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Original Article

Technological potential of under-utilized starches from eight varieties of legumes grown in Cameroon

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(With 3 figures)

Abstract

Starch samples from eight legumes cultivars instar of one variety of Vigna unguiculata L. (Cowpea), one variety of Vigna subterrenea V. (Bambara groundnut) and six varieties of Phaseolus vulgaris L. (Common bean), grown in Cameroon were isolated, and their physicochemical and pasting properties were evaluated. The objectives of the study were to investigate the starch properties and processing characteristics of different bean varieties, and to establish the basic foundation of improving the functionality of beans and their starch grown in the region. The result revealed significant differences amongst the properties of the starches. The swelling power of the legume starch isolates put them in the category of highly restricted-swelling starch. This characteristic is desirable for the manufacture of value-added products such as noodles and composite blends with cereals. The pasting properties were determined using a rapid visco analyzer, and various legumes bean starches exhibited different pasting profiles. The high breakdown viscosity (BV) was founded for Cowpea and Bambara groundnut and confirmed their low. ability to resist heat and shear stress when compared to Common bean varieties studies. The factors which influence the pasting characteristics resulting to decrease in peak viscosity (PV), trough viscosity (TV) and final viscosity (FV) of starch are attributed to the interaction of starch with the protein, fat, etc. which depended to their variety.

Keywords*:* common bean, Cowpea, Bambara groundnut, starch, physico-chemical properties, pasting properties, functional properties.

Potencial tecnológico de amidos subutilizados de oito variedades de leguminosas cultivadas nos Camarões

Resumo

Foram isoladas amostras de amido de oito cultivares de leguminosas ínstar de uma variedade de Vigna unguiculata L. (feijão caupi), uma variedade de Vigna subterrenea V. (amendoim Bambara) e seis variedades de Phaseolus vulgaris L. (feijão comum), cultivadas nos Camarões, e suas propriedades físico-químicas e de pasta foram avaliadas. Os objetivos do estudo foram investigar as propriedades do amido e as características de processamento de diferentes variedades de feijão e estabelecer as bases básicas para melhorar a funcionalidade do feijão e do amido cultivado na região. O resultado revelou diferenças significativas entre as propriedades dos amidos. O poder de inchamento dos isolados de amido de leguminosas os coloca na categoria de amido com inchamento altamente restrito. Esta característica é desejável para o fabrico de produtos de valor acrescentado, tais como macarrão e misturas compósitas com cereais. As propriedades de pasta foram determinadas usando um analisador rápido de visco, e vários amidos de feijão leguminosos exibiram diferentes perfis de pasta. A alta BV foi fundada para o amendoim Cowpea e Bambara e confirmou sua baixa. capacidade de resistir ao calor e tensão de cisalhamento quando comparado com estudos de variedades de feijão. Os fatores que influenciam as características colantes resultantes da diminuição do pico de viscosidade (PV), da viscosidade mínima (TV) e da viscosidade final (FV) do amido são atribuídos à interação do amido com a proteína, gordura, etc., que dependem da sua variedade.

Palavras-chave: feijão comum, feijão-frade, amendoim bambara, amido, propriedades físico-químicas, propriedades de pasta, propriedades funcionais.

1. Introduction

Legumes seeds are important ingredients of a balanced human diet in many parts of the world due to their high protein (15-40%) and starch (35-60%) contents (Saikia et al., 1999; Tharanathan and Mahadevamma, 2003). Starch constitutes a major energy supply for humans worldwide and is produced as a reserve carbohydrate in plants. Starch constitutes a major energy supply for humans worldwide and is produced as a reserve carbohydrate in plants. Starch is a carbohydrate consisting of a large number of glucose units joined together by glycosidic bonds. This polysaccharide is produced by all green plants as an energy store. It is the most common carbohydrate in the human diet (Whistler and Bemiller, 1997). Storage starch is produced in amyloplasts as discrete granules with distinct morphology in different plants, ranging from round, oval, ogival or elongated to flat, lenticular or polyhedral, and sizes from sub-microns to more than 100 µm in diameter (Leach et al., 1959; Bertoft, 2017). Although a great number of vegetables present considerable starch contents, only a few of these sources have been commercially explored, from which corn, wheat, rice, potato and cassava stand out (Murphy, 2000). The food industry is the greatest starch consumer, but other industries, especially chemical and textile industries, also use this polymer. Research on new starchy raw materials has intensified in recent years, due mainly to restrictions imposed by the food industries on the use of modified starches. Starch was modified physically or chemically in order to obtain heat stable or resistance towards heat product, stable during freeze-thaw process and easily dissolve either in hot or cold suspension (Syahariza and Yong, 2017). Recent study on using chemically modified starch in replacing fat in yogurt-based products for example, suggested a good effect in syneresis and good flow and better viscoelastic characteristics (Lobato-Calleros et al., 2014). However, there are two major disadvantages of utilizing solely pure starch which first is high attraction towards water and second is extreme rigidity (Ramírez-Hernández et al., 2017). The disadvantages of using chemical modification are easily causing chemical residue to be left after modifying starch and definitely not an eco-friendly even though it is a fast, simple, extensively used and efficient method (Li et al., 2018). Food industry favors starches which is stable, white in color and odorless thus making legume seed as a perfect candidate by having around 60% starch (Nawab et al., 2016). It has been shown recently that some legume seed like Bambara groundnut (Vigna subterranea) are an underutilized food crops in Africa and currently explored of its potential in terms of starch isolation (Oyeyinka, et al., 2018). It is crucial to explore new and underutilized starch as it offers multiple functions in food and non-food industry (Irani et al., 2017). Thus, throughout the world, starch producing companies are increasing their search for natural starches with characteristics that attend the interests of the different types of industries, with special attention given to the food industry (Leonel and Cereda, 2002).

