Characterization and evaluation of starches from different sources

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A B S T R A C T

Five types of starches extracted from different local Sudanese cereal cultivars (wheat, sorghum, millet, rice) and cassava were used in this study. Proximate composition, mineral content, functional properties and color of the starches were investigated. The results indicated that the five starches were significantly different in their chemical composition and mineral content. Wheat and cassava starches were found to be most acidic (0.03mg/100g) compared to sorghum, millet and rice starches (0.05mg/100g). Analysis of variance indicated that there are highly significant differences among the five starches in their falling number, water retention capacity (44.44 to 122.20 ml/100g), fat absorption capacity (50.00 to 95.00ml/100g), gelatinization temperature, cold and hot viscosity and amylose content. On the other hand, wheat and cassava starches gave significant high bulk density (0.67 and 0.63 gm/ml). Rice starch showed the lowest dispersibility (70%) which was significantly lower compared to the other starches. Wettability grade for the five starches was good. Sorghum and cassava starches gave very strong gel, while wheat, millet and rice starches gave strong gel at 10% concentration. The results indicated that cassava starch was whiter compared to other starches (95.71%). Millet starch showed high gelatinization temperature and low amylose content

Keywords: Cassava, Functional properties, millet, rice, sorghum, starch, wheat

INTRODUCTION

Starch is the most important carbohydrate in the human diet and in many stable foods (Anne, 2004). It is a natural, cheap, available, renewable and biodegradable polymer produced by many plants as a source of stored energy. Starch is the main reserve carbohydrate of several crops; it is highly abundant in nature and can be easily extracted with high purity and low cost (Cereda , 2001). The most common plant sources for food starches used all over the world are corn, wheat, potato and cassava. Depending on the source, the starches have different applications, improving consistency, stability, and other properties (Smith, 1998).Pure starch is white, tasteless and odorless that is insoluble in cold water or alcohol. It consists of two types of molecules: the linear and helical amylose and the branched amylopectin. Starch generally contains 20% to 25% amylose and 75% to 80% amylopectin (Frazier , 1997).

There are many potential uses of starch such as unmodified starch which can be used in paper, mining and building industries, also it can be modified and converted to starch derivatives, isosugar, high fructose syrup and ethanol. Starch also can be used in Pharmaceutical applications such as, disintegrating agent, binder, film forming material, microspheres, colon targeting of drugs and nanoparticles (IENICA, 2003). It is used in making foods for cattle, pigs, poultry and humans. It is associated in

jellies and gum, food thickeners, yogurts and puddings, bakery fillings for cream and fruits pies and doughnuts, dry mixes for cakes and muffins, brownies and cookies.

Wheat starch makes up 80% of wheat meal and has a great impact on the functionality of wheat products as reported by Belderok (2000). Schober (2005) stated that Sorghum starch plays an important role in both the production of food products and the fermentation of sorghum to produce products such as fuel ethanol. Burton , (1972) reported that Starch was the main carbohydrate component of pearl millet grain and is smooth with a gel viscosity. Starch content of pearl millet in general is found to range between 50.4 to 69.5% as reported by Uprety and Austin (1972). Rice starch is used as an additive in various food and industrial products. With the inherent merits of small and uniform size distribution of rice starch and its white color and clean odor, deserts and bakery products are some of the favorable applications among processed foods (BeMiller, 1984).Klucinec and Thompson 1999 found that Cassava starch has many remarkable characteristics including high paste viscosity, high paste charity and high freeze-thaw stability, which are advantageous to many industries.

Martine and Michael, (2006) reported that All starch granules swell when heated in the presence of water. This process requires the prior loss of at least some of the ordered structures within the native granule, and is often regarded as the final stage in the process of gelatinization. A functional property is any nonnutritional property of a food or food additive that affects it's utilization (Rhee, 1985).Chou and Morr (1979) reported that Water absorption capacity was defined as the ability of material to hold water against gravity. Kinsella (1976) reported that fat absorption of food products is an important functional property that improves mouth feel and flavor. Gelation may be defined as protein aggregation in which polymer-polymer and polymer solvent interaction as well as attractive and repulsive forces are so balanced that a tertiary network of matrix is formed (Schmidt, 1981). The dispersibility of a mixture in water indicates its reconstitutability, the higher dispersibility the better reconstitutability as reported by Kulkarni , (1991). Adamson, (1990) found that wettability may be a convenient parameter providing information on surface properties of starch gels 'surface. The wettability of a solid surface can be determined by a relatively simple method, measuring the so-called contact angle. Higher bulk density is desirable since it helps to reduce the paste thickness, which is an important factor in convalescent and child feeding (Padmashree , 1987). Lorenz and Hinze (1976) reported that holding the temperature of the starch paste at 92°C for 30 min reduced the viscosity of millet starches and increased those of wheat and rye. The objective of this study was to characterize starches from different sources and to compare the five types of starches in their component.

