Direct Research Journal of Agriculture and Food Science
Vol. 10(3), Pp.65-70, March 2022
ISSN 2354-4147
DOI: https://doi.org/10.26765/DRJAFS43860703
Article Number: DRJAFS43860703
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Full-Length Research Paper

Comparative Analysis of Some Physicochemical Properties of Starch from Acha (*Digitaria exilis and Digitaria iburua*) and Corn (*Zea mays*) obtained in Gwagwalada -Abuja, Nigeria

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Received 13 February 2022; Accepted 21 March 2022; Published 30 March 2022

ABSTRACT: Starches from acha species (*Digitaria exilis and Digitaria iburua*) and that of corn (*Zea mays*) were extracted and some physicochemical properties such as moisture content, amylose and amylopectin content, water absorption capacity, bulk density, and cooking properties were carried out on the starches. The starch paste was characterized using Rapid visco analyzer. The results showed that both starches from these cereals are of normal, non-waxy type of cereal based on their amylose content and they also exhibited a two stage pattern of swelling and solubility properties similar to other non-waxy cereal starches. Starches from *Digitaria* species and that of corn possessed high water absorption capacity but that of *digitaria* did not swelled as much as corn starch. The corn starch exhibited a higher peak viscosity and a high breakdown in the viscosity in comparison to that of acha. Starches from acha and corn show relatively similar properties suitable for use in food industry, pharmaceutical, consumption and other purposes.

Keywords: Acha, amylose, amylopectin, rapid visco analyzer, physicochemical properties

INTRODUCTION

Cereal grains, tuber and roots are the main sources of starches for industrial and consumer applications, although some are found in the piths and leaves of plants as well as in nuts, seeds and fruits. Starch molecules are classified as either linear amylose or branched amylopectin and are arranged together in a relatively water insoluble granule of definite size, shape, and morphology characteristic of the particular plant source, most native starches contain 20 -30 % by weight of amylose (Zobel, 1984; Gott *et al*., 2016). Although, starch is widely spread in plants, only a few sources are sufficiently abundant to make the extraction of the starch commercially feasible. The various sources are corn tapioca, potato, waxy maize, wheat, sorghum, rice, cassava, cocoyam and acha etc. Starch is an important industrial raw material and it found several applications

in bakery products, ice cream, and miscellaneous food uses (Ranken *et al*., 1997). It also serves many purposes in candy as gelling agent and the most prominent technical uses are in textile, paper, tobacco, and tanning etc.

A starch usage and derivatives is fully defined by a number of factors such as plant source, prior treatment, amylose/amylopectin ratio or content. Each starch is unique in terms of granular organization and structure of its constituent's polymer, and it is believed that chemical and molecular structures of starch polymers, amount of structure of other constituents differ from plant source to plant source and probably from location to location within a single plant, and knowledge pertaining to the properties of a particular starch could be used to predict its behaviour under actual cooking and cooling conditions (Buleon *et al*. 2016; Jideani *et al*., 1996). With such knowledge, the starch could be modified if necessary to suit products and processing needs. Therefore, this work extracted and gelatinized starches from acha species and corn, thereafter compared the physicochemical properties such as cooking properties, water binding capacity, amylose content, bulk density of the starches. The inter-relationship between the parameter as it affects their applications was also investigated. However, properties of starch from corn have been adequately researched while starch from acha (*Digitaria species*) is with limited reports which necessitates this work.

MATERIALS AND METHODS

Samples: Grains of two species of cultivated acha (*Digitaria exilis* and *Digitaria iburua*) and corn procured from the local market in Gwagwalada Abuja, Nigeria was used for the study. The samples were shelled, cleaned, packed in a sealed container.

Isolation and purification of starch from Acha

The seeds were washed and kept under magnetic stirrer for 3hrs in 0.1% (W/V) solution of NaOH. The Sample was left overnight. This operation was repeated twice and each time the supernatant was discarded and replaced with fresh NaOH solution, after steeping, the grains were wet milled in a warring blender for 2 minutes and thereafter screened through sieve. The process was repeated until no more starch could be separated. The starch suspension was then centrifuged at 1000 rpm for 20 minutes and the dark upper layer of proteins was scrapped off with spatula and discarded. The starch was then suspended in distilled water and centrifuged again till disappearance of the alkaline reaction. The starch was subsequently re-suspended in a 2% (w/v) NaCl solution, centrifuged, washed with propan -2-ol until white starch apparently free from protein was obtained. Thereafter, the starch was air dried and kept in a sealed container for analysis.

