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Influence of Different Conventional Processing Methods on the Resistant Starch Content and Diastatic Power of Bambara Groundnut (*Vigna subterranean*) Starch

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Abstract

The edible seeds in the pods of legumes have been used in the management of protein-energy malnutrition after undergoing food processing operations to promote their utilization. However, starch were obtained from the raw seeds when subjected to operations like drying, germination, soaking, boiling, and milling. Therefore, this study investigated the effect of conventional processing methods such as drying, boiling, and germinating on the starch qualities of Bambara groundnut for value addition in the food system and healthy therapy. The seeds were divided into four batches (native, boiled, germinated and dried) while starch was isolated from each using alkaline methods and the products were compared in terms of starch yield, color, amylose content, resistant starch, and diastatic power. The starch yield was 38, 32 and 28% for the germinated, dried and boiled samples, respectively when compared to the native sample (44%). The higher lightness (whiteness) obtained for the native starch (84.57) over the processed starches was due to its low pigmentation level. Meanwhile, the amylose contents of native and processed starches were in the range of 26.48 to 27.49%. The resistant starch ranged from 17.56 to 18.03%, with cooking (boiling) process significantly increasing the resistant starch contents, which may be attributed to the effect of retrogradation on the boiled starch after cooling. Contrarily, the diastatic power was very high in the germinated starch sample (9.34 ^{o}L) when compared with other samples due to the malting or germination process of the seeds before starch extraction. However, the information generated from this study could be useful for indigenous promotion and effective utilization of Bambara groundnuts both domestically and industrially as a functional and nutraceutical food.

Keywords: *Bambara groundnut; resistant starch; amylose; color; diastatic power*

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1. Introduction

Legumes are plants belonging to the family Leguminosae that produced seeds within a pod (Maphosa and Jideami, 2017), mostly dried beans and pulses from edible seeds as they matured within these pods, thus found very rich in fiber, protein, folate, iron, potassium, and magnesium (Garden-Robinson and McNeal, 2019). They have historically been part of inexpensive meals globally as they have a major role in the fight against malnutrition. Legumes are believed to be one of the first crops cultivated by mankind and have remained a staple food for many cultures all over the world. Some common types of legumes include kidney beans, soybeans, chickpeas, black-eyed peas, and lentils (GLNC, 2015). Legumes could constitute an affordable and convenient supplement to commonly used foods since the nutritional value of complementary foods for the growing human population is a priority (Lopriore and Muehlhoff, 2003). The consumption of legumes played an important role in the prevention and management of several health conditions due to their high concentration of health-promoting nutrients (Polak *et al.*, 2015) such as hypocholesterolemic, antiatherogenic, anticarcinogenic, and hypoglycemic properties (Ndidi *et al.*, 2014). Legumes were known to be consumed by humans since the earliest practice of agriculture because they provided less energy than the cereals, due to their almost double amylose content and the properties of the granules. Interestingly the carbohydrate fraction of legumes is primarily composed of starch (65%-72%) and dietary fiber (10%-20%) (Keskin *et al.*, 2021). Hence, the inclusion of starchy legumes into the human diet in developing countries offered protective effects against chronic diseases (Amarowicz and Pegg, 2008). Factually, starch is composed of two molecules called amylose and amylopectin with some small portion of the starch physically inaccessible to digestive enzymes, typically known as resistant starch. Although, raw

dried legumes contain about 20-30% resistant starch by weight (Grosby, 2002) but a higher percentage of slowly digestible resistant starch resulted in a low glycemic index and acted as functional food (Keskin *et al*., 2021). The amount of resistant starch in foods is therefore, highly dependent on the methods used to analyze the resistant starch. Most importantly, the processed legumes containeda significant amounts of Resistant Starch compared to other foods such as cereals, tubers, and unripe foods (Utrilla-Coello *et al.,* 2007).

