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Research paper

Isolation and Characterization of Physicochemical Properties of Starch of Jackfruit Seeds (*Artocarpus heterophyllus Lam*)

Sagar Nagnath Hundekari[1] and Shrikant Baslingappa Swami[2*]

[1]Department of Agricultural Process Engineering, College of Agricultural Engineering and Technology, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Dist Ratnagiri, Maharashtra State, India
[2]Department of Post-Harvest Engineering, Post Graduate Institute of Post-Harvest Technology and Management, Killa-Roha. Dist: Raigad (Maharashtra State) (Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli-Campus Roha) India

*Corresponding author: swami_shrikant1975@yahoo.co.in

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ABSTRACT

Starches are used in food industry are extracted from roots, tubers and cereals. Jackfruit (*Artocarpus heterophyllus Lam*) is one of the most popular tropical fruits growing in Asia. The objective of this work is to study physicochemical properties of jackfruit seeds starch. Physicochemical properties of jackfruit seeds starch such as Ash content, pH, Moisture content, Gelatinization temperature, Water absorption capacity, Bulk density, Particle size, Swelling volume, Swelling power and Solubility were investigated. Starch granules showed round and bell shape and some irregular cuts on their surface similar to cereals starches. The jackfruit seeds starch contains average values of ash content, pH, bulk density, particle size, moisture content, gelatinization temperature, water absorption capacity, swelling volume, swelling power and solubility were 0.58±0.05 %, 4.97±0.59, 0.504±0.05 g/cc, 7.25±3.33 μm, 7.94±0.01 %, 74.00±3.54 °C, 1.184±0.08 g/g, 1.53±0.22 ml, 8.21±0.73 g/g and 1.712±0.50 % respectively.

Keywords: Jackfruit, Ash, seeds, swelling volume, swelling power, solubility

Starch is one of the most versatile biomaterials in the food, textile, cosmetics, plastics, adhesives, paper and pharmaceutical industries. It is a renewable and almost unlimited resource material. About 54 % of the starches produced globally are utilized for food applications with 46 % for non-food applications. The diverse industrial usage of starch is premised on its availability at low cost, high caloric value, inherent excellence physicochemical properties and the ease of its modification to other derivatives. The industrial utilization of starch is determined by starch morphology and its physicochemical characteristics which are typical of its biological origin (Gebre-Mariam and Schmidt, 1996).

Starch is the most important, digestible food polysaccharide and is therefore a major source of energy in our diet. Common food starches are derived from cereals grains (e.g. corn, rice, sorghum and wheat), tubers and roots (e.g. potatoes, sweet potatoes, cassava, arrow roots), Legumes (e.g. peas, beans), Fruits (e.g. green bananas, unripe apples) and Leaves (e.g. tobacco). The present sources of commercial starch are corn (maize), wheat, potato, cassava and rice. Corn is the major source used globally. In 2009, the world starch production was 68 million MT and projected to be 72 million MT in 2015

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(Xiaohui Wang, 2007). The global share of corn starch accounts for more than 80 %, whereas cassava starch is only 7.5 % (Patil *et al*. 2012).

The most common use of starch in our daily life is as food ingredient. It is the most common source of glucose in the body. Starch has very low cost and significant properties which are being used or can be used for benefits of human being. Cereals and tubers are normally consumed as staple food all over the world. For the past few decades there has been continuous research on establishing an alternate source for good quality starch. Starch from non-conventional sources can supply to the huge demand without affecting the supply of staple crops for table consumption.

