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EFFECT OF SPROUTING AND PRE-GELATINIZATION ON THE PHYSICOCHEMICAL PROPERTIES OF SORGHUM-PIGEON PEA COMPOSITE BLEND USED FOR THE PRODUCTION OF BREAKFAST CEREAL

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ABSTRACT

Sprouted (96-hour) and pregelatinized (78^0C) sorghum grains were milled and blended with graded proportion of pigeon-pea and used in formulating flaked breakfast cereal. A commercial ready-to-serve breakfast cereal served as product control. The flour blends and formulated products were subjected to the physicochemical quality analyses using standard methods. Results of the amylose content of the pregelatinized sample showed higher ($p<0.05$) amylose content than the sprouted samples. The sorghum samples used for the study showed pregelatinization temperature range of 68^0C and time of 10 minutes, respectively. Pregelatinization treatment increased the amylose content. Supplementation of sorghum with pigeon pea significantly ($p<0.05$) increased the protein and fat contents of the composite flour and reduced the ash and moisture contents significantly ($p <0.05$). Both treatments (pregelatinization and sprouting) reduced tannin, cyanide and phytic acid contents.

Key words: Sprouting, Pregelatinization, Breakfast cereal, Sorghum, Pigeon-pea

INTRODUCTION

In many developing countries such as Nigeria, malnutrition is a common dietary problem that is said to be endemic (Okoh, 1998; Nnanyelugo, 1996). It is characterized by micronutrient-deficiency (Nnanyelugo, 1996) and protein-energy malnutrition (Damarjati and Widowati, 1989). Animal protein products are quite expensive and above the reach of low-income family can to afford such protein source. As a result, dietary diversification has been employed as a solution to malnutrition challenges (Blum, 1997). Studies have been carried out to find other ways of enriching our locally –prepared cereal dishes with indigenous plant legumes (Nkama, 1994; Nkama and Malleshi, 1998). By so doing, it involves the use of commonly consumed grains and/or legumes in more than one form to meet the dietary need of the target people.

Some raw materials like soybean and maize are amply being used (Houssou and Ayemor, 2002; Echendu, *et al.*, 2004, Gupta, 2004, Lasekan and Akintola, 2004) but they are not sufficiently available to meet the demand of the populace due to their excessive industrials uses. Other good alternative like sorghum and pigeon pea (Onimawo and Asugo, 2004), which possesses interesting food potential or characteristics and large production ratio have not been fully exploited for products such as breakfast cereal materials.

Breakfast cereal is defined as food obtained by soaking, swelling, roasting, toasting, grinding, rolling/flaking, shredding of puffing of any cereal and which is usually eaten at breakfast. Flaking is one of the methods of processing breakfast cereal, which involves cleaning, and conditioning to suitable moisture content of the whole grain and lightly rolled between smooth rolls to fracture the outer layer (Kent, 1975). The grains so prepared are cooked and flavoured, dried to 25-20% moisture content, rested for 24-42 hours for conditioning to occur and conditioned grains baked on heavy flaking rolls, toasted in a traveling oven, cooled and packaged. Thus, flaking is a relatively simple process consisting in its most elemental form.

Although the cereal grains (including sorghum) provide the bulk of the protein requirement because of its low cost, they are reach in the essential sulphur- containing amino acids, methionine and cystine but deficient in lysine. Therefore the combination of cereal grains and legumes (such as pigeon pea) in traditional food preparation complement each other since the latter are found to be rich in lysine but deficient in both methionine and cystine (Nkama and Sopade, 1990). Thus, the cereal-legume blends could serve as

major sources of calorie, proteins, minerals and vitamins. Consequently, the supplementation of the grain legumes has been suggested as one way of improving the protein quality of cereal based diets Nkama, *et al.*,1995). Legumes are rich and economic dietary source of good quantity protein, carbohydrates, soluble and insoluble fibre components and a variety of minerals and vitamins. (Venter and Van Eyssen, 2001). Therefore, the research was aimed at formulating flaked breakfast cereal from pre-treated sorghum-pigeon pea composite flour blends.