One major way of utilizing legumes is through appropriate food processing, not only because it improved its palatability but it reducesd the levels of anti-nutrients and resulted in increased bioavailability of nutrients (Tharanathan and Mahadevamma, 2003; Subuola *et al.,* 2012). The common processing methods for legumes have been dehulling, soaking, germinating, sprouting (malting), fermenting, boiling/cooking, milling, frying, and roasting (Subuola *et al.,* 2012). However food processing involved techniques of converting raw materials into semi-finished and finished products that can be consumed or stored. Bambara groundnut (*Vigna subterranean* L. Verdc) is considered the third most important food legume in Africa after peanut (*Arachis hypogaea*) and cowpeas (*Vigna subterranean*) (Khan *et al.,* 2021). The seeds were consumed in various forms either immatured or fully matured, such as in raw, boiled, grilled, or dried into a powdery form to make cakes. Immatured Bambara groundnuts may be consumed fresh or grilled, whereas the ripe seeds demanded extended periods of soaking and boiling to render them edible (Adebowale and Lawal, 2002; Sirivongpaisal, 2008). The seed coats were usually removed to reduce the anti-nutritional factors and fiber content, resulting in better appearance, texture, cooking quality, palatability, and digestibility of the products (Bamshaiye *et al*., 2011). The Bambara groundnuts could be just boiled and eaten with salt or fried like peanuts. For instance, in Nigeria, freshly harvested pods or seeds were cooked, shelled, and eaten as snacks (Alobo, 1999) or milled into nutritious flour used for the preparation of *moin moin* analog called okpa which is very popular among the Igbo tribe of the Eastern Nigeria (Enwere, 1998; Olapade and Adetuyi, 2007] but could not be kept for more than 12 h. Since Bambara is very nutritious and of economic importance, it could be utilized in the development of more acceptable stable food products and forms.

Several reports have been made on the functional and physicochemical parameters of Bambara groundnut (Adebowale and Lawal, 2002). For instance Sirivongpaisal, (2008) compared the water absorption capacity(WAC) of Bambara groundnut flour and its starch and reported a high WAC in flour due to more hydrophilic, higher protein and carbohydrate contents in flour. The fractionation of starch isolated from Bambara groundnut amylopectin and amylose was also investigated (Lawal, *et al.,* 2004) to provide information on their effective utilization. However, processing methods, such as soaking, germination, and cooking have been reported to improve the nutritional and functional properties of legumes (Waldron, 2001). Therefore, this present research work is aimed to investigate the influence of conventional processing methods such as boiling, germination, and drying especially on the starch color, amylose content, resistant starch content, and diastatic power of Bambara groundnut starch. This will provide further useful insights and value addition to broaden the scope of its utilization in the food system and health application.

2. Materials and methods

2.1. Acquisition of Bambara groundnut seeds and processing

Bambara groundnut seeds (*Vigna subterranean*) used for this study were purchased from the local market in Akure, Ondo State, Nigeria. The seeds were sorted to remove extraneous materials and randomly divided into four batches for different traditional processing methods. The first batch was soaked in distilled water for 8 h, manually dehulled, milled, and processed into fine starch without any treatment (control sample). The whole seeds of the second batch were soaked in distilled water in the ratio of 1:10 (w/v) for 8 h and boiled at about 105 °C for 30 min, thereafter manually dehulled, milled, and isolated its starch. The third batch was allowed to germinate at room temperature after soaking with distilled water for 8 h covered with a moist cloth and kept in the dark for 2 days. The sprouts were washed with distilled water, manually dehulled, milled, and isolated its starch. The fourth batch was soaked for 8 hrs in distilled water, manually dehulled and sun-dried for 72 hrs, and finally milled into fine flour for starch isolation.

2.2. Starch isolation

The alkaline method of Adebowale and Lawal, (2002) was employed in starch isolation with little modification. Bambara groundnut slurry (5 kg) was suspended in 10 L of 0.5 M (w/v) sodium hydroxide (NaOH) solution and stirred for 4 h. After stirring, the suspension was squeezed through double-layered cheesecloth and sieved through a 200 µm sieve successfully. The homogenate was allowed to settle for a minimum of 4 h at room temperature, after which the supernatant was discarded and the sediments were re-suspended in distilled water, and centrifuged (this process was repeated three times). The starch suspension was neutralized and the sediment starch was air dried for 24 h, then milled and sieved into fine powder.

