ISSN No:-2456-2165

In Vitro Digestibility of Starch Extract and Flours of Some Underutilized Legumes

Ogundiran Olubunmi A., Ariwoola Matthew O., Isaac Ernest, Iorhuna Boniface T., Onunze Chukwudi E.
Department of Chemistry, Taraba State University, Jalingo, Taraba State – Nigeria

Abstract:- Digestibility of underutilized legumes (African yam beans, Bambara groundnut, Fava beans, Lima beans, and Pigeon pea) was studied and related to their proximate compositions, functional and rheological properties. The aim of this study was to extract starch and prepare flour from these selected legumes: African yam beans (*Sphenostylis stenocarpa*), Bambara groundnut (*Vigna subterranean L. Verdc*), Fava beans (*Vicia fabas*), Lima beans (*Phaseolus lunatus L.*), and Pigeon pea (*Cajanus cajan*). The reducing sugar contents of the legume starch and flours range from 0.05 – 0.09 mg/g and 3.21 – 20.1 mg/g. The starch damage of starch and flour range from 0.81 – 10.7 % and 2.8 – 8.6 % respectively. The overall result obtained from these analyses imply that both starch and flours from the under-utilized legumes could be the future food in the feeding of the teaming world population for the amelioration of protein energy malnutrition to provide baseline data for future commercial exploitation and overcoming malnutrition associated problems.

Keywords:- *African Yam Beans, Bambara Groundnut, Fava Beans, Lima Beans, Pigeon Pea, Underutilized, Proximate Compositions, Functional And Rhetorical Properties.*

I. INTRODUCTION

Legumes have been recognized to be second most valuable plant source for human and animal nutrition. Legumes are designated to be the third largest family among flowering plants, consisting of approximately 650 genera and 20,000 species. Several common proteinaceous edible legumes like soybean, cowpea and others that are available in the market, in most instances, production rate compared with consumption (as feed and food) has remained unmet. Legumes occupy an important place in the diets of the population in third world countries. They are a rich source of ‘‘lente’’ carbohydrates, which provide several beneficial physiological effects [1].

Legume seeds have an average of twice as much protein as cereals and the nutritive value of the proteins are usually high. Legume seeds are of prime importance in human and animal nutrition due to their high protein content (20 - 50%) [2] and have historically been utilized mainly as the whole seeds. Recently, they are now being fractionated into their main constituents which are starch and protein. Starch, the principal carbohydrate constituent of majority of plant materials, merits a detailed investigation to understand better its biochemical and functional characteristics as well as variations. Starch is considered of commercial importance due to its high industrial demand as an ingredient for a variety of processed foods. The growing demand for starches for the modern food industry has created interest for new sources of the polysaccharides [3].

Due to poor digestibility compared to that of other cereals, legume starches promote slow and moderate postprandial glucose and insulin responses, and have low glycemic index (GI) values [4]. Several properties of legumes affect starch digestibility, including high content of viscous and soluble dietary fibre constituents, the presence of various antinutrients, including polyphenols and phytic acid, and relatively high amylose/amylopectin ratios [5].

Legumes such as African yam beans, bambara groundnut, Fava beans, Lima beans and pigeon pea are underutilized due to long time cook-ability, seasonality and availability. Studies have revealed the importance of these underutilized legumes such as African yam bean (AYB) in the management of chronic disease like diabetes, hypertension and cardiovascular disease because of its high dietary fibre. It has high metabolizable energy, low true protein digestibility, moderate mineral content that compares favourably with most pulses. AYB though deficient in sulphur containing amino acids, methionine and cysteine, but high in lysine can be utilized as a complementary protein in carbohydrate-based foods for improved nutritional quality and attributes [6]. Therefore, this study intends to study the underutilized legume starch and flour and establish some of the functional properties and digestibility so that their usefulness in food and non-food industry can be maximized

II. MATERIALS AND METHODS

A. Legumes identification and Starch Extraction

African yam beans (*Sphenostylisstenocarpa*), Bambara groundnut (*Vigna subterranean L. Verdc*), Fava beans (*Viciafabas*), Lima beans (*Phaseoluslunatus L*) and Pigeon pea (*Cajanuscajan*) were purchased from a local market at Bodija in Ibadan, Oyo State, Nigeria. The legumes were identified in Crop Soil Pest Management Department, Federal University of Technology Akure. The defective legumes were separated and discarded. The beans were screened and sieved with muslin cloth and defective ones were removed. The extraction of starches from legumes was carried according to methodology described by [7]. The legumes seed were cleaned and washed before stepping. The stepped legumes were steeped and were wetly milled and allowed to settle to isolate the starch from the suspension.