MATERIALS AND METHODS

Sample Preparation

White variety of sorghum (*Sorghum bicolor L.)* and brown variety of pigeon pea (*Cajanus cajan)* were purchased from Nsukka market. The sorghum grains were cleaned, sorted and 3kg divided into three equal portion (1kg) each. The first portion was soaked for 22 hours-wet steep, 4 hours air rest and 22 hours wet steep at $28^0C \pm 2^0C$. The steeped grains were sprouted for 5 days and dried at 55^0C for 20 hours. The dried grains were kilned at 85^0C and for 4 hours. The rootlets and coleoptiles were devegetated. The sprouted grains were dry-milled using a hammer mill (Thomas Wiley mill Model ED-5). The flour obtained was sieved to pass through a 1mm pore sized sieve and designated sprouted sorghum flour (SSF) for the different sprouting periods respectively and used for analyses. The second lot after cleaned, sorted was milled into flour, stored and designated as a untreated/unsprouted sorghum flour (USF) and used for analyses.

The last portion was cracked using a disc attrition mill (Bentall Superb Model 200L, 090) to produce grits which were weighed into sub-portions of 10g each. Each portion of grits was moistened with 10ml of water and heated in a Gallenkamp water bath at different temperatures ($60\text{-}100^0C$) for 5-60 minutes to estimate the optimal gelatinization conditions. The pregelatinized grits here dried at 55^0C to a constant weight and milled in hammer mill, sieved to pass through a 1mm pore sized sieve, stored in polythene bags and designated on pregelatinized sorghum flours (PSF).

Pigeon pea seeds were cleaned, cracked for easy oil absorption, mixed with 1% edible, oil (Kings vegetable oil) and allowed to stand for 3 hours to aid seeds, decortication. The dehulled seeds were milled into fine flour using a hammer mill, sieved, packaged in bags as *Cajanus cajan* flour (CCF) used for product developed and used for analyses.

Proximate analysis

Composites/graded blends (100:0; 80:20; 70:30; 60:40; 50:50) of the treated sorghum and *Cajanus cajan* flours were prepared and analysed for proximate composition using standard AOAC (1995) methods for moisture, crude fat, ash and protein contents using nitrogen to protein conversion factor of 6.25. Carbohydrate was determined by difference (Oyenuga, 1968).

Determination of Total Energy

Gross energy was calculated using Atwater factors (4x protein, 9x fat and 4 x carbohydrate) by method of Oyenuga (1968).

Amylose content determination

Amylose content was determined by colorimetric method of Chrastil (1987) as an index of optimal sprouting conditions. This method involved three states viz:

i) Lipid extraction
ii) Solubilization
iii) Determination of the amylose

i. **Lipid extraction**: Two hundred grams (200g) of the sprouted sorghum flour (24-120 hours sprout samples) were weighed into test tubes and extracted with 85% methanol (5ml) for 30 minutes at 60^0C with occasional stirring. The samples were centrifuged and the supernatant discarded. The extractions were repeated twice.

ii. **Solubilization:** A 2ml of molar sodium hydroxide (NaOH) and 4ml of water were added to the lipid-free sample and the test-tubes were capped and heated for 30 minutes in a water bath at 95^0C with occasional mixing to give solution I. Other samples were solubilized for 30 minutes at 100^0C with 6ml of Urea-bimethylsulfoxide (Me_2SO).

iii. **Determination of Amylose:** Solution 1(0.1ml) was mixed with 5m1 of 5ml of 0.5% trichloroacetic acid (TCA) in a separate test-tube and subsequently mixed with 0.05ml of 0.01N iodine-potassium iodide (I_2-KI) solution (1.27g of iodine per liter+3g of Potassium iodine per litre) was added and mixed immediately. The blue colour was read at 620nm after 30 minutes rest at $251 \pm ^0C$ against water in a Spectrophotometer (Corning, model 253). The absorbance of the reaction blanks read zeros and the amount of amylose or the amylose content was approximated by the following formula:

$Ax45.8$ = mg of amylose per liter

Where;

A = Absorbance of the sample

Determination of optimal gelation conditions

Optimal gelation temperature and time were determined using a modification of the unmethod of Ott (1987). Two grams of the sample was weighed into a 50ml graduated beaker containing 10ml distilled water and stirred to

disperse. The beaker was heated in a water bath with continual string. A thermometer was inserted and used to determine the temperature of the water bath. The temperature was regulated to between 60^0C and 100^0C using a regulator (Erweka Regulator, W. Germany). The temperature and time at which a gel is formed on cooling of the starch paste refers to the optimal gelation conditions.

