Evaluation of Pasting and Functional Properties of Flour Blends Made from African Yam Bean (*Sphenostylis stenocarpa*) and Corn (*Zea mays*) Seeds

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Abstract:-

Background: The need to achieve food security for all initiated the development of new food products from available food sources.
Objectives: The study evaluated the pasting and functional properties of flour blends made from African yam bean (Sphenostylis stenocarpa) and corn (Zea mays) seeds.
Materials and Methods: African yam bean (AYB) seeds roasted at 191^{0}C for 40 min and corn seeds oven-dried at 50^{0}C for 24 h were finely milled, and formulated into 5 flour samples in the ratios of AYB (70): Corn (30), AYB (50): Corn (50), AYB (30): Corn (70), AYB (100: 0), and Corn (100: 0) to yield one-third ($^1/_3$) of the daily dietary fiber requirement (12.7 g) of a reference man (70 kg). The samples and the control (wheat flour) provided 6 samples which were evaluated for pasting and functional attributes using standard procedures. Data generated were analyzed using the IBM Statistical Product for Service Solution (version 21.0) and presented as means and standard deviations. Analysis of variance (ANOVA) was used to compare the means and significance was accepted at $p < 0.05$.
Results: The results showed the range of pasting properties of AYB and corn flour samples as 1066.00BU to 2844.50BU for peak, 1008.50BU to 1687.50BU trough, 26.00BU to 1157.00BU breakdown, 1454.50BU to 2629.50BU final, and 298.50BU to 942.00BU setback viscosities; 6.23 to 7.00mins for peak time and 67.73^{0}C to 84.80^{0}C pasting temperature). The functional properties ranges were 0.72% to 0.77% (bulk density), 1.98% to 2.04% (water absorption capacity), 0.73g/ml to 2.62g/ml (oil absorption capacity), 0.72sec to 2.03sec(wettability), 1.04g/ml to 6.64g/ml (swelling index), 60.65^{0}C to 71.00^{0}C (gelatinization temperature), 1.52% to 13.17% (foaming capacity), 2.03 to 5.82g/ml (emulsion capacity) and 0.62% to 1.41% (foaming stability). High starch yield, peak and setback viscosity was observed.
Conclusion: Samples could be used for making new and varied products

Keywords:- *Food Insecurity, African Yam Bean, Corn, Pasting, and Functional Properties, Flour Blends.*

I. INTRODUCTION

Food insecurity exists when people lack sustainable access to adequate, safe, nutritious, and socially acceptable food for a healthy and productive life, thus, resulting in chronic hunger and malnutrition [1]. It is one of the most pressing problems in developing countries. Globally, protein-energy malnutrition continues to be a major health burden and the most important risk factor for illnesses and death, especially among young children in developing countries; it is associated with several co-morbidities such as lower respiratory tract infections including diarrhea [2]. Under-5 mortalities in developing countries have long been attributed to protein-energy malnutrition. It is very common in Nigeria. Idowu [3] proposed the use of plant sources of protein and calories to solve the malnutrition problem in Nigeria. This underscored the utilization of nutritious and locally available crops in the food system. African yam bean (*Sphenostylis stenocarpa*) AYB is an underutilized tropical legume with high nutritional value [4]. The seeds are important food sources that can be exploited, particularly in developing countries where there is a shortage of animal protein [4]. The seeds (AYB) possess lysine, histidine, arginine, aspartic acid, threonine, serine, glutamic acid, proline, glycine, and methionine [5]. Although it contains anti-nutritional factors such as haemagglutinins, tannins, and oligosaccharides [6], different processing methods (soaking, dehulling, roasting) are known to destroy these anti-nutritional factors and the processed products are safe for consumption with no health problems [7]. AYB is currently under extinction threat due to non/poor consumption resulting from nutrition transition. Corn (*Zea mays* L.) also known as maize is commonly used as an inexpensive source of calories in Nigeria and some other countries. It (corn) is the third most important cereal in the world after rice and wheat and ranks fourth after millet, sorghum, and rice in Nigeria [8], [9]. Corn is an important source of nutraceuticals known to enhance health and prevent diseases; it contains phenolics, carotenoids, anthocyanins, phlobaphenes, insoluble and soluble dietary fiber, polar and nonpolar lipids [10]. It has extensive usage in Nigeria for making *ogi, tuwo, donkunnu, masa, popcorn, cornflour, aadun,* and *Kokoro* which are rich in carbohydrates [11]. Corn flour is especially rich in carbohydrates [3]**.** Corn products are widely consumed among the low-income community, thus necessitating their fortification with an inexpensive protein from a plant source.