The starch yield was calculated as the percentage yield of Bambara groundnut starch (Ybs):

$$\%\, Ybs = \frac{Weight\ of\ isolated\ starch}{Initial\ weight\ of\ seeds}\, x\ 100$$

2.3. Determination of starch color

This was determined using a colorimeter (Color Tec PCMTM, Color Tec Associates Inc., Clinton, USA). The colorimeter operated on the CIE (Commission Internationale de l'Eclairage) of L*, a*, b* colour scheme. Multiple measurements of several points on samples were made. The instrument was first standardized (L=93.24, a=00.96, b=-02.75) with a Business Xerox 80 g/m2 white paper with 136 CIE whiteness D65. About 3 g of starch was put on a clean paper and the color meter was placed on the sample by allowing the sensor to touch the sample. The reading was taken directly for L*. The instrument displayed three-dimensional color differences in uniform color space (L.a.b) coordinates. The uniform color space defined the three directions *viz*: a light

to dark direction called L*, a red to green direction called a*, and a blue to yellow direction called b*.

2.4. Determination of amylose content

The amylose content of the starch was determined by defatting the starch samples with refluxing 85% methanol for 16 h at 65 °C in a soxhlet extractor, then dried and analyzed for apparent amylose content using the method of Kumari *et al.,* (2007) based on the reaction between amylose and iodine. Briefly, starch (100 mg) was weighed accurately and dissolved in ethanol (1 mL, 95%) and NaOH (1N, 9.2 mL), left overnight, and made up to 100 mL in a volumetric flask. An aliquot (5 mL) of this solution was added with acetic acid (1N, 1 mL) and iodine solution (2 mL, 0.2% I2 in 2% KI), while the volume was made up to 100 mL with distilled water and thoroughly mixed. After 20 min, the absorbance was measured at 620 nm (Shimadzu spectrophotometer UV-2401, Shimadzu, Kyoto, Japan) using a blank with 5 mL 0.09 N NaOH, 1 mL acetic acid, and 2 mL iodine solution made up to 100 mL in total volume.

2.5 Determination of Resistant Starch Content

Resistant starch content was determined according to the method of Goñi, *et al.,* (1996) with some modifications. About 100 mg of the prepared sample on a dry basis was dispersed in 9 mL of water, incubated with 1 mL amylase solution ("EC 3.2.1.1"enzyme activity 2,500 U mL-1) at 37 ºC for 24 h under constant shaking to hydrolyze digestible starch, deposited with 95% ethanol (ethanol volume was four times of the residue) for 12 h. The residue obtained was washed with 95% ethanol twice, air-dried, and treated with KOH solution (4 mol L-1, 3 mL) to solubilize resistant starch. The resistant starch solution obtained was adjusted to pH 4.75 with 2 mol/L hydrochloric acid and 0.4 mol L-1 sodium acetate buffer, incubated with 1 mL amylo-glucosidase solution (enzyme activity 1,500 U mL-1) at 60 ºC for 45 min under constant shaking and heat-treated in a water bath at 95 ºC for 5 min to inactivate the enzymes. Glucose content formed in the solution was determined by titration with Fehling reagent. The resistant starch was calculated as glucose (g) × 0.9 and the content was expressed as a percentage of resistant starch in the analyzed samples.

