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# PHYSICOCHEMICAL PROPERTIES OF STARCHES EXTRACTED FROM DIFFERENT CULTIVARS OF SWEET SORGHUM GRAINS

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**ABSTRACT**

Sweet sorghum is cultivated for the purpose of mainly making sugar. However, the stalk as well as grain can also be useful for other industrial purposes. In this study, starch was extracted from seven different cultivars of sweet sorghum grain and the physicochemical properties of the starch extracted were determined. The different cultivars of sweet sorghum under study had starch yield ranging from 64.26% to 14.70%. The physicochemical characterization studies of the starches isolated from the grains showed that they compared favourably with starches from other sources. NRSSS0005 starch which had the lowest foam capacity of 3% had the highest emulsion capacity of 60%. The browning and charring temperature ranges were quite lower than that reported for other starches. The water holding capacities of all the starch samples fell within a range of 46 – 62.05 mg/100g which were low when compared to starches obtained from other sources. The swelling powers for all the starches were quite appreciable and demonstrated temperature relaxation between 50 – 60 ºC and also at 90 ºC. The physicochemical properties of all the starches showed that the starches can serve as a biomaterial in pharmaceutical, cosmetics, textiles and food industries.

**Keywords**: Biomaterial, Industrial, Physicochemical, Sorghum, Starch.

## INTRODUCTION

Sweet sorghum (*Sorghum bicolor* (L.) Moench) belongs to the grass species and commonly called great millet. It has the ability to accumulate sucrose in its stem parenchyma. Sorghum is a tropical plant belonging to the family *poaceae*. It is one of the most important plants in Africa, Asia and Latin America. More than 7000 sorghum varieties have been identified as reported by Oden [1]. While most are produced for human consumption, the remainder are cropped for industrial applications.

Sweet sorghum is cultivated explicitly for the purpose of making sugar as reported by Akbulul and Ozcan, [2]. Its rich sugar stalks provide grain and the stalk can be used for several industrial applications. As by-product from some of its industrial applications, the stalk bagasse can be deployed as feedstock in the production of animal feeds. The grains could also serve as a source of starch among other materials [3].

Starch is one of the most abundant organic chemicals on earth. It is synthesized in the plastids of green plants and found in the leaves of such plants. It is also synthesized in the amyloplasts of seeds, grains, roots and tubers of most plants where it serves as the storage for chemical energy [4]. Starch is a natural biodegradable biopolymer which has wide industrial applications. It is the only qualitatively important digestible polysaccharide and has been regarded as nutritionally superior to low molecular weight carbohydrate or sugars [5].

There are many potential uses of starch industrially: unmodified starch can be used in the pharmaceutical, paper, mining and building industries. It can be modified and converted to starch derivatives [6]. Starch is also one of the most widely used biomaterial in the food, textile, cosmetics, plastics, adhesives, paper and pharmaceutical industries. The diverse industrial usage of starch is based on its availability at low cost, high calorific value and inherent excellent physicochemical properties [7]. The versatility of starch in industrial applications is clearly defined by its physicochemical properties.

Therefore, a thorough evaluation of the necessary parameters is important in elucidating its industrial uses. The morphology and physicochemical characteristics of starch are typical of its biological origin hence starch from each plant source will vary somewhat in appearance, biochemical composition and properties.

As a result of the competing demands for starch as food, pharmaceutical and industrial uses coupled with the need to attain self-sufficiency in starch production, there is also a need to find other high yield sources different from cassava, maize and potato [8]. Starch extracted from various locally available tubers, rhizomes and fruits have been studied by many researchers and found applications in several industries. Little or no work appears to have been done on the isolation and comparative physicochemical characterization of starches from different cultivars of sweet sorghum.

The purpose of this study is to extract, characterize and provide data on the various physicochemical parameters of starches extracted from sweet sorghum cultivars as a new starch feedstock for industrial use which can reduce the burden on other starch sources such as cassava, corn, yam and potatoes.

Some lesser known and unconventional crops could be good sources of nutrients and starch and even have the potential of broadening the present narrow food base of the human species but lack of data on the chemical composition and properties of such plants has limited the prospects for their utilization [9]. The acquisition of good quality grain is fundamental to produce acceptable food product as well as industrial raw materials [10]. It is in tandem with this that the study on some cultivars of sweet sorghum was carried out as a new source for industrial raw material for the feeds and other industrial applications.