Jackfruit (*Artocarpus heterophyllus L.*) is a shrub belonging to the family Moraceae and is widely distributed in tropical countries such as India, Brazil, Thailand, Indonesia, Philippines and Malaysia (Chowdhury, Raman, and Mian, 1997). In India it is generally found in west and south region of the country. Fruit is rich source of carbohydrate, fibre and total minerals. Jackfruit are composed of several berries of yellow pulp and brown seeds encased in a hard shell and are rich in carbohydrates, complex B vitamins and minerals. However, only 15–20% of the fruit is used as food, which can be cooked, baked or roasted on coals (Silva *et al.* 2007). The berries are eaten fresh or processed in the form of jams, compotes, frozen fruit pulps, juices and soft drinks. It is native to Western Ghats of India and Malaysia. It produces heavier yield than any other tree and bear mass from 10 to 60 or even as much as 110 lb (4.5 – 20 or 50 kg), Jackfruit is an evergreen tree that is popular in several tropical countries. It is also called *jack-fruit, phanas* in India. It is an excellent example of a food prized in some areas of the world. Their consistency can be slightly hard or completely soft, hence the distinction of two varieties popularly known as ‘‘soft jackfruit’’ and ‘‘hard jackfruit’’ (Silva *et al*. 2007). Jackfruit seeds are from 2 to 4 cm long, and a fruit can contain from 100 to 500 seeds, which represent 8–15% of the total fruit weight. The seeds usually are consumed roasted, boiled, steamed, and are eaten as a snack. However, fresh seeds have short shelf-life. The addition of jackfruit seed flour in the preparation of biscuits, sweets and breads has been investigated as an alternative use of this by-product (Aldana *et al.* 2011; Bobbio, El-Dash, Bobbio *et al*. 1978; Mukprasit and Sajjaanantakul, 2004).

Jackfruit is an ancient fruit that is widely consumed as a fresh fruit. The use of jackfruit bulbs and its parts has also been reported since ancient times for their therapeutic qualities. The beneficial physiological effects may also have preventive application in a variety of pathologies. The health benefits of jackfruit have been attributed to its wide range of physicochemical applications (Swami *et al*. 2012).

Jackfruit seeds are good sources of protein and starch. Jackfruit seed also contains lignans, isoflavones, saponins, that are called phytonutrients and they have numerous health benefits such as anti-cancer, anti-ageing and antioxidant. Seeds represent about 8-15% from the fruit that can weigh around 2-36 kg. Seeds of jackfruit are abundant and contain high amounts of starch. They are discarded during the fruit processing or consumption and can be an alternative source of starch. Starch is the major storage carbohydrate in plants. The annual worldwide production of starch is 66.5 million tons (FAOSTAT, 2002). Growing demand for starches in the industry has created interest in new sources of this polysaccharide, such leaves, legume seeds and fruits (Betancur- Ancona *et al*. 2004). Starch has found immense industrial use in the manufacture of products such as food, textile, paper, adhesives, and pharmaceuticals. Starch can also serve as a thickening, gelling, and film-forming properties (Alabi *et al*. 2005).

Starch is widely distributed in various plant species as a reserve carbohydrate and is abundant in cereal grains, legumes, tubers and immature fruits (Lajolo and Menezes, 2006). It consists of two macromolecules: amylose (20–30%) and amylopectin (70–80%), which are associated with each other by hydrogen bonds (Singh *et al.* 2003). The proportions in which these structures appear differ in relation to their botanical sources, varieties of the same species and even within the same variety, and according to the plant maturity level (Tester *et al.* 2004). Vandeputte and Delcour (2004) reported that the starch granules are round, ovoid, or polyhedral shapes having the particle size (2–100 μm). The particle size distribution in the starch are unimodal, bimodal, or trimodal of granules are characteristic of biological origin and are responsible for the technological properties and industrial applications for its use as a thickener, stabiliser, or gelling agent of starch in the food industry.

The increasing demand for new products has imposed to food industry the use of starches with characteristics such as absence of syneresis, transparency, stability and solubility to cold, which added to the restrictions on the use of chemically modified starches.

The objective of present work was isolation of starch from Jackfruit seed and determination of physicochemical properties of starch.

MATERIALS AND METHODS

Raw materials

Jackfruit seeds for experimentation was procured from the farmers field at Kudal in the jurisdiction of Dr. B.S.K.K.V Dapoli.