Nigeria produces cereals and legumes for both domestic and industrial consumption. However, despite their relatively high production, Nigeria imports a huge quantity of wheat flour. This importation results in poor and /non-consumption of locally available staples with a resultant threat to the extinction of some local staples as well as the enormous expense of foreign currency. Composite flour is crucial for the production of numerous food products. It has various advantages which include but are not limited to the reduction of wheat flour importation, encouragement of the use and consumption of locally grown crops, preventing the extinction of the crop, and saving some foreign exchange which could be used to develop other areas of the economy [12]. The combination of AYB and corn seed flour is a value addition strategy to improve and increase the nutrient density of the composite. Evaluation of the functional and pasting properties of composite flour from AYB and corn will determine their applicability in food the system. Pasting property is an index for predicting a food's ability to form a paste when subjected to heat applications [13]. It is one of the most important properties that influence the quality and aesthetic considerations in the food industry since they affect texture and digestibility as well as the end-use of starch-based food commodities [14]. Pasting property includes peak viscosity, trough viscosity, breakdown viscosity, final viscosity, setback viscosity, peak time, and pasting temperature [15]; while functional properties are the fundamental physicochemical properties that reflect the complex interaction between the composition, structure, molecular conformation, and physiochemical properties of food components together with the nature of the environment in which these are associated and measured [16]. The behavior of flour during food processing depends on its functional properties which include but are not limited to bulk density, water absorption capacity, oil absorption capacity, gelatinization temperature, and so on [17]. These properties will enhance the food and industrial application of composite flour. Therefore, this study aims at evaluating the functional and pasting properties of flour blends made from nutritious and locally available food crops, AYB, and corn seeds.

II. MATERIALS AND METHODS

A. *Study Design:*

The study employed an experimental design.

B. *Collection and Identification of Raw Materials*

Corn grains and African yam bean seeds were purchased from Ndioru Main Market in Ikwuano Local Government Area, Abia State. The raw materials were identified by an agronomist E.N. in the Department of Agronomy, Michael Okpara University of Agriculture, Umudike.

C. *Raw Material Preparation*

Processing of AYB and corn seeds into flour: AYB seeds were sorted to remove extraneous materials, washed with tap water, drained in a colander, and roasted on medium gas mark 191^{0}C for 40minutes with continuous stirring (until cracking sets in). The whole seeds were finely milled into flour, packaged in a polyethylene bag, and refrigerated. Corn grains were sorted to remove extraneous materials, washed in tap water, drained in a colander, and dried in an oven (Gallenkemp, 300 Plus, England) at 50 ºC for 24h. The dried whole corn seeds were finely milled in an attrition mill (7hp China) and stored in an air-tight container inside the refrigerator until use.

Formulation of composite flour: The flour samples were blended in the ratio of 70(AYB): 30(Corn), 50(AYB): 50(Corn), 30(AYB): 70(Corn), 100(AYB), and 100 (Corn), measured in quantities of 70.85g (70% AYB:30% corn), 82.84g (50% AYB:50% corn), 94.81g (30% AYB:70% corn), 52.87g (100%AYB), 112.79g (100% corn) that will contribute 1/3 of the daily dietary fiber intake as in [18]; and coded as 101, 102, 103, 104, and 105 respectively. The quantity of Wheat flour that will provide 12.7g dietary fibre was also calculated from literature (118.69g) and coded as sample 106 the control.