In this study, starch was extracted and isolated from seven different cultivars of sweet sorghum. The starches were thereafter comparatively analyzed for their physicochemical properties and the results compared with other starches used industrially.

## MATERIALS AND METHODS

Samples of seven cultivars of sweet sorghum grains were collected from the Raw Material Research and Development Council, Abuja, Nigeria (and labeled as NTJ-2, NRSS012, NRSS0003, DAN SADAU, 503, NRSS0005 and 501). They were stored in a polythene bag until samples were needed for starch extraction. All reagents used for the analysis were of analytical grade and were used without further purification.

### Starch Isolation

Starch was extracted from each sample of the sweet sorghum using the method of Adama *et al*., [11]. Basically, the dried sweet sorghum grains were separated from dirt and washed. The washed grains were weighed and soaked in sodium metabisulphite solution (2 L 1 % w/v) at room temperature (27 °C). Thereafter, the grains were removed and wet milled into slurry using an industrial blender. The paste was dispersed in a large volume of 1% sodium metabisulphite solution and filtered through muslin cloth. The suspension was centrifuged at 3500 rpm for 10 min to facilitate the removal of dirt. The supernatant was carefully decanted and the mucilage scraped off. The process was repeated three times with the mucilage on the starch scraped continuously until a pure starch was obtained. The resulting starch was dried in the sun and further dried at 60 °C in a hot air oven, pulverized, weighed and stored in sample bottles for analysis.

**Physicochemical Analysis of Starch samples**

Each of the different starch samples extracted from the seven cultivars of sweet sorghum grain was analyzed for their physicochemical properties as described below:

**Swelling profile**

The method described by Afolayan *et al* [4] was used to determine the swelling profile. The starch sample (0.1 g) was weighed into a test tube and 10 ml of distilled water was added. The mixture was heated in a water bath at a temperature of 50°C for 30 min with continuous shaking. In the end, the test tube was centrifuged at 1500 rpm for 20 min in order to facilitate the removal of the supernatant which was carefully decanted and weight of the starch paste taken. The swelling power was calculated as follows:

$$\text{Swelling power} = \frac{\text{Weight of powder paste}}{\text{Weight of dry powder sample}}$$

This was carried out over a temperature range of 50 °C – 95 °C.

**Solubility Index**

The method described by Afolayan *et al* [4] was also used to determine the solubility index. Starch sample (0.5 g) was added to 10 ml distilled water in a test tube. This was subjected to heating in a water bath with a starting temperature of 50 °C for 30 min. It was then centrifuged at 1500 rpm for 30 min. Exactly 5 ml of the supernatant was decanted and dried to constant weight. The solubility was expressed as the percentage (%) by weight of dissolved starch from heated solution. This was carried out over a temperature range of 50 °C – 90°C.

**pH**

A 20% w/v dispersion of the sample was shaken in water for 5 minutes and the pH was determined using a pH meter [11].

**Browning and Charring Temperature**

The method of Builders *et al* was used [12]. Some of the starch samples were put into a capillary tube, the browning and charring temperatures were determined using a melting point apparatus with model Electrothermal 9100.

**Foam Capacity**

The method of Omojola *et al* was used with slight modifications [7]. Starch sample (1 g) was homogenized in 50 ml distilled water using a vortex mixer (vortex 2 Genie set at shake 8) for 5 minutes. The homogenate was poured into a 100 ml measuring cylinder and the volume recorded after 30 s. The foam capacity was expressed as the percent increase in volume.

**Emulsion Capacity**

Sample (1 g) was dispersed in 5 ml distilled water using a vortex mixer for 30 seconds. After complete dispersion, 5 ml vegetable oil (groundnut oil) was added gradually and the mixing continued for another 30s. The suspension was centrifuged at 1600 rpm for 5min. The volume of oil separated from the sample was read directly from the tube. Emulsion capacity is the amount of oil emulsified and held per gram of sample [4].

**Gelatinization Temperature**

This was evaluated using the method of Attama *et al*, [13]. The starch sample (1g) was put in a 20 ml beaker and 10 ml of distilled water was added. The dispersion was heated on a hot plate. The gelatinization temperature was then read with a thermometer suspended in the starch slurry.