MATERIALS AND METHODS

Materials:

Sorghum (Tabat) and Millet (Ashana) were brought from Agricultural Research Corporation (Sinnar Research Station), season 2010 – 2011. Wheat (Imam) is brought from Agricultural Research Corporation (Wad Madani Research Station), season 2010 – 2011. Sudanese Rice was purchased from Kosti Local Market season 2011 – 2012. Cassava was purchased from Khartoum Local Market season 2011 – 2012.

Chemicals and reagents:

Some chemicals and reagents were purchased from local Market (Sodium metabisulfite) other chemicals and reagents were purchased from outside the Country (Potassium iodide, Resublimed iodine and amylose standard) the rest of chemicals and reagents were obtained from Food Research Centre (FRC).

Methods:
Preparation of starch:

Wheat, Sorghum, Millet, Rice and Cassava were cleaned from impurities and foreign matter and prepared for extraction of starch by using Wet Milling process.

Wet milling process:

Two hundred grams from each sample of Wheat, Sorghum, Millet, Rice and Cassava were weighed and soaked in a distilled water with 0.3% of sulfur dioxide (by adding Sodium meta bisulfite), for about 48 hours for all samples except for Cassava which was soaked for 72 hours, and its distilled water was changed daily for three days, then the soaked samples were stored in a refrigerator (4°C).

The steep grains were taken out of the steeping solution and washed several times with tap water and then with distilled water, then ground in water using a blender for one minute. The blended grains were sieved through 180 microns sieve (Tyler standard screen scale, opening in inches. 0097 meshes to the inch 60 U.S.A series equivalent OH1044060 U.S.A).The slurry was kept a side in a clean container and the remaining over the sieve was blended again.

The process of blending and sieving was repeated several times until most of endosperm was reduced. The slurry was centrifuged for 10 minutes at 2000 rpm (Dentrfu-oversize, serial No. A080-5, Shanghai food package, Machinery Branch Corp.

China). The supernatant liquid was discarded and protein layer on the top of the starch was removed out with stainless steel spatula.

The starch and protein were spread on wide trays and left until dried by air, then dispersed in distilled water and mixed with hand, then sieved through 150 micron sieve(Tyler standard screen scale, opening in inches. 0058 meshes to the inch 100 U.S.A series equivalent OH1044060 U.S.A).

Again the starch and protein were centrifuged and the protein layer was removed as before. Centrifugation step and protein removal were repeated to get white starch. The starch was taken out and directly air- dried. The collected clean, white and granulated starch of each sample was kept in a clean and dry container.

Analytical Methods:

Analysis was carried out for each starch sample of wheat, sorghum, millet, rice and cassava. The Moisture content was determined according to the method of A.A.C.C (1999) by using Buhler Rapid Moisture Tester (Model ML 11000). The ash content of the sample was measured according to the A.O.A.C method (2000) using the muffle furnace (Carbolite Company). Protein was determined according to A. O. A. C. method (1990) by micro Kjeldahl technique. Total fat was determined according to the A.O.A.C method (2000).Mineral contents were determined according to Pearson (1970).The titeratable acidity was conveniently determined according to the AOAC (1984) method. pH was determined in 2% aqueous solution at room temperature using a pH meter (Hanna pH 211, Instruments microprocessor pH meter, serial number 805465 Woonsocket –RI – USA, made in Romania).

Falling number

Falling number was carried according to Perten (1996) method. Three grams of starch were weighed and put into falling number tube; 25 ml of distilled water were added, then shake and put into the falling number apparatus.

Color

Half kg of starch sample was taken for color test using Chroma meter – CR -400/410 instrument. The instrument is attached directly to starch sample and the reading appeared directly in the screen after one second. The high reading value means whiter color of starch.

