

Physicochemical properties of flour and extraction of starch from jackfruit seed

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Abstract: The chemical, physico-chemical and functional properties of flour and starch from three varieties of jackfruit seed were analyzed in this study. Starch was isolated using distilled water, alkaline and α -amylase enzyme. All varieties of jackfruit seed flour had moisture content 6.28-9.16%, protein 9.19-11.34%, fat 1.18-1.40%, ash 1.53-2.66%, amylose 26.49%-30.21% and starch contents 81.05%-82.52%. Gala variety had highest amount of water soluble index, swelling water capacity and water absorption index than Khaja and Durasha varieties. On the other hand, isolated starch varied 8.39 to 12.20% moisture, 1.09 to 3.67% protein, 1.18 to 1.40% fat, 0.03 to 0.59% ash content. Starch isolated with distilled water had higher protein content, yield, amylose and total starch than starch isolated with alkaline and enzyme. However, purity was depended on the variety and extraction conditions. Enzymatic method gave highest amount of water absorption index and water soluble index as compared to distilled water and alkaline method. Results from this study suggest that jackfruit seed flour can be used as partial replacement of wheat flour and good source of starch.

Keywords: Jackfruit Seed, Starch, Alkaline, α -amylase enzyme, Amylose

1. Introduction

Jackfruit (*Artocarpus heterophyllus*) belongs to the family Moraceae and is widely grown in Southeast Asia including Bangladesh, India and Thailand. It is the national fruit of Bangladesh (Kirtikar *et al.*, 2003). In Bangladesh, the jackfruit covered an area of 9236.44 hectares and its annual production was 974760 metric tons during the year 2008-2009 (BBS, 2009). Various cultivars are grown in Bangladesh such as Khaja, Gala and Durasha (Haque, 1993). Khaja is characterized by the bulb of hard and crispy, Gala is soft and juicy and mostly melting bulb. On the other hand, Durasha is an intermediate between Khaja and Gala. Normally jackfruit are eaten as fresh or processed into jam, jellies juice, beverage, squash and syrup. Usually Jackfruit seed is 2-3 cm in long, 1-2 cm in diameter and each fruit contains 100 to 500 seeds. The seeds are eaten as

cooked, roasted or fried and its flour also used to prepare various baked products such as bread, cake and so on.

Jackfruit seeds are good sources of protein and starch. Jackfruit seed also contain lignans, isoflavones, saponins, that are called phytonutrients and they have numerous health benefits such as anti-cancer, anti-ageing and antioxidant. 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 (Gebre and Schmidt, 1996; Alabi, *et al.*, 2005).

Several studies have been done on physicochemical properties (Bobbio *et al.*, 1978), rheological properties

(Tulyathan *et al.*, 2002) and pasting characteristics (Roy & Mitra, 1970; Kumar *et al.*, 1988) of jackfruit seed. However, various extraction methods such as 5% sulphur dioxide (Han & Hamaker, 2002), alkali, enzyme, detergent and sodium hydroxide (Lim *et al.*, 1999; Matsunaga *et al.*, 2003) have been used to enhance starch quality as well as pasting properties. Usually wet milling extraction method was used to extract starch from flour. (Zheng *et al.*, 1998). It has been found that alkaline extraction technique gives high yield and purity than wet milling (Han and Hamaker, 2002) and enzymatic method (Liu, 2005; Andersson *et al.*, 2001). Alkaline extraction technique also gives lower pasting temperature and higher pasting viscosity as compared to wet milling (Han and Hamaker, 2002). Usually different enzymes such as protease, amylase and cellulase could be used to enhance quality and purification of starch. Enzyme also produced low level of starch damage (Puchongl Kavarin *et al.*, 2005). On the other-hand, starch damage increased when addition of alkali, sodium hydroxide and sodium dodecyl-sulphate. Combination of enzyme and sonication was also used to reduce the starch damage (Wang and Wang, 2004). Enzymes are that can be used to obtain higher recovery of starch from tuber crops (Klacik, 1988). Johnston and Singh (2004) used bromalin enzyme during milling process for extraction of corn who found that the starch yield was equal to conventional yield. In addition, alkaline extraction methods are not frequently used in the food industry due to high cost and time consuming process for removal of salt (Otto *et al.*, 1997b; Sosulski, 1989).

