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Effect of African yam bean (*Sphenostylis stenocarpa*) supplementation on millet (*Penniset umglaucum*) flour and stiff porridge ("Ruam-nahan")

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Abstract
Stiff porridge ("ruam-nahan") was prepared from Millet and African yam bean flours in the following ratios 100:0, 90:10, 80:20, 70:30, 60:40, 50:50, respectively. The effect of the supplementation was evaluated by studying the chemical composition and sensory attributes of the stiff porridges ("ruam-nahan"), as well as functional properties such as bulk density, swelling index, water absorption capacity, least gelation capacity and viscosity of the flour samples. Chemical composition increased with increased level of African yam bean supplementation except for carbohydrate and fat content whose values decreased. The protein content of sample F (50%millet and 50%African yam bean) was the highest 19.70%, while sample A (100% millet) had the least protein value of 10.90%.There were no significant differences in the bulk densities however, samples D, E and A were significantly different from each other. There were no significant difference in the swelling index of samples A and B and samples D and F, however, samples C and E were significantly different from each other. Sample C had the highest value (0.40) and sample E had the least swelling index of 0.10. The water absorption capacity of Samples increased with supplementation. The least gelation capacity of samples showed that all the samples gelled at 2 % concentration at 4 ^{O}C. Viscosity of the flour slurry decreased at increased temperature, for each level of African yam bean substitution and speed of revolution. Responses to shear rate exhibited pseudoplastic behavior while response to temperature exhibited Dilatancy. Results of sensory analysis on the "ruam nahan" indicated that sample F (50:50 millet and African yam bean) was the most acceptable with the mean value 7.2.

Keywords: African yam bean, chemical properties, functional properties, millet, supplementation, sensory attributes

Introduction

World protein requirements persist to be a worldwide matter with heightened concerns about food security and protein malnutrition De-Frias *et al.*, (2010) [1]. It is a major bottleneck in developing and underdeveloped countries. Dietary proteins for human beings are derived from animal and plant materials. Meats together with sea foods provide essential amino acids needed in our diets. The plant protein sources in contrast to livestock products are lacking some essential amino acids. Legumes are vital sources of dietary protein for a large sector of the world's population. The consumption is predominant in countries where utilization of animal protein is limited owing to poverty, non-availability, religious or cultural lifestyles (Boye *et al.*, 2010) [2]. Cereals are staple foods for human nutrition and their incorporation into various products is of great economic importance (Pena *et al.*, 2006) [3]. Due to insufficient supply of food proteins, legumes are used as nutritional supplements in cereals to minimize protein malnutrition (Ofuya and Akhidue, 2005) [4]. From the nutritional point of view, legumes are of particular interest for the reason that they contain high amounts of protein (18-32%). In addition to providing a source of essential amino acids and bioactive peptides, pulse proteins possess functional properties such as fat binding, water holding, foaming and gelation that boost up their potential use in wide variety of food products (Sirtori and Lovati, 2001) [5]. Plant food diets have been shown to improve nutritional status due to lower cholesterol level increase the level of fibre intake which reduces the risk of bowel diseases, including cancer of the colon and also reduction in incidence of osteoporosis (Fasoyiro *et al.*, 2006) [6]. Legumes are therefore ideal supplements to cereals in vegetarian diets with increased attention and concentration as functional ingredient.

African yam bean (AYB) (*Sphenostylis stenocarpa*) is an underutilized grain legume in Nigeria and is a good source of protein, fibre and carbohydrate as well as minerals such as phosphorus, iron and potassium. However, it contains some anti-nutrients, such as trypsin inhibitor, phytate, tannin, oxalate and other alkaloids (Boye *et al.*, 2010) [2].

Millet is the staple food of millions of people in drier parts of tropical Africa. It has been reported that air – dried grains contain approximately 12.4% water, 11.6% protein, 5% fat, 67.1% carbohydrate, 1.2% fibre and 2.7% ash. However, its protein is low in methionine. Millet varieties are good sources of minerals e.g., calcium, iron, zinc, copper and manganese. Studies have been carried out in an effort to improve the nutritional quality of carbohydrate-based foods (Achinewhu *et al.*, 1992) [7]. For both nutritional and economic reasons, there is need to fortify indigenous foods with lesser used legumes with a view to solving the malnutrition- related problems that have contributed to increasing mortality and morbidity rates in developing countries of the world. Considering the important role of millet in the diets of low income individuals, coeliac patients and diabetics, improving its protein quality becomes necessary. Thus, fortification with other cheap but protein- rich vegetables such as AYB will be beneficial to the poor and rural populace as well as encourage utilization of this lesser known legume.

