Physico-chemical evaluation of jackfruit seed starch and its application in cupcake

V C Khang1,2, V T Thanh1,3, N P T Nhan1,2, T T Yen Nhi1,3, D T Nguyen4, T T Luu3 and N T Quoc3,*

1NTT Hi-Tech Institute, Nguyen Tat Thanh University, Ho Chi Minh City, Vietnam
2Center of Excellence for Functional Polymers and NanoEngineering, Nguyen Tat Thanh University, Ho Chi Minh City, Vietnam
3Center of Excellence for Biochemistry and Natural Products, Nguyen Tat Thanh University, Ho Chi Minh City, Vietnam
4Agro-Forestry-Fisheries Quality Assurance Department
5Center for Agricultural Extension and Services, Tien Giang Province, Vietnam

*Corresponding author: quoctg@gmail.com; labasm2013@gmail.com

Abstract. Human widely uses starch as a rich carbohydrate source and inexpensive. They are used in many fields such as food, cosmetics, medicine due to the diverse structure and functionality of starch. Corn and tapioca starch are widely used and available in the market. Meanwhile, jackfruit starch is a new starch and people are concerned because they can bring economic benefits for manufacturers as well as their physical and chemical properties. The purpose of this study is therefore to evaluate the physicochemical properties of starch from jackfruit seeds, corn starch and cassava starch to select appropriate starch and apply jackfruit seed starch in food. Jackfruit starch was extracted from jackfruit seeds by alkaline steeping extraction method. Corn starch and tapioca starch were bought in the market. Some biological and physiochemical properties of starch seed from jackfruit such as nutrition, morphology, particle size distribution, viscosity, XRD and FTIR were approximately similar with tapioca and corn starch. The obtained results showed that jackfruit seed starch could be a potential alternative to the conventional starches. Moreover, can replace 15% of wheat flour into jackfruit seed starch in the process of cupcake. These result will generalize the characteristics of type of starches so that it can be applied to each specific process.

1. Introduction
Starch is known as a natural polysaccharide as well as macro-constituent of many foods. Starch is found in many cereals such as wheat, corn, rice and bean [1]. Starch can bind a large quantities of water to change the desirable texture of food products [2]. The income of commercial starches was $51.2 billion in 2012 and is forecast at 7.1% of yearly growth rate between 2012 and 2018 to reach $77.4 billion. The starch derivative market is expected to growth strongly from 2014 to 2019 by a rate of 6.2% because of technological developments happening in the field [3].

Jackfruit (Artocarpus heterophyllus) is a common tree in Vietnam and is also found in some tropical regions like as Thailand, India and China. [4]. Jackfruit seeds contains a large starch but they are normally discarded during material processing in manufacture chain of food products such as dried
jackfruit, canned jackfruit or pie filler [5]. Therefore, the extraction of jackfruit seed starch can improve the value of jackfruit as well as reduce cost in environmental treatments [6].

Jackfruit seed accounts for 10-15% of the total fruit weight and contains abundant carbohydrate, protein and a wide array of minerals, saponins and isoflavones [7-8]. It has been indicated that battered products constituted by higher content of native jackfruit seed starch showed improved textural properties and better consumer preferences in comparison with those abundantly made of wheat flour [9]. This is possibly due to better viscoelasticity, oil resistance and uniformity of starch network of jackfruit starch-enriched products.

Many studies have been conducted to find the new source of starch from cheap, underexploited and available by-product for industries uses [10-16]. The difference in natural origin of starches make the different granular structure and functional properties. Therefore, new sources need to be explored of starch to meet special demand of food industries as well as other industries. In this study, we investigated and compared some physicochemical properties of jackfruit seed starch with those of commonly manufactured starches in the food industry, namely corn starch and tapioca starch. In addition, the application possibility of jackfruit seed starch in cupcake formulation was examined. Obtained results are expected to give a deeper insight into functional properties of jackfruit seed starch and justify the recycling of jackfruit seed in production of a new sources of starch.

2. Methods and materials

2.1. Materials

Jackfruit seed (Artocarpus heterophyllus) were collected at Tien Giang province, Viet Nam. The jackfruit seed was stored in refrigerator for starch production. Two commercial native starches, corn starch and tapioca starch, were purchased at Tayky Company.