Nowadays, it is well known that fruits by-products not only good source of bioactive compounds but also could be used as various value-added products. Huge amount of seeds are obtained during processing which could be used as source of starch as well as value-added products. So that, now time to use by-products as different functional foods. However, till to date no information is available regarding of starch extraction from jack fruit seeds using aforementioned methods in Bangladesh. Therefore, the objective of this research is to evaluate the physicochemical and functional characteristics of jackfruit seeds flour and isolated starch from jackfruit seeds.

2. Materials and Methods

2.1. Sample Collection and Seed Treatment

Various varieties (Gala, Durasha and Khaja) ripe Jackfruit (*Artocarpus heterophyllus Lam*) were collected from the local market. The ripened fruits were cut manually with a sharp knife and the seeds were collected from the bulbs. The collected seeds were washed with tap water to remove their impurities. The white aril (seed coats) was peeled off manually. Then it was soaked with 5 % sodium hydroxide (NaOH) and 5% citric acid for 2 minutes at room temperature removed brown layers (Spermoderm covering)

and washed with running water again. The cotyledon was used to prepare flour.

2.2. Preparation of Jackfruit Seeds Flour

The washed seeds were sliced into small pieces (2-2.5 mm thickness) with knife. Then the seed was dried at a cabinet drier (model- 136-12, Seoul, Korea) at 60°C for 24 hour followed by grinding into flour by using a blender (Japan CM/L- 7360065). The flour was sieved through a sieve (42 mesh size) and packed in a plastic bag. The obtained flour was sealed and stored in a refrigerator (<5°C) until further use.

2.3. Extraction of Jackfruit Seed Starch Using Distilled Water Method

The extraction of jackfruit seed starch was isolated according to the method of Singh and Singh (2001) with minor modification. 5gm jackfruit seed flour was added into 100 ml distilled water and soaked (6 h and 8 h) at room temperature then stirred constantly. The slurry was filtered through 212 mesh stainless sieve and remaining sediment was washed with distilled water for three times. The filtrates were combined and precipitated overnight at 4°C. The supernatant was discarded and the crude starch was cleaned with distilled water. This step was repeated three times and starch cake was dried at 40°C for 24 h in oven dryer. The starch was ground with a mortar and pestle. The starches were packed in a plastic bag and kept at room temperature until further use. Optimum conditions 6 h soaking time were selected on the basis of the yield.

2.4. Extraction of Jackfruit Seed Starch Using Alkali Method

The extraction of jackfruit seed starch was isolated using some modification of Bobbio *et al.*, (1978) and Singh and Singh (2001). Jackfruit seed flour (5gm) was added in various concentrations (0.1%, 0.25% and 0.5%) of alkali such as NaOH and soaked (6 h and 8 h) at room temperature then stirred constantly. The slurry was filtered through 212 mesh stainless sieve. The remaining sediment was washed with distilled water for 3 times. The filtrates were combined and precipitated overnight at 4°C. The supernatant was discarded and the crude starch was cleaned with distilled water. These steps were repeated three times and starch cake was dried at 40°C for 24 h in oven dryer. The starch was ground with a mortar and pestle. The starches were packed in a plastic bag and kept at room temperature until further use. Optimum conditions 0.5% NaOH and 6 h soaking time were selected on the basis of the yield.