ISSN No:-2456-2165

The isolated starch was further sieved, disinfected and dried to obtain dry starch.

B. Preparation of legume

The legume flour was gotten according to methodology described by [8] with slight modification. The legumes were cleaned, peeled and sun dried. The dried beans were subsequently milled into flour, the flour sample were stored in a plastic container for analysis.

C. Chemical Analysis

Proximate analysis of legume starch and flour were carried out according to methodology described by [9]. Samples were milled passing a 1-mm screen and analysed in triplicate for moisture, ash, fat, crude protein (CP, Kjeldahl N×6.25), carbohydrate, and crude fibre (CF). Gelatinization temperature, swelling power and solubility index [10], reducing sugar [11], amylose and amylopeptin [12], and starch damage [11] were determined.

D. In Vitro Starch Digestibility with Alpha-Amylase

Aliquots (3 ml) of freshly prepared starch suspension were transferred to 6 ml plastic falcon tubes which were placed on a rotating table (33.3 rpm) at a fixed angle to give constant end-over-end mixing. The table was located in an incubator maintained at 37 °C. After 30 minutes, 10 µl of a suitably diluted solution of amylase in PBS containing 0.1 mg/ml BSA was added to the tubes. At 30 seconds, and then at further timed intervals of a few minutes up to a total of 120, aliquots of 200 µl were removed from each reaction tube and immediately spuned in a microfuge for 30 seconds.

To sediment undigested starch, the supernatant was then transferred to a new microfuge tube and placed in boiling water for 2 minutes to inactivate the enzyme. Preliminary work established that this exposure to boiling water inactivated the enzyme completely. The samples were then frozen for later analysis of reducing sugar content. Unless otherwise indicated, the concentration of porcine pancreatic amylase in reaction mixtures was maintained at 0.033 units per ml where 1 unit, as defined by the suppliers, will liberate 1 mg of maltose from starch in 3 minutes. This unit is equivalent to 16.2 nanokatal. Enzyme concentrations [E_o] were calculated using a molecular weight of 56,000 $gmol^{-1}$ for amylase and the supplier's estimate of a mean activity of 1,000 units per mg protein. This means that for routine assays, the concentration was assumed to be 0.59 nM. Measured activities are expressed as µl maltose formed per mm. Our units can be converted to nanokatal by multiplying by the factor 0.05.

E. Result validation

The values reported are mean of triplicate analysis the chemicals were of analytical grade, reagents were standardized (where necessary) and the equipment were calibrated. Experiments were performed in triplicates and the sets of data generated were analyzed statistically with Microsoft Excel 2010 and recorded as the mean value after calculating the standard deviation (Mean ± standard deviation). Analysis of variance and least significant different test were carried out using statistical packages of social sciences (SPSS) 16.0, significance was accepted.

III. RESULTS AND DISCUSSION

A. Proximate analysis of legume flour and starch Moisture content

The moisture content observed for starch and flours extracted from African yam bean, pigeon pea, fava beans, Bambara groundnut and lima bean are represented in Table 1(a & b). PP, LB and FB exhibited the least and similar moisture content of 9.40 ± 1.43 %, 9.21 ± 0.74 % and 7.50 ± 0.09 % respectively, while AYB and BB starch had significant higher moisture content of 12.35 ± 0.41 % and 13.2 ± 0.21 %.

However, FB flour exhibited the least moisture content of 9.23 ± 0.395 % as shown in Table 1a. Also, Bambara groundnut, Lima bean flour and Pigeon pea flour exhibited higher percentage moisture content of 14.20 ± 0.03 %, 13.5 ± 0.38 % and 13.32 ± 0.06 % respectively. The moisture content observed for PP, FB, AYB and LB starch and flour were similar with the result of [13] which reported that crops with low moisture content can be easily stored due to high resistance of the crop to microbial attack and growth. [14] reported (10 to 20 %) as the recommended range for starch moisture contents. He also revealed that the lower the moisture content, the longer the shelf life of the crop and food products produced from them. Pigeon pea, lima bean and fava bean starch exhibited quite low moisture content than their respective flour which indicates the legume starch product will have storage or long shelf life than their corresponding flour product. In addition, [15] also revealed that starch with low moisture content such as pigeon pea and fava bean can be used for low moisture starch applications over cereal starches. Higher moisture content observed in Bambara groundnut starch and other legume flours is comparable with the moisture content of cassava starches earlier reported by [16].