Isolation and purification of starch from corn

The starch was extracted from the composite kernel according to the method described by Boyer *et al*.(1976), with little modifications.(Kolawole *et al*., 2013). The kernels were placed in a beaker containing 0.45 % (w/v) $Na_2S_2O_3$ solution. The $Na_2S_2O_3$ solution was allowed to cover the corn to a particular level. It was thereafter steeped in a 50^{o}C water bath for 24 hrs. After this period, germ and pericarp were removed. The endosperm was macerated with mortar and pestle and then placed in a warring blender. 0.05M NaCl solutions were added and the samples were homogenized with a warring blender. The resulting slurry was then filtered with a sieve to remove large debris and a solution of 0.05 M NaCl was used to finished the washing process (Kolawole *et al*., 2013).

The collected solid was placed in a big beaker and allowed to stand for 1 hour. Thereafter, the supernatant was decanted and the precipitated starch was transferred into a centrifuge tube. Thus, the extracted samples were purified five times with 5:1 (v/v) 0.05M NaCl- Toluene ratio, mixed with a vortex mixer, 15minutes shaking time, and a 5minutes centrifugation at 1900rpm.

The purified samples were then washed with 10ml distilled water, and with 10ml acetone. With the last two washes, the sample were once again mixed, shaken for 15minutes and centrifuged for 5 minutes. The resulting starch pellets were allowed to dry under laboratory hood for 24 hours before storing in a sealed container for the next analysis.

Amylose content determination

The simple procedure described by Juliano and William was used for the determinations (Landers *et al*.,1991). An accurately weighted 0.1g starch sample was poured into 100ml volumetric flask and this was done in duplicate. Thereafter 1ml of 95% ethanol and 9ml of 1M NaOH were added to the samples. The samples were later heated for 10minutes in a boiling water bath to gelatinize the starch sample. After cooling, the sample was made up to the volume with water. Thereafter, 5ml portion of the starch solution was pipetted in 100ml volumetric flask after which 1ml of 1M ethanoic acid, and 2ml Iodine solution was added and made up to the volume with distilled water. The absorbance of the solution was then determined at 620nm after 20minutes.
The amylose content was then calculated from the relationship below :
Amylose content =3.06 × Abs value × 20% (Chen *et al*.,

2017; Wang *et al*., 2017).

Amylose content on dry basis= (F ×Abs × 20) × 100/(100-MC)

Where F= Conversion factor = 3.06, Abs = Absorbance value
MC = Moisture content of the sample used (Chen *et al*., 2017; Wang *et al*., 2017).
Moisture Content: 5 gram of the samples were placed in an oven and dried at 105°C for 3h. The percentage moisture was thereafter calculated as follow.

$\%Moisture = M_{initial} - M/M_{Initial} \times 100$

Where $M_{Initial}$ = Mass of sample before drying and
M = Mass is sample after drying

Water Absorbance Capacity (WAC): The procedure describe by Sosulski was used in which 2.5g of the starch sample was weighed and 30ml distilled water was added into the sample in a weighed centrifuge tube (Kaushal *et al*., 2012; Sanni *et al*., 2006). The tube was agitated on a vortex mixer for 2 minutes and thereafter centrifuged at 4000 rpm for 20 minutes. The supernatant was later decanted and discarded, and all the adhering drops of water were removed. The weight of the tube and sample was later determined. The weight of the sample was calculated and expressed as the weight of water bound by 100g dry starches.

Bulk density of starch

The bulk density of the starch was determined by using the method described by Narayanan and Narasinga Rao in which a calibrated centrifuged tube was weighed and was filled with samples to 5ml by constant tapping until there was no further change in volume (Kweon *et al*., 1997). The tube and the content were later weighed. Thereafter the weight of the sample was determined by difference.

Bulk Density (g/ml) = Weight of sample/ Volume Occupied

Swelling and solubility

4g of the starch was accurately weighed and quantitatively washed with distilled water in a dry 100ml centrifuge bottle. This was then reweighed on a sensitive torsion balance. Sufficient distilled water was added to give a total volume water equivalent to 81g. The resulting solution was then clamped on a support and stirred by using a string motor attached to a support stand, and thereafter heated gently at constant temperature for 30 minutes in a water bath. The bottle was removed, wiped dry on the outside and neck and thereafter weighed on a torsion balance. The stirrer was removed and rinsed into the bottle with sufficient distilled water to bring the total amount of water present to 90g, including the original moisture of the starch sample.