2.5. Extraction of Jackfruit Seed Starch Using Enzyme

Perez *et al.* (1993) and Singh and Singh (2001) with minor modification methods were used to isolated starch from jackfruit seed. Five gram jackfruit seed flour was added into various concentration (0.1 g, 0.25 g and 0.5 g)

of enzyme (α -amylase) and soaked (6 h and 8 h) into 100 ml water at room temperature then stirred constantly. The solution pH was maintained at 6.0. The slurry was filtered through 212 mesh stainless sieve. The remaining sediment was washed with distilled water for 3 times. The filtrates were combined and precipitated overnight at 4°C. The supernatant was discarded and the crude starch was cleaned with distilled water. These steps were repeated three times and the starch cake was dried at 40°C for 24 h in oven dryer. The starch was ground with a mortar and pestle. The starches were packed in a plastic bag and kept at room temperature until further use. Optimum conditions 0.25 g enzyme and 6 h soaking time were selected on the basis of the yield.

3. Characterization of Flour and Starch

3.1. Starch Yield

Yield was calculated by following formula

$$\% \text{ yield} = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \times 100$$

3.2. Determination of Proximate Composition

AOAC method 7.045 (2000) was used to determine the moisture, ash, crude fat, crude protein content of jackfruit seed powder.

3.3. Determination of Amylose Content

Amylose content was determined by Sompong (2011) method with some modification. Jackfruit seed powder (0.02 g) was taken into a volumetric flask. Then 0.2 ml of ethanol (95%) was added. After that 1.8 ml of 1N NaOH was added and made 20 ml total volume by adding distilled water. It was kept 20min. at room temperature and boiled for 10 min. at 45°C. It was filtered using Whatman filter paper (540). Then 1 ml filtrate was transferred to a 50 ml tube and 0.2 ml of 1M acetic acid and 0.4 ml Lugol's solution were added and made total volume 20 ml by adding distilled water. The mixture was mixed and kept for 20 min at room temperature. Then the absorbance was taken at 620 nm. The amylose content was determined using potato amylose standard curve.

3.4. Determination of Starch

The starch content was determined by Lane and Eynon method (2000). Jackfruit seed powder (5g) was taken in a beaker and 30 ml of water was added. It was transferred to the water bath and heated at 60°C for 25 min. Then 100 ml of 95% ethanol was added to it and stirred by magnetic stirrer for 15 min. It was filtered through Whatman filter paper no.2. The residue was soaked in the 50% ethanol solution for 1hr. After that, the residue was washed on the filter paper with the 50% ethanol solution for 4 hr. The residue was collected to a round bottom flask and 100 ml of

water and 20 ml of HCl added to it. The flask was attached with the condenser and heated for 2.5 hr. Then it was allowed to cool and neutralized by adding NaOH solution (40%). After that 10 ml of Fehling solution was taken in to a conical flask and titrated against neutralized sample solution. When copper sulfate like color was observed, then 3 drops of methylene blue indicator was added and continued titration. The end point was indicated by brick-red color.

3.5. Determination of Purity

Purity was calculated by the difference between the yield of starch and the total content of ash, lipids, protein and crude fibre.

3.6. Determination of Water Solubility Index (WSI) and Water Absorption Index (WAI)

WAI and WSI were determined following the method described by Anderson (2001). Each sample (0.83 g) was suspended in 10 ml of distilled water and stirred for 30 min. Subsequently, the dispersions were centrifuged at 4000 rpm for 30 min. The supernatants were poured into pre weighed petri dish and the residue was weighed after oven drying overnight at 70°C. WAI and WSI were calculated using following equations:

$$\text{WAI} = \text{weight of sediment} / \text{weight of dry solids}$$

$$\text{WSI} = \text{weight of dissolved solids in supernatant} \times 100 / \text{weight of dry solids}$$

3.7. Determination of Swelling Water Capacity

Swelling capacity was determined according to Lai and Cheng (2004) using the equation

$$\text{SWC} = \text{weight of sediment} / [\text{dry weight of sample} \times (1 - \text{ws}\% / 100)].$$

3.8. Statistical Analysis

Each experiment included three replications. Data were analyzed using statistical software (MSTAT-C for Windows Version 2.10). A multi-factorial analysis of variance was carried out. Individual effects and interaction between the factors have been calculated.