B. Crude fibre content

The crude fibre content of the flour and starch extracted from the selected legumes are shown on Table 1(a & b). Fava beans starch exhibited the least percentage fibre content of 1.67 ± 0.021 % while, Lima bean has a significantly higher value of 4.55 ± 0.007 % as fibre content.

The fibre content observed for the extracted starch is higher than the reported fibre content revealed by [17], suggesting that the underutilized legume starch are better source of fibre than cocoyam and sweet potato starch. [18] reported that dietary fibres reduce incidence of certain diseases such as diabetes, coronary heart diseases, colon cancer and various digestive disorders and capable of softening stools and lowers plasma cholesterol level in the body. Therefore the high fat content revealed in lima bean and African yam bean starch and flour marked them for management of diabetes and other related diseases.

C. Crude protein content

Table 1(a & b) also revealed the crude protein observed for the extracted starch and flour. The starch extracted from the legumes revealed similar crude protein content as shown in Table 1a. However, Lima bean starch exhibited the least protein content of 3.40 ± 0.06 %, while, African yam bean exhibited higher protein content of 3.69 ± 0.07%. In addition, the result presented in Table 1(a & b) revealed that Bambara groundnut flour exhibited the least percentage protein content of 3.50 ± 0.14, while other flours exhibited similar protein content. Meanwhile Fava bean flour revealed high percentage protein content of 3.85 ± 0.02. All the underutilized legume starch and flour revealed low protein content when compared with the observed protein content of indian jack bean [3]. However the observed protein content was similar to that of sorghum and millet and higher than maize and other carbohydrates reported by [15].

D. Crude fat

PP and LB starch has the least and similar percentage crude fat of 0.86 ± 0.03 % and 0.90 ± 0.07 % as shown in statistical analysis presented in Table 1(a & b). Higher fat content of 1.11 ± 0.01 and 1.20 ± 0.01 % was observed for Fava bean and Bambara groundnut starch respectively. The statistical analysis shown in Table 1a revealed that Fava bean flour exhibited the least percentage fat content of 2.80 ± 0.04 %, while African yam bean and lima bean flour exhibited higher and similar fat content of 4.93 ± 0.04 % and 4.94 ± 0.05 % respectively.

Starch extracted from the underutilized legume exhibit low fat content than the flours that have fat content similar with the report of [19] that reported the range of 2.40 - 3.33 % fat content for African yam bean seeds. Such low fat content has been attributed to one of the advantages of storage [19]. In addition higher fat content was observed in African yam bean and Lima bean flour. Such fat rich flour has also been reported by [20] on Improved Bean (*Phaseolus vulgaris L.*) flour. Literature has revealed that fat serve as energy store in the body that can be broken down in the body to release glycerol and free fatty acids. The released glycerol can be converted to glucose by the liver and used as a source of energy [4].

E. Crude carbohydrate

African yam bean and Bambara groundnut starch has similar and low Carbohydrate content of 79.3 ± 0.28 % and 78.5 ± 0.56 % as shown in Table 1 (a & b).

Higher carbohydrate content of 85.3 ± 0.49 %, and 83.5 ± 0.14 % was observed for starch extracted from pigeon pea and Fava bean respectively. However, Lima bean flour revealed low carbohydrate content of 68.2 ± 0.31 %, while pigeon pea flour and fava bean flour exhibited higher carbohydrate content of 73.2 ± 0.16 % and 78.7 ± 0.21 % respectively. High carbohydrate content revealed for starches and flour in this study indicates that the underutilized legumes are potential good source of carbohydrate than the Indian jack bean that has been reported to exhibit lower carbohydrate content [3]. Fava bean starch exhibited higher carbohydrate content, comparable to that of red cocoyam and sweet potato as reported by [21]. Such highly-rich carbohydrate legume provides energy to cells such as brain and blood when carbohydrates are not available [22]. In other words Fava beans can substitute most carbohydrate crops on the basis of carbohydrate content.