Estimation of amylose content of starches

A rapid colorimetric method described by Williams (1975) was used for estimating the amylose content of starches.

Functional properties

Viscosity for 1% aqueous solution of sample was determined by the method of Quinn and Beuchat (1975).The water retention capacity (WRC) for starches was measured by the method of Lin (1974) with modification described by Quinn and Beuchat (1975).The bulk density was determined by the method of Wang and Kinsella (1976).The fat absorption capacity (FAC) of the samples was measured by a modified method of Lin , (1974).Least gelation concentration of the sample was measured according to Coffman and Garcia (1977).The gelatinization temperature was measured according to Abdalla (2009).The dispersibility was measured according to the method of Kulkarni (1991).The wettability was determined according to the method of Regenstein and Regenstein (1984).

Statistical analysis

The data were statistically analyzed by the Completely Randomized Design as described by Montgomery ((2001) and the mean differences were tested by Duncan Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

Chemical composition of the starches:

The chemical compositions of cereal and cassava starches are shown in table (1).The moisture content of wheat, sorghum, millet, rice and cassava starches are found to be 8.30, 9.23, 8.44, 6.89 and 8.61% respectively. Statistical analysis of the results showed significant differences among the five starches in their moisture content. Rice starch showed low moisture content compared to the other starches and the highest value was observed in sorghum starch. Moisture contents of wheat, millet and cassava starches are in the agreement with values obtained by Idris (2001) and Abdelnour (2001).The moisture content value of the rice starch agreed with values obtained by Ali (2008) and Singh , (2003).These values were in good agreement with that reported by Abdalla , (2009). The ash content of the five starches was 0.17, 0.27, 0.24, 0.20 and 0.07% respectively. These results were in a good agreement with the values reported by Abdalla , (2009), Singh , (2003), Idris (2001) and Ali (2008).

Table 1. Chemical composition (%) of cereal and cassava starches

Source of starch	Moisture content	Ash content	Protein content	Fat content
Wheat	8.30 ± 0.11^c	0.17 ± 0.01^d	0.58 ± 0.01^a	0.85 ± 0.05^{ab}
Sorghum	9.23 ± 0.22^a	0.27 ± 0.03^a	0.50 ± 0.02^c	0.92 ± 0.06^a
Millet	8.44 ± 0.11^{bc}	0.24 ± 0.02^b	0.55 ± 0.03^b	0.83 ± 0.08^{ab}
Rice	6.89 ± 0.03^d	0.20 ± 0.03^c	0.31 ± 0.02^e	0.77 ± 0.03^b
Cassava	8.61 ± 0.01^b	0.07 ± 0.01^e	0.45 ± 0.01^d	0.65 ± 0.05^c
Lsd$_{0.05}$	0.2153*	0.0005753*	0.0005733*	0.9965*
SE±	0.06831	0.0001826	0.000183	0.03162

Values are mean∓ SD.
Any two mean value(s) having same superscript(s) in a column are not different significantly (P≤0.05).
NS = not significant   * = significant   ** = highly significant

Statistical analysis for ash content for the five starches showed significant differences. The protein content of the five starches was 0.58, 0.50, 0.55, 0.31 and 0.45% respectively. The results obtained were closed to the values reported by Steinke and Johnson (1991) who found 0.56% protein. Statistical analysis of the results showed significant differences among the five starches in their protein content. The decrease in protein content of the starch may be due to the better steeping and proper separation of the starch. The fat content of the five starches was 0.85, 0.92, 0.83, 0.77 and 0.65 respectively. Analysis of variance showed significant differences among the five starches in their fat contents. From these results of chemical composition of the five starches it could be observed that sorghum starch has higher moisture, ash and fat content compare with the starches under study.