Determination of cyanide content

Cyanide content was determined on 2g of sprouted and unsprouted samples using the method of Harbourne (1973). Stock solution of fresh enzyme, linamarase was prepared from cassava tuber and absorbance of working standard of known concentration prepared were reacted with potassium cyanide and alkaline sodium picrate. The dilutions were incubated at 94^0C for 5 minutes for colour development and allowed to cool at room temperature before the optical densities of the deep red colour was read at 540nm.

Each sample (2g) was homogenized in 10ml of distilled water mixed with 10ml of crude linamarase enzyme and allowed to incubate for one hour at room temperature. Following the incubation, the sample was steam distilled until 200ml distillate was collected. The distillate was diluted to 300ml and to 20ml of each sample distillate was added 10ml of alkaline sodium picrate for colour development. The fractions were incubated for 5 minutes at 94^0C, allowed to cool to room temperature and optical densities of deep red colour was read at 540nm.

The cyanide content was calculated as**:**

$$mgC\overline{N}\ per\ Kg = \frac{mgC\overline{N}}{20ml} \times \frac{300}{20} \times \frac{1000}{w}$$

Where;

300 = total volume used to develop colour

20 = volume used to develop colour

W = weight of sample used

Determination of phytate or phytic acid

Phytate was determined by the method of the Thompson and Erdman (1982). A sprouted and unsprouted sorghum flour (2g) was extracted in a flask into which 100.0 ml of 1N Hydrochloric acid (HCl) and 10% sodium tetraoxosulphate VI (Na_2SO_4). The flask was stoppered and shaken for 2 hours on a mechanical shaker. The extract was vacuum filtered through No.4 Whatman filter paper and 10.0ml of the filtrate was pipetted into a 50ml centrifuge tube. To the filtrate was added 10ml deionized water added, followed by 12ml of Iron III chloride ($FeCl_3$) solution. The tubes were stirred, heated for 75 minutes in a boiling water bath, cooled, covered and allowed to stand for one hour at room temperature which they were centrifuged at 1000rpm for 15 minutes. The supernatant was decanted and discarded and the residue was thoroughly washed thrice with a solution of 0.6% hydrochloric acid (HCl) and 2.5% sodium tetraoxosulphate VI (Na_2SO_4). After each wash, the contents were centrifuged at 1000rpm for 10 minutes and the supernatant discarded and washed residue was added to 10ml concentrated trioxonitrate (HNO_3) and the content transferred quantitatively to a 400ml beaker with several small portions of deionized water. Four drops of concentrated tetraoxosulphate VI (H_2SO_4) was added and the contents were heated approximately 30 minutes on a hot plate to almost dryness. Approximately 4-5ml of 30% hydrogen peroxide (H_2O_2) was added and the mixture was returned to the hot plate at a low heat until bubbling ceased. The residue was dissolved in 15ml 3N hydrochloric acid (HCl) and heated for 10-15 minutes. The resulting solution was made up to 100.0ml volume diluted 1:5 and then analyzed for phytic acid (iron) using Franson, *et al.*, (1975) procedure. Iron formed an insoluble salt with phytic acid and because iron phytate reacts with bipyridine, to the resulting solution and absorbance of 519nm, colour change within 0.5-1min was red against distilled water. Also, 4:6 Fe: P molecular ratio was used to calculate phytin phosphorus and phytic acid content . Total phosphorus was determined spectrometrically (Pye Unicom) by the phosphor-vanado molybdate method (AOAC, 1995).