D. *Chemical Analyses*

The pasting property of the flour samples was determined using a rapid Visco-analyzer (RVA) as in [19]. Three grams of the flour sample was added to 50 ml distilled water. The paddle was placed into canisters containing the samples and water. The samples were then inserted in the rapid visco-analyzer. The analysis was carried out at programmed heating and cooling cycle where the samples were held at 50˚C for 1 minute, heated at 95˚C for 3.8mins, and held at 50˚C for 1.4mins, and then pasting performance of the flour samples were automatically recorded on the graduated sheet of the instrument. The functional properties: bulk density, water, and oil absorption capacity, gelatinization temperature, wettability, swelling index, and emulsion capacity were determined with the methods described in [20]. The foam capacity and stability were determined as in [21].

E. *Statistical Analysis*

Data generated from the study were reported as the mean of duplicate analyses. One-way analysis of variance (ANOVA) using the Statistical Product for Service Solution version (23.0) was used to compare between the mean values while treatment means were separated using Duncan multiple range test at 95% confidence level ($p<0.05$).

III. RESULTS

Table 1 shows the pasting properties of AYB and cornflour blends. The peak viscosity (PV) of the study samples ranged from 1066.00 to 2844.50. The control sample 106 (100% wheat flour) had a high value compared to other samples. There was a significant difference at p> 0.05 for all the samples except for samples 102 (50%AYB: 50% corn) and 105 (100% corn). Trough viscosity (TV) of the samples was also significantly different (P>0.05). The TV values of the study samples ranged from 1008.50 to 1687.50, with the control 100% wheat flour having the highest value. The study samples breakdown viscosity (BV) ranged from 26.00 in sample 103 (30%AYB: 70% corn) to 1157.00 in the control sample106 (100% wheat flour). The final viscosity (FV) values of the study samples had similar a trend with their BV and ranged from 1458.00 in sample 103 (30% AYB: 70%

corn) to 2629.50 in 106(100% wheat flour). The trend continued in their setback viscosity (SBV) 298.50 in 103 (30%AYB: 70% corn) to 942.00 in 106 (100% wheat flour) although 101 (70% AYB: 30% corn) and 104 (100% AYB) had appreciable SBV (777.50 and 768.00) values respectively. The peak time of the samples ranged from 6.23 to 7.00mins. Sample 106 (100% wheat flour) had the least peak time and there was no significant difference among the other samples. The pasting temperature of the samples ranged from 67.73 to 84.80^{0}C.

Table 2 shows the functional properties of the study samples. Significant differences ($p<0.05$) were found in the functional parameters of the flours. The bulk density of the samples ranged between 0.72 to 0.77 g/cm^3, sample 101 (70% AYB: 30% corn flour) and 103 (30% AYB: 70% corn flour) were significantly higher (0.77 g/cm^3) than the other samples. The water absorption capacity (WAC) of flour samples ranged from 1.98 to 2.04mg/100g. Sample 103 (30% AYB to 70% corn flour) had significantly ($p>0.05$) lower WAC (1.98mg/100g) when compared with other samples including the control. The oil absorption capacity (OAC) of sample 101 (70% AYB to 30% corn flour) 2.62 mg/100g was significantly higher when compared with other blends, this was followed by sample 104 (100% AYB). These values were higher than 0.72mg/100g of the control 106 (10% wheat flour). The control sample 106 (100% wheat flour) had higher wettability (2.03 sec) when compared to other blends with a range of 0.72 to 1.82 sec. The swelling index of the study ranged from 1.04 to 6.64mg/100g. Sample 101 (70% AYB to 30% corn flour) 6.64mg/100g was significantly higher when compared with other samples. This was followed by sample 104 (100% AYB flour) 4.98 mg/100g, which was significantly different from the control 106 (100% wheat flour) 1.22 mg/100g. Gelatinization of the study samples ranged from 60.65°C in 101 (70% AYB to 30% corn flour) to 71.00°C in 103 (30% AYB to 70% corn flour). The latter was significantly higher than the other samples including the control. The foam capacity of the study samples varied from 1.52 mg/100g in 101 (70% AYB to 30% corn flour) to 13.17mg/100g in 103 (30% AYB to 70% corn flour). The latter was closely related to the control (100% wheat flour) value 13.01 mg/100g. The emulsion capacity of the study samples ranged from 2.03 to 3.39g/ml significantly lower than 5.82g/ml of the control sample 106(100% wheat flour). The foam stability of the study samples ranged from 0.62 to 1.41mg/100g. The control sample 106 (100% wheat flour) had the highest foam stability value of 1.41 mg/100g than other flour samples, and sample 103 (30% AYB: 70% corn) had 1.31mg/100g higher when compared with 102 (50% AYB: 50% corn) 1.23 mg/100g and 101 (70% AYB: 30% corn) 1.03 mg/100g.