Generally, starch is convertible to many useful materials by chemical and biochemical techniques, as well as by fermentation (Eliasson, 1996; David and William, 1999). It plays an important role in food industries because it affects the physical properties of many foods, and it mainly uses as thickener, water binding, emulsion stabilizer and gelling agent. Starches from various plant sources have their own unique properties that enable them to tolerate a wide range of processing techniques as well as various distributions, storage and final preparation conditions via either chemical or physical modified methods (Daniel and Weaver, 2000;). The determination of the proximate composition of starch and a microscopic examination are of fundamental importance in characterizing the susceptibility of the starch to a determined technological treatment. Therefore, it is possible to relate morphological and chemical characteristics to the physical and rheological properties of the products obtained from a determined starch (Ferreira et al., 2012) Starches from different sources can be characterized according to the different shapes and sizes of their granules and to the presence of crystalline zones. Starch characteristics such as swelling power and solubility pattern, physico-chemical and functional properties are important for improved quality of food products. Dry legume starches have been recognized as a potential food ingredient containing a relatively high proportion of amylose when compared to cereal starches (Xu et al., 2013; Pahane et al., 2017; Nurulain et al., 2018). Legume starches have a higher resistance to swelling and rupture than do cereal starches. Among the commonly consumed food legumes, common bean (Phaseolus vulgaris L.) and cowpea (Vigna subterranea) are the most widely produced and consumed legumes in the world and occupies an important place in human nutrition in East and Great Lakes Regions of Africa (Shimelis and Rakshit, 2005; Doughty and Walker, 1982; De Godinez et al., 1992). Greater attention is actually being paid to improve and diversify production of dry legume seeds common beans in Africa. In this respect, ongoing programs work towards development of high-yielding and disease resistant varieties through adaptation, selection and hybridization. Improving the use of dry seeds for protein and starch ingredients in food industries will go a long way open new avenue for new and value-added products developments.

Therefore, our present investigation was undertaken to study and compare physicochemical, and pasting properties of starches from eight varieties of bean cultivars grown in Cameroon.

2. Materials and Methods

2.1. Sources of legume seeds and sample preparation

Eight varieties of dry legume seeds belonging to 2 genus (Vigna sp. and Phaseolus sp.) were used for this study. They were purchased from a local market in the Adamawa and west regions of Cameroon in the Central Africa. The dry seeds of each variety were separately cleaned, uniformed in size and color, and freed from foreign or abnormal seeds, odors and living or dead insects. For each variety, 2 kg portions of breeding seeds were placed in an aluminum box and transported to the Laboratory. For each lot, sufficient amount of legume seeds was taken as required, rinsed four times in deionized water to eliminate dust and the insecticide (used for protecting treatment), dried at room temperature and packed in plastic bags and stored at 4 °C until used. All the chemicals used were analytical grade.

2.2. Starch extraction

Starches were extracted from legume seeds by the method adopted by Sathe, Salunkhe (1981). In the procedure of starch extraction, 0.5 kg seeds was washed abundantly with tap water, soaked for 12h, manually dehulled and ground to obtain a paste. Water (5 L) was then added to the paste and mixed manually. The mixture was kept for 12h during which the starch settled. The precipitated was then resuspended in 1 L NaCl 1% and gently mixed. The mixture was kept for 12h, centrifuged (3800g, 20 min, 20°C). The precipitate was collected, washed twice with distilled water, suspended in 1L NaOH 0.03M, gently mixed and kept at 4°C for 12h. The starch solution was again centrifuged at 3800g for 20 min. the precipitate was washed with distilled water through a sieve mesh 125μm to eliminate fibers and the obtained solution was centrifuged (3800g, 20 min, 20°C). The resulting precipitate was dispersed on a tray and dried at 45°C for 45 min, grounded into powder in a mortar, packaged in polyethylene bag and stored at 4°C until used. Commercial rice starch (S-7260) purchased from Sigma Chemical Co (St. Louis, Mo., U.S.A) and was used as a control.