Materials and Methods

1. Material procurement

Seeds of African yam bean, and millet were obtained from Wurukum market in Makurdi Benue state, Nigeria.

2. Sample preparation

2.1 Preparation of millet flour

About 1kg of millet grains were thoroughly cleaned by winnowing to discard dust and unviable seeds. The seeds were then washed with tap water and thoroughly rinsed with distilled water. They were dried in a solar drier at a temperature range of 55-59 ^{O}C for $8^1/_2$ hours. Seeds were milled using attrition mill. The resultant flour was sieved using a 500µm mesh and packed in high density polyethylene sachets as described by Ocheme (2007) [8].

2.2 Preparation of African Yam bean Flour

The African yam bean flour was prepared according to the method described by Eneche (2006) [9]. Two kilograms of African yam bean seeds which were free from foreign particles such as stones, leaves and sticks as well as damaged and infested seeds were weighed, cleaned and soaked in tap water containing 0.1 % sodium metabisulphite ($NaHS0_3$) for 12 hours. The soaked seeds were manually dehulled, drained and boiled for 8 min. The dehulled and boiled seeds were spread on trays and dried in the tray dryer at 60 ^{0}C for 10 hours. The dried seeds were milled (attrition mill) and sieved through a 500 µm mesh sieve. The cooked African yam bean flour produced was finally packaged in sealed high density polyethylene sachets.

2.3 Preparation of "ruam-nahan"

"Ruam-nahan" was prepared by pouring 100 ml of cold water into a stainless steel pot and heated to boil. About 25 g each of the flour formulations consisting of millet and African yam bean were added to the boiling water and allowed to boil for 3 min. This was then stirred with a wooden paddle vigorously until a food gel/dumpling ("ruam-nahan") was formed. Total cooking time was about 5 min.

3. Methods

3.1 Functional properties

Functional properties such as Water Absorption Capacity, Bulk Density (BD), least gelation capacity and Swelling Index were according to methods described by Onwuka (2005) [11].

3.2 Proximate composition

The stiff porridge samples were subjected to proximate analysis to obtain values for the moisture content, crude protein, crude fibre, crude fat and ash content following the procedures described by AOAC (2012) [10].

3.3 Determination of mineral content

The ash content was determined as described by the method of AOAC (2012) [10]. Calcium, magnesium and potassium were determined using Jenway Digital Flame Photometer (PFP7 model).While iron was determined using Buck Atomic Absorption Spectrophotometer. The phosphorous content was determined by using vanadomolybdate reagent at 400nm using colorimetric method.

3.4 Sensory evaluation

The stiff porridge samples were presented to a voluntary panel of fifteen judges made up of male and female students of the Department of Food Science and Technology, University of Agriculture, Makurdi. Panelists were provided with product information and requested to evaluate the products for appearance, texture, flavor and general acceptability using the 9 – point hedonic scale with 9: representing like extremely and 1: representing dislike extremely. Sample with 100 % millet flour stiff porridge was used as the control.

Results and Discussion

The results of functional properties of composite flours from millet and African yam bean consisting of bulk density, water absorption capacity, swelling index and least gelation capacity are shown in Table1. The proximate composition of stiff porridge produced from millet and African yam bean flours is as shown in Table 2. The mineral content of samples of stiff porridge ("ruam-nahan") produced from millet and African yam bean flours is presented in Table 3. Minerals such as calcium, potassium, magnesium, phosphorus and sodium were analyzed and the results obtained from the composites were compared with the control (sample A; 100 % millet) Results of sensory analysis of the stiff porridge produced from the flour composites are presented in Table 4. "ruam-nahan" was presented to 15 trained panelists whose judgments were based on the appearance, texture, flavor and general acceptability.

Table 1: Functional Properties of "Ruam-Nahan" flour

Sample	Bulk density (g/ml)	Swelling index (g/ml)	WAC (g/ml)	LGC (2 % conc)
A	1.80 ± 0.010^a	0.75 ± 0.005^a	2.20 ± 0.010^c	Gel
B	0.71 ± 0.006^c	0.75 ± 0.006^a	2.50 ± 0.027^b	Gel
C	0.69 ± 0.010^d	0.62 ± 0.010^b	2.30 ± 0.010^b	Gel
D	0.71 ± 0.006^c	0.58 ± 0.060^c	2.40 ± 0.013^a	Gel
E	0.76 ± 0.010^b	0.49 ± 0.025^d	2.40 ± 0.010^a	Gel
F	0.72 ± 0.006^c	0.56 ± 0.006^c	2.64 ± 0.170^a	Gel
LSD	0.015	0.021	0.517	

Values represent means + standard deviation of duplicate determinations. Means within the same column with different superscript vary significantly from one another. Means followed by the same superscript in a column are not significantly different.