4. Results and Discussion

4.1. Proximate Analysis

The proximate composition of jackfruit seed flours and starches are shown in Table-1 and Table-2, respectively. The moisture content of all seed flours were varied between 6.28%-9.16%. Highest (9.16%) moisture content was found in Durasha jackfruit seed flour whereas lowest (6.28%) moisture content was found in Khaja jackfruit seed flour. These results were similar with the findings of Ocloo *et al.*, (2010) who reported that the moisture content of jackfruit seed flour was 6.09%. These values also were consistent with Tulyathan and Jaiboon (2002) who observed that the

moisture content of jackfruit seed flour was 8.57%. The moisture content of jackfruit seed starch ranged from 8.39-12.20%. Enzymatic method gave highest (11.57-12.20%) moisture content followed by alkaline method (8.39-8.58%) and distilled water method (9.56-10.44%) of jackfruit seed starch. These values were close to the Mukprasirt and Sajjaanantakul (2004) and Kong *et al.*, (2009) who reported that the moisture content of jackfruit seed starch and amaranthus starch was 9.94% and 11.6% to 13.9%, respectively. Variation of moisture content of different varieties jackfruit seed flour and starch might be due to varietal differences, location of growing areas and extraction method (Tulyathan and Jaiboon, 2002).

The protein content of jackfruit seed flour of Gala, Durasha and khaja were 11.34%, 9.75% and 9.19%, respectively. Gala variety had highest protein value (11.34%) as compared to Khaja (9.19%) and Gala (9.75%) variety. Significant differences were observed in protein content in all flour samples. The protein content jackfruit seed flour was lower than those obtained by Ocloo *et al.*, (2010) who observed the protein value of jackfruit seed flour was 17.2%. These values were similar to Singh *et al.*, (1991) who reported that the protein content of jackfruit seed flour was 11.17%. These results were much higher than that reported by Mukprasirt and Sajjaanantakul, (2004) for jackfruit seed flour (6.34 –8.57%). The variation of protein content could be due to maturation of the seeds and environmental conditions (Ocloo *et al.*, 2010). The protein content of jackfruit seed starch in distilled water method, alkaline method and enzymatic method were 3.41-3.67%, 1.26-2.30% and 1.09-1.28%, respectively. The present results were higher than that found by Mukprasirt and Sajjaanantakul (2004) who reported the protein content of jackfruit seed starch was 0.81%. These values were close to those reported by Naguleswaran *et al.*, (2010) who observed that protein content of palmyrah starch was 2.5%. The difference in protein value of jackfruit seed starch might be due to differences in starch isolation procedure.

In this study, the variation of fat content among different varieties jackfruit seed flour was 1.18-1.40%. No significant differences were found among different varieties of jackfruit seed flour. This value was much

higher than found by Goswami *et al.*, (2010) who reported that the fat content of the raw seeds were 0.68%-0.80% and roasted seeds were 0.54%-0.71%. These results were similar with the findings reported by Ocloo *et al.*, (2010) who found that fat content of flour was 1.27%. This result was lower than compared to pearl millet (7.6%) and quinoa (6.3%) (Oshodi *et al.*, 1999), pigeon pea flour (1.80%, Okpala and Mammah, 2001) and wheat flour (3.10%, Akubor and Badifu, 2004). Starch extracted with distilled water method had highest fat content (0.03-0.04%) as compared to extracted with alkaline method (0.02-0.03%) and enzymatic method (0.02-0.03%). This value was lower than that of Mukprasirt and Sajjaanantakul (2004) who obtained fat value of jackfruit seed starch was 0.90%. The ash content of different varieties jackfruit seed flour was 1.53-2.61%. There were no significant differences among different varieties of jackfruit seed flour.

