potato flour. *Industrial Journal of Plant Science*;3: 69-76.

Butt, M. S. and Batool, R. (2010). Nutritional and functional properties of some promising legume protein isolates. *Pakistan Journal of Nutrition*; 9 (4): *374-379.*

Duenas, M., Hernandez, J., Estrella, I and Fernandez, D. (2009). Germination as a process to increase the polyphenol content and antioxidant activity of lupin seeds (*Lupines augustifolius L.).Food Chemistry*;*117:599-607.*

Elofosson, C. Dejmek, P. Poulso, M and Burlria, H (1997) Characterization of a cold why concentrate. *International Journal of Dairy Science*; 7: *601-607.*

Falmata, A.S., Modu, S., Badau, H.D., Babagana, M and Bintu, B.P. (2014). Formulation and evaluation of complementary weaning food prepared from single and combined sprouted fermented local red sorghum (*Sorghum bicolor)* variety blended with cowpea (*Vigna unguculata)* and groundnut (*Arachis hypogeal).International Journal of Biotechnology and Food Science*. *2(8):149-155.*

FAO (2010). *State of Food and Agriculture*. Rome, Italy: Food and Agriculture Organization in Developing Countries. Pp. 200-205.

Faris, D.G. and Singh, U. (1990). *Pigeon Pea: Nutrition and Products. In: The Pigeon pea* (*Nene Y.L; Hall S.D and Sheila V.K. Eds).* CAB International, UK. Pp. 401-434.

Fasasi, O.S., Eleyinmi, A.F. and Oyarekua, M.A. (2007). Effect of some traditional processing operations on the functional properties of African bread fruit seed (*Treculiaafricana)* flour. *LWTFood Science and Technology*. *40:153-159*.

Giami, S.Y. and Bekebain, D.A. (1992). Proximate composition and functional properties of raw and processed full-fat fluted pumpkin (*Telfairia occidentalis*) seed flour. *Journal of Food Science and Agriculture*; 59(3): 321-325.

Hamad, A. M. and Fields, M. C. (1997). Reduction of protein quality and available lysine of germinated and ungerminated cereals. *Journal of Food Science*;*44: 456- 459.*

Iwe, M. O., Onyeukwu, U. and Agiripa, A. N. (2016). Proximate, functional and pasting properties of FARO 44 rice, African yam bean and brown cowpea composite flours. *Cogent Food and Agriculture;* 2: *114-122.*

Leonel, M., Santos, T.B. and Mischan, M.M. (2009). Physical characteristics of extruded cassava starch. *Brazilian Journal of Chemical Engineering*;20: *129-137*.

Machiyo, W., Tomoko, M., Kikuchi, T., Hirochi, K and Naofumi, M. (2004). Application of pre-germinated brown rice for bread making. *Cereal Chemistry*;3:*293-317*.

Malomo, O., Ogunmoyela, O.A., Olewajoba, B.S.O. and Kukoyi, I. (2012). Effect of germinated soy flour on the sensory acceptability of soy-wheat composite bread. *AsianJournalof Natural and Applied Sciences;*2: 48-53.

Mbaeyi, I.E. and Onweluzo, J.C. (2010). Effect of sprouting and pre-gelatinization on the physicochemical properties of sorghum-pigeon pea composite blend used for the production of breakfast cereal. *Journal of Tropical Agriculture, Food, Environment and Extension*;9(1): 8-17.

Newport Scientific (1996). *Applications Manual for The Rapid Visco Analyser using Thermocline for Windows*. *Newport Scientific Pty Ltd.1/2 Apollo Street, Warriewood NSW 2102, Australia.* Pp. 2-26.

Nsa, E. E. and Ukachukwu, S.N. (2009). Effect of thermal processing methods on the proximate composition, gross energy, mineral and ricin content ofundecorticated castor oil seed (*Ricinus communis*).*Global Journal of Agricultural Science*; 8(2): 244-252.

Nwosu, J.N, Ojukwu M, Ogueke C.C; Ahaotu I. and Owuamanam C (2013). The anti-nutritional properties and ease of dehulling on the proximate composition of pigeon pea (*Cajanus cajan*) as affected by malting. *International Journal of Life Sciences;* 2(2): 60-67.

Okaka, J.C., Akobundu, E.N.T and Okaka, A.N.T (2006). *Food and Human Nutrition. An Integrated Approach.*Ocjano Academic Publishers, Enugu, Nigeria. Pp. 373-395.

Omojola, A., Isah, O., Adewumi, M., Ogunsola, O. and Attah, S. (2004). Evaluation of the effects of various additives on the acceptability of kilishi. *Tropical Journal of Animal Science*;6:10-43.

Onimawo, A.I. and Akubor, P.I. (2005). *Food Chemistry with Biochemical Approach*. Ambik Press Ltd, Benin City, Edo State Nigeria. Pp.222-228.

Onwuka, G.I. (2005). *Food Analysis and Instrumentation. Theory and practice*. Naphthali publishers, Lagos, Nigeria. Pp 48-56.

Osundahunsi, O. F., Fagbemi, T. N., Kesselman, E. and Shimoni, E. (2003). Comparison of the physicochemical properties and pasting characteristics of flour and starch from red and white sweet potato cultivars. *Journal of Agriculture and Food Chemistry*;51: 2232−2236.

Ragaee, S. and Abdel-Aal, E.M. (2006). Pasting properties of starch and protein in selected cerealsand quality of their food products. *Food Chemistry*;95: 9 - 18.

Ridge, I. (1991). *The Regulation of Plant Growth*. In: Ridge, I. (Ed.), *Plant Physiology*. Hodder and Stoughton, London, U.K., Pp. 282-333.

Steve, I.O (2012). Influence of germination and fermentation on chemical composition, protein quality and physical properties of wheat flour (*Triticum aestivum*).*Journal of Cereals and Oil Seeds;* 3(3): 35-47.

Uche, S.N, Charity, U.N, Abbas O. Aliyu, M., Francis, G.B. and Oche, O. (2014). Proximate, anti-nutrients and mineral composition of raw and processed (boiled and roasted) Sphenostylisstenocarpa seeds from Southern Kaduna, Northwest Nigeria.*International Scholarly Research Notices*;20(4):280-287.

Ugwu, F.M. and Oranye, N.A. (2006). Effects of some processing methods on the toxic components of African breadfruit *(Treculiaafricana). African Journal of Biotechnology*;6:*234-246*.

Usman, M.A., Bolade, M.K. and James, S. (2016).Functional properties of weaning food blends from selected sorghum (*Sorghum bicolor* (L.) Moench) varieties and soybean (*Glycine max*). *African Journal of Food Science*;10(8): 112-121.

Valdez-Anguino, D.M., Herrera-Cabrera, E., Davila-Oritz, G., Oomah, B.D., Cardador-Martinez, A. and Jimenez-Martinez, C. (2015). Content and distribution of nutritional and non-nutritional compounds during germination of three Mexican faba bean (*Vicia faba*). *International Journal of Research in Agriculture and Food Sciences*; 2(9): 2311-2476.