Table2: Proximate Composition of Stiff Porridge from Millet-African yam bean flour Blends

	Sample						
Parameter (%)	A	B	C	D	E	F	LSD
Moisture	24.49 ± 0.02^f	24.80 ± 0.10^e	25.50 ± 0.3^d	26.40 ± 0.08^c.	32.00 ± 0.10^b	37.50 ± 0.10^a	0.14
Protein	10.90 ± 0.10^f	12.00 ± 0.15^e	13.13 ± 0.06^d	14.40 ± 0.10^C	15.30 ± 0.01^b	19.70 ± 0.20^a	0.26

Fibre	1.30±0.02^{e}	1.50±0.03^{d}	1.59±0.02^{c}	1.80±0.06^{b}	1.80±0.01^{b}	2.00±0.06^{a}	0.08
Ash	0.43±0.01^{c}	0.44±0.02^{de}	0.45±0.02^{cd}	0.46±0.01^{c}	0.08±0.01^{b}	0.55±0.01^{a}	0.02
Fat	0.80±0.10^{a}	0.75±o.01^{b}	0.65±0.01^{c}	0.60±0.03^{d}	0.50±0.01^{e}	0.40±0.01^{f}	0.03
CHO	62.07±0.04^{a}	60.51±0.01^{b}	58.80±0.02^{c}	56.42±0.02^{d}	49.90±0.01^{e}	39.85±0.01^{f}	0.03

Sample A = 100% millet flour (Control); Sample B = 90% millet flour + 10% African yam bean flour, Sample C = 80% millet flour + 20% African yam bean flour; Sample D = 70% millet flour + 30% African yam bean flour, Sample E = 60% millet flour + 40% African yam bean flour; Sample F = 50% millet flour + 50% African yam bean flour

Table 3: Mineral Composition of Stiff Porridge from Millet-African yam bean flour Blends

	Sample						
Parameter (%)	**A**	**B**	**C**	**D**	**E**	**F**	**LSD**
Ca(mg/10)	0.68.±0.01^{f}	0.75±0.01^{c}	0.77±0.2^{d}	0.86±0.01^{c}.	0.91±0.01^{b}	1.11±0.10^{a}	0.02
Mg(mg/100g	10.90±0.10^{f}	12.00±0.15^{e}	13.13±0.06^{d}	14.40±0.10^{C}	15.30±0.01^{b}	19.70±0.20^{a}	0.26
Fibre	1.30±0.02^{e}	1.50±0.03^{d}	1.59±0.02^{c}	1.80±0.06^{b}	1.80±0.01^{b}	2.00±0.06^{a}	0.08
Ash	0.43±0.01^{c}	0.44±0.02^{de}	0.45±0.02^{cd}	0.46±0.01^{c}	0.08±0.01^{b}	0.55±0.01^{a}	0.02
Fat	0.80±0.10^{a}	0.75±o.01^{b}	0.65±0.01^{c}	0.60±0.03^{d}	0.50±0.01^{e}	0.40±0.01^{f}	0.03
CHO	62.07±0.04^{a}	60.51±0.01^{b}	58.80±0.02^{c}	56.42±0.02^{d}	49.90±0.01^{e}	39.85±0.01^{f}	0.03

Sample A = 100% millet flour (Control); Sample B = 90% millet flour + 10% African yam bean flour, Sample C = 80% millet flour + 20% African yam bean flour; Sample D = 70% millet flour + 30% African yam bean flour, Sample E = 60% millet flour + 40% African yam bean flour; Sample F = 50% millet flour + 50% African yam bean flour

Table 4: Sensory Evaluation of Stiff Porridge Produced from Millet and African Yam Bean Flours

	Sample						
Parameter	**A**	**B**	**C**	**D**	**E**	**F**	**LSD**
Appearance	5.93^{a}	5.93^{a}	6.53^{a}	6.47^{a}	6.80^{a}	7.60^{a}	1.049
Texture	6.47^{b}	6.80^{a}	7.13^{a}	6.73^{a}	6.80^{a}	7.07^{a}	0.996
Flavour	6.60^{a}	6.40^{a}	6.67^{a}	6.13^{b}	6.00^{a}	6.60^{a}	1.257
Overall accept.	6.93^{a}	6.80^{a}	6.60^{a}	6.80^{a}	6.87^{a}	7.53^{a}	0.834