**Water Holding Capacity**

The method described by Omojola *et al* was used to determine the water absorption capacity [7]. The starch sample (5% w/v) was dispersed in a pre-weighed centrifuge tube. The tube was agitated in a vortex mixer for 2 min. The supernatant was then discarded and the weight of the tube and hydrated sample taken. The weight was calculated and expressed as the weight of water bound by 100 g dry starch.

**Bulk and Tapped Density**

The bulk density of the starch was determined using the method described by Narayana and Narasinga Rao with slight modifications [14]. Starch powder (50g) was poured into a 250 $cm^3$ calibrated measuring cylinder by means of a short – stemmed glass funnel. The volume occupied by the starch was noted to determine the bulk density.

$$\text{Bulk density } (g/cm^3) = \frac{\text{Weight of sample}}{\text{Volume occupied}}$$

For the tapped density determination, the cylinder was tapped continuously using a ruler until a constant volume was obtained.

## RESULTS AND DISCUSSION

Starch from the seven sweet sorghum samples exhibited grey like to off white colour with yield ranging from 64.26% (503) to 14.70% (NRSSS0003). The yield was considered to be appreciable when compared with yields of starches from other grains and tubers [4]. The NRSSS0003 cultivar however had a very low yield when compared with others.

Table 1 shows the results of the physicochemical analyses carried on the seven starch samples gotten from the different cultivars while comparison of densities (bulk and tapped) is shown in Figure 1.

Table 1: Physicochemical properties of starches from sweet sorghum samples

| Sample | Yield (%) | Foam capacity (%) | Emulsion capacity (%) | Water holding capacity (mg/100g) | pH | Bulk density (g/cm^3) | Tapped density (g/cm^3) | Gelatinization Temp (°C) | Browning Temp (°C) | Charring Temp (°C) |
|---|---|---|---|---|---|---|---|---|---|---|
| NTJ-2 (G) | 33.88 | 5.00 | 27.50 | 57.70 | 5.82 | 0.65 | 1.00 | 70 | 165.4 - 178.2 | 200.5 - 228.6 |
| NRSSSO 12(G) | 35.55 | 7.00 | 25.00 | 58.31 | 6.54 | 0.63 | 0.83 | 62 | 172.3 - 184.2 | 208.2 - 214.7 |
| NRSSS0 003 (G) | 14.70 | 5.00 | 55.00 | 60.03 | 6.51 | 0.50 | 0.91 | 65 | 175.2 - 185.3 | 235.1 - 258.6 |
| DANSA DAU (G) | 25.13 | 4.00 | 50.00 | 51.00 | 6.44 | 0.50 | 0.77 | 70 | 180.3 - 191.0 | 260.2 - 286.0 |
| 503 (G) | 64.26 | 11.00 | 32.50 | 62.05 | 6.82 | 0.65 | 0.89 | 65 | 160.2 - 172.5 | 205.4 - 219.3 |
| NRSSS0 005 (G) | 34.45 | 3.00 | 60.00 | 58.11 | 6.55 | 0.53 | 0.91 | 65 | 172.1 - 182.4 | 241.0 - 281.0 |
| 501 (G) | 35.19 | 3.00 | 35.00 | 46.00 | 6.30 | 0.55 | 0.80 | 71 | 170.5 - 186.4 | 212.0 - 220.8 |