Ocloo *et al.*, (2010) reported that ash content of flour was 2.70%. These results also were lower than that found by Morton, (1987) who recorded ash content of jackfruit seed was 2.76 – 3.31 %. The variation in ash content in different varieties jackfruit seed flour might be due to the locality (Ocloo *et al.*, 2010). Enzymatic method had highest (0.45-0.59%) ash contents than that of distilled water method (0.03-0.04%) and alkaline extraction method (0.03-0.04%). These values were close to Rengsutthi and Charoenrein (2011) who found that the ash content of jackfruit seed starch was 0.04%. The disparity of ash content might be due to the extraction method of starch and botanical properties (Rengsutthi and Charoenrein, 2011).

Table 1. Proximate composition of jackfruit seed flour.

Parameters (%)	Varieties		
	Gala	Durasha	Khaja
Moisture	9.02 ± 0.84 ^a	9.16 ± 0.79 ^a	6.28 ± 0.11 ^b
Protein	11.34 ± 0.09 ^a	9.75 ± 0.09 ^b	9.19 ± 0.09 ^c
Fat	1.40 ± 0.19 ^a	1.32 ± 0.09 ^a	1.18 ± 0.16 ^a
Ash	2.66 ± 0.87 ^a	1.53 ± 0.71 ^a	2.51 ± 1.34 ^a

Mean values with different subscripts within the same row are significantly different (P<0.05)
Mean ± SD

Table 2. Proximate composition of jackfruit seed starch.

Extraction Method	Parameters											
	Moisture (%)			Protein (%)			Fat (%)			Ash (%)		
	1	2	3	1	2	3	1	2	3	1	2	3
Distilled water	^B 9.56±	^B 10.01±	^B 10.44±	^A 3.47±	^A 3.67±	^A 3.41±	^A 0.03±	^B 0.04±	^A 0.03±	^B 0.04±	^B 0.04±	^B 0.03±
	0.13 ^a	0.71 ^a	0.46 ^a	0.15 ^a	0.18 ^a	0.23 ^a	0.01 ^a	0.01 ^a	0.002 ^a	0.01 ^a	0.01 ^a	0.01 ^a
Alkaline	^B 8.58±	^C 8.43±	^C 8.39±	^B 1.41±	^B 1.26±	^B 2.23±	^A 0.02±	^A 0.02±	^A 0.03±	^B	^B 0.03±	^B 0.03±
	0.82 ^a	0.44 ^a	0.36 ^a	0.09 ^c	0.09 ^b	0.15 ^a	0.01 ^a	0.002 ^a	0.01 ^a	0.04±0.01 ^a	0.004 ^a	0.01 ^a
Enzymatic	^A 12.20±	^A 11.57±	^A 11.91±	^B 1.28±	^B 1.09±	^C 1.18±	^A 0.03±	^A 0.02±	^A 0.03±	^A 0.45±	^A 0.59±	^A 0.56±
	0.42 ^a	0.48 ^a	0.33 ^a	0.41 ^a	0.05 ^a	0.02 ^a	0.01 ^a	0.01 ^a	0.01 ^a	0.05 ^b	0.04 ^a	0.05 ^a

Mean ± SD

^{a-c} Means followed by different subscript alphabets in each row are significantly different (P<0.05).

^{A-C} Means followed by different subscript alphabets in each column are significantly different (P<0.05).