Extraction of Jackfruit seed starch by wet grinding

The seeds of jackfruit were washed with tap water and surface water was removed. The seeds were soaked in Sodium Hydroxide (5g/100 ml) and separately soaked in citric acid (5g/100 ml) for 2 minutes and then washed with water. The seeds were removed from the solution, the brown spermoderm covering cotyledon was removed by peeling it. The cotyledon portion of the seeds after washing in tap water were sliced around 2 mm thickness and mixed with water with 1:2 proportion. The mixture was wet grounded in food processor (mixer cum grinder) (make: Jaipan industries limited model: LX-025). The mixture was screened through a muslin cloth and allowed to settle and decanted. After removing the water the decanted starch was washed 2-3 times with distilled water. The washed starch was taken into pettry dish and dried at 45^{o}C in a tray dryer up to 7.5 h. The weight loss of sample with pettry dish was observed at each 1 h interval, till the constant weight was observed, the end point of drying. The moisture content of the starch was 7.94 %(d.b.). The starch samples so dried were packed in high density polyethylene (thickness 1 mm) and placed in an airtight boxes.

Physicochemical properties of Jackfruit seed starch

1. Determination of Ash Content

The ash content of jackfruit seed starch was determined as per procedure described by (Akpa *et al.* 2012). 15 g of sample was weighed into a crucible of known weight. The crucible was put into a muffle furnace and the sample left as ash at 650^{0}C about 4 hrs. After ashing, the crucible was brought out of the muffle furnace, cooled to room temperature and weighed. The ash content of the sample was calculated using the formula:

$$\text{\% of ash in sample} = \frac{\text{Weight of ash in sample}}{\text{Weight of sample}} \times 100$$

2. Determination of pH

The pH of jackfruit seed starch was determined as per procedure by AOAC, (1984). 5 g of starch sample on dry basis (d.b.) was weighed into beakers and mixed with 20 mL of distilled water. The suspensions was stirred for 5 min using glass rod and allowed to settle for 10 min. The pH of the water phase was measured using a calibrated pH meter.

3. Determination of Bulk Density (Bd)

The bulk density of jackfruit seed starch was determined as per procedure described by Narayana and Narasinga (1982). 30 g of jackfruit seed starch sample was put into an already weighed 50 ml measuring graduated cylinder (W_1) it was gently tapped to dominate air spaces between the starch in the measuring graduated cylinder and the volume was noted to be the volume of the starch sample used. The new mass of the sample and measuring graduated cylinder was recorded (W_2). Both the volume and mass of the starch sample was determined, the bulk density was computed as:

$$\text{Bulk density} = \frac{W_2 - W_1}{\text{Volume of sample}}$$

4. Particle Size Determination

The particle size determination of jackfruit seeds starch was done by using Image analysis system (Make: Expert vision labs Pvt Ltd model: KOZO XJD 403) using Biovis Image plus v4.11 software by using digital microscope. Some quantity of jackfruit seeds starch was taken on the glass slide and sample was put under the microscope observed under 40x. The software gives images of the particles sizes of starch. Also the software directly gives the particle size ranges (0 to 5: 5 to 10: 10 to 15 and 15 μm and above) of jackfruit seeds starch on the computer display.

5. Moisture content in Jackfruit seed starch

Moisture content was determined according to Alves *et al.* (2007). 150 g Jackfruit seed starch was dried in an air oven for 3 h at 105°C. The samples were transferred to a desiccator and allowed to cool to room temperature and the difference in the weight of starch was used to calculate the apparent moisture content:

$$\text{Moisture content (db)} = \frac{W_m}{W_d} \times 100$$

Where,

W_m = weight of moisture, *g*

W_d = weight of bone dry material, *g*

6. Determination of Gelatinization Temperature

The Gelatinization temperature of jackfruit seed starch was determined as per procedure described by (Akpa *et al.* 2012). 1.5g of jackfruit seeds starch sample was dissolved in a beaker with 10 ml of distilled water and mixture is stirred, a thermometer (Make: m/s G H Zeal Ltd London, England) sensor was inserted and beaker placed in a water bath. The temperature of water bath was about 75^0C.The solution was stirred continuously until its colour became milky and thickened. This is the gel point and the temperature at this point was read as the gelatinization temperature.