Minerals content

Minerals content of five starches (wheat, sorghum, millet, rice and cassava) were presented in table (2).Sodium content of the five starches was 5.40, 5.53, 4.50, 3.27, and 3.10 mg/100g respectively. The highest value of the sodium content was observed in sorghum starch, while the lowest value was in cassava starch. Statistical analysis showed significant differences between the five starches in their sodium content. These values were in a good agreement with the range mentioned by Hoseney (1978) and Huang (2012).Potassium content of five starches was 51.67, 40.33, 38.33, 23.33 and 39.33 mg/100gm respectively. Statistical analysis showed significant difference between the starches in their potassium content. Compared to the other starches, wheat starch gave the highest value and rice starch gave the lowest value in potassium content. Calcium content of starches was 6.07, 6.40, 6.43, 4.40 and 4.07 mg/100gm respectively. There is significant difference among the five starches in their calcium content. The low value of calcium content was observed in cassava starch, while the high value was in millet starch. These results are close to the values obtained by Abdalla (2009) who reported the range to be between 5.0 and 8.33mg/100gm. Elkashan (2006) found the range between 5.00 and 10.83 mg/100gm for millet starch. The phosphorus content of wheat, sorghum, millet, rice and cassava starches was 16.33, 15.33, 18.00, 14.67 and 12.33 mg/100gm, respectively. Statistical analysis of the results showed significant differences among the five starches in their phosphorus content. Cassava starch gave the lowest value of phosphorus content, while the highest value was in millet starch. Hoseney (1978) indicated the range to be from 63 to 135 mg/100gm for millet starch. Ling , (2001) found the higher values of phosphorus content for rice, wheat, cassava and sorghum were ranging from 27 to 288 mg/100gm.Iron content of starches was 240.00, 233.30, 243.30, 220.00 and 190.00 μ/gm respectively. Statistical analysis showed highly significant differences in their iron content. Cassava starch gave the lowest value of iron content, while millet starch gave the highest value. These results are in good agreement with the results reported by Elkashan (2006) and Abdalla (2009).In general mineral concentration is affected by many factors, which include type and variety, field location, milling methods and analytical methods (Betschart, 1988).The greater concentration of minerals was in the covering layers and the germs than in the endosperm portion for most of cereal grains, thus the reduced mineral content in the starches can be attributed to the proper removal of both outer layer and germ during the extraction procedure.

Table 2. Minerals content of cereals and cassava starches

Source of starch	Na (mg/100g)	K (mg/100g)	Ca (mg/100g)	P (mg/100g)	Fe μ/g
Wheat	5.40 ± 0.10^a	51.67 ± 2.52^a	6.07 ± 0.06^a	16.33 ± 1.53^{ab}	240.00 ± 10.00^a
Sorghum	5.53 ± 0.35^a	40.33 ± 2.08^b	6.40 ± 0.10^a	15.33 ± 1.53^{ab}	233.30 ± 15.28^a
Millet	4.50 ± 0.36^b	38.33 ± 3.51^b	6.43 ± 0.05^a	18.00 ± 1.00^a	243.30 ± 15.28^a
Rice	3.27 ± 0.25^c	23.33 ± 1.53^c	4.40 ± 0.03^b	14.67 ± 1.53^{bc}	220.00 ± 20.00^a
Cassava	3.10 ± 0.26^c	39.33 ± 1.53^b	4.07 ± 0.04^b	12.33 ± 1.53^c	190.00 ± 10.00^b
Lsd$_{0.05}$	0.5113*	4.279**	0.581*	2.616*	26.57**
SE±	0.1623	1.358	0.1844	0.8301	8.433

Values are mean± SD.
Any two mean value(s) having the same superscript(s) in a column are not different significantly (P≤0.05).
NS = not significant   * = significant   ** = highly significant

Acidity of starches

The pH of wheat, sorghum, millet, rice and cassava starches is presented in table (3). The values are 5.90, 6.43, 5.83, 5.35 and 5.73 respectively. Statistical analysis of the results showed significant differences among the starches. The highest pH value was observed in sorghum starch, while the lowest was in rice starch.

pH is an important property in the starch industrial applications, being used generally to indicate the acidic or alkaline properties of the liquid media. From these results, it could be observed that cereal starches and cassava starch have low acid content. The total acidity of starches were found to be 0.03, 0.05, 0.05, 0.05 and 0.03 mg/100gm respectively as shown in table (3). There is significant difference between the starches in their total acidity.

Falling number

The falling number of the five starches ranged between 61.67 to 186 seconds as shown in table (3). Analysis of variance indicated that there are highly significant differences among the five starches. The highest mean falling number value (186 seconds) was for cassava starch followed by sorghum starch (180.30 second), they are significantly greater than the values of all other starches. The lowest value of falling number was observed in wheat starch (61.67 second).