IV. DISCUSSION

Pasting properties are the characteristics of an aqueous suspension of starch when heated above a critical temperature. Starch granules can swell irreversibly and the amylose content leaches into the aqueous phase to increase the viscosity at high temperatures. Peak viscosity (PV) is a measure of the ability of the starch to form a paste and swell freely before physical breakdown [22]. Since PV is directly associated with starch damage, the control sample 106 (100% wheat flour) had a significantly higher viscosity than other samples. The PV of the study samples was higher than 325-398 BU for starch extracted from sorghum obtained in [23], and 639-726 BU for yam starches obtained in [24]. This could be because PV increases with an increase in protein content, and blends with higher AYB (a protein source had higher PV values. Also, the high peak viscosity observed in the samples implies that they may be suitable for products requiring high gel strength, thick paste, and elasticity example custard. Trough viscosity (TV) measures the viscosity of swelled starch granules upon shearing and heating disruption. This study samples had higher TV values than 93.34BU Gru and 190.79BU Una-ngwa in [25]. "Reference [26] defined breakdown viscosity as the ability of flour starch to withstand collapse during cooling or the degree of disintegration of granules or paste stability''. Higher breakdown viscosity implies a lower ability of the sample to withstand heating and shear stress during cooking. Wheat flour (100%) had the highest breakdown viscosity when compared with other samples. This study had lower BV than the range 145-216 BU for sorghum and 15-385 BU for yam starches in [23] and [24]. Final viscosity is a measure of the ability of starch to form viscous paste after cooking and cooling. The samples formed weak gels compared to 100% wheat flour. This could be due to starch reduction in the study samples as in [27]. "Reference [26] described setback viscosity (SBV) as a measure of the re-association of flour starch and the cohesiveness of paste respectively". This definition indicates that wheat flour had a higher re-association of starch and paste cohesion than the study samples. This study samples had higher SBV values than 104-140BU for sorghum and 79-339 BU for yam obtained in [23] and [24] respectively. Low setback values are appreciated in products that require low viscosity and paste stability at low temperatures like weaning foods, as confirmed in [28]. Thus these study samples could be used in products like gruels. Conversely, starch from these flours may be useful for products such as bread, cake, and doughnut that require high cohesive pastes. The samples had low peak time compared with 17.40-17.55mins reported in [24] for yam flour varieties. Flours with a shorter pasting time could be used for products that require a shorter processing time. Sample 106 (100% Wheat flour) had the least pasting temperature, among the samples. The pasting temperature is an indication of the pasting temperature of the samples that could be compared with 75.1 to 77.3°C of baked products obtained in [24]. Samples with higher pasting temperatures had higher peak times. "Reference [19] explained that the minimum temperature required for sample cooking is an indication of the energy cost involved, gelatinization time, and other components stability".