That is, Make up weight = weight of dry centrifuge bottle + Dry basis weight of starch = 90g

This was later centrifuged for 15minutes at 2200rpm. The supernatant was drained off using a Pasteur pipette up to 0.5cm of the top surface of the sediment paste. Thereafter, an aliquot, that is, 45ml of the supernatant was evaporated to dryness on a steam bath. The evaporating dish was then dried for 4hours in an oven at 120°C, cooled in a dessicator and weighed.
% Solubility **=** Weight of soluble starch/weight of Sample in dry basis ×100

To obtain the swelling power, the last 0.5cm of the supernatant over the sedimented starch was drained off by the suction as carefully and quantitatively as possible and discarded. Thereafter, the bottle and the contents were then weighed accurately to give the weight of the swollen starch granules. Swelling power = Weight of sedimented paste/ Weight of sample on dry basis = 100 - % soluble on dry basis × 100.

For each sample, the swelling power and percent solubility was measured in triplicate and thereafter averaged. The swelling power and percent solubility for the starches were determined over a range of temperature with interval of 5°C from 50°C to 95°C.

Starch Paste Characterization Using Rapid Visco Analyzer: 3.0g of the starch samples weighed and added to 25.0ml of water in a sample cup. The disposable plastic stirring paddle was placed in the sample cup and rotated by hand for 15-30 seconds to wet the sample. The sample cup and the paddle were inserted into the RVA (Machine) such that the paddle was held firmly in the drive motor clutch. The test cycle was activated and the split copper block automatically clamped around the can. After which the paddle automatically started spinning at 900 rpm for 7 seconds to disperse the sample and then the speed was reduced to 160rpm. The test thereafter proceeded and terminated automatically, and the viscosity profile were recorded.

RESULTS AND DISCUSSION

The amylose content of the starches value range between 24.58 % to 26.55% as shown in (Table 1). The values indicated that the starches analyzed are non-waxy starch type. The amylose content in *Digitaria exilis* is

Table 1: Showing amylose content, water absorption capacity, bulk density and moisture content of the starches.

Starches	Amylose Content (%)	Water Absorption Capacity (%)	Bulk Density(g/ml)	Moisture Content (%)
Digitaria exilis	24.58	84.55	0.60	11
Digitaria iburua	24.66	82.22	0.62	11
Corn (*Zea mays*)	26.55	98.30	0.69	12

Table 2: Swelling patterns of the starches.

Temperature (℃)	*Digitaria exilis*	*Digitaria iburua*	Corn (Zea mays)
50	1.8	1.5	3.4
55	1.9	1.7	3.6
60	4.0	3.7	7.5
65	4.5	4.0	8.0
70	5.2	4.7	8.5
75	5.6	5.0	13.5
80	17.9	18.2	19.1
85	18.9	21.6	28.2
90	23.2	27.7	30.2
95	24.0	29.0	31.2

slightly lower than that of *Digitaria iburua* that is 24.58 % as against 24.66% indicating that the two *Digitaria* species would probably have similar properties, since properties of gelatinized starch are mainly those of its fractions, amylopectin and amylose. However, differences were observed between acha (*Digitaria* species) and that of corn. Higher amylose content improves the starch granule to absorb water to hydrogen-bond or retrograde.

Water absorption capacity (WAC)

The result of the water absorption capacity as indicated in table 1 shows that *Digitaria* exilis had higher percentage of water absorption capacity than *Digitaria Iburua*. That is 84.55% as against 82.22%. The value reported by Maria carcea and Rita Acquistucci shows 80% for Koulii starch and 88% for Hothia starch. Thus, WAC value for *Digitaria exilis* is close to that of Hothia while *Digitaria iburua* value is similar to that of kouilli starch which was in agreement with that obtained by Jideani *et al*. (1996). However, these values were lower than that of corn analysed (98.30%). Variations in water absorption could be due to different proportions of crystalline and amorphous regions within the granule. Thus, starch granule with a smaller proportion of weakly bonded amorphous material would presumably imbibe less water. Water binding capacity is a room temperature measurement and does not indicate the behavior of the starch when heated. The *digitaria* species exhibited a similar water binding or absorption capacity due to their close range of amylose content. Thus, they showed a considerably low water absorption capacity when compared to that of corn with higher amylose content. This agrees with the fact that starches with low amylose content have low water binding capacities. Low water binding is attributed to a close association of starch polymers in the native granules.

The results of the swelling power and solubility of *digitaria* exilis, *digitaria* iburua and corn starches determined at 5^{o}C interval over a pasting temperature range of 50^{o}C - 95^{o}C is as shown in (Tables 2 and 3) representing the pasting range of most starches. Swelling and solubility pattern of starches gives an indication of the associative forces within the granules. Swelling patterns show the water absorption characteristics of the individual starch granules during heating.