2.3. Physico-chemical properties of legume starch extracts

2.3.1. Chemical composition assessment

The chemical analysis of the isolated starch fractions included the determination of moisture using modified vacuum-oven method (AACC, 1983; Method 26-30), crude lipid content using Sox Tec service unit 1046 and Fibertec I and M systems (Foss Tecator, Sweden) according to method 923.05 and 962.09 respectively, of the Official Methods of AOAC (2000). Total ash content was also analyzed according to method 923.03 of the AOAC Official Methods (AOAC, 2000). Crude protein (N x 5.7 for starch) was performed using Kjeldhal block digestion and steam distillation (2200 Kjeltec Auto distillation, Foss Tecator, Sweden) method according to AOAC (2000) official methods 979.09.

2.3.2. Water absorption capacity, swelling power and solubility pattern

Solubility index, water absorption and swelling power patterns at 60 and 90°C were determined using a modified version of Sathe and Salunkhe (1981) method. Briefly, 40 mL of a starch suspension (4, 6 and 8%, w/v) was prepared in a previously tared 50 mL centrifuge tube. A magnetic agitator was put in the tube, which was placed in a water bath for 30 min at a constant temperature (60 or 90°C). The suspension was then centrifuged at 2120 g for 15 min, the supernatant decanted and the swollen granules weighed. The supernatant was placed in a crucible and dried in an air convection oven (Imperial V) at 120 °C for 4 h to constant weight. Solubility expressed in g particle/100g starch and swelling power expressed in g water/g starch were calculated using the Formulas 1, 2 and 3:

$$\%\ \text{solubility} = \frac{\text{dry weight at } 120°\text{C}}{\text{sample weight}} \times 100 \quad (1)$$

$$\text{Swelling power} = \frac{\text{weight of swollen granules}}{\text{sample weight} \times (1 - \%\text{solubility})} \quad (2)$$

Water absorption capacity expressed in g water/100g sample was measured using the same conditions as above, but expressed as weight of the gel formed per sample, divided by treated sample weight.

$$\text{Water absorption capacity}\,(\%) = \frac{\text{weight of swollen granules}}{\text{sample weight}} \times 100 \quad (3)$$

2.4. Pasting profiles

A Rapid Visco Analyzer (Model RVA-4, Newport Scientific Pty. Ltd., Sydney, Australia, 1995) with Thermocline for windows software was used to evaluate the pasting properties of the dry legume starches. Test runs were conducted following standard profile 1 which include 1 min of mixing, stirring, and warming up to 50°C, 3 min and 42 sec of heating at 12°C /min up to 95°C, 2.5 min of holding at 95°C, 3 min and 48 sec of cooling down to 50°C, at the same rate as the heating (12°C /min) and 2 min holding at 50°C, where the process ends after 13 minutes (Deffenbaugh and Walker, 1989). Starch gelatinization (pasting) curves were recorded on RVA and viscosity was expressed in terms of centipoises (Cp).

2.5. Statistical analysis

Three tests were conducted for each type of analysis. Results were expressed as the means ± standard deviation. For all data obtained, one-way analysis of variance (ANOVA) was conducted and the least significant difference (LSD) test was performed using Statistica software (version 10.0). The differences are significant at $p < 0.05$. Pearson correlation ® for the relationships between the investigated properties was also calculated.