Determination of tannin content

Tannin was determined by the method of Price and Butler (1977). Two (2ml) of each sample of the sprouted and unsprouted samples was weighed into a 250ml flasks followed by 200ml of 0.0004M potassium iron III cyanide [$K_2Fe(CN)_6$]and 10ml of 0.008M Iron III chloride ($FeCl_3$) in 0.008N hydrochloric acid (HCl). Colour developed within seconds, then deepened slowly over the next few minutes as more tannin was extracted as viewed visually. The colorimetric estimation was then done. The prepared flasks were swirled occasionally for 20 minutes. After settling for 10 minutes, 1ml aliquot was removed. To this was added 2ml of 0.008M Iron III chloride ($FeCl_3$) in 0.008N hydrochloric acid (HCl) and 10ml of 0.0015M potassium iron III cyanide [$K_2Fe(CN)_6$]. The absorbance of tannin at 720nm was read 30 seconds after adding the final reagent.

Tannin (mg/100g) = An/aAs x C x 100/V X Vf/Va

Where:

An = absorbance of test sample

As = absorbance of standard solution

C = concentration of standard solution

W = weight of sample used

Vf = Total volume of extract

Va = Volume of extract analyzed

RESULTS AND DISCUSSION

Effect of treatment of amylose content

The amylose content of the treated samples is represented in Table 1. Both sprouting (0- 96 hours) and pregelatinization increased the amylose content of sorghum flour but pregelatinization showed 80% greater increased than sprouting. In both treatments, the amylose increased with increase in the pregelatinization temperature and time as well as sprouting time. This increase could probably be as a result of the breakdown of the starch by the amylolytic enzymes inherent in the seeds during sprouting into simple sugars (amylose). Obizoba and Atii (1991) observed similar increase in the reducing sugar content during germination. Chavan, *et al.,* (1991) reported a 10-fold increase in some reducing sugars and disappearance of galacto-oligosaccharide during sprouting of sorghum grains. Heating also produced a similar effect as was evident in the pregelatinization treatment (Table1). As the treatment temperature and time increased, the amylose content also increased. Probably increasing the heating temperature and time increased the extent of hydrolysis of starch and oligosaccharides to simpler soluble sugars. Heerden and Glennie (1987) and Chrastil (1987) made similar observations during the heating of sorghum grain.

Table 1: Effect of Sprouting and Pregelatinization on the amylose content of sorghum grains

Sample	Amylose Content
SSF (Control, 0 hour)	0.9160±0.000058
SSF (24 hours)	2.5600±0.0000116
SSF (48 hours)	3.2060±0.00000
SSF (72 hours)	8.4730±0.00000
SSF (96hours)	8.7020±0.00058
PSF (Control 60^0	8.2240±0.000058
PSF (65^0C)	9.3890±0.000116
PSF(68^0C)	9.5264±0.003333
PSF(70^0C)	10.3050±0.00058
PSF(75^0C)	10.9920±0.00000
PSF(78^0C)	11.6790±0.00058
PSF(80^0C)	12.660±0.00000
PSF(90^0C)	13.5110±0.00058
PSF(100^0C)	13.9690±0.00000

Values are means of triplicate determinations ±SEM of triplicate readings
SSF = Sprouted Sorghum flour;
PSF = Pregelatinization Sorghum flour

Effect of gelatinization temperature and time on gel strength

Table 2 shows the optimal gelatinization temperature range and time of sorghum grits. The sorghum grits pregelatinized at 65^0C for 60 minutes formed very weak gels and at 72^0C for 40 minutes weak gels were also formed while those pregelatinized at 74^0C for 30 minutes formed strong gels. This disparity in the gel strength with increase in temperature and heating time was attributed to increased water uptake by the sorghum grits due to increase contact time. Thus, an increase in the heating time increases the strength of the gels formed as the time increased (Banks and Greenwood, 1975). The optimal ranges for the gelation of sorghum starch was therefore deduced to between 68^0C-78^0C**.** The degree of gelation was noted at an optimal temperature of 78^0C. With the optimal temperature, the samples (2g of the sprouted and the pregelatinized flour) were used to obtain optimal gelation time by varying the heating time between 5 and 60 minutes.

