

Comparison of the Physicochemical Properties of Starch from Ginger (*Zingiber officinale*) and Maize (*Zea mays*)

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Abstract: Starches were extracted from ginger and maize, and thereafter characterized based on their physicochemical properties. The properties of starch from ginger were then compared with the starch from maize and the following results were obtained: Percentage solubility for ginger at 80°C was determined to be 0.9%, while for maize was 1.2%, the swelling power for ginger and maize at 80°C gives 2.11% and 10.44% respectively. Foam capacity, emulsion capacity, pH, gelatinization temperature, and water holding capacity obtained for ginger was 55, 5.7, 6.54, 78°C, 90 while for maize was 52, 5.2, 5.92, 72°C, 93 respectively. The results obtained showed that the physicochemical properties of ginger starch compares favourably with that from maize and is therefore a potential industrial starch especially in the food industries.

Keywords: Physicochemical, gelatinization, emulsion capacity, water holding capacity, foam capacity

1. Introduction

Starch is one of the most abundant organic chemicals on earth and it is synthesized in the amyloplasts of seeds, grain, roots and tubers of many plants where it serves as the chemical storage form of energy from the sun [1]. It is a carbohydrate consisting of a large number of glucose units joined by glycosidic bonds. This polysaccharide is produced by all green plants as an energy store. It is the most common carbohydrate in the human diet and is contained in large amounts in such staple foods as potatoes, wheat, maize (corn), rice, and cassava^[2]. Pure starch is a white, tasteless and odourless powder that is insoluble in cold water or alcohol. It consists of two types of molecules: the linear helical amylose and the branched amylopectin. Depending on the plant, starch generally contains 20 to 25% amylose and 75 to 80% amylopectin by weight [2]. Glycogen, the glucose store of animals, is a more branched version of amylopectin. Starch is an important ingredient in various food systems as thickening, gelling and binding agents. It imparts texture to a great diversity of foodstuffs such as soups, potages, sauces processed foods etc. Starch is one of the most widely used biomaterials in the food, textile, cosmetics, and plastic, adhesives, paper and pharmaceutical industries. The diverse industrial usage of the material is premised on its availability, low cost, high caloric value, inherent excellent physicochemical properties and the ease of its modification to other derivatives. The versatility of starch in industrial applications is clearly defined by its physicochemical properties; therefore a thorough evaluation of the necessary parameter is important in elucidating its industrial use. The morphology and physicochemical characteristics of starch are typical of its biological origin; hence starch from each plant source will vary somewhat in appearance, composition and properties. The search for starch with excellent properties from conventional non-conventional source will therefore continue to excite scientists and technologists, as genetic background and the environment have been found to be responsible for changes

in morphology and composition of corn starch during plant development, which is also applicable to other starches [3].

Ginger or ginger root is the rhizome of the plant *Zingiber officinale*, consumed as a delicacy, medicine, or spice. It is from a family (*Zingiberaceae*). Ginger cultivation began in South Asia and has since spread to East Africa and the Caribbean. Ginger produces clusters of white and pink flower buds that bloom into yellow flowers. Because of its aesthetic appeal and the adaptation of the plant to warm climates, ginger is often used as landscaping around subtropical homes. It is a perennial reed-like plant with annual leafy stems, about a meter (3 to 4 feet) tall.

1.1 Gelatinization Properties

The term gelatinization generally is used to describe the swelling and hydration of granular starches. In the natural state, starch granules are at moisture equilibrium with surrounding environment and, under ordinary atmospheric conditions, contain 8-12% moisture [4]. Starch granules are generally insoluble in cold water. They undergo a reversible reaction in cold water, swelling slightly and become hydrated. However, when heat is applied, the change becomes irreversible, and the granules swell faster and gradually become a paste. The sequence of change from dispersion to paste is known as starch gelatinization [5].

It can be seen that the onset temperature (T_o), peak temperature (T_p) and set temperature (T_e) value for starches are similar, and since, gelatinization temperature reflect the degree of orderliness of the molecules in the granules, it therefore follows that starches possess about the same structural rigidity. The gelatinization temperature of starch depends upon the plant type and the amount of water present, pH and concentrations of salt, sugar, fat and protein in the recipe, as well as derivatisation technology used. Some types of unmodified native starches start swelling at 55°C, other types at 85°C. The gelatinization temperature depends on the degree of cross linking of the amylopectin,

and can be modified by genetic manipulation of starch synthase genes.

1.2 Swelling and Solubility Properties

The swelling behaviour is an indication of absorption characteristics of the granules during heating. Generally, the solubility and swelling profiles show a general trend of increase with increase in temperature. Although, a slight two-stage swelling pattern for starches can be observed, first a rapid increase till around 60-70°C followed by a slight level-off and another rapid increase around 80-90°C. This pattern has been attributed to two sets of internal bonding forces that relax at different temperatures [6].