3. Results and Discussion

3.1. Physico-chemical properties of legume starches

The chemical composition of the dry legume starches studied is presented in Table 1. The values found in this chemical characterization of legume starches show that they are similar in terms of moisture content, but protein, fat and ash contents show significant difference ($p < 0.05$) among the legume starches. Protein content ranged 0.30 to 2.71 g/100g, crude fat 0.40 to 0.96 g/100g, ash 0.17 to 0.35 g/100g and moisture 9.2 to 11.3 g/100g dry starch. These values are in the range reported for other legumes seeds (Ferreira et al., 2012) obtained the values of 16 to 18% for crude proteins and 1 to 4% for crude lipids in three varieties of legume starch; Ashogbon and Akintayo (2013a) obtained the values of 0.36 to 0.45% for crude proteins and 0.15 to 0.54% for crude fat in four Nigerian legume starch). The presence of components other than starch represents impurities, and in this case, they were less than 4%. This is probably consequence of washing procedures used including NaCl and NaOH washings as also reported in earlier studies (Galvez and Resurreccion, 1993). Xu et al. (2013) reported in their study the range moisture content of potato starches higher (13.5-18.2%) than that of bean starches (10.8-11.0%). While the moisture contents of our starch samples were consistent with literature, they were lower compared to that of potato starch. According to Swinkels (1985), potato starch typically has higher moisture content than the other starches. The values found for moisture are similar because the starches were submitted to the same drying and storage processes.

Ash content showed significant difference and the values are from 0.17 for red beans to 0.35g/100g dry starch for black beans. It has been suggested that higher ash contents of starch is a result of the presence of material commonly referred to as "fine fiber" (Ratnayake et al., 2001). Similar contents were reported earlier (Lee, 2007) obtained 0.14 to 0.25% ash content for four bean starches; Ashogbon and Akintayo (2013a) obtained 0.24 to 0.36% ash content for legume starches).

3.2. Water absorption capacity, water solubility index and swelling power

The swelling power and solubility of the dry legume starches at 60°C and 90°C are shown in Table 2. The swelling power (14.48%) and solubility index (17.0%) of Bambara starch at 90°C were the highest, followed by that of Cowpea starch with 12.7% swelling power and 13.1% solubility. The solubility index of the five varieties of common bean (range 10.0 to 11.1 g/100g) at 90°C did not significantly ($p<0.05$) vary each other with values range. In other hand at 90°C, the swelling power of green bean, Yellow bean and Black bean did not significantly varied (range from 6.72 to 7.8%), and White bean, Red bean and Red spotted bean had swelling power of 11.3, 10.2 and 10.3%, respectively. it can easily be seen from the table that WAC, SP and WSI increased with increase in temperature. Comparatively to properties of rice starch used as reference in these analysis with values at 60°C and 90°C of WAC (407% and 1395%), WSI (2 and 14%) and SP (4% and 16%), the legume starches exhibited significantly lower values. Therefore, the resulting swelling power indicated that the starch extracts obtained were highly restricted type according to Schoch and Maywald (1968). The difference between the swelling powers of starch isolates might be due to the amylose content, the protein-amylose complex formation (Pomeranz, 1991; Adebowale and Lawal, 2003). The observation reported by Lai and Varriano-Marston (1979)

Table 1. Chemical composition of starches from 8 dry legume seeds.

Variety	Moisture (%)	Crude proteins (%)	Crude fat (%)	ash (%)
cowpea	10.22±0.204a	2.71±0.054c	0.54±0.01a	0.24±0.004a
Bambara groundnut	9.25±0.184a	0.3±0.006a	0.5±0.01a	0.28±0.005a
Red bean	11.25±0.224a	0.97±0.019ab	0.4±0.008a	0.17±0.003a
White bean	10.72±0.214a	1.44±0.028b	0.4±0.008a	0.26±0.005a
Green bean	9.23±0.184a	0.62±0.012a	0.6±0.012a	0.21±0.004a
Black bean	9.64±0.192a	1.11±0.022b	0.49±0.009a	0.35±0.007a
Red spotted bean	11.18±0.223a	0.95±0.019ab	0.96±0.019b	0.21±0.004a
Yellow bean	10.72±0.214a	0.6±0.012a	0.51±0.01a	0.31±0.006a

Means ± standard deviation; n=3; values in the same column followed with different letters are significantly different at $p<0.05$.

Table 2. Some functional properties of dry legume seeds at 60 and 90 °C.

Varieties	WAC (%)		WSI (g/100g)		SP (g/g)	
	60°C	90°C	60°C	90°C	60°C	90°C
Cowpea	335±7e	1102±23e	4.0±0.1d	13.1±0.3b	3.5±0.5b	12.7±0.3d
Bambara groundnut	390±8f	1203±23f	4.9±0.2e	17.1±0.3c	4.1±0.3c	14.5±0.5e
Red beans	313±6d	920±18c	4.0±0.1d	10.0±0.3a	3.3±0.5b	10.2±0.4b
White beans	303±6cd	1005±20d	3.0±0.1c	11.1±0.4a	3.1±0.4b	11.3±0.2c
Green beans	243±5b	703±14b	2.9±0.1c	10.1±0.2a	2.5±0.1a	7.8±0.5a
Black beans	208±4a	605±12a	4.0±0.1d	10.2±0.2a	2.2±0.2a	6.7±0.3a
Red spotted beans	290±6c	918±18c	1.9±0.1b	11.1±0.5a	3.0±0.2b	10.3±0.4b
Yellow beans	200±2a	603±13a	1.0±0.1a	10.2±0.2a	2.0±0.1a	6.7±0.4a
Rice Starch	407.5±8g	1375±27g	2±0.1b	14±0.6b	4.1±0.1c	16.2±0.4f