The results show that *digitaria* species do not swell as much as corn starch. However, there are no differences in the swelling power of the *digitaria* species except at 80^{o}C where *digitaria* iburua shows an appreciable increase in its swelling power. The swelling power observed for starch from the *Digitaria* species when compared to that of corn starch might not be unconnected with the differences in the molecular arrangement of the starch granules due to species, or as a result of low amylose content in *digitaria* species compared with that of corn analysed. Thus, the low swelling power indicates stronger bonding forces within the granules of the *digitaria* species. However, corn starch swells far better than the starches from *digitaria* species. As expected, increase in the pasting temperature increased the swelling power and solubility percentage of all starches.

As experienced in the swelling power, starches for

Table 3: Percentage solubility of starches.

Temperature(°C)	*Digitaria exilis*	*Digitaria iburua*	Zea may
50	1	0.1	1
55	2.1	0.7	2.5
60	4.3	2	5.3
65	6.2	3.6	7.2
70	7.3	5	8.2
75	12	10	14.1
80	15.8	16.5	16.9
85	16.3	17.2	18
90	18.6	20.4	22.9
95	22.1	24	27.4

Table 4: The pasting profile of starches.

Starches	Peak Viscosity (RVU)	Trough (RVU)	Break Down (RVU)	Final Viscosity (RVU)	Set Back From Trough (RVU)	Set Back From Peak (RVU)	Peak Time (MIN)	Pasting Temperature (°C)
Digitaria exilis	254.92	196.25	58.67	28.83	86.58	27.90	5.31	63.15
Digitaria Iburua	252.33	176.56	75.77	252.25	75.69	-0.08	5.25	65.55
Corn *(Zea mays)*	283.50	167.33	116.17	234.90	67.58	-48.60	4.33	63.75

digitaria species show a lower solubility percentage as compared to that of corn in all the pasting range. This low solubility can be attributed to their amylose content. That is, during pasting it is mainly the amylose component which leaches out, thus, resulting in a low solubility percentage. At higher temperature of about 70°C to 80°C, the *digitaria* species starches exhibited similar solubility percentage and this could suggest the existence of stronger starch granules as compared to that of corn and thus, require higher energy input to cause relaxation.

The viscosity profile graphs for the starches are shown in the (Table 4), even though, the viscosity curves produced during heating and cooling starches generally showed a similar shape of pasting curves, nevertheless they reached quite different viscosity values, and at different time which can be used to characterize the starches. The Corn starch exhibited the highest peak viscosity at the lowest peak time of 4.33min. Though, the starches of the *digitaria* species exhibited a close range of peak viscosities but that of *Digitaria exilis* is slightly higher than that of *Digitaria iburua.* However, the *Digitaria* species both exhibited considerably low peak viscosities at higher peak time when compared to that of corn.

Starch from *Digitaria iburua* exhibited the highest pasting temperature while starches from *Digitaria exilis* and corn show similar pasting temperature. The pasting temperature provides an indication of the minimum temperature required to cook a given sample and it has implications for the stability of other components in a formula, and also indicates energy cost. Thus, *Digitaria iburua* starch will require more energy for it to be cooked than *Digitaria exilis* and corn starches.

The corn starch attained peak viscosity at the shortest time of 4.33mins while that of *Digitaria iburua* and *Digitaria exilis* are 5.25 mins 5.31mins respectively.

From the result, *Digitaria exilis* starch exhibited the lowest breakdown in viscosity i.e 58.67 RVU followed by *Digitaria iburua* with 75.77 RVU while corn starch exhibited the highest breakdown in viscosity with 116.17 RVU.

The setback in viscosity exhibited by *Digitaria exilis* starch was greater than that of *Digitaria iburua* starch. This is 86.58 RVU against 75.6 RVU while that of corn is considerably lower than that exhibited by the *digitaria* species. The setback region involves retrogadation or re-ordering of the starch molecules. Setback has been correlated with texture of various products in food industry, for example, staling of bread is associated with retrogradation which is an important effect in food industry as it causes instability in starch paste.

Conclusion

Starches from different plant species and sources vary in terms of their functional properties such as final viscosity of paste, gelatinization onset temperature, formation of

two-phase pastes or paste stickiness and thus in their end-uses. This variation stems from differences in the structure of starch, such as the size of starch granules, their composition, and molecular architecture of the constituent polymers. Thus, starches from the acha species and corn from Gwagwalada possessed similar characteristics in terms of composition such as amylose and amylopectin content which in turn indicates the functional and structural properties. Starches from these cereals are of normal, non-waxy type of cereal based on their amylose content and they also exhibited a two stage pattern of swelling and solubility properties similar to other non-waxy cereal starches. Acha and corn show relatively similar properties suitable for use in food industry, pharmaceutical, consumption and other purposes.

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