1.3 Pasting Properties

The peak viscosity is an important distinguishing feature of every starch. Specially constructed water bath is maintained at the boiling point with live steam. Samples are cooked in a reproducible manner with fixed time intervals for heating and stirring. Thus, the flow characteristic of the cooked pastes is determined at the temperature of the water bath. The pasting temperatures of starch are normally observed to be (70°C). The pasting properties are known to be influenced by the degree and type of molecular association in the starch. The pasting temperature is one of the pasting properties which provide an indication of minimum temperature required for sample cooking energy costs involved and other component stability.

2. Materials and Methods

Grains of maize (*Zea mays*) and fresh sample of ginger root (*Zingiber officinale*) were purchased from Gwagwalada market in Abuja, Nigeria. The samples were cleaned and packed in sealed containers at room temperature until needed.

2.1 Preparation of Reagent Used

1% Sodium metabisulphite, 1g of Sodium metabisulphite was weighed and dissolved in distilled water in a 100ml volumetric flask. This was properly dissolved and made up to the 100ml mark.

2.2 Isolation and Purification of Starch from Maize (*Zea mays*)

The starch was extracted from the composite kernel samples according to the method described by Boyer et al with little modification [7]. The maize (2.5Kg) was washed in water, and soaked in water for 2days at room temperature of (28°C), after the maize was homogenized with a warring blender for 2mins to obtain a fully ground sample. The paste was dispersed in a large volume of 1% sodium metabisulphite and the resulting slurry then filtered with a muslin cloth to remove large debris. The suspension was allowed to settle and the supernatant decanted. The sediment starch layer was re-suspended in sodium metabisulphite solution and the process was repeated for four times. At each stage of washing, the suspension was allowed to stand for about 90mins for proper sedimentation after which the supernatant was decanted. The mucilage on the starch was

scraped continuously until a pure starch was obtained. The resulting starch was dried under normal room temperature and then at 60°C in hot air oven, pulverized, weighed and stored in a sample bottle for analysis [3].

2.3 Isolation and Purification of Starch from Ginger (*Zingiber officinale*)

The fresh roots of ginger of about 2.1kg were peeled and washed and the sample were chopped into small pieces and soaked in sodium metabisulphite solution (2 L 1% w/v) at room temperature (25°C). Thereafter, the pieces of root were removed and wet milled into slurry using a grater. The paste was dispersed in a large volume of 1% sodium metabisulphite and filtered through muslin cloth. The suspension was centrifuged at 3500rpm for 10min to facilitate the removal of dirty, the supernatant was carefully decanted and the mucilage scraped off. The process was repeated for four times with the mucilage on the starch scraped continuously until a pure starch was obtained. The resulting starch was further dried at 60°C in hot air oven, pulverized, weighed and stored in a sample bottle for analysis [3].

2.4 Determination of Swelling Power

The method described by Daramola and Osanyinlusi was used to determine the swelling power with slight modification [8]. The starch sample (0.1g) was weighed into a test tube and 10ml of distilled water was added. The mixture was heated in a water bath at a temperature of 50°C for 30min with continuous shaking. The test tube was centrifuged at 1500 rpm for 20min 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:

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

This was carried out over a temperature range of 50°C-100°C

2.5 Determination of Solubility Power

Solubility index was determined over a temperature range of 50°C-100°C as follow: starch sample (0.5g) was added to 10ml distilled water in a test tube. This was subjected to heating in a water bath with a starting temperature of 50°C for 30min. Thereafter, it was centrifuged at 1500 rpm for 30min. 5ml 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

$$\% \text{ Solubility} = \frac{\text{Weight of the starch paste}}{\text{Weight of sample on dry basis}} \times 100$$

2.6 Gelatinization Temperature

This was evaluated using the method of Attama A.A *et al* the starch sample (1g) was put in a 20 ml beaker and 10 ml of distilled water was added [9]. The dispersion was heated on a hot plate. The gelatinization temperature was then read with a thermometer suspended in starch slurry.

2.7 Determination of Water Holding Capacity

The method of Omojola et al was used with slight modification [3]. 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 100g dry starch. Weight of water = Weight of boiling tube + hydrated sample - supernatant

2.8 Foam Capacity

The method of Omojola et al was used with slight modifications [3]. Starch sample (1g) 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 30s. The foam capacity was expressed as the per cent increase in volume.

