Introduction

Cowpea (Vigna unguiculata L. Walp) is a popular legume that is widely used in West Africa and it serves as an economic source of proteins and calories [1-3]. Cowpea protein shows a well-balanced amino acid content but has deficiencies in the sulphur-containing amino acids, methionine, tryptophan and cystine [4]. Cowpeas provide several B-complex vitamins to the diet and in addition to its nutritional impact, cowpea protein reduces plasma low density lipoprotein when consumed and its utilization provides one of the simplest ways of combating malnutrition in developing countries.

Even though cowpea is cultivated worldwide, it is reported that two-thirds of the total crop worldwide is harvested on the African continent [5,6]. However, the utilization of cowpea as food is below its potential. The underutilization of cowpea has been attributed to factors such as its high susceptibility to diseases and pest attack, thereby rendering the food useless, inedible and unworthy of utilization. The cowpea beetle, Callosobruchus maculatus walp has been identified as the principal storage pest in sub-Saharan Africa [7]. The major post-harvest loss affecting its utilization is the poor storage technique. The individuality of starch expresses itself at various levels, but perhaps most prominently in the morphology of the granules. Their shape and size is so characteristic that examination of the botanical source of the starch, even within a given population of granules, there is much evidence of variation and individuality [14]. Physico-chemical and structural characteristics of starch vary among different varieties of the same botanical sources. Good quality starch with a high starch content and paste viscosity will have a low solubility and high swelling volume and swelling power. High solubility, low swelling volume and swelling power are indicative of poor quality starches that produce thin, low stability paste when cooked [15-17]. Several studies have indicated

Keywords: Starch; Microscopy; Physico-chemical properties; Functional properties; Cowpea; Legumes

Abstract

The microstructure, physico-chemical and functional properties of legume starches affect their cooking quality as well as the texture and rheological behaviour of foods processed from them. Thus, this study sought to establish the microstructural, physico-chemical and functional properties of the native starches of four cowpea varieties - Bengpla, Asotenapa, Asontem and CR-06-07, that have been developed against disease and pest infestation. The starches were extracted from the cowpeas and their gelation capacity, pasting characteristics, solubility, swelling volume and swelling power were studied using standard analytical methods. Microstructures of the starches were examined using light microscopy. Isolated starch granules from the microstructural examination showed irregular shapes with predominance of spheroid and oval forms in varying sizes. Starch granule sizes ranged from 1.9 mm in Asotenapa to 2.9 mm in Asontem. Swelling power, solubility and swelling volume at 95°C was highest in Bengpla with Asotenapa recording the lowest. However Asontem had the highest value in terms of solubility. With the exception of gelation capacity, significant differences (P ≤ 0.05) were observed in all the studied parameters amongst the different cowpea varieties. Thus, the cowpea starches showed wide variations in microstructure, physico-chemical and functional properties among the studied varieties and these could be used in the selection of the varieties for specific food processing applications.
relationships between different starch characteristics and effects on various food matrices [18-20].

The textural and rheological characteristics of food; the presence of other food components, such as proteins, lipids and non-starch polysaccharides; and the changes and interactions occurring in them during breeding, bio-fortification and food processing largely influence the type of native starch present in the food, its structural, physico-chemical and functional characteristics [20,21-23]. Thus, this study sought to characterize the microstructural, physico-chemical and functional properties of the native starches of four newly developed cowpea varieties, namely Bengpla and Asotenapa (both white-flesh), and Asontem and CR-06-07 (both red-flesh) that have been developed by the Crop Institute of Ghana for pest and disease resistance.

Materials and Methods

Materials

Four newly developed cowpea (Vigna unguiculata) varieties namely Asontem, CR-06-07, Bengpla and Asotenapa that have been developed against diseases and pest infestation through breeding were obtained from the Project Coordination Unit – Grain and Legumes Development Project, Crop Research Institute, Fumesua, Kumasi in the Ashanti Region of Ghana and used for the study.

Methods

Cowpea starch extraction: Cowpea starch was extracted from non-defective legume grains in accordance with the fractional scheme of Schoch and Maywald [24] with some modifications as shown in Figure 1.

Microscopic examination of cowpea starches: Photomicrograph of starch granules mounted in 50% glycerin-water mixture was taken by method of Pearson [25]. The starch samples were observed microscopically under polarized light with an Olympus microscope (Olympus Optical Co. Ltd., Tokyo, Japan). Measurements of diameter sizes of at least 40 granules of three different slides of same variety were measured.

Gelation capacity of cowpea starches: The method of Sathe and Salunkhe [26] was used to determine the least gelation concentration of the samples.