7. Determination of Water Absorption Capacity

Water absorption capacity of jackfruit seed starch was determined using the method of Sathe *et al.* (1982) 10 ml of distilled water was added to 1.0 g of jackfruit seed starch sample in a beaker, the suspension was stirred using magnetic stirrer for 3 minutes and the 100 rpm the suspension was centrifuged (Make: REmi Electrotechnik Ltd, Model: R-4C DX) at 3,500 rpm for 3 minutes and supernatant measured in 10 cm^3 graduated measuring cylinder. The density of water was assumed to 1 g/cm^3. Water absorbed was calculated as the difference between the initial volume of water added to the sample and the volume of the supernatant, water absorbed was calculated from excess weight of the sample.

$$\text{Weight (\%)} = \frac{\text{Volume of water absorbed}}{\text{Weight of sample}} \times 100$$

8. Determination of Swelling Volume

The swelling volume was determined as per procedure Hirsch and KoKini, (2002). 0.2 g of jackfruit seeds starch samples were poured into test tubes containing distilled water about 5 ml. The solution was stirred, placed in a water bath heated to 95°C while shaking the sample gently to ensure that the starch granules remain in suspension until gelatinization occurs. The gelatinized samples were held at 95°C in the water bath for 1 hour. The samples were cooled to room temperature under running water and centrifuged for 30 minutes at 1000 rpm. After centrifuging, the swelling volume was obtained by reducing 5 ml (distilled water) minus the volume of swollen sediment in the tube.

9. Determination of Swelling Power

The swelling power was determined as per procedure Hirsch and KoKini, (2002). The swollen sediment obtained in section 2.3.8 was taken for this test. The starch swelling power was calculated as ratio of weight of swollen sediment to initial weight of dry starch. The starch swelling power was determined according to below equations.

$$\text{Swelling Power} = \frac{\text{Weight of swollen sediment}}{\text{weight of dry starch}}$$

10. Determination of Solubility

The solubility was determined as per procedure Hirsch and KoKini, (2002). The supernatant was separated from the sediment obtained in section 2.3.8 was taken for this test. The supernatant put in a metal dish, dried at 105°C for 1 hour, and weighed. The starch solubility was calculated as ratio of weight of dry supernatant to initial weight of dry starch. The starch solubility was determined according to equations).

$$\text{Solubility} = \frac{\text{weight of dry supernatant}}{\text{weight of starch sample}} \times 100$$

RESULTS AND DISCUSSION

Table 1 shows the physicochemical properties of Jackfruit seeds starch i.e., Ash content, pH, Bulk density, Particle size, Moisture Content, gelatinization temperature, Water absorption capacity, Swelling volume, Swelling power and Solubility.

Ash Content

The Ash content of jackfruit seed starch were ranged between 0.52 to 0.63 %. The average ash content of jackfruit seeds starch was 0.58±0.05 %. The ash content of a sample is the non-volatile inorganic matter of a compound which remains after subjecting it to a high decomposition temperature. During heating, the organic compounds are decomposed or released leaving behind the residue which consists mainly of other inorganic matters. The main component of ash or mineral matter in starch was phosphorus which affected swelling power, solubility, and pasting properties of starch (Karim *et al.* 2007). Nuwamanya *et al.* (2010) stated that ash contents is high among cereal starches than root and tuber starches. The Ash content of Cassava, Potato, Sweet Potato, Maize, wheat, Sorghum were 0.31, 0.25, 0.28, 0.46, 0.60 and 0.63 % respectively

pH

The pH of a substance is the degree of acidity or alkalinity of that substance. The average pH of jackfruit seeds starch was 4.97±0.59. The pH of jackfruit seeds starch are ranged 4.44 to 5.90. Mukprasit & Sajjaanantakul, (2004) reported that the pH value of jackfruit seed starch was 6.55. The pH of the starches varied independently for different raw materials. These variations could be due to the influence of the composition of starch and presence of impurities (Sangeetha-Mishra, 2006). Nuwamanya *et al.* (2010) stated that the pH of Cassava, Potato, Sweet Potato, Maize, wheat, Sorghum Starches are 5.17, 8.74, 6.71, 2.35, 5.88 and 3.23 respectively.