2.6 Determination of Diastatic Power

The diastatic power (DP) was determined using Fehling's solution as described by the Institute of Brewing's recommended method of analysis (IOB, 2007), and DP was reported as Linter (°L). Fischer chemical starch was used to prepare the starch solution (2%) for this determination. A starch infusion extract of the starch was prepared by pipette ml aliquot of the extract was pipetted into 100 ml of 2 % buffered starch solution in a 200 ml flask. The mixture was shaken and maintained at room temperature for 1 h from the time the aliquot was added. In the end, 15 ml of 0.1 NaOH was added to stop the reaction, and the total volume was now raised to 200 ml with distilled water. Into a 150 ml narrow-necked boiling flask, 5 ml Fehling solutions A and B were also added. Titration was effected by adding a burette containing the digested starch solution to the flask with 1 ml of the endpoint. The contents of the flask were thoroughly mixed and boiled for 2 min and 3 drops of methylene blue indicator were added to complete the titration. The endpoint was attained when the methylene blue had been changed to reddish color in appearance. The blank was prepared by titrating the undiluted 2% starch solution against 1 ml of mixed Fehling's solution A and 2 ml of Fehling's solution B using a methylene blue indicator as described above.

The diastatic power was calculated using this formula:

$$\text{Diastatic Power} = \frac{2000-200}{xY-xS}$$

Where x = Volume of ml of starch extract

Y = Volume of ml of converted starch to 5ml of the Fehling's solution

S = Titre for starch blank (ml)

2.7 Statistical analysis

Each sample analysis was performed in triplicate. The one-way analysis of variance (ANOVA) was performed to determine the significant differences between the means while the means were separated using the new Duncan multiple range test. Significance was accepted at $p<0.05$ levels.

3. Results and Discussion

3.1 Effect of Conventional Processing Methods on Starch Yield of Bambara Groundnut Seeds

The result of the starch yield from Bambara groundnut seeds was presented in Figure 1. Different conventional processing methods employed showed profound changes in the level of starch yield. Processing reduced the level of starch yield to 38% in germinated, 32% in dried, and 28% in boiled starches. A decrease in starch yield after germination of the seeds for 48 h may be attributed to the fact that some of the carbohydrates present in the seeds must have been converted to energy and used up during the germination process. Ayernor and Ocloo (2007) reported a decrease in starch content during germination as a result of hydrolytic enzymes such as alpha and beta-amylases which hydrolyzed starch into low molecular weight carbohydrates. The lower yield obtained in the boiled sample may be a consequence of leaching out of soluble starch portions and soluble sugars by boiling water during the cooking process. A similar observation had been reported for black gram (Rehman, 2007) and chickpea (Apata, 2008). The starch yield obtained in native starch was similar to 45.57% reported for Bambara starch (Sirivongpaisal, 2008) and 40.35% reported by Afolabi (2012) but higher than 37.50% reported by Adebowale and Lawal, (2002), and 38.5% from mango kernels (Oliveira *et al*., 2018) and 16.9% reported for jackfruits (Kittipongpatana and Kittipongpatana, 2011). The higher yield could be attributed to the use of an improved alkaline method of isolation of the leguminous starch.

3.2 Effect of conventional processing on the Amylose Content of the Bambara Starches

Amylose content is one of the key aspects of starch quality. It has a straight-chain polymer structure formed by an arrangement of about 1000 alpha-glucose molecular bound by α (1, 4- glycosidic bonds) to form a straight-chain polymer and they are more resistant to digestion than other molecules due to its solid helical structure (Subroto *et. al*., 2020). The relative proportion of amylose greatly influences the nutritional properties of starch. Higher amylose content is desirable in many human diets as amylose is usually more slowly digested. Amylose content of both native and treated starches was

presented in Figure 2. In both native and treated starches, the amount was ranges from (26.48 to 27.49%) the values obtained were higher than 21.5% in chestnuts (Demiate, *et al.,* 2001), 21.67% in Bambara starch (Sirivongpaisal, 2008), 20.20% in cassava starch (Ashogbon, 2014) and 20.0% in potato starch (Moorthy, 2002). Generally, legume starches have higher amylose content than non-legume starches (Hoover and Manuel, 1995; Gemat, *et al*., 1990). Higher amylose content starches had been associated with the formulation of harder and firmer gels (Novelo-Cen and Betancur-Ancona, 2005). The amylose content greatly influences the physicochemical, thermal, and functional properties of starches especially, since amylose plays a fundamental role in the gelatinization and paste process (De Dios-Avila *et al*., 2022).