Table 2: Gelatinization of Sorghum as Influenced by Temperature and Time

Temperature (^{0}C)	Time of gelation (minutes)						
60	5	10	20	30	40	50	60
65	-	-	-	-	-	-	-
66	-	-	-	-	-	-	+
67	-	-	-	-	-	-	+
68	-	-	-	-	+	+	+
69	-	-	-	-	+	+	+
70	-	-	-	-	+	+	+
71	-	-	-	-	++	++	++
72	-	-	-	-	++	++	++
73	-	-	-	-	++	++	++
74	-	-	-	++	++	++	+++
75	-	-	-	++	++	+++	+++
76	-	-	-	+++	+++	+++	+++
77	-	-	-	+++	+++	+++	+++
78	-	++	++	+++	+++	+++	+++
79	-	++	++	+++	+++	+++	+++
80	++	++	++ +	+++	+++	+++	+++
85	++	++	++ +	+++	+++	+++	+++
90	++	++	++ +	+++	+++	+++	+++
95	++	++	++ +	+++	+++	+++	+++
100	++	++	++ +	+++	+++	+++	+++

Key: - → No gel; + → **very weak gel**; ++ → **Weak gel**; +++ → strong gel

Effect of sprouting and pregelatinization on the proximate composition of sorghum-pigeon-pea flours and their blends

The proximate composition of the treated and untreated samples and their compositions were recorded in Table 3. Treatment influenced the composition of the grains to varying extent.

Crude protein

Sprouting and pregelatinization increased the protein content of the treated and untreated sorghum and *Cajanus cajan* flour from 9.85% to13.15% could probably be as a result of protein supplementation from the legume (pigeon peas). The protein content of the pregelatinized sample blended with *Cajanus cajan* (9.45% to 14.35%) did not follow a particular trend just as the untreated sample, which showed an increase protein content from 8.75% to 14.85% in the blends. The range of the protein content was higher than those obtained from wheat-plantain composite flour blends which was between 5.6-10.2% (Mepha, *et al., 2007).* In comparing the pregelatinized sample and untreated blends, it was observed that the untreated samples had lower protein content than the pregelatinized composites and sprouted blends. The higher protein content in both pregelatinized and sprouted blends was probably due to the blending. The protein content of pigeon pea complemented the lower protein content of sorghum. Results obtained by Eneche (1999) showed an increase in the protein content of millet when complemented with pigeon pea. The substitution of sorghum flour with pigeon pea flour produced the desired effect of increasing the protein content of the blends, which would invariably improve the nutritional quality of the product from these blends. Similar substitution of maize flour with pigeon pea flour increased the protein content according to Echendu, *et al.,* (2004). However, statistically, there was no significant differences between the protein content of both the treated and untreated samples. Expectedly, the addition of pigeon pea to the sorghum increased the protein while reduced the total carbohydrate. Similar results were obtained by Rampersad *et al.,* (2003). This implies that the protein levels of the flours were influenced by the supplementation and the increase in protein demonstrated the beneficial effect of supplementing more than one or two foods. Similar increase in the protein content of sprouted samples were also observed by Obizoba (1983, 1986; 1990). Results from Obizoba (1990) showed that the controlled malting remarkably increased the protein content. The increases in protein could be attributed to release of free amino acid for the synthesis of protein for the embryo due to the breakdown of tannin-protein complexes by the pretreatment (Hamad and Fields, 1979. Chavan, *et al.,* 1981; Wu and Walls, 1989;

Ash content

The ash content (Table 3) of the untreated flour blends ranged between 1.50% -2.50% while the ash content of samples containing pregelatinized flour decreased as the proportion of the pigeon pea flour content (CCF) increased. Sprouting decreased that ash content. The unblended pigeon pea flour (CCF) has the highest ash content of 4.00%. The flour blend were found to have an ash content lower than the unblended pigeon pea flour. The treatments (sprouting) aided the removal of the vegetative part of the seeds during milling leading to losses in dry matters and leaching of the nutrients. In contrast, the ash content of breakfast cereal from maize-soybean-cassava starch blends was higher probably due to the inclusion of ripe fruits pulp thereby fortifying the product with minerals and hence the total ash (Enwere and Ntuen, 2005).