FLOURS					
	AYB	**PP**	**FB**	**BB**	**LB**
Moisture content (%)	$10.2^{b}\pm0.26$	$9.1^{c}\pm0.36$	$7.3^{d}\pm0.33$	$11.1^{a}\pm0.07$	$9.15^{c}\pm0.06$
Fat (%)	$9.5^{b}\pm0.29$	$8.4^{c}\pm0.24$	$6.6^{d}\pm0.06$	$8.5^{c}\pm0.03$	$10.6^{a}\pm0.09$
Fibre (%)	$1.9^{c}\pm0.05$	$2.1^{b}\pm0.03$	$1.7^{d}\pm0.04$	$2.1^{b}\pm0.02$	$4.6^{a}\pm0.04$
Protein (%)	$21.4^{b}\pm0.63$	$18.1^{d}\pm0.39$	$17.7^{d}\pm0.36$	$19.8^{c}\pm0.20$	$22.9^{a}\pm0.20$
Ash (%)	$2.3^{b}\pm0.08$	$2.3^{b}\pm0.06$	$2.4^{a}\pm0.12$	$2.2^{b}\pm0.03$	$2.1^{b}\pm0.03$
CHO (%)	$54.8^{d}\pm0.89$	$59.6^{b}\pm0.76$	$64.4^{a}\pm0.68$	$56.2^{c}\pm0.24$	$50.6^{e}\pm0.21$
STARCH					
	AYB	**PP**	**FB**	**BB**	**LB**
Moisture content (%)	$6.1^{d}\pm0.03$	$7.7^{b}\pm0.13$	$5.1^{e}\pm0.04$	$9.4^{a}\pm0.10$	$7.0^{c}\pm0.07$
Fat (%)	$0.9^{c}\pm0.03$	$0.8^{d}\pm0.04$	$1.1^{b}\pm0.05$	$1.2^{a}\pm0.03$	$0.9^{c}\pm0.25$
Fibre (%)	$0.2^{c}\pm0.03$	$0.4^{b}\pm0.04$	$0.1^{d}\pm0.02$	$0.3^{c}\pm0.02$	$0.6^{a}\pm0.03$
Protein (%)	$8.0^{a}\pm0.09$	$6.14^{d}\pm0.14$	$5.5^{e}\pm0.10$	$6.4^{c}\pm0.56$	$7.2^{b}\pm0.04$
Ash (%)	$1.2^{a}\pm0.02$	$1.0^{d}\pm0.03$	$1.2^{a}\pm0.02$	$0.8^{e}\pm0.02$	$1.0^{c}\pm0.11$
CHO (%)	$83.6^{c}\pm0.1$	$84.0^{b}\pm0.29$	$87.1^{a}\pm0.20$	$81.9^{e}\pm0.11$	$83.27^{c}\pm0.11$

Table 1a: Proximate composition of flours and starch extractsfrom African yam beans, pigeon pea, fava beans, Bambara groundnut and lima bean

Results of both starch and flour are the mean of triplicate determinations ± standard deviation. Mean with different superscripts in the same column are significantly different ($p < 0.05$).

African Yam Bean (AYB), Pigeon Pea (PP), Fava Bean (FB), Bambara (BB), Lima bean (LB)

	AYBF	AYBS	PPF	PPS
Moisture content (%)	$10.2^{b} \pm 0.26$	$6.1^{d} \pm 0.03$	$9.1^{c} \pm 0.36$	$7.7^{b} \pm 0.13$
Fat (%)	$9.5^{b} \pm 0.29$	$0.9^{c} \pm 0.03$	$8.4^{c} \pm 0.24$	$0.8^{d} \pm 0.04$
Fibre (%)	$1.9^{c} \pm 0.05$	$0.2^{c} \pm 0.03$	$2.1^{b} \pm 0.03$	$0.4^{b} \pm 0.04$
Protein (%)	$21.4^{b} \pm 0.63$	$8.0^{a} \pm 0.09$	$18.1^{d} \pm 0.39$	$6.14^{d} \pm 0.14$
Ash (%)	$2.3^{b} \pm 0.08$	$1.2^{a} \pm 0.02$	$2.3^{b} \pm 0.06$	$1.0^{d} \pm 0.03$
CHO (%)	$54.8^{d} \pm 0.89$	$83.6^{c} \pm 0.1$	$59.6^{b} \pm 0.76$	$84.0^{b} \pm 0.29$