Solubility, swelling volume and swelling power of cowpea starches: The method of Mat-Hashim [17] was employed. Swelling volume was obtained directly by reading the volume of the volume of the swollen sediment in the tube. Swelling power was determined by weighing the sediment and expressing swelling power as the weight (g) of swollen sediment (g) dry starch. Evaporating the supernatant and weighing the residue determined solubility. Solubility was expressed as the percentage (by weight) of the starch sample that was dissolved molecularly after heating.

Pasting characteristics of cowpea starches

The pasting properties of 6% slurry on dry weight basis of starch samples were determined using the Brabender Viscosylograph (Brabender Instrument Co. Duisburg, Germany) equipped with a 700 cmg sensitivity cartridge. The samples were heated at 1.5°C/min from 25°C to 95°C for 30 minutes and then cooled at the same rate to 50°C and held for another 15 minutes [27] (Table 1).

<table>
<thead>
<tr>
<th>Cowpea variety</th>
<th>Pasting temperature (°C)</th>
<th>Peak viscosity (B.U)</th>
<th>Brabender viscosity (B.U)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>95°C</td>
<td>50°C</td>
<td>50°C</td>
</tr>
<tr>
<td>Bengpla</td>
<td>63.7</td>
<td>1100</td>
<td>530 500</td>
</tr>
<tr>
<td>Asontem</td>
<td>68.5</td>
<td>1210</td>
<td>530 505</td>
</tr>
<tr>
<td>Asotenapa</td>
<td>64.7</td>
<td>1008</td>
<td>520 505</td>
</tr>
<tr>
<td>CR-06-07</td>
<td>63.1</td>
<td>1170</td>
<td>495 470</td>
</tr>
</tbody>
</table>

*Results are means of triplicate analysis

Table 1: Pasting characteristics of cowpea starches*.

Statistical analyses

The data obtained from the physico-chemical and functional analyses were statistically analyzed using Statgraphics (Graphics Software System, STCC, Inc., Rockville, MD, USA). Comparisons between the cowpea varieties and the studied indices were done using one-way analysis of variance (ANOVA) with a probability (P<0.05). All the treatments and analyses were conducted in triplicates and the mean values reported.

Results and Discussion

Microscopic examination of cowpea starches

The isolated starch granules observed with the light microscope showed irregular shapes with predominance of spheroid and oval forms. The sizes were also variable and significantly different in terms of their average diameter sizes. The granule size distribution in the
different varieties ranged from 1.891 mm (Asetenapa) (Figure 2b) to 2.868 mm in the Asontem (Figure 2a) variety. The second largest were the CR-06-07 granules (Figure 2d) with an average size of 2.770 mm, followed by Bengpla (Figure 2c) with 2.719 mm. With larger average sizes, bound water is likely to diffuse slowly into the starch granules [28]. This suggests that bound water in the Asetenapa variety would diffuse much faster as compared to the other varieties due to the comparatively smaller average size (1.891 mm).

**Gelation capacity of cowpea starches:** Gel formation in starch is consequently believed to be primarily the function of amylose rather than amylopectin, by the formation of a three-dimensional network of starch molecules, by interactions through attractive forces between the molecules and particularly through hydrogen bonding with water molecules [29]. During cooking, there is the withdrawal of moisture from the surrounding matrix, which hydrates the starch granules. Expansion of the starch granules then causes a firmer gel to form, during cooking [30]. The gel structure contributes to the texture and acts as a matrix for holding water as well as fat and other components [31]. A high amylopectin starch produces a cohesive gel because it has the ability to bond large amount of water and swell to larger diameters [32], whereas low amylopectin starches result in weak and brittle gels [31]. The gelation capacities of the starch of the various cowpea varieties were all 2%, indicating their purity.

**Pasting characteristics of cowpea starches:** The indices of interest in the cooked paste characteristics of the cowpea starch samples were studied. These were the pasting temperatures, peak viscosity, and viscosity at 95°C, viscosity after holding at 95°C for 30 minutes, viscosity at 50°C and viscosity after holding at 50°C for 15 minutes. Pasting temperature shows the change in viscosity as the starch granules begin to swell in the slurry with the increase in temperature. There were differences in the pasting temperatures. CR-06-07 had the lowest pasting temperature of 63.1°C followed by Bengpla 63.7°C. These starch samples would therefore cook more easily as compared to the Asontem (68.5°C) and Asetenapa (64.7°C) varieties. With the low pasting temperature and relatively higher viscosity, CR-06-07 starch sample would be easier to cook.