Any two mean scores not followed by the same superscript on the same row are significantly different from each other. Sample A = 100% millet flour (Control); Sample B = 90% millet flour + 10% African yam bean flour Sample C = 80% millet + 20%African yam bean flour Sample D = 70%millet flour + 30%African yam bean flour Sample E = 60%millet flour + 40%African yam bean flour Sample F = 50%millet flour + 50%African yam bean flour

1. Functional properties of flours produced from millet and African yam bean

Bulk density

There was no significant difference (P>0.05) in the bulk density of samples B, D and F. It showed that particle sizes were closely related to one another because bulk density is closely related to particle size (Onwuka 2005) [11]. The high bulk densities of the flours suggest their suitability for use in various food preparations and will give benefits of packaging, storage and transport when compared to a low density powder (Kusunose *et al* 1991) [12]. Sample A being the heaviest will occupy less space per unit weight compared to the other samples. However, sample B to F would be easier to transport as they were lighter. on the other hand, since sample F was the least dense it would occupy greater space and therefore would require more packaging material per unit weight and so could have higher packaging cost compared to the other samples (Ocheme *et al*., 2010) [13].

According to Padmasshree *et al.* (1987) [15], higher bulk density is desirable for greater ease of dispersibility of flours. In contrast, however, low bulk density would be an advantage in the formulation of complementary foods (Oluwatosin *et al*., 1996) [14]. Since sample F had the least bulk density it could be the most suitable for production of complementary foods (Ocheme *et al*., 2010) [13]. Reported a bulk density of 2.55 and 2.76 for composite flour of wheat and plantain. Bulk density of foods increase with increase in starch content, this explains why the bulk density decreased as the level of African yam bean flour increased. Bulk density also indicates the volume of the packaging material required.

1.1 Swelling Index

From the ANOVA results of swelling index, no significant difference was observed between samples A and B. However, there was a significant difference between samples C and E. sample E showed the lowest swelling index while samples D and F had no significant difference between them. The result of the swelling index may be attributed to the fact that cold water was used and that gelatinization temperature was not attained. Increased temperature provides energy to break intermolecular hydrogen bond causing swelling of the granules (Chinma *et al*., 2008) [20]. Swelling index is relevant for use as they determine the bulk forming ability of flours when they absorb water (Owunka, 2005) [11].

1.2 Water absorption capacity

There were no significant differences in the water absorption capacities of the samples (p>0.05). The water absorption capacity was highest for sample F (2.64). Deshpande *et al*, reported 2.55 g/g of water absorption capacity for a composite flour of wheat and bean flours. Sosulski and Fleming, (1977) [19], reported 2.04 g/g water adsorption capacity for sunflower. Proteins are one of the components with active sites responsible for water uptake in soy flour. This could be the reason for the high water binding properties of legumes. Butt and Batool, (2010) [21] reported that protein functions in water binding.

The water absorption capacities were higher than the 1.60 and 1.94 g/g reported by Chinma *et al* in 2008 [20], for some cowpea varieties in Nigeria. According to Butt and Batool, (2010) [21], protein has both hydrophilic and hydrophobic properties, and so can interact with water in foods.

Carbohydrates have also been reported to influence water absorption capacity of foods (Adejuyitan *et al*., 2009) [22]. The ability of protein to bind water is indicative of its water absorption capacity. The observed variation in water absorption among the millet AYB composite flour blends may be due to different protein concentration, their degree of interaction with water and their conformational characteristics. On the other hand, Kuntz (1971) [23] reported that lower water absorption capacity is due to less availability of polar amino acids in flours. The observed high water absorption capacity of the cowpea flours could be attributable to the presence of hydrophilic proteins.

The water absorption capacity determines the quantity of water that may be added to a given amount of flour or its composite (blend) to make a good food product. Water binding capacity is a useful indication of whether flour can be incorporated into aqueous food formulations especially those involving dough handling (Giami 1993) [25]. The high water absorption capacity of the flours suggests that they would be useful functional ingredients in bakery products.

1.3 Least Gelation Capacity

There were no significant differences in the least gelation capacity of the samples. The samples all gelled at a concentration of 6%. The gelation abilities of the samples may be attributed to the good gelation properties of soybean flour (Iwe 2003) [26]. Least gelation capacity is the time taken for a solution of the material to form a gel when treated at a constant temperature. Least Gelation Capacity is useful in predicting the texture of food products and as well affects water hydration capacity. Gelatinization affects the digestibility and texture of fat containing foods (Lawal *et al*., 2004) [27].