	FBF	FBS	BBF	BBS
Moisture content (%)	$7.3^{d} \pm 0.33$	$5.1^{e} \pm 0.04$	$11.1^{a} \pm 0.07$	$9.4^{a} \pm 0.10$
Fat (%)	$6.6^{d} \pm 0.06$	$1.1^{b} \pm 0.05$	$8.5^{c} \pm 0.03$	$1.2^{a} \pm 0.03$
Fibre (%)	$1.7^{d} \pm 0.04$	$0.1^{d} \pm 0.02$	$2.1^{b} \pm 0.02$	$0.3^{c} \pm 0.02$
Protein (%)	$17.7^{d} \pm 0.36$	$5.5^{e} \pm 0.10$	$19.8^{c} \pm 0.20$	$6.4^{c} \pm 0.56$
Ash (%)	$2.4^{a} \pm 0.12$	$1.2^{a} \pm 0.02$	$2.2^{b} \pm 0.03$	$0.8^{e} \pm 0.02$
CHO (%)	$64.4^{a} \pm 0.68$	$87.1^{a} \pm 0.20$	$56.2^{c} \pm 0.24$	$81.9^{e} \pm 0.11$

	LBF	LBS
Moisture content (%)	$9.15^{c} \pm 0.06$	$7.0^{c} \pm 0.07$
Fat (%)	$10.6^{a} \pm 0.09$	$0.9^{c} \pm 0.25$
Fibre (%)	$4.6^{a} \pm 0.04$	$0.6^{a} \pm 0.03$
Protein (%)	$22.9^{a} \pm 0.20$	$7.2^{b} \pm 0.04$
Ash (%)	$2.1^{b} \pm 0.03$	$1.0^{c} \pm 0.11$
CHO (%)	$50.6^{e} \pm 0.21$	$83.27^{c} \pm 0.11$

Table 1b: Comparison of proximate composition of flours and starch extracts from African yam beans, pigeon pea, fava beans, Bambara groundnut and lima bean

Results of both starch and flour are the mean of triplicate determinations ± standard deviation. Mean with different superscripts in the same column are significantly different ($p < 0.05$).

African Yam Bean (AYB), Pigeon Pea (PP), Fava Bean (FB), Bambara (BB), Lima bean (LB)

➢ *Reducing Sugar*

The result shown in Table 2(a & b) revealed the reducing sugar content of extracted starch and flour from the selected legumes. Fava bean starch exhibited the least reducing sugar value of 0.05 ± 0.006, while higher reducing sugar value of 0.09 ± 0.006 was observed in Lima bean starch. The statistical analysis presented in Table 2a revealed that pigeon pea flour exhibited the least reducing sugar of 3.1 ± 0.017 mg/g, while 15.6 ± 0.007 mg/g, 19.2 ± 0.04 mg/g, 20.1 ± 0.03 mg/g was observed for Bambara groundnut, fava bean and African yam bean flour respectively.

Low reducing sugar obtained in this for the legume starches is less with the observed reducing sugar reported by [21] on comparison of the nutrient composition of four sweet potato cultivated in Rwanda. However the extracted flour reducing sugar revealed comparable values with American cultivars sweet potato reported by [23]. [24] observed that during storage of the tubers some starch were converted into reducing sugars and subsequently into sucrose. Such rapid conversion may result to high reducing sugar observed in the extracted flours.

- *Amylose and Amylopectin content*

Fava bean starch exhibited the least amylose content of 30.3 ± 0.16 % and higher amylopectin content of 99.6 ± 0.04 % respectively as shown in Table 2b. However, African Yam Bean starch exhibited higher amylose content of 40.4 ± 0.09 % and least amylopectin content of 89.1 ± 1.46 %. The statistical analysis presented in Table 2b. Low amylose content observed in this study for the underutilized legumes is similar with the report of [25]. However, [3] reported high amylose content for indian jack bean starches. The extracted flour exhibited higher amylose content that fall into acceptable range previously mentioned by [26]. Studies has revealed that the higher the amylose content, the lower the amylopectin and the less the tighter structure of the granule that affects binding capacity [27]. The tightness conferred by high amylopectin in flour or starch granule reduces solubility and also affect digestibility of such food crop. Such food crops like lima bean and pigeon pea with high amylopectin content could be recommended for diabetic or patient suffering from obesity.