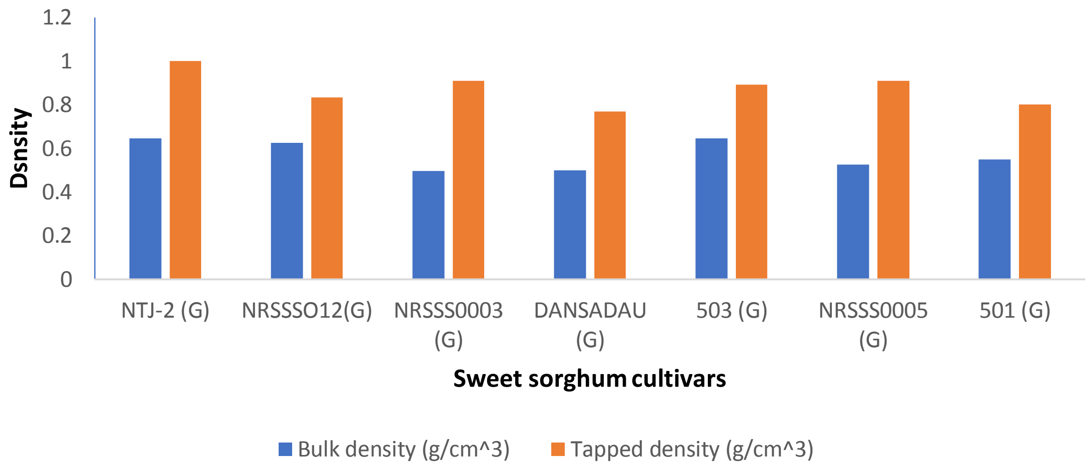


Figure 1: Comparison of densities of starches isolated from different sweet sorghum cultivars

The swelling power and solubility index at different temperatures for each starch sample is shown in Figures 2 and 3 respectively.