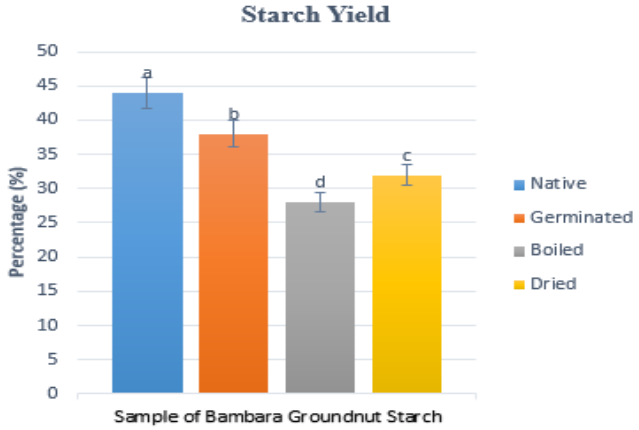

Figure 1: Starch yield of Bambara groundnut seeds

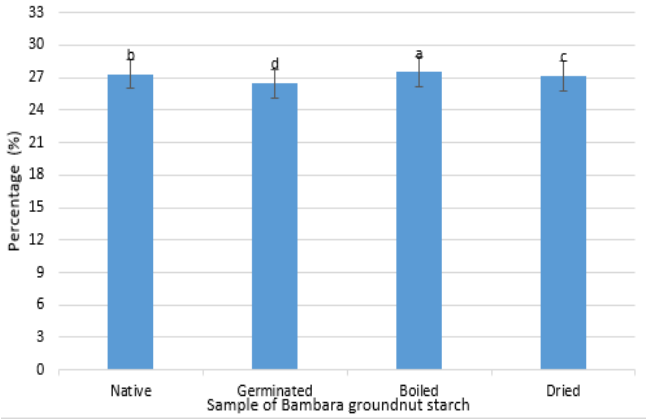

Figure 2: Effect of Conventional Processing on Amylose Content.

3.3 Effect of Conventional Processing Methods on Proximate Composition

The proximate composition of the Bambara groundnut starch was presented in Table 1. The moisture content ranged from 13.55 to 16.69 dry weight with significant differences ($p \leq 0.05$) in the level of moisture content of the germinated, boiled and dried starches when compared to the native starch. A low moisture content indicated that the starch has a stable shelf life as shown in the Table 1. Chetia (1991) reported that increased in moisture content could be observed during cooking (boiling) due to the dilution effect of nutrients. Similar trends have been reported by several reports on starch from legumes (Khattak *et al.,* 2007; Bhagya *et al.,* 2007 and Kakati, 2010). Low moisture content indicates potentials for higher shelf life on dried products, since increase in water retention was attributed to the surface area of the starch phase (Yamazaki *et al.,* 1997).

The starches had low protein content ranging from 0.87 to 1.89%, which varied significantly ($p<0.05$) from one traditional processing treatments to the other. The higher crude protein level observed in boiled starch could be as a result of breaking down of the polypeptide bonds during the boiling process to improve the nutritive value and acceptability of the food legumes [(Bressani, 1990).]. The increase in protein content observed during the germination process might also be due to the release of free amino acid after enzymatic hydrolysis for the synthesis of new protein (Bliss, 1975). Another study reported the germination process to increase protein content of the legume starch due to enzymatic hydrolysis of the insoluble protein to soluble protein, which increased the protein availability (Echendu *et al.,* 2009). Several findings observed increased in protein content after germination in legumes (Ghavidel *et al.,* 2007 and Osman, 2007). The protein value (0.99%) observed in native starch was similar to previous reports on native Bambara groundnut starches such as 0.61% (Sirivongpaisal, 2008) and 0.59% (Netta, 2011) but higher than 0.4% previously reported by (Lawal, 2004) which might be due to the differential variation in seed variety. The fat content ranged from 0.50 to 0.67%. The result showed no significant difference ($p>0.05$) in the crude fat content of Bambara groundnut starches after employing different conventional processing treatments compared to the native starch (Table 1). However, the result obtained in this study (0.50-0.67%) was similar to the 0.44 and 0.42% previously reported for Bambara groundnut starch (Sirivongpaisal, 2008 and Netta 2011) respectively. The values obtained for the total ash content of the starch was 1.02 to 1.10%. The decrease in ash content may be due to the loss of minerals during soaking of seeds prior to starch isolation. The carbohydrate content also varied from one treatment to another. The highest value of carbohydrate was recorded for native starch (97.39%) and lowest in boiled starch (96.46%), which might be due to continuous leaching of the soluble sugars during the boiling process. Carbohydrates have been an inexpensive source of food energy, hence the high percentage of carbohydrate content in all the starch samples suggested that them as good sources of energy. In general, the native and treated starches had low protein, fat and ash contents, which is an indication of the effectiveness of the isolation method and purity of the resultant starch.