Table 1: Result of physicochemical properties of Jackfruit seeds Starch Samples

Sample	Ash %	pH	Bulk density (g/cc)	Particle size (μm)	Moisture %	Gel. Temp. (°C)	WAC (g/g)	Swelling Volume (ml)	Swelling Power (g/g)	Solubility (%)
1	0.52	4.76	0.56	5.86	7.82	69	1.23	1.56	7.25	1.526
2	0.63	4.44	0.46	3.04	7.47	75	1.16	1.70	8.30	2.384
3	0.62	4.57	0.46	6.40	6.51	78	1.27	1.20	9.00	1.102
4	0.55	5.90	0.48	9.24	9.38	72	1.19	1.44	7.71	2.026
5	0.58	5.18	0.56	11.71	8.52	76	1.07	1.76	8.80	1.523
Mean	**0.58**	**4.97**	**0.504**	**7.25**	**7.94**	**74**	**1.184**	**1.53**	**8.21**	**1.712**
SD	**0.05**	**0.59**	**0.05**	**3.33**	**0.01**	**3.54**	**0.08**	**0.22**	**0.73**	**0.50**

Bulk density

The bulk density of jackfruit seeds starch was ranged between 0.46 to 0.56 g/cc. The average bulk density of jackfruit seeds starch was 0.504±0.05 g/cc. The bulk density of a powder describes its packing behavior during the various unit operations of tableting such as die filling, mixing, granulation and compression. Higher bulk density is advantageous in tableting due to reduction in the fill volume of the die. The bulk properties describe the density, packing and flow of a powder mass (Aulton, 2001). Abida Ali (2014) Stated that the bulk densities of Rice and Corn starches are 0.48 g/cc and 0.55 g/cc.

Particle size determination

The particle size of jackfruit seeds starch was observed between 3.04 to 11.71 µm. The average particle size of jackfruit seeds starch was 7.25±3.33 µm. Bobbio *et al*. (1978) reported that the particle size of jackfruit seed starch ranged from 7 to 11 µm. The difference in particle size of jackfruit seed starch found in this study and that of Bobbio *et al.* (1978) may be because of differences in the growing location and variety of raw materials. According to Charley (1982), the average diameter of cassava and maize starches ranged between 12 and 25 µm. Particle size of starch is one of the major factors affecting rheological properties of starch suspension used in food industry.

Moisture Content

The moisture content of jackfruit seeds starch was in the range of 6.51 to 9.38 %. The average moisture content of jackfruit seeds starch was 7.94±0.01 %. The moisture content of starch is the amount of moisture present in it. The higher the moisture content the lower the amount of dry solids in the starch. The maximum allowable limit for moisture in starch is 14 % (Austin, 1984). Higher values promote growth of organisms which causes odours and off-flavour. Moisture content may be affected by the environment and the method of storage used for starch and the moisture content of the starch was generally depended upon the duration of the drying process .Moisture content of dry starch varies from 6-16 %, depends on the process used for drying the starch. Higher levels of moisture can lead to microbial damage and subsequent deterioration in quality (Redley, 1976). Nuwamanya *et al.* (2010) reported that moisture content of cassava, potato, sweet potato, maize, wheat, sorghum, and millet starch are 16.50%, 13.67 %, 9.33 %, 13.65 %, 10.00 %, 9.20 %, and 9.30% respectively.