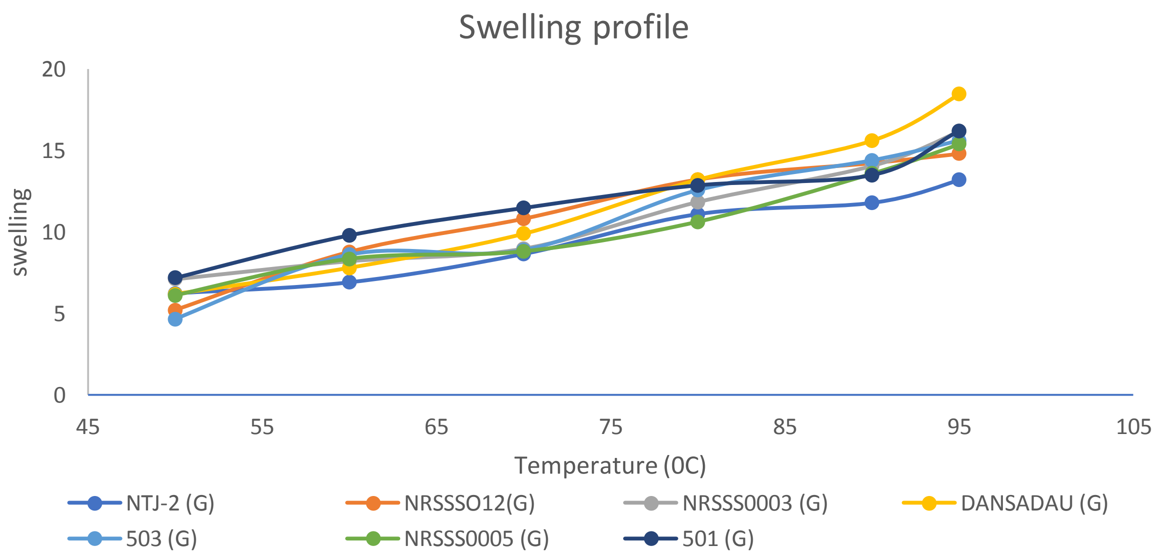


Figure 2: Swelling profile of starches isolated from sweet sorghum cultivars

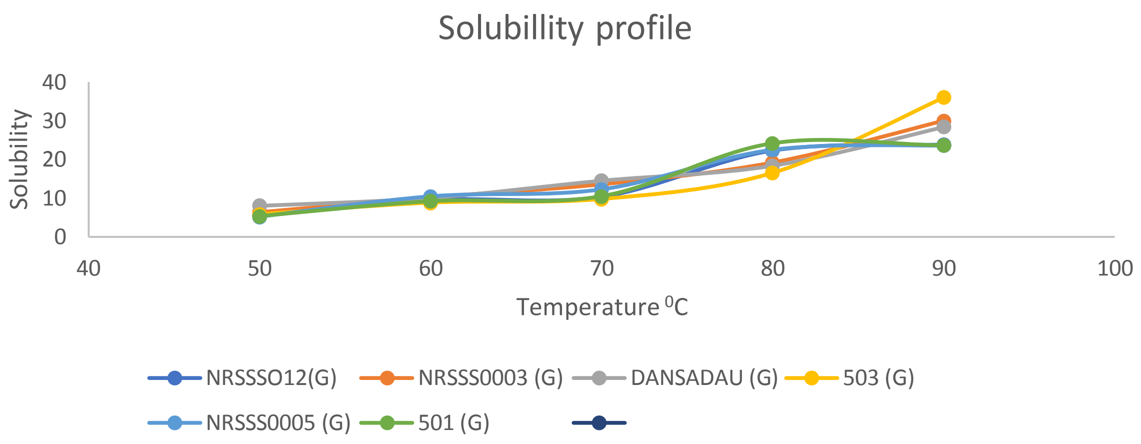


Figure 3: Solubility profile of starches isolated from sweet sorghum cultivars

The foam capacity obtained for all the starches is comparable with that reported for starches isolated from other grains like finger millet [15]. NRSSS0005 and 501 starches were observed to have very low foam capacity values of 3% while 503 starch had a value as high as 11%. The emulsion capacities also fell within the range of other starches previously studied [15]. NRSSS0005 starch which had the lowest foam capacity had the highest emulsion capacity of 60% among all the starches; this is quite high and may be indicative of a high fat content. The high emulsion capacity of NRSSS0005, NRSSS0003 and DANSADAU starches shows that they may be used as an emulsifying agent in industries.

The water holding capacities of the starch samples are very low when compared to starches obtained from other sources like ginger, tiger nut, *Icacina trichantha*, *Anchomanes difformis*, finger millet and maize [6]. The water holding capacity was as low as 46 mg/100g for starch from 501 while the highest value was 62.05 mg/100g for 503 starch. These values are lower when compared with starches like maize starch which has a water holding capacity of 93 mg/100 g [4]. The variation in water absorption capacities of the starches could be due to different proportions of crystalline and amorphous regions within the starch granule and could have an effect on the swelling capacity of the starches.

The pH values of the starches under study are all comparable with those previously reported for starches and fall within the pH range of 3 – 9 obtained for most starches used in the pharmaceutical, cosmetics and food industries [11].

The bulk and tapped densities are in conformity with the findings of Shihii *et al* as reported and falls within the range indicated for maize starch. This shows that the starch can be compressed well [16]. A comparison of all the starches isolated from the cultivars shows that the bulk and tapped densities are very much comparable with each other with minor variations.

Starch isolated from NRSSSO12 had the lowest gelatinization temperature of 62 $^oC$ while that from 501 had the highest gelatinization temperature of 71 $^oC$; all the gelatinization temperatures gotten falls within the range commonly observed for starches. Starch isolated from 503 had the lowest browning temperature range of 160.2 - 172.5 $^oC$ among all the isolated starches under study while that isolated from DANSADAU had the highest browning temperature range of 180.3 - 191.0 $^oC$. NRSSS0005 starch however had the highest charring temperature range of 241.0 - 281.0 $^oC$ while NTJ-2 starch had the lowest charring temperature range of200.5 - 228.6 $^oC$. Browning and charring temperatures of starches indicates the temperature to which it can be heated without browning and charring. For all the starches isolated from sweet sorghum cultivars being studied it is observed that the browning and charring temperature ranges are quite lower than that reported for maize starch, tiger nut starch and others [11]. This implies that industrial use of these starches may be limited to industries that use starch at not too high or extreme temperatures.

The swelling and solubility profiles of all the starches over a temperature range of 50 – 95 $^oC$ are illustrated in Figures 2 and 3 respectively. The profiles show a general trend of increase with increase in temperature for all the starches although a slightly two – stage swelling pattern can be observed. This is an indication of the water absorption characteristic of the granules during heating. The swelling curve for most of the starches demonstrated temperature relaxation between 50 – 60 $^oC$ and also at 90 $^oC$ just like it was reported for several other starches. This pattern has been attributed to two sets of internal bonding forces that relax at different temperatures [17]. The swelling powers for all the starches are quite appreciable. Increase in swelling power is indicative of suitability of a starch being used as a disintegrant in the pharmaceutical industry; hence the starches can be effectively used as a disintegrant in the formulation of tablets. Also high swelling power results into high digestibility and ability to use starch in solution suggesting improved dietary properties and the use of the starches in a range of dietary applications [18]. This confirms the applicability of sweet sorghum starches in other industries. The solubility profile for the starches also shows an increase in solubility with temperature rise.

## CONCLUSION

The physicochemical properties of the sweet sorghum starches indicate that the starches extracted are comparable with standard starches from corn and other sources. These properties suggest that the starches can serve as a source of starch for use as a biomaterial in pharmaceutical, cosmetics, textiles, food and other industries.

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