Table 1: Effect of Different Conventional Processing Methods on the Proximate Composition of Bambara Groundnut Starch (dry weight %)

Component	Native	Germinated	Boiled	Dried
Moisture	15.86 ± 0.14^{c}	18.55 ± 0.35^{b}	21.69 ± 0.15^{a}	18.95 ± 0.69^{b}
Crude Protein	0.99 ± 0.01^{c}	1.50 ± 0.00^{b}	1.89 ± 0.00^{a}	0.87 ± 0.01^{d}
Fat	1.09 ± 0.69^{a}	0.91 ± 0.69^{a}	1.01 ± 0.69^{a}	1.17 ± 0.06^{a}
Total Ash	1.02 ± 0.01^{c}	1.06 ± 0.01^{b}	1.10 ± 0.02^{a}	1.05 ± 0.01^{b}
Carbohydrate	97.39 ± 0.21^{a}	96.94 ± 0.22^{b}	96.46 ± 0.22^{c}	97.39 ± 0.56^{b}

Mean with different values in the same row are significantly different ($p \leq 0.05$). Values are mean ± standard deviation from triplicate determinations.

3.4 Effect of Processing Methods on the Color of the Starches

The desired starches should possess a high value for lightness and a low value for chroma. There was a color significant difference ($p \leq 0.05$) in the starch samples in terms of lightness (L*), greenness (a*), and yellowness (b*) compared to native starch (Table 2). The native starch had a higher value for lightness (84.57) which is an indication of whiteness and low pigmentation of the starch over the treated starches. While the lower values obtained in treated samples may be due to the presence of a few amounts of pigments such as polyphenol oxidase and phenolic compounds which undergo denaturalization or browning easily during starch isolation and drying process (Chen, 2003). The chromaticity coordinate a* which ranges from -100 (green) to +100 (red) was higher in boiled starch (2.23) followed by dried starch (2.17) and the chromaticity coordinate b* which ranges from -100 (blues) to +100(yellow) was also high for boiled and dried starches. An increase in values of chromaticity of boiled and dried starch may be attributed to poor sedimentation of these starches. This result is in agreement with Moorthy (1994) who reported that starches that are slow to sediment may be colored by contamination from protein and lipids. Rivera *et al.* (2019) reported 70 lightness, 18 greenness, and 28 yellowness for avocado seeds. Color variation can be improved by an additional purification process of the starch where fibers, proteins, pigments, and other impurities can be removed.

Table 2: Effect of different conventional processing methods on color values of Bambara Groundnut starches

Starch	Colour Values		
	L* (Whiteness)	a*	b*
Native	84.57 ± 0.02^{a}	1.46 ± 0.04^{c}	10.79 ± 0.01^{d}
Germinated	84.24 ± 0.03^{b}	1.58 ± 0.01^{b}	10.88 ± 0.01^{c}
Boiled	73.86 ± 0.01^{d}	2.23 ± 0.01^{a}	11.00 ± 0.02^{a}
Dried	77.51 ± 0.01^{c}	2.17 ± 0.01^{a}	10.93 ± 0.10^{b}

Values with a different superscript in a column are significantly different ($p \leq 0.05$).