Crude fibre

Table 3 shows that the fibre content was quite low having a mean of 1.50%-4.00% probably due to the fact that the fibre in both the hull and bran were removed during processing. The fibre content of the untreated flour blends (USF) increased as the pigeon pea incorporated increased. The fibre content of the pregelatinized flour blends ranged between 2.50%-3.50%. Similar results were obtained by Echendu, *et al.,* (2004). The unblended pigeon pea flour (CCF) had 4.00% fibre. Ene-Obong and Carnovale (1992) reported similar results for pigeon pea. According to FAO (1989) sorghum has a mean crude fibre 1.9% (1.0%-3.4%). The major insoluble fibre component of sorghum is cellulose and it varies from 1.19 to 5.23% depending on the sorghum variety (Kamath and Belavady, 1980).

Moisture content

The moisture content of the untreated blends (USF) as seen from Table 3 ranged between 8.05%-10.00% in the sprouted sample and between 6.00%-10.50% in the pregelatinized samples. The sprouted flour blends had a moisture content of 7.05%-9.50% unlike the unblended pigeon pea (CCF) sample which has a moisture content of 12.45%. The variation in the moisture content is due to drying level and the ability of the dehydrated samples to absorb moisture in the environment of high range of relative humidity of 80.4%-85.6%. The moisture content of the pregelatinized samples was between the moisture content of sprouted and untreated samples (6.00%-10.50%). Similar results by Gomez, *et al.,* (1987) reported comparable moisture content of (8.00-10.00%) of sprouted and unsprouted sorghum samples while to Obizoba and Atii (1991), reported moisture content range of 6.00%-10.00% germinated and ungerminated sorghum flour. The observed low moisture content of the samples may have an added advantage of enhancing shelf stability.

Table 3: Proximate Composition (%) of Sorghum and Pigeon Pea Flours and Their Blends

Sample (2g)	Crude protein (%)	Ash (%)	Crude fibre (%)	Moisture content (%)	Crude fat (%)	Carbohydrate content (%)	Energy/caloric value (Kcal/100g)
USF+CCF (100:0)	9.85±0.2848	2.50±0.0000	1.00±0.1667	8.80±0.5774	10.65±0.0000	67.20±0.0002	404.05
USF+CCF (80:20)	8.95±0.0848	2.60±0.0002	1.50±0.000	10.00±1.5275	8.70±0.5774	8.25±0.1443	387.10
USF+CCF (70:30)	8.75±0.0443	1.50±0.0887	2.50±0.000	9.95±0.000	8.95±0.0000	68.35±0.2021	316.46
USF+CCF (60:40)	12.95±0.3180	1.50±0.0887	2.00±0.2887	8.05±0.002	12.00±0.0551	63.50±0.5774	386.50
USF+CCF (50:50)	14.85±0.2833	2.50±0.0000	2.00±0.2887	9.49±0.5774	14.20±0.1155	55.96±0.0000	411.04
PSF+CCF (100:0)	9.45±0.1607	2.00±0.3333	1.00±0.000	9.50±0.3333	3.10±0.001	74.95±0.57754	365.50
PSF+CCF (80:20)	9.35±0.1202	1.50±0.0000	2.50±0.000	10.50±0.3333	2.50±0.4410	71.65±0.5774	346.50
PSF+CCF (70:30)	14.35±0.2000	1.50±0.2000	3.00±0.1667	9.50±0.5774	5.80±0.0000	65.75±0.5774	372.60
PSF+CCF (60:40)	10.95±0.2000	1.50±0.2000	1.50±0.0000	10.00±0.000	7.15±0.0002	68.90±0.5774	383.75
PSF+CCF (50:50)	13.78±0.2000	1.50±0.4410	1.00±0.0000	6.00±0.5774	7.55±0.0.000	70.17±0.0000	403.75
SSF+CCF (100:0)	9.85±0.2000	1.50±0.2000	2.50±0000	7.05±0.0002	5.10±0.5774	74.00±0.5774	381.30
SSF+CCF (80:20)	10.95±0.2000	2.50±0.4410	3.00±0.2887	9.15±0.0002	6.75±0.1000	67.65±0.2205	375.15
SSF+CCF (70:30)	11..85±1.0569	2.50±0.2000	2.50±0.4410	9.30±0.1732	4.60±0.0000	69.25±0.5774	365.80
SSF+CCF (60:40)	12.03±0.2000	1.50±0.200	3.50±0.0000	7.45±0.000	10.80±0.8819	64.72±0.3333	404.20
SSF+CCF (50:50)	13.15±0.1500	2.00±0.2404	3.00±0.000	9.50±0.2887	10.60±0.0002	58.75±0.3333	383.00
CCF (100:0)	14.75±0.0015	4.00±0.000	4.00±0.000	12.45±0.0034	9.700±.0053	55.10±0.010	366.70