Means ± standard deviation; n=3; values in the same column followed with different letters are significantly different at $p<0.05$. WAC water absorption capacity; WSI water solubility index; SP swelling power.

for black bean starch was 17.9% solubility at 95oC. Lii and Chang (1981) reported higher values of WSI (25%) and SP power (32%).

Both solubility and swelling power of dry seeds starches varied with temperature and it can be generally concluded that solubility and swelling power increase with temperature increment (Lai and Varriano-Marston 1979; Ngatchic Metsagang et al., 2013). Solubility of legume starch for all the 8 varieties in this study ranged between 10 to 17%. Lower value of solubility and swelling power of starch at low temperature is due to the crystalline nature of starch. Generally, starch absorbs less water at temperature lower than the gelatinization temperature. When starch is heated at higher temperature, the granule crystalline structure is disorganized and begins to swell. As the swelling increased amylose is leach out of the granules to increase the soluble fraction.

Results of the water absorption capacity (WAC) of legume starches are also shown in Table 2. Starch from Yellow bean, Black bean and Green bean varieties registered lower WAC than other varieties studied with respective values of 200, 208 and 243 g/100g at 60°C and 603, 605 and 703 g/100g at 90°C. It is known that water binding by starches is a function of several parameters including size, shape, conformational characteristics, steric factors, hydrophilic-hydrophobic balance in the starch molecule, lipids and carbohydrates associated with the proteins, thermodynamic properties of the system (energy of bonding, interfacial tension, etc.), physicochemical environment (pH, ionic strength, vapor pressure, temperature, presence/absence of surfactant etc.), solubility of starch molecules and others (Chou and Morr, 1979; Yang and Chang, 1999). Red bean and red spotted bean exhibited non-significant difference with respective values at 60 and 90°C of 313 and 920 g/100gC, and 290 g/100g to 918 g/100g. In addition, white bean, cowpea and Bambara starches registered respective values of 303, 335 and 390 g/100g at 60°C and 1005, 1103 and 1203 g/100 at 90°C. Sathe and Salunkhe (1981) obtained the value of 293g/100g at 21°C for water absorption of Northern green bean starch. Comer and Fry (1978) have reported cold water absorption of the purified pea starch to be 92-105%.

A positive correlation values were obtained between the water absorption capacity and the water solubility index (r=0.79), the swelling power (r=0.99); a positive correlation was also observed between WSI and SP (r=0.84) at $p<0.05$. It was therefore possible to determine the multiple correlation value of WAC, WSI and SP which is R(z/xy)=0,99 and the probability value p=0.00.

The response surface plot (Figure 1) was generated to visualize SP changing depending on WAC and WSI values. The highest SP was observed at the highest WAC and WSI. However, the influence of WSI was much lower than the influence of WAC content in the increase of swelling power. This may imply that swelling hinders the exudation of amylose out of starch granule. Dengate (1984) observed also that the result of granule swelling permitting the exudation of amylose.

3.3. Pasting behavior

The pasting characteristics of the legume starches are shown in Figure 2. The curve showed the behavior characteristic of starch with viscosity remaining fairly constant when temperature increases from 1 to 60-70 °C. Over this limit temperature called pasting temperature, the viscosity increases exponentially to a pic viscosity over which the viscosity decreases to a final viscosity. As the temperature decreases, the viscosity of the solution increases to a final value. The pasting profile varied with starch legume seeds varieties and the starch concentration (Table 3).