3.5 Resistant Starch Content of Native and Treated Bambara groundnut Starches

The result of the resistant starch content of the native and treated Bambara groundnut starches is presented in Figure 3. The results showed that boiling increased the amount of resistant starch (18.03%) over native (17.56%), germinated (17.85%), and (17.95%) dried starch respectively. Resistant starch is a starch that is resistant to the enzymatic digestion process and this is a result of the strong interactions between amylose-amylose or amylose-amylopectin chains within the native starch granules, forming crystallites that could hinder the accessibility of glycosidic bonds to oxygen to hydrolytic enzymes. Resistant starch is categorized as resistant starch 1 to resistant starch 4 (Tetlow, 2018).

The Bambara groundnut starch had high content of resistant starch (17.56 to 18.03%) which was higher than the resistant starch content of potato 0.6 - 0.90, 11.2 and 12-20% reported for potato (Correia *et al.*, 2012), native banana starch (Hung *et al.*, 2013) and legume seed (Liu, 2005) starches, respectively. Meanwhile, resistant starch 1 is found in whole grains and legumes and is entrapped in a non-digestible matrix (Sawicka and Gupta, 2018), which could be increasingly released out during boiling process (18.03%).

This increment may be attributed to the effect of retrogradation of the boiled starch after cooling (Hung *et al.*, 2013). This corroborated with the work of Lin *et al.* (2011), where native corn starch increased significantly after heat-moisture treatment. Gonzalaz–Soto *et al.* (2007) also reported an increase in the amount of resistant start due to the reorganization of the starch chain by retrogradation, thus the process of cooking and then cooling caused the starch to go from the digestible form to the form resistant to the action of digestive enzymes, thereby resulted to starch and its decomposition products not absorbed in the small intestine (Sawicka and Gupta, 2018). Moisture content has also been the key factor in resistant starch formation, since water created hydrogen bonds between molecular chains within the starch granule (Kurakake *et al.*, 1997). Sharma *et al.* (2015) reported that heat moisture treatment increased the resistant starch content of Pearl millet starch as compared to native starch. Hence, the resistant starch content is an important parameter to be considered mainly from a nutritional point of view as the starch in this form is less easily digested and did not provide much energy but it thus has a positive anti-hyperglycemia effect on the health (Hendrich, 2010; Lin, 2018).

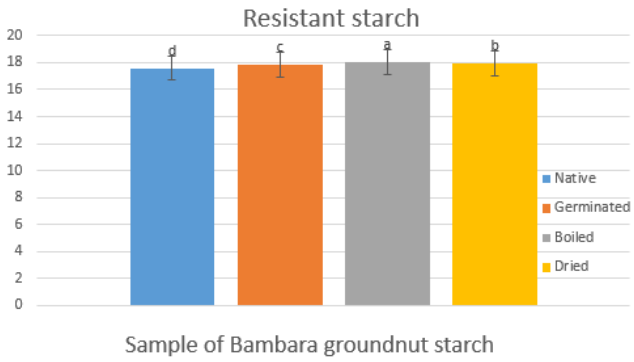

Figure 3: Effect of different conventional processing on resistant starch content.

3.6 Effect of Conventional Processing on Diastatic Power of Starches

The result of diastatic power (DP) of Bambara starches, presented in Figure 4, ranged from 8.25 to 9.34 °L, with a germinated starch sample having the highest value followed by boiling while the lowest is the dried starch sample. DP measured the amount of enzyme available to convert complex carbohydrates/starches into fermentable sugars during mashing (Ackley, 2018). It referred to the total saccharifying power activity, which is considered as a contribution of α- and β-amylases as well as glucosidases that converted maltose to glucose. A good DP is a measurement of a malted grain's enzymatic content. This is because, when grain is malted, enzymes were produced during germination and these enzymes were responsible for converting the starches of the grains into sugar during mashing. Thus, DP is an indicator of the number of enzymes available to convert those starches into sugar. The activity of the beta-amylases is regarded as being the major contribution to diastatic generation (Delcour and Verschaeve, 1987). Malting of the Bambara groundnut seeds for 48 h before starch extraction contributed to the highest DP