1=Gala variety 2=Durasha variety 3=Khaja variety

4.2. Physico-Chemical Properties

Table-3 and Table-4 shows the physico-chemical properties of jackfruit seed flour and extracted starch, respectively. Amylose contents observed in all flour samples ranged from 26.49% to 30.21% (Table-4). Durasha seed flour had higher amylose content than Gala seed flour. The value was lower than that found by Tulyathan and Jaiboon (2002) who observed the amylose content of jackfruit seed flour was 32%. The variation in amylose content of jackfruit seed flour might be due to use different species and growing condition (Singh *et al.*, 2003). Starch extracted with distilled water had higher amylose content (26.57-31.37%) compared to enzymatic method (22.10-22.17%) (Table-4). The values were consistent with jackfruit seed starch (26.13%, Tulyathan *et al.*, 2002), Corn starch (22.20%; Singh *et al.*, 2004) and Potato starch (25.2%, Alvani *et al.*, 2011), but higher than rice starch (92%, Sandhu *et al.*, 2010). This disparity of starch may be due to extraction method of the starch and leach out of the starch granules (Zobel, 1984). Starch contents of jackfruit seed flour was 81.05-82.52% (Table-4) which was higher than that of maca root (23.17%, Rodan-Sanabria *et al.*, 2009) and pinion seed (63.37% Henriquez *et al.*, 2008). The starch content of isolated starch using distilled water method, alkaline method and enzymatic method were 83.83 to 86.71%, 79.35 to 83.15% and 72.58 to 80.21 %, respectively (Table-4). The highest starch contents were observed in distilled water method (83.83-86.71%) as compared to alkaline method (79.35 to 83.15%) and

enzymatic method (72.58-80.21 %). These values were higher than pinion seed starch (77%, Henriquez *et al.*, 2008) but lower than maize starch (93.4%, McCleary *et al.*, 2006). This variation of starch content of isolated starch might be due to different methodologies used to extract the starch (Henriquez *et al.*, 2008). Purity of isolated starches was 93.83 to 97.92% (Table-4). These values were higher than pinion seed starch (90%, Henriquez *et al.*, 2008).

The yields of jackfruit seed starch in distilled water method, alkaline method and enzymatic method were 83.62-84.48%, 55.95-58.75% and 50.69-55.51%, respectively (Table-4). This value was higher than that found by Henriquez *et al.*, (2008) who observed the yield of pinion seed starch was 35.9% and yields of dark and white sorghum samples were 27.73 ±1.0% and 30±0.5%, respectively (Sira and Amaiz, 2004). Distilled water had higher yield as compared to alkaline and enzymatic method. The high yield of starch in distilled water might be attributed to the high amount of protein, fat and ash content than alkaline and enzymatic method.

Table 3. Physico-chemical properties of jackfruit seed flour.

Parameters (%)	Varieties		
	Gala	Durasha	Khaja
Amylose	26.49 ± 0.26 ^b	30.21 ± 0.13 ^a	30.09 ± 1.02 ^a
Starch	81.05 ± 11.91 ^a	82.52 ± 15.75 ^a	81.32 ± 14.36 ^a

Mean values with different subscripts within the same row are significantly different (P<0.05).
Mean ± SD

Table 4. Physico-chemical properties of jackfruit seed starch.

Extraction Method	Parameters											
	Amylase (%)			Total starch (%)			Purity (%)			Yield (%)		
	1	2	3	1	2	3	1	2	3	1	2	3
Distilled water	^A 26.57	^A 30.61	^A 31.37	^A 86.71	^A 83.83	^A 85.86	^B 94.08	^A 92.98	^A 95.58	^A 84.33	^A 83.62	^A 84.48±0.26 ^a
	±0.13 ^c	±.18 ^b	±0.9 ^a	±1.79 ^a	±3.15 ^a	±1.84 ^a	±1.70 ^b	±2.69 ^a	±0.92 ^a	±0.39 ^a	±0.12 ^b	
Alkaline	^B 25.14	^B 25.75	^B 25.49	^B 83.15	^B 80.87	^B 79.35	^A 97.72	^A 95.65	^A 94.80	^B 58.75	^B 55.95	^B 57.34±0.91 ^a
	±0.09 ^a	±.18 ^a	±0.9 ^a	±2.86 ^a	±2.73 ^a	±5.72 ^a	±1.32 ^a	±2.75 ^a	±1.69 ^a	±0.95 ^a	±0.85 ^b	
Enzymatic	^C 22.13	^C 22.17	^C 22.10	^B 80.21	^C 73.46	^B 72.58	^B 95.06	^A 93.18	^A 93.83	^C 55.51	^C 50.69	^C 52.74±1.23 ^b
	±0.14 ^a	±.09 ^a	±0.14 ^a	±1.59 ^a	±1.31 ^b	±1.34 ^b	±1.58 ^b	±3.11 ^a	±3.22 ^a	±0.23 ^a	±0.75 ^c	

Mean ± SD

^{a-c} Means followed by different subscript alphabets in each row are significantly different (P<0.05).