Table 3. pH-value, total acidity (mg/100g) and falling number (sec) of cereal and cassava starches

Source of starch	pH-value	Total acidity	Falling number
Wheat	5.90±0.00[b]	0.03±0.00[b]	61.67±0.58[c]
Sorghum	6.43±0.02[a]	0.05±0.00[a]	180.30±4.04[b]
Millet	5.83±0.02[c]	0.05±0.00[a]	64.00±2.65[c]
Rice	5.35±0.01[e]	0.05±0.00[a]	62.00±0.00[c]
Cassava	5.73±0.06[d]	0.03±0.00[b]	186.00±3.00[a]
Lsd$_{0.05}$	0.05753*	0.0005753*	4.65**
SE±	0.1826	0.0001826	1.476

Values are mean± SD.

Any two mean value(s) having same superscript(s) in a column are not different significantly (P≤0.05).

NS = not significant   * = significant   ** = highly significant

Functional properties of starches

The functional properties of cereal and cassava starches are shown in table (4).The Water retention capacity (WRC) of wheat, sorghum, millet, rice and cassava starches was found to be 55.56, 44.44, 66.67, 122.20 and 66.67 ml/100gm respectively. Rice starch gave the highest value among the other starches (122.20 ml/100gm), while the lowest value was observed in sorghum starch (44.44 ml/100gm).Statistical analysis of the results showed highly significant differences between the starch samples. The Fat absorption capacity (FAC) of starches was found to be 50.00, 75.00, 75.00, 95.83 and 75.00 ml/100gm respectively. Statistical analysis showed highly significant differences between the five starches. Rice starch gave the highest value of fat absorption capacity (95.83ml/100gm), while wheat starch gave the lowest value (50.00 ml/100gm). The bulk density of five starches was 0.67, 0.59, 0.50, 0.56 and 0.63 g/ml respectively. Statistical analysis of the results showed significant differences among the five starches. The highest value of bulk density was observed in wheat starch (0.67g/ml), while the lowest value was observed in millet starch (0.50 g/ml), this is due to that, the wheat starch granules has largest particle size, while millet starch granules has smallest size.

Venktesh and Prakash (1993) reported that higher moisture content in addition to the higher and greater regulatory in shape of the starch granules, resulting in dense packing of the starch particles. High bulk density is the desirable characteristic when powdered food materials of high nutrients content are to be packed in a limited space or area; also it helps to reduce the paste thickness which is an important factor in convalescent and child feeding (Padmashree , (1987). As indicated in table (4), wheat, sorghum, millet, rice and cassava starches showed dispersibility values of 83.33, 83.33, 76.67, 70.00 and 83.33% respectively. Statistical analysis showed significant differences between starches in their dispersibility. Rice starch showed the lowest dispersibility (70.00%) which is significantly lower compared to other starches. This is similar to what is reported by Abdulla (2009) 83.30% for millet starch from Ashana and Dembi cultivars. Starch dispersibility is a measure of reconstitution of starch flour in water, the higher the dispersibility the better the flour reconstitutes in water (Kulkarni , 1991). The gelatinization temperature of the wheat, sorghum, millet, rice and cassava starches gave values of 68.33, 68.67, 75.00, 70.00 and 64.67 C° respectively. Millet starch showed significantly higher gelatinization temperature of 75.00 C°, while cassava showed significantly lower gelatinization temperature (64.67 C°).

Statistical analysis showed significant differences between starches in their gelatinization temperature. These results are close to the results obtained by Leach (1959) who found that sorghum starch gelatinization temperature ranged from 68 to 70 C°. Ubwa (2011) found the gelatinization temperature of white and brown sorghum starches ranged from 74 to 82 C°. Morales-Sanchez (2009) obtained the gelatinization temperature of wheat starch as 52 to 66 C° and rice starch 66 to 82 C°.