The functional properties (bulk density, water, and oil absorption capacity, wettability, swelling index, gelatinization temperature, foam and emulsion capacity, and foam stability) determine the application and the use of food materials for various food products [29]. Bulk density is an indication of the porosity of a product and a function of flour wettability which influences packaging design and could be used in determining the required type of packaging material [30]. As a reflection of the load the sample can carry if allowed to rest directly on another, the bulk density of the flour samples, were higher than the 0.69 g/cm^3 and 0.57–0.71 g/cm^3 reported for taro flours in [31], and 0.31 0.51g/cm^3 b for AYB flour and protein isolates in [32]; but lower than that of cooked trifoliate yam flour observed in [33] was 0.86 g/cm^3. These differences have been attributed to differences in particle size. “Reference [34] documented that bulk density is influenced by the structure of starch polymers, and lose structure is an indication of low bulk density”.

Water absorption capacity (WAC) is the ability of a substance to absorb water in poor water conditions and increases with an increase in protein content [35]. This definition could explain the trend observed in this study samples 101 (70% AYB to 30% corn), and 102 (50% AYB: 50% corn), with higher contents of AYB (legume high in protein). This study samples’ WAC could be compared to those reported for untreated AYB flour (1.47 to 2.53 ml/g) and soaked AYB (1.66 to 2.25 ml/g) in [36]; and 0.31 to 4.39g/g for AYB flour and protein isolated in [32]. The WAC values of the study samples could be explained in [37], that the ability of food material to absorb water is sometimes attributed to its protein and starch contents, and to the capacity of boiling to dissociate or alter the protein molecules to monomeric subunits which may have more water binding sites respectively. The no significant difference between samples 101(70% AYB: 30% Corn), 102(50% AYB: 50% Corn), 105(100% Corn) indicates that the increase in WAC is not related to an increase in African yam beans to corn flour. This is in line with [38] where there was no increase of WAC with an increase in African yam beans flour. This study’s WAC (ability to absorb water in deficient water condition) value suggests that African yam beans and corn flour blends would be useful as bakery products and will require hydration to improve handling features since WAC increases with an increase in protein level. “Reference [39] revealed that flours with high water absorption capacity can be used in the formulation of some foods such as sausage and bakery products”. Sample 101 (70% AYB to 30% corn flour) high (2.62 mg/100g) OAC could be rated best among other samples as it reflects higher emulsifying capacity an important parameter in baking flour as documented [40]. The high OAC of samples 101 (70% AYB to 30% corn flour) and 104 (100% AYB flour) is an indication that an increase in AYB to corn flour increases the oil absorption capacity. This study samples’ OAC was were closer to the control (100% wheat flour) but lower than 22.0 to 27.5% in [41]. The blends nearness to OAC of wheat flour is an indication of being better emulsifiers, flavor retainers, improved palatability with a better mouthfeel. “Reference [42] and [43] listed the usefulness of OAC in bakery products to include flavor retention, improvement of palatability, and extension of shelf life. There was a significant difference in the wettability of the study samples. The samples including the control 106(100% wheat flour) had lower wettability compared with [44] who recorded different flour varieties of *D. alata* (27-35 sec.). Wettability is important in food formulations, and is affected by surface polarity, topography, texture, area, size, and microstructure of the protein particles, but not the amount of native structure. The higher swelling index of sample 101 (70% AYB to 30% corn flour) 6.64mg/100g is an indication that an increase in African yam bean to corn flour increases the swelling index. There was a significant difference ($p<0.05$) among the flour samples. This study’s swelling index could be rated good compared with [45] 5.5 mg/100g cocoyam samples to other root crops like cassava 1.2 mg/100g. This is because of the type of granules cocoyam starch has and its highly digestible nature. The starch grain of cocoyam is about one-tenth of potato starch grain [46]. The swelling index of flours depends on particle size, types of variety, and the processing methods or unit operations. Swelling index and swelling capacity are functions of loose particles. The study gelatinization temperature could be compared to those in [17] which examined some functional properties of different cultivars of cocoyam (*Xanthosoma agittifolium* and *Colocasia esculenta*) cormels. *Ede-ofe* had 63.75 ºC gelatinization temperature; 69.75 ºC was reported for *Cocoindia*. *Ede-ocha* and 65.00 ºC for *Ede-uhie* and that in [47], 62.45°C. gelatinization temperature of *D alata* The ability of the gel structure to provide a metric to hold water, oil, flavor, and other additives is very useful in a variety of food products.