2. Proximate Composition of Stiff Porridge

The result of the proximate composition of composite stiff porridge is presented in Table 7. "ruam-nahan" made from blends of millet and AYB flours were high in protein, crude fibre, ash and low in carbohydrate and fat content as compared to the control sample.

There was significant difference in moisture content of the samples ranging from 24.49 to 37.50% which is in the range with the findings of Gayle *et al*. (1986) [28] who recorded a moisture content of 29.20% for his bread samples from wheat supplemented with pigeon pea. High moisture content implies a short shelf life of the products since microbial activities thrives best at high moisture levels. The high moisture content of sample F suggests the high water binding properties of legume flours as reported by Okaka and Isaiah (1990) [29].

There was significant difference in the protein content of the samples. Protein content increased significantly from 10.90 in 100% millet "ruam-nahan" to 19.7% in "ruam-nahan" with 50% supplementation of AYB. The increase was expected due to the high protein content of AYB flour. This means that an increase in legume flour proportions will increase the protein content of the composite "ruam-nahan" and will make it more suitable as food supplement in any food product made from millet and AYB.

The crude fibre content of the composite "ruam-nahan" increased from 1.3 in the control sample to 2.0 in sample E. The increase might be due to the addition of AYB which contributes its fibre to the composite flour. They are within the range of the 2.0% recommended by NRMRDC (2004) [30]. Crude fibre adds bulk to the food thus facilitating bowel movement and preventing gastrointestinal disease in man.

The fat content of the "ruam-nahan" decreased from 0.8 in sample A to 0.4 in sample F. The decrease in fat content was due to increase in AYB from 10% to 50%.

The decline in carbohydrate content with increased substitution of AYB could be attributed to subtraction effect similar to the findings of Olaoye *et al*, (2007) [31] who confirmed the sudden increase in protein content of biscuits with 10% supplementation of soy-cassava flour and a drastic decrease in its carbohydrate content. The decline in fat and carbohydrate contents was similar to the report of Okoye *et al*, (2010) [32].

2.1 Mineral composition of stiff porridge produced from millet and African yam bean flours

The result of mineral composition (mg/g) of the stiff porridge prepared from millet and its composite is shown in Table 3, the result of the study revealed that sample F had the highest value of calcium (1.107±0.01%), magnesium (0.9±0.006mg/g), potassium (0.817±0.005mg/g), phosphorous (0.951±0.00425%) and iron (6.23±0.01ppm). The calcium content of the "ruam-nahan" ranged between 0.68-1.107% for samples A-E and there was significant difference at P<0.05 among all the samples analyzed. The calcium content of sample A was the least, and this increased as the level of AYB in the "ruam-nahan" increased with sample F having the highest value as earlier mentioned. The magnesium, potassium, phosphorus and iron also followed the same trend as described in the case of calcium. There was significant difference in all the minerals determined, sample F had the highest values of calcium, magnesium, potassium, phosphorous iron while sample A had the lowest of all the minerals analyzed.

3. Sensory analysis

3.1 Appearance

There were no significant differences in the appearance of the "ruam-nahan" (stiff- porridge). Sample F having the highest mean value of 7.60, followed by sample E and D. Sample C ranked 4th with the mean value of 6.53, while samples B and A had the least mean value of 5.93. The poor appearance of sample A may be attributed to the met.

3.2 Texture

There were no significant difference in the texture of the "ruam-nahan", sample A was however significantly different from the other samples. Sample C had the highest mean value of 7.13 while sample A had the least value of 6.47. This could be attributed to high gel strength of the sample.

3.3 Flavor

There were no significant differences in the flavor of the "ruam-nahan" samples as shown in Table 3. Sample C had the highest value of 6.67 while sample E had the least value of 6.00.

3.4 Overall Acceptability

Sample C was mostly accepted by the panelist in terms of appearance and texture as compared to the other samples, sample F however was most acceptable by the panelists in terms of appearance. It was generally observed that sample F was highly recommended by the consumers.

Conclusion

From the results obtained from the various analyses, it can be concluded that the substitution of millet with African yam bean flour for stiff porridge ("ruam-nahan") preparation improved the nutritional value of the product especially its mineral and protein whose deficiency has been a major health challenge in developing countries. The results also indicates that chemical composition of the stiff porridge made from millet flour increased with the level of African yam bean substitution. Results of sensory evaluation of the stiff porridge revealed that, all samples were accepted by the panelist, however, sample F (50% millet: 50% African yam bean) was the most acceptable.

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