Foam calculation = $\frac{\text{average change in volume}}{\text{Initial volume}} \times 100$

2.9 Emulsion Capacity

The method of Omojola *et al* was again used with slight modifications [3]. Sample (1g) was dispersed in 5 ml distilled water using a vortex mixer for 30 seconds. After complete dispersion, 5ml vegetable oil (groundnut oil) was added gradually and the mixing continued for another 30seconds separated. The suspension was centrifuged at 1600 rpm for 5 min. The volume of oil from the sample was read directly from the tube. Emulsion capacity is the amount of oil emulsified and held per gram of sample. The amount of oil emulsified = initial amount of oil use – final amount of oil gotten.

2.10 Browning and Charring Temperature

The method of Builder et al [10] was used. Some of the starch sample was put into a capillary tube, the browning and charring temperatures were determined using a melting point apparatus with model Electrothermal 9100 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. All the above parameters were determined in triplicates and the mean and standard deviations were recorded.

2.11 Paste Clarity

This was determined spectrophotometrically. Accurate concentrations of the starch slurry between 0.15-2.5% w/v were made in different boiling tubes and heated in a water bath for 30 minutes. The transmittance was determined at 580 nm using a UV spectrophotometer [10]. Transmittance = 1 / Absorbance.

3. Results and Discussion

Table 1: The results of the physicochemical properties of maize and ginger starches

Parameters	Maize	Ginger
Foam capacity (%)	10 ± 0.00	5 ± 0.10
Emulsion capacity (%)	5.2 ± 0.2	5.7 ± 0.1
Gelatinization Temperature (°C)	72.5 ± 0.00	78 ± 0.01
Water holding capacity (ml)	93 ± 0.01	90 ± 0.02
pH	5.92 ± 0.02	6.54 ± 0.03
Browning Temperature (°C)	261.0 – 286.4	268.9 – 281.5
Charring Temperature (°C)	296.2 – 302.3	289.4 – 299.8

The swelling and solubility profiles are shown in Figures 1 and 2 below respectively while the paste clarity is shown in Figure 3

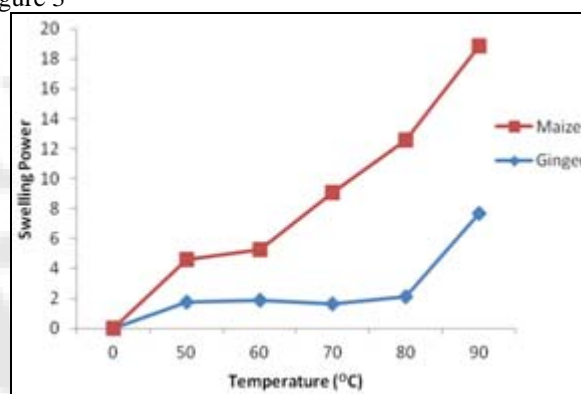


Figure 1: Swelling profile for maize and ginger starch

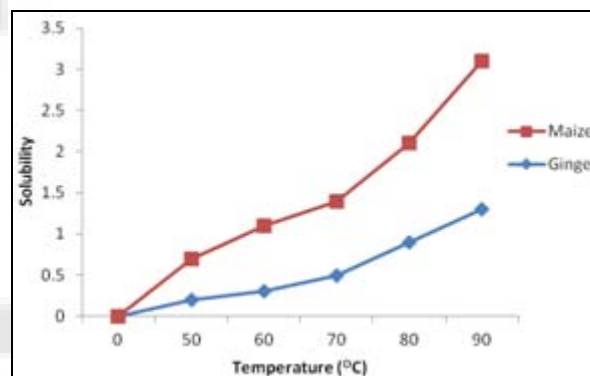


Figure 2: Solubility profile for maize and ginger starch

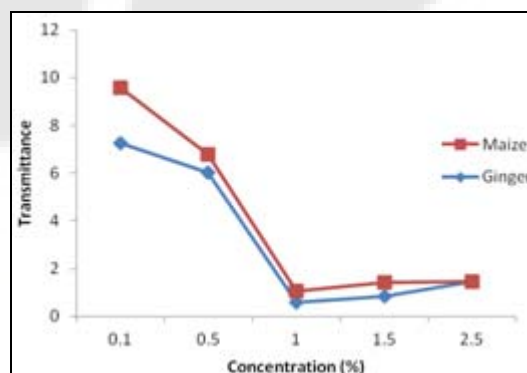


Figure 3: Paste clarity for maize and ginger starch.

3.1 Discussion

The starch obtained was white, tasteless with no smell and the yield was about 35% wt / wt for the maize starch while for the ginger starch the yield was 11% wt / wt at 70% purity. Based on the yield and purity, ginger starch cannot be regarded as a commercial product because of the %yield i.e. not all the carbohydrate is stored as starch. The pH is 6.54 for the ginger starch while for the maize starch it is 5.92 which are within the pH range of 3-9 obtained for most other starches used in the pharmaceutical, cosmetic and food industries [3].