- *Damaged and undamaged starch*

African yam bean flour exhibited the least percentage of starch damage of 8.2 ± 0.02% and higher undamaged starch of 92.1 ± 0.04%. Also, Bambara bean flour exhibited higher starch damage of 92.5 ± 0.06% and least undamaged starch of 73.5 ± 0.02%. The statistical analysis presented in Table 2a reveal that African yam bean starch and pigeon pea starch exhibit similar and least starch damage of 8.1 ± 0.02 and 8.7 ± 0.08 with higher undamaged starch of 92.5 ± 0.06% and 73.5 ± 0.02% respectively. Bambara groundnut starch, pigeon pea and fava bean flour exhibited quite high starch damaged and low starch undamaged which is comparable with starch damaged reported on potato starch by [28]. [29] reported that such starchy food with high starch damage can bind water with high capacity while other authors reveal that high damaged starch are susceptible to alpha amylase attack. However the studies of [30] reveal that the use of congo red and iodometric method is limited to local injury and may not truly estimate the susceptibility of the flour and starch to alpha amylase digestion. However the knowledge of starch damage only revealed the percentage of bonding interactions that has been broken. Therefore high starch damage observed in flour reveal that vast number of intermolecular bonds in the flour granule has been broken and this might hasten rapid digestion over starch. Starch damage revealed for African yam beans, pigeon pea and lima bean starch is comparable with the report of [31] on 7 cultivars of wheat. Starch damage causes profound changes in starch granular structure and in amylopectin molecules. Such changes greatly influence the rheological and functional properties of starch. [17] revealed that, in food processing industries, starch is commonly gelatinized. In-depth characterization of the effect of starch damage on rheological properties of gelatinized starch pastes will aid in understanding changes caused by starch damage and will permit better prediction of final product quality.

STARCH					
	AYB	**PP**	**FB**	**BB**	**LB**
Reducing sugar (mg/g)	$0.08^a \pm 0.01$	$0.07^b \pm 0.01$	$0.05^c \pm 0.01$	$0.08^a \pm 0.01$	$0.09^a \pm 0.01$
Amylose (%)	$40.4^a \pm 0.09$	$39.3^b \pm 0.46$	$30.3^e \pm 0.16$	$37.4^c \pm 0.09$	$31.4^a \pm 0.15$
Amylopectin (%)	$89.1^d \pm 1.46$	$90.4^c \pm 0.07$	$99.6^a \pm 0.05$	$92.4^b \pm 0.05$	$98.7^a \pm 0.05$
Starch damage (%)	$0.81^e \pm 0.02$	$8.7^d \pm 0.08$	$14.3^b \pm 0.03$	$92.5^a \pm 0.06$	$10.7^c \pm 0.06$
Starch undamaged (%)	$92.1^a \pm 0.05$	$91.3^b \pm 0.02$	$86.6^d \pm 0.13$	$73.5^e \pm 0.03$	$89.7^c \pm 0.29$

FLOUR					
	AYB	**PP**	**FB**	**BB**	**LB**
Reducing sugar (mg/g)	$20.1^a \pm 0.03$	$3.1^e \pm 0.02$	$19.2^b \pm 0.04$	$15.6^c \pm 0.04$	$8.0^d \pm 0.03$
Amylose (%)	$27.6^a \pm 0.04$	$24.1^d \pm 0.10$	$26.8^b \pm 0.25$	$25.6^c \pm 0.07$	$24.4^d \pm 0.06$
Amylopectin (%)	$72.2^d \pm 0.22$	$75.6^a \pm 0.12$	$73.1^c \pm 0.44$	$74.3^b \pm 0.03$	$75.6^a \pm 0.06$
Starch damage (%)	$8.6^b \pm 0.03$	$6.6^c \pm 0.03$	$9.2^a \pm 0.03$	$2.8^e \pm 0.01$	$4.6^d \pm 0.03$
Starch undamaged (%)	$91.4^a \pm 0.03$	$33.3^d \pm 0.08$	$20.3^e \pm 0.04$	$75.8^b \pm 0.04$	$51.8^c \pm 0.19$

Table 2a: Functional and Rheological properties of flours and starch extracts from African yam beans, pigeon pea, fava beans, Bambara groundnut and lima beans

ISSN No:-2456-2165

Results of both starch and flour are the means of triplicate determinations ± standard deviation. Means with different superscripts in the same column are significantly different ($p < 0.05$).