^{A-C} Means followed by different subscript alphabets in each coulm are significantly different (P<0.05).

1=Gala variety 2=Durasha variety 3=Khaja variety

4.3. Functional Properties

4.3.1. Water Absorption Index (WAI)

Figure-1 and Figure-2 shows the water absorption index of jackfruit seed flour and extracted starch, respectively. Water absorption index of 1.66-2.31% was obtained from the various jackfruit seed flour. Highest (2.31%) amount of water absorption index was found in Gala variety seed flour whereas lowest (1.66%) amount was found in Khaja seed flour. This value was lower than that found by ocloo *et al.*,

(2010) who reported water absorption index of jackfruit seed flour were 25%, but higher than sweet potato flour (Ahmed *et al.*, 2010). Water absorption index of extracted starch varied between 7.96-8.98%. The highest WAI was found in enzymatic method (8.29-8.98%) and the lowest WAI was in alkaline method (7.96-8.80%). This value was lower than that found by Ihegwuagy *et al.*, (2009) who observed that the water absorption index of pakirka starch was 116%. High amount of WAI might be due to high amount of swelling capacity (Dewilligan, 1964). Another

reason for variation of WAI could be due to the crystalline molecular structure of starch is broken and the water molecules are bonded to the free hydroxyl groups of amylose and amylopectin by hydrogen bonds (Singh *et al.*, & Gill, 2003).

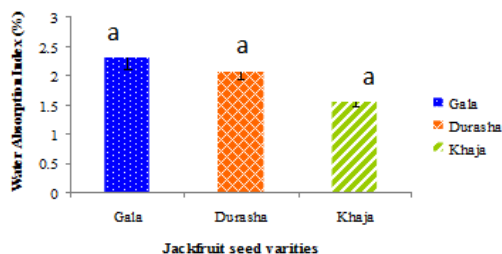


Figure 1. Water absorption index of jackfruit seed flour.

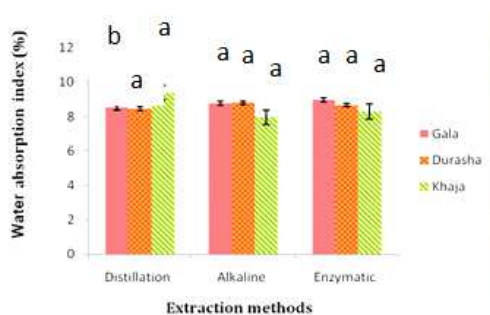


Figure 2. Water absorption index of jackfruit seed starch.

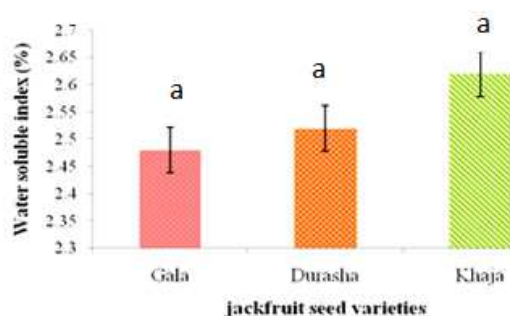


Figure 3. Water soluble index of jackfruit seed flour.