Table 4. Functional properties of cereal and cassava starches

Source of starch	Water retention capacity (ml/100g)	Fat absorption capacity (ml/100g)	Bulk density (g/ml)	Dispersibility (%)	Gelatinization temperature ($^{\circ}$C)
Wheat	55.56 ± 19.25^b	50.00 ± 0.00^c	0.67 ± 0.00^a	83.33 ± 0.00^a	68.33 ± 1.53^b
Sorghum	44.44 ± 19.25^b	75.00 ± 0.00^b	0.59 ± 0.00^c	83.33 ± 0.00^a	68.67 ± 1.53^b
Millet	66.67 ± 0.00^b	75.00 ± 0.00^b	0.50 ± 0.00^e	76.67 ± 0.00^b	75.00 ± 0.00^a
Rice	122.20 ± 19.24^a	95.83 ± 7.22^a	0.56 ± 0.00^d	70.00 ± 0.00^c	70.00 ± 0.00^b
Cassava	66.67 ± 0.00^b	75.00 ± 0.00^b	0.63 ± 0.00^b	83.33 ± 0.00^a	64.67 ± 0.58^c
$Lsd_{0.05}$	27.12**	5.872**	0.0005753*	0.00058*	1.819*
SE±	8.607	1.863	0.0001826	0.000183	0.5774

Values are mean ± SD.
Any mean value(s) having the same superscript(s) in a column are not different significantly (P≤0.05).
NS = not significant   * = significant   ** = highly significant

Wettability

The wettability of wheat, sorghum, millet, rice and cassava starches was good since it wet slightly when it comes in contact with water, and after 30 minutes the samples were completely wet and sank to the bottom. Sufficiently fast stirring for one minute dispersed the samples.

Gelation concentration

The least gelation concentration of wheat, sorghum, millet, rice and cassava starches was shown in table (5). Sorghum and cassava starches gave a very strong gel at concentration of 10% (w/v) while wheat, millet and rice starches gave strong gel at the same level of concentration. Wheat, millet and rice starches formed a weak gel at 8%, a very weak gel at 6% and no gel was obtained at 2% and 4%. Sorghum and cassava starches formed strong gel at 8%, a weak gel at 6%, a very weak gel at 4% and no gel was obtained at 2%.

Singh and Singh (1991) reported that the lower least gelation concentration may be due to the starch and starch protein interactions.

Table 5. Least Gelation Concentration of Cereal and Cassava Starches

Sample	Concentration (g starch/100ml water)				
	2%	4%	6%	8%	10%
Wheat starch	−	−	±	+	++
Sorghum starch	−	±	+	++	+++
Millet starch	−	−	±	+	++
Rice starch	−	−	±	+	++
Cassava starch	−	±	+	++	+++

Where:
− No gel   ± Very weak gel   + Weak gel   ++ Strong gel   +++ Very strong gel

Viscosity

The cold viscosity (at room temperature) and hot viscosity (hot slurries) of wheat, sorghum, millet, rice and cassava starches were shown in table (6). Cold viscosity was found to be 106.70, 152.00, 112.70, 143.30 and 108.00 cps respectively. Statistical analysis revealed highly significant differences among the five starches in their cold and hot viscosity. Upon heating at (70 C°) the viscosity increased to 121.30, 157.00, 155.00, 148.30 and 149.40 cps for wheat, sorghum, millet, rice and cassava starches respectively. Sorghum starch gave the highest value in cold and hot viscosity, while wheat starch gave the lowest value.

Circle (1964) stated that at a given concentration, heated dispersions gain greater viscosity than unheated dispersions. The viscosity can be used to test the thickening potentiality of food materials to be used in fluid food and beverages as reported by Kinsella (1979). Important factors that influence paste viscosity are: the degree to which the granules swells (indicated by swelling potential), the dispersibility of the swollen granules and the amount exudates in the intergranular spaces (Hamaker and Griffin, 1993).

Table 6. Cold and hot viscosity (cps) of cereal and cassava starches

Source of starch	Cold viscosity	Hot viscosity
Wheat	106.70 ± 5.77^b	121.30 ± 1.15^c
Sorghum	152.00 ± 5.00^a	157.00 ± 4.00^a
Millet	112.70 ± 3.79^b	155.00 ± 4.36^a
Rice	143.30 ± 3.21^a	148.30 ± 1.15^b
Cassava	108.00 ± 7.21^b	149.40 ± 1.55^b
$Lsd_{0.05}$	9.453**	5.151**
SE±	3.0	1.635

Values are mean ± SD.   Any two mean value(s) having same superscript(s) in a column are not differ significantly (P≤0.05).
NS = not significant   * = significant   ** = highly significant

Amylose and Amylopectin contents of extracted starch:

The starch amylose and amylopectin is shown in table (7). Wheat, sorghum, millet, rice and cassava starches contain 30.94, 28.66, 22.60, 22.88 and 23.59% amylose respectively. Also contain 69.06, 71.34, 77.40, 77.12 and 76.41% amylopectin respectively. Statistical analysis confirms that the five types of starches are significantly different in their amylose and amylopectin contents. The high value of amylose content was observed in wheat starch, while the low value was in millet starch. Millet Starch had high value of amylopectin, whereas wheat Starch had low value of amylopectin.