	AYBS	AYBF	PPS	PPF
Reducing sugar (mg/g)	$0.08^{a}\pm0.01$	$20.1^{a}\pm0.03$	$0.07^{b}\pm0.01$	$3.1^{e}\pm0.02$
Amylose (%)	$40.4^{a}\pm0.09$	$27.6^{a}\pm0.04$	$39.3^{b}\pm0.46$	$24.1^{d}\pm0.10$
Amylopectin (%)	$89.1^{d}\pm1.46$	$72.2^{d}\pm0.22$	$90.4^{c}\pm0.07$	$75.6^{a}\pm0.12$
Starch damage (%)	$08.1^{e}\pm0.02$	$8.6^{b}\pm0.03$	$8.7^{d}\pm0.08$	$6.6^{c}\pm0.03$
Starch undamaged (%)	$92.1^{a}\pm0.05$	$91.4^{a}\pm0.03$	$91.3^{b}\pm0.02$	$33.3^{d}\pm0.08$

	FBS	FBF	BBS	BBF
Reducing sugar (mg/g)	$0.05^{c}\pm0.01$	$19.2^{b}\pm0.04$	$0.08^{a}\pm0.01$	$15.6^{c}\pm0.04$
Amylose (%)	$30.3^{e}\pm0.16$	$26.8^{b}\pm0.25$	$37.4^{c}\pm0.09$	$25.6^{c}\pm0.07$
Amylopectin (%)	$99.6^{a}\pm0.05$	$73.1^{c}\pm0.44$	$92.4^{b}\pm0.05$	$74.3^{b}\pm0.03$
Starch damage (%)	$14.3^{b}\pm0.03$	$9.2^{a}\pm0.03$	$92.5^{a}\pm0.06$	$2.8^{e}\pm0.01$
Starch undamaged (%)	$86.6^{d}\pm0.13$	$20.3^{e}\pm0.04$	$73.5^{e}\pm0.03$	$75.8^{b}\pm0.04$

	LBS	LBF
Reducing sugar (mg/g)	$0.09^{a}\pm0.01$	$8.0^{d}\pm0.03$
Amylose (%)	$31.4^{a}\pm0.15$	$24.4^{d}\pm0.06$
Amylopectin (%)	$98.7^{a}\pm0.05$	$75.6^{a}\pm0.06$
Starch damage (%)	$10.7^{c}\pm0.06$	$4.6^{d}\pm0.03$
Starch undamaged (%)	$89.7^{c}\pm0.29$	$51.8^{c}\pm0.19$

Table 2b: Comparison of Functional and Rheological properties of flours and starch extracts from African yam beans, pigeon pea, fava beans, Bambara groundnut and lima beans

Results of both starch and flour are the means of triplicate determinations ± standard deviation. Means with different superscripts in the same column are significantly different ($p < 0.05$).

IV. CONCLUSION

Starch and flour extracted from the underutilized legumes exhibited low moisture content which makes them resistant to microbial growth and rapid spoilage. The flour extracted exhibited high and reasonable amount of fat, fibre, protein, ash and carbohydrate content more than the starch. However, lima bean and African yam bean flour exhibited higher fibre, protein and low carbohydrate content which can be used in management of Type 1 diabetic patients. In addition, high amylose content was observed for legume flours than the starch, while the starch exhibited higher amylopectin content. Bambara groundnut exhibited higher starch damage while African yam bean exhibited the least starch damage. Pigeon pea flour was rapidly digested than other extracted flour while fava bean starch was rapidly digested among other extracted starch. The flours that were least digested such as fava bean flour and African yam bean flour can be used in management of obesity and Type 1 diabetic patient since most of the carbohydrate in the legumes will pass out as faeces due to low digestibility.

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