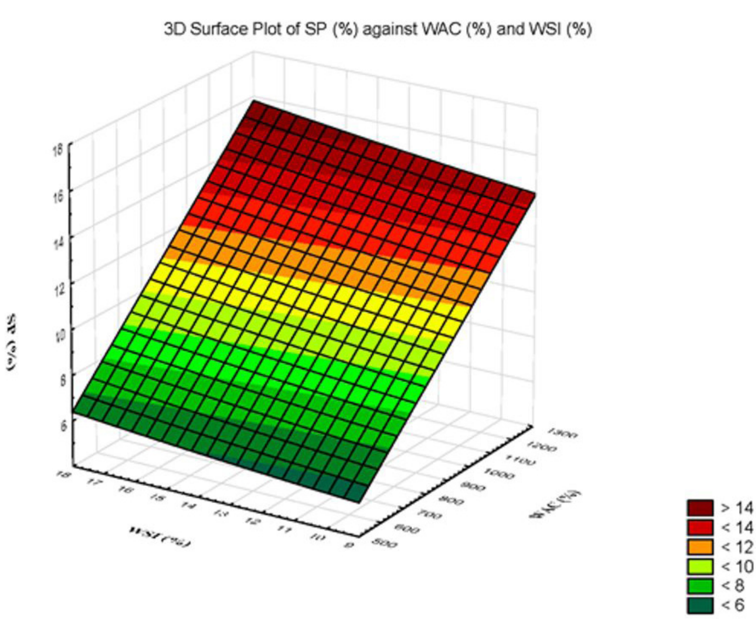

Figure 1. Influence of water absorption capacity and water solubility index on swelling power.

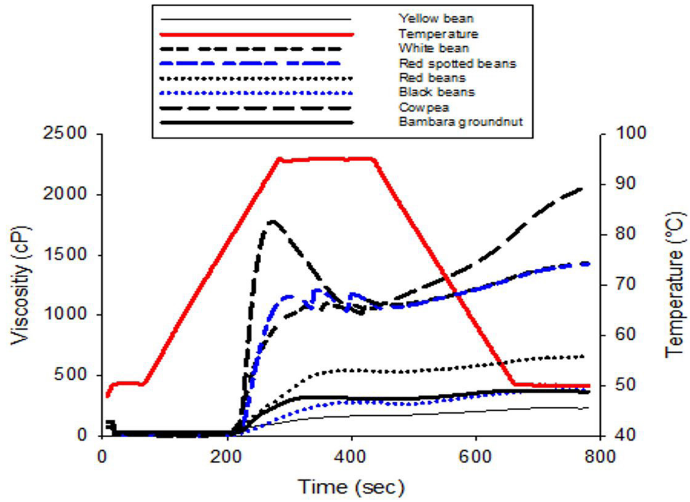

Figure 2. Pasting profile of different beans starch varieties (at 8% of starch concentration).

Table 3. Pasting properties of dry legume starches.

Variety	Starch Concentration (%)	PT (°C)	PV (cP)	TV (cP)	BV (cP)	FV (cP)
White Bean	4	71.7±1.43aa	44±0.88aa	34±0.68aa	10±0.2ba	55±1.1aa
	6	75.8±1.51bb	295±5.9ba	289±5.78bb	6±0.12aa	321±6.42ba
	8	78.15±1.56ca	1097±21.94ce	930±18.6ce	167±3.34cd	1430±28.6ce
Yellow Bean	4	71.7±1.43aa	44±0.88aa	34±0.68aa	10±0.2ba	55±1.1aa
	6	71.7±1.43aa	295±5.9ca	289±5.78ca	6±0.12aa	321±6.42ca
	8	78.15±1.56ba	168±3.36ba	105±2.1ba	63±1.26ca	226±4.52ba
Black Bean	4	75±1.5ab	44±0.88aa	34±0.68aa	10±0.2aa	55±1.1aa
	6	78.5±1.57bc	295±5.9ca	251±5.02ca	44±0.88bb	321±6.42ba
	8	79±1.58ba	277±5.54bb	213±4.26bb	64±1.28ca	379±7.58cc
Red Bean	4	76.55±1.53ab	44±0.88aa	34±0.68aa	10±0.2aa	55±1.1aa
	6	78.15±1.56ac	295±5.9ba	251±5.02ba	44±0.88bb	321±6.42b
	8	77.45±1.55aa	539±10.78cd	445±8.9cd	94±1.88cb	653±13.06cd
Red Spatted Bean	4	76.55±1.53ab	44±0.88aa	34±0.68aa	10±0.2ba	55±1.1aa
	6	78.15±1.56ac	295±5.9ba	289±5.78bb	6±0.12aa	321±6.42ba
	8	79±1.58aa	1211±24.22cf	1085±21.7cf	126±2.52cc	1423±28.46ce
Green Bean	4	76.55±1.53ab	44±0.88aa	34±0.68aa	10±0.2ba	55±1.1aa
	6	78.15±1.56ac	295±5.9ba	289±5.78cb	6±0.12aa	321±6.42ba
	8	79.9±1.6aa	321±6.42cc	258±5.16bc	63±1.26ca	363±7.26cb
Cowpea	4	76.55±1.53ab	44±0.88aa	34±0.68aa	10±0.2ba	55±1.1aa
	6	78.15±1.56ac	295±5.9ba	289±5.78bb	6±0.12aa	321±6.42ba
	8	78.2±1.45aa	1774±33.4cg	1104±22.08cf	670±13.4ce	2060±41.2cf
Bambara Groundnut	4	72.5±1.45aa	44±0.88aa	34±0.68aa	10±0.2aa	55±1.1aa
	6	78.15±1.56bc	295±5.9ba	289±5.78bb	6±0.12ba	321±6.42ba
	8	78.2±1.45ba	1774±35.48cg	1104±22.08cf	670±13.4ce	2060±41.2cf