Sample 103 had the highest (13.17mg/100g) foaming capacity, indicating that a high level of AYB to corn flour could have reduced the foam capacity as shown in sample 101(70% AYB to 30% corn flour). The significant difference ($p<0.05$) among the study samples conforms to the work of Ajani *et al*. (2016) *coco-india* (10.78%) in the functional properties of composite flour where the foaming capacity decreases with an increase in composite flour. “[48] described foam capacity and stability as the level of adsorbed air on the air-liquid interface during whipping or bubbling, and its ability to form a cohesive viscoelastic film by way of intermolecular interactions”. This description clarified AYB flour blends’ reduced ability to absorb air compared to the other blends. “Reference [48] revealed that foam stability is related to the amount of solubilized protein, and the amount of polar and non-polar lipids in a sample However earlier reports showed that foam capacity and foam stability are a function of the types of protein, pH, processing method, viscosity and surface tension [49].

The emulsion capacity of samples 102 (50% African yam bean to 50% corn flour) and 103 (30% AYB to 70% corn flour) though lower than 5.82g/ml of wheat flour could serve as good emulsifiers in food products. The foam stability refers to the ability of the protein to stabilize against gravitational and mechanical stress. The highest value for foam stability was observed in the control sample 106 (100% wheat flour) 1.41 mg/100g There was a significant difference ($p<0.05$) among the samples. This study foam capacity range was higher than 1.08 mg/100g reported by Ajani *et al*. (2016) but lower than 2.01mg/100g of wheat and composite flour in [38].

V. CONCLUSION

African yam bean and cornflour samples can be used for the production of new food products, especially as bakery materials or gruel in complementary foods. The samples had good pasting and functional properties which could be appropriate for formulating new and varied food products and will be beneficial in homes, industries, and Health sectors.

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Table 1: Pasting Properties of flour blends made from African yam bean and corn seeds

Sample	**Peak viscosity** (BU)	**Trough viscosity** (BU)	**Breakdown viscosity** (BU)	**Final viscosity** (BU)	**Setback viscosity** (BU)	**Peak Time** (sec.)	**Pasting Temperature** (^{0}C)
101	$1121.00^{c}\pm4.24$	1064.00^{c}±i1.41	$57.00^{b}\pm5.66$	$1841.50^{b}\pm9.19$	$777.50^{b}\pm10.61$	$7.00^{a}\pm0.00$	$82.38^{b}\pm1.17$
102	$1079.50^{e}\pm7.78$	$1026.50^{cd}\pm6.36$	$53.00^{b}\pm1.41$	$1454.50^{d}\pm9.19$	$428.00^{d}\pm15.56$	$7.00^{a}\pm0.00$	$84.80^{a}\pm0.07$
103	$1185.50^{b}\pm7.78$	$1159.50^{b}\pm9.19$	$26.00^{c}\pm1.41$	$1458.00^{d}\pm1.41$	$298.50^{e}\pm7.78$	$6.97^{a}\pm0.05$	$83.95^{a}\pm0.07$
104	$1108.00^{d}\pm15.56$	$1042.50^{cd}\pm10.61$	$65.50^{b}\pm4.95$	$1810.50^{b}\pm23.33$	$768.00^{b}\pm12.73$	$7.00^{a}\pm0.00$	$83.55^{ab}\pm0.57$
105	$1066.00^{e}\pm16.97$	$1008.50^{d}\pm16.26$	$57.50^{b}\pm0.71$	$1575.50^{c}\pm38.89$	$567.00^{c}\pm22.63$	$7.00^{a}\pm0.00$	$84.73^{a}\pm0.04$
106	$2844.50^{a}\pm19.09$	$1687.50^{a}\pm44.55$	$1157.00^{a}\pm25.46$	$2629.50^{a}\pm54.45$	$942.00^{a}\pm9.90$	$6.23^{b}\pm0.05$	$67.73^{c}\pm0.04$