Gelatinization Temperature

The gelatinization temperature of jackfruit seeds starch are ranged between 69 to 78 °C .The average gelatinization temperature of jackfruit seeds starch was 74±3.54 °C The gelatinization temperature of starch is the temperature at which the starch forms a completely transparent gel. Gelatinization is a process that breaks down the intermolecular bonds of starch molecules in the presence of water and heat and allows the starch molecules to engage more water. This penetration of water increases randomness in the structure of the starch. As expected the stronger the bond between the starches molecules, the higher the amount of heat required to break the inter-molecular bond and therefore, the higher the gel temperature (Singh-Sodhi and Singh, 2005). Akpa *et al.* (2012) stated that Gelatinization Temperature of Five Cassava starch samples are 69 °C, 75 °C, 79 °C, 74 °C and 77 °C respectively. A. Gunaratne and R. Hoover (2001) stated that gelatinization temperature of potato, true yam, taro, new cocoyam and cassava are 59.6, 75.3, 76.8, 71.5 and 63.5 °C respectively.

Water absorption capacity

The water absorption capacity (WAC) of jackfruit seeds starch was ranged between 1.07 to 1.27 g /g respectively. The average value of WAC of jackfruit seeds starch was 1.184±0.08 g/g. Water absorption capacity represents the ability of a substance to associate with water under a limited water condition. The differences in WAC of starches from different types could probably be attributed to the variation in their granular structure. The engagement of hydroxyl groups to form hydrogen and covalent bonds between starch chains lowers WAC (Hoover and Sosulski, 1986). The loose association of amylose and amylopectin molecules in the native starch granules has been observed to be responsible for high WAC (Soni *et al.* 1987). Nuwamanya *et al.* (2010) reported that water absorption capacity of cassava, potato, sweet potato, maize, wheat, sorghum, and millet starch are 0.98, 1.06, 0.92, 1.10, 0.93, 1.03 and 1.06 g/g respectively

Swelling Volume

The swelling volume of jackfruit seeds starch samples was ranged between 1.20 to 1.76 ml. The average swelling volume of jackfruit seeds starch was 1.53±0.22 ml respectively. When an aqueous suspension of starch is heated, as the temperature increases and exceeds gelatinization temperature, the starch granules become weakened and the intermolecular bonds of the starch molecule become distorted. This enables water molecules to become more attached to the starch molecules. The granules continue to swell as they absorb more water (Gunarantne and Corke, 2007).

Swelling Power

The swelling power of jackfruit seeds starch samples are ranged between 7.25 to 9.0 g/g. The average swelling power of cassava starch was 8.21±0.73 g/g. Abida Ali (2014) reported that swelling power of jhelum rice, kosher rice, PS-43 corn and Shalimar maize were 9.23±0.15, 8.67±0.25, 8.33±0.21 and 8.50±0.17 g/g respectively. Nuwamanya *et al.*, (2010) reported that swelling power of cassava, potato, sweet potato, maize, wheat, sorghum, and millet were 8.58, 8.44, 6.88, 3.96, 6.31, 5.25 and 5.16 g/g respectively.

Solubility

The Solubility of jackfruit seeds starch samples are ranged between 1.102 to 2.384 %. The average solubility of jackfruit seeds starch was 1.712±0.50 %. Abida Ali (2014) reported that Solubility of jhelum rice and kosher rice were 4.00±0.00 and 2.00±0.00 %. Nuwamanya *et al.* (2010) reported that solubility of cassava, potato, sweet potato, maize, wheat, sorghum, and millet were 1.230, 0.770, 0.577, 0.997, 0.247, 0.803, and 0.205 % respectively.

CONCLUSION

Results of the present study shows that jackfruit seeds starch has very good characteristic as compare to other starches. The jackfruit seeds starch contains average values of ash content, pH, bulk density, particle size, moisture content, gelatinization temperature, water absorption capacity, swelling volume, swelling power and solubility were 0.58±0.05 %, 4.97±0.59, 0.504±0.05 g/cc, 7.25±3.33 µm, 7.94±0.01 %, 74.00±3.54 °C, 1.184±0.08 g/g, 1.53±0.22 ml, 8.21±0.73 g/g and 1.712±0.50 % respectively. So it is concluded that jackfruit seeds starch is useful for many food and non-food industry applications.

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