At 95°C HOLD, there was a general reduction in the viscosities, indicating a somewhat lower resistance to shear at high temperatures in all starch samples. The retrogradation tendency of the cooked paste was observed at 50°C. On cooling the starch slurries, all the viscosities increased for all varieties with CR-06-07 and Bengpla having the highest values of 1030 BU and 1010 BU respectively. The two varieties also registered higher paste stabilities. The cold paste viscosity after 15 minutes holding, were high for all the samples indicating the tendency of the starch samples to associate or retrograde. Outstanding amongst these were the Asontem and CR-06-07 varieties (Figures 3-6).
Isolated starch samples from four cassava varieties had a pasting temperature range of 63.94-67.10°C [33], which was comparable to that of the cowpea samples (63.1-68.5). However, some cereal starches from wheat, barley, waxy-corn, and rye had comparatively lower pasting temperatures of about 54°C, 51.5°C, 62°C, and 57°C, respectively, indicating their lower resistance to swelling and rupture [34]. Statistical analysis on the data showed that the cowpea variety significantly affected (p<0.05) all the pasting characteristics of the cowpea starches (Table 2).

Solubility, swelling power, and swelling volume of cowpea starches: Good quality starch with a high starch content and paste viscosity will have a low solubility and high swelling volume and swelling power. High solubility, low swelling volume, and swelling power are indicative of poor quality starches that produce thin, low-stability paste when cooked [16,27]. Comparative evaluation of the swelling power, solubility, and swelling volume at around 95°C revealed that Bengpla had the highest swelling power (29.7162), followed by the CR-06-07 variety (27.2886), Asontem (24.9193), and the Asetenapa variety (21.7581). Correspondingly, the above samples displayed a similar trend in the swelling volume. However, Asontem had the highest solubility (80.617%) with Asetenapa having the lowest (74.3658%).

Swelling power and solubility provide evidence of non-covalent bonding between starch molecules. Factors like amyllose-amylopectin ratio, chain length and molecular weight distribution, degree/length of branching and conformation also decide the swelling and solubility [35]. There is a possible relationship between cooking quality and swelling volumes. The higher the swelling volume, the better the cooking quality [35]. A high amylose content and presence of stronger or greater numbers of intermolecular bonds can reduce swelling [35].

Swelling of starch varies with its origin and also depends on a number of factors like inter-associative forces, swelling power, and presence of other components [35]. Analysis of variance (ANOVA) conducted on

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Table 2: Significant F-ratios of process variables of the physico-chemical and functional properties.

<table>
<thead>
<tr>
<th>Index</th>
<th>Cowpea variety</th>
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</thead>
<tbody>
<tr>
<td>Gelation capacity</td>
<td>-</td>
</tr>
<tr>
<td>Pasting temperature</td>
<td>8.942</td>
</tr>
<tr>
<td>Peak viscosity</td>
<td>12.542</td>
</tr>
<tr>
<td>Viscosity at 95°C</td>
<td>12.829</td>
</tr>
<tr>
<td>Viscosity at 95°C-HOLD</td>
<td>19.746</td>
</tr>
<tr>
<td>Viscosity at 50°C</td>
<td>10.826</td>
</tr>
<tr>
<td>Viscosity at 50°C-HOLD</td>
<td>16.772</td>
</tr>
<tr>
<td>Solubility</td>
<td>10.783</td>
</tr>
<tr>
<td>Swelling power</td>
<td>16.224</td>
</tr>
<tr>
<td>Swelling volume</td>
<td>15.489</td>
</tr>
</tbody>
</table>

Significance at p≤0.05
the data showed that the cowpea variety significantly affected (p<0.05) all the solubility, swelling power and swelling volume of the cowpea starches (Table 2).

Conclusion

The different cowpea starches showed wide variations in microstructure, physico-chemical and functional properties with the various studied cowpea varieties. The isolated starch granules observed with the light microscope showed irregular shapes with predominance of spheroid and oval forms. The sizes were also variable and significantly different in terms of their average diameter sizes. Comparative evaluation of the swelling power, solubility and swelling volume at around 95°C, revealed that Bengla had the highest swelling power (29.7162), followed by the CR-06-07, Asontem and then Asetenapa varieties. The high solubility and low swelling volume and power of Asontem starch produces a thin, low stability paste during cooking. The high pasting temperature and peak viscosity of the Bengla starch suggests its presence of weak associative forces in its granular structure and physico-functional properties could be used in the evaluation of the swelling power, solubility and swelling volume at different in terms of their average diameter sizes. Comparative structures as compared to the other varieties. The observed differences in structure and physico-functional properties could be used in the selection of the best varieties for specific food processing applications.

Acknowledgement

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References