value of the germinated starch sample. This increment may be due to the availability of more diastase enzymes (α - and β - amylases), which are produced and secreted during the germination of the seeds compared when compared to native, boiled and dried starches since the germination process mobilized and increased enzymatic activity as previously reported (Guzmán-Ortiz *et al*., 2018). The Values obtained in this present study (8.25-9.34°L) were lower compared to 39 and 42°L reported for blue and red maize malts, respectively after malted for 7 days at 25ºC but similar to 9 and10°L for blue and red maize at 15ºC after malted for 3 days (Hernández-Carapiaa, *et al*., 2021). The temperature and time of germination also affected the DP values which did increase with an increase in temperature. Beside, another study Ghavidel and Davoodi (2011), showed a significant increase in amylase activity in mungbean, cowpea and lentil from 24 to 72 h of germination. A higher DP is reportedly desirable during the malting process of the pulse because it helped in improving the nutritional composition and causesd a reduction in the levels of antinutritional compounds such as phytic acid, stachyose, and raffinose (Goyoaga, *et al.*, 2011). The lowest DP value observed in dried starch (8.25 ºL) may be a result of heat treatment employed on the seeds before starch extraction, which can highly be denatured or reduced the number of amylolytic enzymes available for starch conversion potential (diastatic power) due to the contributory degradation of valuable enzymes by heat (Mukhtar, *et al.*, 2021).

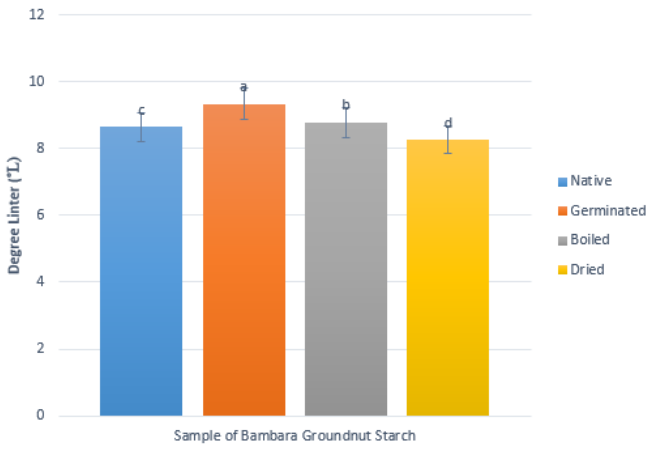

Figure 4: Effect of conventional processing on diastatic power

4. Conclusion

This study investigated the effect of different conventional processing methods such as germination, boiling, and drying on Bambara groundnut starch. The finding showed that boiling process increased the amylose and resistant starch contents while germinated starch had the highest diastatic activity. Therefore, cooking of pre-soaked beans and germination held good potential for improving the nutritional value of the Bambara groundnut thereby promoting and increasing its indigenous utilization as a source of food in Nigeria. The implication of this is that the conventional processing methods of leguminous starch have the potential of increasing the health benefits associated with the consumption of legumes and found beneficiary as a functional food in controlling diets and lifestyle-related diseases, such as diabetes mellitus and coronary heart diseases. However, further empirical studies on the effect of temperature and time on the starch content of germinated and boiled Bambara seed samples could still lead to improved processing techniques. This is because, the domestic utilization and industrial application of Bambara groundnut starch as a functional ingredient in food products and as a dietary modification for those suffering from high-sugar diet-related diseases, have been the global awareness and scientific concerns.

Author Contributions

Author FMA was involved in formulating the study concept, investigation, provision of study materials, formal analysis, writing, preparation and presentation of original draft. Author OFO actively contributed towards research activity planning, mentorship, supervision and, critical revision of the manuscript for intellectual content. Author SAM contributed actively for statistical analysis, reviewing and editing of the manuscript for intellectual content**.** All authors contributed equally to the conception and design of the study.

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