The lower the amylose content, the better is the starch for industrial use, particularly in the food industry as a thickener. When however starch contains high percentage of amylose, it may be modified by oxidation to give it physical properties like the clarity of its paste, the viscosity of its paste, the tendency of its paste to retrograde and the temperature of complete paste formation depend upon the fraction of the amylose percent (Radley, 1968).

Table 7. Amylose and amylopectin contents of the extracted starch

Source of starch	Amylose %	Amylopectin %
Wheat	30.94[a] ±0.19	69.06[e] ±0.19
Sorghum	28.66[b] ±0.11	71.34[d] ±0.11
Millet	22.60[e] ±0.23	77.40[a] ±0.23
Rice	22.88[d] ±0.04	77.12[b] ±0.04
Cassava	23.59[c] ±0.08	76.41[c] ±0.08
$Lsd_{0.05}$	0.2698[*]	0.2698[*]
SE±	0.08563	0.08563

Values are mean± SD.
Mean(s) bearing same superscript(s) are not significantly different (P≤0.05)

Color

The color of the starches was shown in figure (1). From these results it was observed that cassava starch has the highest reading (95.71%) followed by wheat starch (92.09%). The lower reading was observed in millet (80.98%) and sorghum (84.80%) starches. (High reading means whiter color). The lower reading of millet and sorghum may be due to the pigments in the pericarp.

Starch made from certain white-seeded cultivars can be off-white because of non-carotenoid pigments in the endosperm (Watson 1955). If the pigments could be removed, the color and appearance of the isolated starch would improve. The discoloration of starch may be due to the presence of pigments in the pericarp that are leached into the endosperm either in the field or during steeping for wet milling (Norris, 197 *I*).
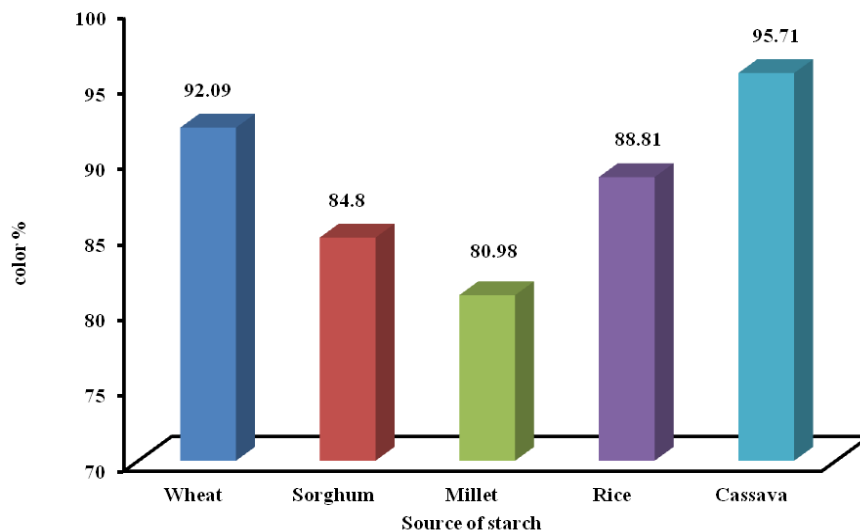

Fig. 1. Color of cereal and cassava starches

Conclusion
- The five starches showed variations in composition, gelatinization temperature and falling number.
- The pH values of five starches have low acid content and the total acidity was acceptable.
- Rice starch has high water retention and fat absorption capacities compared to other starches.
- High bulk density was observed in wheat starch.
- Wheat, sorghum and cassava starches have the same values of dispersibility.
- Wettability of five starches gave good grade and the least gelation concentration of starch gave a strong get at concentration of 10%.
- Sorghum starch has high cold and hot viscosity with slightly dull grey white color.
- The amylose and amylopectin ratios differ among the five starches.
- Cassava starch has a whiter color compared to other starches.

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