Values are mean ± standard deviation of duplicate samples; $^{a-f}$ Means with similar superscripts within the same column are not significantly different ($p>0.05$)

Key:

101– (70% African yam beanflour:30% Corn flour)
102– (50% African Yam bean: 50% Corn flour)
103– (30% African yam bean: 70% Corn flour)
104– (100% African yam bean flour)
105– (100% Corn flour)
106– Control (100% Wheat flour)

Table 2 Functional Properties of flour blends made from African yam bean and corn seeds

Sample	**Bulk Density** g/cm^{3}	**Water absorption capacity (g/ml)**	**Oil absorption capacity (g/ml)**	**Wettability (Sec)**	**Swelling index (g/ml)**	**Gelatinization temperature (◦C)**	**Foam capacity (%)**	**Emulsion capacity (g/ml)**	**Foam stability (%)**
101	$0.77^{a}\pm0.01$	$2.04^{a}\pm0.10$	$2.62^{a}\pm0.01$	$1.27^{c}\pm0.01$	$6.64^{a}\pm0.01$	$60.65^{e}\pm0.00$	$1.52^{f}\pm0.02$	$2.03^{f}\pm0.01$	$1.03^{e}\pm0.03$
102	$0.73^{b}\pm0.01$	$2.04^{a}\pm0.01$	$1.28^{e}\pm0.01$	$0.87^{e}\pm0.01$	$2.71^{d}\pm0.01$	$67.16^{b}\pm0.01$	$9.67^{c}\pm0.01$	$3.33^{c}\pm0.01$	$1.23^{c}\pm0.01$
103	$0.77^{a}\pm0.02$	$1.98^{b}\pm0.01$	$0.73^{f}\pm0.01$	$0.72^{f}\pm0.01$	$1.04^{f}\pm0.01$	$71.00^{a}\pm1.41$	$13.17^{a}\pm0.01$	$3.91^{b}\pm0.01$	$1.31^{b}\pm0.01$
104	$0.73^{b}\pm0.01$	$2.01^{ab}\pm0.01$	$2.07^{b}\pm0.01$	$1.82^{b}\pm0.01$	$4.98^{b}\pm0.01$	$63.42^{d}\pm0.01$	$5.01^{e}\pm0.01$	$2.61^{e}\pm0.01$	$0.62^{f}\pm0.01$
105	$0.72^{b}\pm0.01$	$2.02^{a}\pm0.01$	$1.67^{d}\pm0.01$	$1.01^{d}\pm0.01$	$3.86^{c}\pm0.01$	$65.28^{c}\pm0.01$	$7.35^{d}\pm0.01$	$2.96^{d}\pm0.01$	$1.18^{d}\pm0.01$
106	$0.72^{b}\pm0.01$	$2.03^{a}\pm0.01$	$1.75^{c}\pm0.01$	$2.03^{a}\pm0.02$	$1.22^{e}\pm0.01$	$65.32^{c}\pm0.02$	$13.01^{b}\pm01$	$5.82^{a}\pm0.02$	$1.41^{a}\pm0.01$

Values are mean ± standard deviation of duplicate samples; $^{a-f}$ Means with similar superscripts within the same column are not significantly different ($p>0.05$)

Key:

101– (70% African yam beanflour:30% Corn flour)
102– (50% African Yam bean: 50% Corn flour)
103– (30% African yam bean: 70% Corn flour)
104– (100% African yam bean flour)
105– (100% Corn flour)
106– Control (100% Wheat flour)