Values are means of triplicate determination ± SEM

USF ⇒ Untreated sorghum flour; SSF ⇒ Sprouted sorghum flour; PSF ⇒ Pregelatinized sorghum flour;

CCF ⇒ *Cajanus cajan* flour

Crude fat

Sprouting and pregelatinization decreased that fat content in the blends as the ratio of sorghum to the pigeon pea decreased (Table 3). The crude fat content of the sprouted flour blends ranged between 4.60-10.80% while the fat content of pregelatinized flour composites ranged between 2.50%-7.55%. The fat of the untreated flour composites ranged between 3.10%- 14.42% while the unblended pigeon pea (CCF) had a value of 9.70%. Thus, the sprouted and pregelatinized samples used in this study showed low fat content relative to value reported in literature by other workers.

According to FAO/WHO (1995) and FAO (1989), white variety of sorghum has a crude fat of 3% while Mayhew and Penny (1988) reported a crude fibre content of 1.7% for pigeon pea when sprouted. Processing therefore influenced the lipid levels of these grains. Sprouting decreased the lipid content of the sorghum samples significantly ($p<0.05$) and increased that of pigeon pea. Similar results were obtained by Nnam (2001). The increases were most likely due to the synthesis of fatty acids during germination. The free fatty acids might have reacted with other products of hydrolysis to form esters. This may have accounted for the decrease. The fatty acids might also have been used for synthesis of new lipids during metabolic activities of the microflora in the substrate during germination.

Carbohydrates

The highest carbohydrate content of 74.95% (Table 3) was observed in the pregelatinized sorghum flour while the unblended pigeon pea flour (CCF) showed the lowest carbohydrate value of 55.10%. The untreated sorghum flour had a range of 55.96%-63.50% of carbohydrate content while the treated samples had carbohydrate content of 65.75%-74.95% and 58.75%-74.00% for the pregelatinized samples and spouted samples respectively. Sprouting increased ($p<0.05$) the soluble sugar (carbohydrate) level of sorghum and these changes were attributed to the activities of the hydrolytic enzymes within the seeds during sprouting.

In all these flour samples, starch is the major carbohydrate constituent. Starch is the major storage form of carbohydrate of sorghum ranging from 56.0%-73.0% and an average of 69.5%. Sprouting of the sorghum grains has been shown to increase the digestibility of sorghum starch. This has been attributed to a release of starch granules from the protein matrix rendering them more susceptible to enzymatic digestion (McNeil, *et al.*, 1975 and Harbers, 1975).

Energy/caloric value

The energy value (Table 3) of sorghum and pigeon pea composites ranged between 316.46-411.04 kcal/100g. Sprouted and pregelatinized

samples recorded high-energy values of 346.50-403.75Kcal/100g for pregelatinized samples and 381.30-404.20Kcal/100g for sprouted samples respectively. The high-energy values could be attributed to blending. The untreated samples showed higher energy values ($p<0.05$) while the sprouted samples had relatively low energy. The sprouts used up part of inherent nutrients (carbohydrates, protein, fat) contents. Similar reports were obtained by other researchers. Davis (1978) obtained an energy content of 318.0-447.0Kcal/100g for soyaflour. The high energy content is advantageous for product formulation like breakfast cereals.