3.1.1 Swelling and Solubility Power

The swelling and solubility power of the maize and ginger starch over a temperature range of 50°C – 100°C is as shown in figure 1 and 2 respectively. From the graph it can be seen that maize starch swells more than the ginger starch. This might be due to the fact that maize starch has the capacity of holding water more than the ginger starch. In the solubility profile, the maize starch has higher solubility power than ginger starch. The graph was plotted as swelling power against the temperature range. The profiles show a general trend of increase with increase in temperature although a slightly two stages swelling pattern can be observed for the starches, this is an indication of the water absorption characteristic of the granules during heating. For the maize starch, there is first, a slight decrease from 50°C – 60°C followed by an increase up till 80°C then a slight level off and then another rapid increase from 90°C. However, for the ginger starch there was a level pattern from 50°C until 80°C where a steep curve is observed which indicates a rapid increase in swelling. This means that ginger starch swells considerably only at higher temperature of 90°C and above. This might make it unsuitable for use in applications that desire higher swelling at lower temperatures unlike maize starch. The swelling pattern observed for both starches has been attributed to two sets of internal bonding forces that relax at different temperatures^[6]. The solubility profile for both starches also show an increase in solubility with temperature rise which relaxes at 70°C before rising again. The solubility profile for both starches shows that its solubility increases evenly with increase in temperature. Increase in swelling power is indicative of suitability of a starch being used as a disintegrant in the pharmaceutical industry hence maize starch can be used as a disintegrant in the formulation of tablets [11]. Since it has high swelling at lower temperature which most tablets will be expected to dissolve. Ginger starch however will not swell as much as maize and other standard disintegrants which are already being employed in the industry. Also high swelling power results into high digestibility and ability to use starch in solution suggesting improved properties and the use of the starch in a range of dietary applications [12]. This confirms the applicability of both maize and ginger starches in other industries.

3.1.2 Water Holding Capacity

In the water holding capacity results obtained, maize starch has a higher water holding capacity than ginger starch, maize starch has 93ml in 100g of sample while ginger has 90ml in 100g of sample. Variation in water absorption could be due to different proportion 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 [7]. Water holding capacity is a room temperature measurement and does not indicate the behaviour of the starch when heated. It can be deduced from the water holding capacity results of the two starches that maize starch has more proportion of amorphous regions within its granules than ginger starch. This also has an effect on the swelling capacity of the starches and this explain why maize starch has a higher swelling capacity than ginger starch as water holding capacity is directly proportional to swelling capacity.

3.1.3 Foam Capacity

The results indicate that maize starch has a higher foam capacity than ginger starch, from the result obtained; maize starch has 10% foam capacity while ginger starch has 5% foam capacity. It can be inferred from this result that the ginger starch has a low fat content compared to maize starch as the foam capacity is a direct indication of the fat content.

3.1.4 Emulsion Capacity

The emulsion capacity of ginger starch is higher than maize starch which makes ginger starch to be a better emulsifier. Industries that use starch as an emulsifying agent will find ginger starch preferable.

3.1.5 Paste Clarity

Figure 3 shows the absorbance and the transmittance of the paste from each of the starches at various concentrations. From the graph, it can be seen that the paste clarity of the maize starch is better than that of the ginger starch.

3.1.6 Gelatinization Temperature

Starch from ginger exhibits the higher gelatinization temperature while starch from maize shows a lower gelatinization temperature. Gelatinization is the process whereby starches undergo an irreversible change under heat and absorb water with swelling thereby making the granules swell more and become a paste rather than a dispersion which it forms in cold water. The gelatinization temperature provides an indication of the minimum temperature required to cook a given sample and it has implications on the stability of other components in a formula and also indicates energy cost. Thus, ginger starch will require more energy for it to be cooked than maize starch. Maize starch has a gelatinization temperature of 72.5°C, while ginger starch has a gelatinization temperature of 78°C. These fall within the range of gelatinization temperatures commonly observed for starches.

3.1.7 Browning and Charring Temperature

The browning and charring temperature indicates the temperature to which starch can be heated without changing colour or charring. This is observed to be quite high for both starches and that the value for maize starch is quite higher than that of the ginger starch; this shows that the maize starch can even be heated to a higher temperature without changing colour or charring. This quality will make it a preferable starch in industries that use starch at higher temperature.

4. Conclusion

Some physicochemical properties of ginger starch were determined and compared with maize starch. Ginger starch was found to be white, tasteless and with no smell just like maize starch. The swelling and solubility profile, water holding capacity, paste clarity, foam capacity, emulsion capacity, gelatinization temperature, browning and charring temperature of ginger starch was found to be lower when compared to that of maize. Based on the results of the physicochemical properties of the starches, the study has therefore shown that ginger starch has physicochemical properties that compare favourably with maize starch and is therefore a potential candidate for use in the industries especially in the food industries.

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