Means ± standard deviation; PT pasting temperature; PV peak viscosity; TV trough viscosity; BV breakdown viscosity; FV final viscosity; values in the same column for the same variety followed with different letters are significantly different at $p<0.05$. In the same order, values in the same column for the same parameter at the same concentration followed with different second letters are significantly different at $p<0.05$.

The pasting temperature of legumes seeds starches varies significantly ($p < 0.05$) and ranged from 71.7 to 79.9°C. These values were significantly ($p<0.05$) lower than reported values in literature (Sandhu and Lim, 2008) 50.2 - 52.5°C for black gram (Vigna mung), chickpea (Cicer arietinum), field pea (Pisum sativum), lentil (Lens culinaris), mung bean (Phaseolus aureus), and pigeon pea (Cajanus cajan). The pasting temperatures were closed to 79.5 °C and 75.8 - 80.3°C reported for four cultivars of field pea starches (Ratnayake et al., 2001) and some Indian black gram starches (Singh and Singh, 2001; Singh et al., 2004), respectively.

The pasting profile parameters are represented in Table 3. This table show that the PT pasting temperature were high between 71.7°C to 79.9°C. This high pasting temperature for beans starches indicated their higher resistance towards swelling. Peak viscosity PV (the highest viscosity attainable during heating) corresponds to the point when the numbers of swollen, but still intact starch granules are maximal. It indicates the water binding capacity of the starch granules (Shimelis et al., 2006; Ashogbon et al., 2011) and it also frequently correlated with final product quality. We showed in this study that the Peak viscosity of the solution not only varied with legume variety, but also with the concentration of the starch slurry (Table 3). Dry legume starches presented PV values range from 168 to 1774 Cp at 8% starch varying from one variety to another. PV value was found to be lowest for Yellow bean (168Cp) and highest for Bambara bean and cowpea (1774Cp). However, at 4 and 6% starch concentration, no significant difference of PV was observed among varieties with respective values of 44 Cp and 295 Cp. Higher PV as well as lower PT reflects the capacity of starch granules to swell freely before physical breakdown or rupture as a result of higher temperature and mechanical agitation (Ashogbon and Akintayo, 2013b; Nurulain et al., 2018). Peak viscosity (PV) is accompanied immediately by a reduction in viscosity to a minimum call trough viscosity (TV). The breakdown viscosity (BV) is a measure of the vulnerability of cooked starch to disintegration. BV of the starch samples varied significantly ($P < 0.05$) with the concentration of starch and variety. BV ranged between 63 and 670cp at 8% concentration. The lowest BV was for Yellow bean and green bean, followed by Black bean (64 Cp) and Red bean (94 Cp) starches while the highest BV were for Cowpea and Bambara starches. The higher the breakdown viscosity, the lower is the ability of the starch sample to withstand heat and shear stress during cooking (Tester and Morrison, 1990; Ashogbon and Akintayo, 2013b). Therefore, Cowpea and Bambara starches possess less ability to resist heat and shear stress when compared to Common bean varieties in this study. Similar higher BV values were reported for starches from 2 Cowpea cultivars (Ashogbon and Akintayo, 2013b) and 13 improved Indian black gram cultivars (Singh et al., 2004).

Final viscosity (FV) which indicates the ability of the starch to form a viscous paste varied significantly with concentration and variety of starch. At 8%, FV varied from 226 (Yellow bean) to 2060cp (Cowpea and Bambara). The high FV for the legume starches indicates that their paste could easily form a more rigid gel (Zhang et al., 2005; Barrera et al., 2013). Increase in FV is attributed to the re-association of amylose molecules during cooling and responsible of the starch retrogradation (Miles et al., 1985; Liang and King, 2003). In addition, the differences in pasting characteristics of starches have been associated to factors among which Amylopectine molecular structure and Amylose contents play important role (Juliano et al., 1987). The differences in the degree of randomly limited branching in amylose concentration might have also contributed to varietal differences (Ashogbon and Akintayo, 2012). Other reasons for differences may be inherent to differences in starch structure or may be due to different degree of interactions between starch and its associated compounds during pasting (Sekine, 1996; Zhang and Hamaker, 2008).