Effect of sprouting and pregelatinization on anti-nutritional factors

Table 4 shows the results of tannin, phytate and cyanide content of the treated and untreated sorghum flour.

Table 4: Anti-Nutritional Factors of Treated and Untreated Sorghum Samples

Sample	Anti-nutritional Factors		
	Tannin (mg/100g)	Phytate(mg/100g)	Cyanide (mg/100g)
USF	0.074	0.032	0.178
SSF	0.065	0.027	0.057
SEM	±0.0044	±0.00112	±0.00404

Values are means of triplicate determination ±SEM

USF ⟹ Untreated Sorghum Flour

SSF ⟹ Sprouted Sorghum Flour

Phytic acid/phytate

The phytic acid content of the sprouted samples ranged between 0.005-0.051/100g and the untreated sorghum samples ranged between 0.010-0.056mg/100g (Table 4). Sprouting and dehulling of the samples decreased phytic acid content significantly ($p<0.05$). Thompson and Erdman (1982) reported similar results indicating that the dehulled beans for tempeh, it had less phytic acid than the undehulled beans. The observed decrease in phytate level in flours was probably due to the activities of the enzyme-phytase which causes the degradation of the phytate in cereals and legumes. Such reduction in phytate may increase certain metals and decrease phytate level after treatment. Phytate has also been known to bind calcium and other minerals in the seed. On the contrary, the result obtained for germination agreed with the decreased in phytase activity as reported by Nzelibe and Oyeniran (2001), Turk and Sandberg (1992), and Khorkhor, *et al.,* (1994), Carnonvale *et al*., (1988). Germination of cereals increased the phytate due to an increase in phytase activity which dephosphorylates the phytate, thereby destroying its strong affinity for minerals and proteins (Nzelibe and Oyeniran, 2001). Increase in phytase activity during sprouting/germination enhances the nutritional availability of minerals and alters the texture of plant food by releasing calcium ion for participation in cross-linking.

Tannin content

The tannin content (Table 4) of the untreated samples ranged from 0.035 to 0.130mg/100g while the sprouted samples show a range from 0.027 to 0.11mg/100g. Obviously, sprouting decreased the level of tannin in sorghum grains significantly at ($p <0.05$). Sprouting reduced the discoloration (reddish/brownish colour) imparted by tannins to sorghum. It also made protein available in large quantities because tannins prevent the availability of proteins to the body. Sprouting of sorghum also enhanced protein breakdown and weight of the body of the animal while hindering the deleterious effects due to their strong interactions with proteins (Reichert *et al*., 1980).

Cyanide content

Sprouting reduced the hydrocyanic acid significantly ($p<0.05$) (Table 4). The untreated samples had cyanide content of between 0.164-0.198mg/100mg, which was reduced by sprouting to between 0.035 to 0.080mg/100mg (Table 4). This decrease was attributed to hydrolysis and leaching. Devegetation of the sprouts may also have contributed to the decrease because the removal of the rootlets decreased its cyanide content, which increased in the course of sprouting. Dada and Dendy (1987) had earlier reported that significant reduction occur in the levels of the poisonous phytotoxin such as cyanogenic glycoside in the sprouted grains. Other workers reported increases at the point of sprouting due to increased inherent enzyme activities in the sprouting seeds (Obizoba and Atii, 1991; Panasuik and Bills, 1984). The endogenous enzymes, which were inactive in the dry seeds, were fully activated on rehydration thereby leading to the hydrolysis of the cyanogenic glycosides although devegetation reduced the cyanide content.

CONCLUSION

Sprouting and pregelatinization treatments, reduced the levels of tannins, phytate and cyanide of the flours, which in turn led to increased nutritional value of the formulated product from the blend. The carbohydrate and protein contents increased while fat and ash contents decreased. Thus, the supplementation increased the protein content of the sprouted and pregelatinized samples while ash content decreased significantly ($p<0.05$). The flours could be used in children and adult feeding because of the protein and energy contents respectively, and the reduced anti-nutritional factors and toxicant.

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