4.3.2. Water Soluble Index (WSI) & Swelling Water Capacity (SWC)

Water soluble index (WSI) and swelling water capacity (SWC) are other functional properties of jackfruit seed flour and extracted starch. The water soluble index (WSI) of jackfruit seed flour of Gala, Khaja and Durasha were 2.48%, 2.64% and 2.51%, respectively (Figure-3). Khaja variety had highest (2.68%) water soluble index as compared to gala (2.48%) and Durasha (2.51%) variety. These values were higher than that found by Airani (2007) who suggested that water soluble index Jackfruit seed flour was 1.80%. Starch extracted with distilled water method had highest (10.90-11.52%) water solubility index as compared to enzymatic method (6.99-8.42%) (Figure-4). These values were close to the sandhu and singh (2007) who reported that water soluble index of corn starches was 9.7 to 15% but higher than pinnion seed starch (0.3% to

2.4%, Henriquez, 2008). Swelling water capacity observed in all flour samples ranged from 1.72-2.34% (Fig-5). Highest (2.34%) Swelling water capacity was found in gala variety seed flour and lowest (1.72%) was found in khaja variety seed flour. This value was lower than that obtained by Ocloo *et al.*, (2010) who reported that swelling water value of Jackfruit seed flour was 4.77%. Enzymatic method had highest (11.9-12.93%) swelling water capacity than that of distilled water method (8.79-9.87%) and alkaline method (9.39-10.58%) (Figure-6). These results were close to the Sandhu and Singh, (2007) who obtained the swelling water capacity of various corn starches was 13.7 to 20.7%. Starch extracted with enzyme had higher SWC and lower WSI followed by alkaline and distilled water method. The differences could be presence of lower amount of amylose content and fat. Singh *et al.*, (2003) also reported that SWC and WSI depend on morphological structure of starch granule.

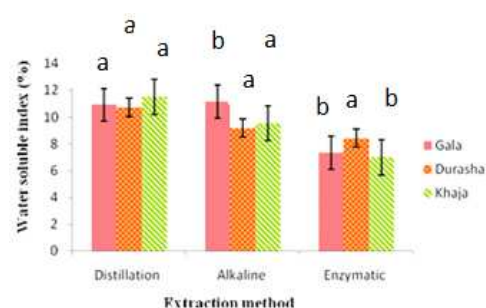


Figure 4. Water soluble index of jackfruit seed starch.

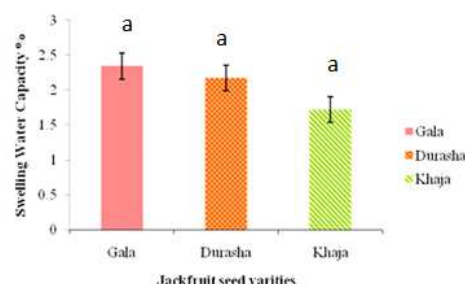


Figure 5. Swelling water capacity of jackfruit seed flour.

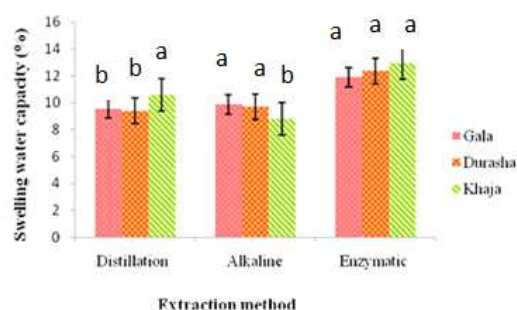


Figure 6. Swelling water capacity of jackfruit seed starch.

5. Conclusions

In this study, flour was prepared from different varieties of jackfruit seed and also starch was extracted using

different extraction condition such as (distilled water method, alkaline and enzymatic method). The results showed that amylose and starch content was higher in Durasha seed flour as compared to Gala seed flour. Gala variety had highest amount of water absorption index, water soluble index and swelling water capacity than Khaja and Durasha varieties. Distilled water method gave highest amount of yield, amylose and swelling water capacity than alkaline and enzymatic method. Enzymatic method gave highest amount of water absorption index and water soluble index as compared to distilled water and alkaline method. The overall results showed that jackfruit seed might be used good source of starch as well as extracted starch could be used as thickening and binding agent in food system.

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