A positive correlation values were obtained between the water absorption capacity WAC and the peak viscosity ($r=0.91$), final viscosity ($r=0.93$), breakdown viscosity ($r=0.71$) ; Similarly, the positive correlation values were also obtained between the swelling power and the peak viscosity ($r=0.91$), final viscosity ($r=0.94$), breakdown viscosity ($r=0.72$) at $p<0.05$. We determined the multiple correlation value of PV, FV and BV which is $R(z/xy)=0{,}86$ and the probability value $p=0.0314$. It was also possible to determine the multiple correlation value of PV, FV and SP which is $R(z/xy) = 0{,}95$ and the probability value $p=0.0024$. A three-dimensional graphics have been plotted (Figure 3)

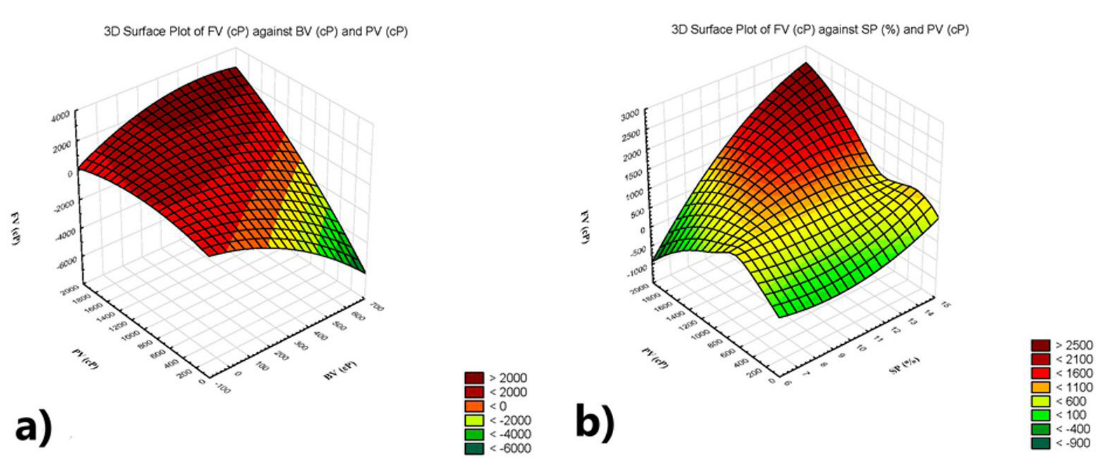

Figure 3. (a) Influence of peak viscosity and breakdown viscosity on the final viscosity; (b) Influence of peak viscosity and swelling power on final viscosity.

for comparison of effect of peak viscosity, Breakdown viscosity and swelling power on final viscosity. As can be seen, FV increased non-linearly with the different parameters. It is evident from the surface plot (Figure 3a) that a high PV and a low BV were necessary for high FV. Likewise, it was also observed by analyzing (Figure 3b) other interaction surface plot that central values of PV and starch with high values of SP were crucial for the maximum FV. Fortunately, there were no significant correlation at $p<0.05$ between crude proteins, crude fat, ash contents and the values of various physicochemical parameters studied. This confirmed the purity of the bean starch extracts and the efficiency of the method used.

Legume starch studied can contribute greatly to the textural properties of many foods and in industries. Starch from six varieties of common bean (Red bean, Red Spotted bean, White bean, Black bean, Green bean and Yellow bean) can be suitable as bulking agent like in beverage and snack. Cowpea starch can be used as thickener and gelling agent while Bambara groundnut starch can be choose like gelling agent.

4. Conclusion

The pasting and functional properties of dry legume starches from different varieties vary significantly. The swelling power of starch isolate from seven common varieties of the legume beans studied fall on the group of highly restricted-swelling starches. This characteristic is desirable for starch extracts to be used for the manufacture of value-added products such as noodles and composite blends with cereals. Despite of the differences among the legume beans, the isolated starches had similar physico-chemical, pasting and functional properties. The significant differences in the functional properties of the legume bean starches especially their pasting properties indicated that these differences observed could be used in their selection for specific food processing applications.

Overall, the physico-chemical, pasting and functional properties obtained indicate that dry seeds starches have useful technological properties for many applications. It can be used in the food processing industry and non-food applications of starch. Research and development studies on African varieties of beans which are constantly released from various research centers will help to meet new demands in the Africa. Finally, in order to boost the small scale bean production and develop new market opportunities to stimulate economic growth in the continent. Further research and development programs in these aspects which can be integrated with other currently ongoing research activities are necessary.

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