2.2. Extraction of starch

Starch was extracted from the jackfruit seeds according to the Luciano et al process with some modifications [17]. The seeds were dried, and the white aril and brown skin were removed. Then, the jackfruit seed would be ground with water at a ratio of 1:3 to the size of < 250 µm for 3 min to extract starch. Next, the ground slurry was filtered with a mesh and then steeped in 0.25% NaOH for about 16 h to remove protein in starch. The upper supernatant was then removed. Settled starch was collected and centrifuged at 5000 rpm for 10 min to remove water in starch. After that, the obtained starch was washed twice with ethanol at a ratio of 1:4, dried at 40°C for 18 h and then stored in a desiccators. The yield of jackfruit seed starch was calculated using Equation 1 as follows [18]:

\[
Yield\ of\ Starch\ (%) = \frac{Weight\ of\ isolated\ starch\ (g) \times 100%}{Weight\ of\ jackfruit\ seed\ sample\ (g)}
\]

2.3. Cupcake formulation

The cupcake formulation used in this study is given in Table 1. The egg was mixed with caster sugar, non-sugar, milk, unsalted butter, baking powder at 2 min. Wheat flour and jackfruit seed starch at a concentration of 0-25% were sifted together and mixed about 1 min. The cupcake batter was baked in preheated gas oven at 180°C for 20 min. After baking, cupcake was packed in polyethylene bags before evaluation tests.
Table 1. The ingredient used in cupcake formulation.

| Ingredients                  | Control | 5%    | 10%   | 15%   | 20%   | 25%   |
|------------------------------|---------|-------|-------|-------|-------|-------|
| Egg                          | 15      | 15    | 15    | 15    | 15    | 15    |
| Caster sugar                 | 22      | 22    | 22    | 22    | 22    | 22    |
| Pure vanilla powder          | 0.25    | 0.25  | 0.25  | 0.25  | 0.25  | 0.25  |
| Wheat flour                  | 30      | 25    | 20    | 15    | 10    | 5     |
| Jackfruit seed starch        | 0       | 5     | 10    | 15    | 20    | 25    |
| Non-sugar milk               | 18.75   | 18.75 | 18.75 | 18.75 | 18.75 | 18.75 |
| Unsalted butter              | 13      | 13    | 13    | 13    | 13    | 13    |
| Baking powder                | 1       | 1     | 1     | 1     | 1     | 1     |
| Total                        | 100     | 100   | 100   | 100   | 100   | 100   |

2.4. Analytical methods

2.4.1. Compositional analysis. The moisture content of starches was determined by an Infrared Moisture Determination Blace (Ohaus MB45). Total protein and lipid content was estimated by the Kjeldahl method and Soxhlet. Ash content was determined by calcination at 600 °C. The total carbohydrate content was computed using the following equation:

\[
\% \text{ Carbohydrate} = 100 - (\% \text{ Moisture} + \% \text{ Ash} + \% \text{ Protein} + \% \text{ Fat})
\]  

2.4.2. Physicochemical properties. Surface morphology of starch granule was observed on Scanning Electronic Microscope (SEM); Evaluation of grain structure by the X-ray diffraction methods with a Cu anode operating at 40 kV and 20 mA. The angular ranger (2θ) was 2-35° with a speed of 2°/mins. Magnification value was ×5000 and ×1000. The FTIR spectra of the starch sample were recorded using FTIR spectrometer. The sample of starch was mixed with KBr and pressed to form a pellet. FTIR spectra were obtained in a region of 400-4000 cm\(^{-1}\). Viscosity was determined according to Spychaj et al with some suitable modifications [10]. 10g of starch was dispersed with 200 ml distilled water and heated to completely gelatinized. Viscosity was measured from 30 to 70 °C with NDJ-8S viscosimeter (China).

2.4.3. Determination of Whiteness Index. Whiteness index was determined by using a Konica Minolta CR-400 and expressed in term of L*, a* and b*. The value of whiteness index was obtained by following equation described in Vargas et al. (2008):

\[
\text{Whiteness} = 100 - [(100 - L*)^2 + a*^2 + b*^2]^{1/2}
\]

where L* is brightness ranges from 0-100, a* is from green to red) and b* is from blue to yellow.

2.4.4. Sensory evaluation. Acceptance of the sensory evaluation was carried out using Abdel-Moemin's description methods (TCVN 3215 - 79). Records from 15 Evaluation Boards is statistical. The indicators of interest in sample are, flavor, texture and overall. Each of these indicators is evaluated at the 5-point scale (1 = very low, poor and 5 = very high, good). The findings were conveyed by definition of the chart and the acceptability point.

2.4.5. Analysis of data. The outcome mean and standard deviation were determined using the Microsoft Excel system (Microsoft Inc., Redmond, WA, USA). The experimental results were evaluated using a one-way variance analysis (ANOVA) study in the Statgraphics system with a significance standard of 5%.
3. Results and discussion

3.1. Approximate composition of starch
Table 2 shows that approximate composition of the jackfruit starch, corn starch, and tapioca starch including moisture, ash, lipid, total protein and carbohydrate. The moisture content of the jackfruit seed starch (8.99±0.24%) was lower than tapioca starch (9.74 ± 0.25%) but higher than corn starch (8.66±0.3%). As long-term storage can reduce the fresh seed quality, the flour form can be an alternative for using in food products [19]. The jackfruit seed starch yield was 21.8 ± 0.7% based on wet basic, which was similar to by Tongdang (18.2%) [20]. This may be due to difference in starch analysis method as well as its botanical properties. Other chemical composition of jackfruit seed starch was not too different for corn starch and tapioca starch. These value are influenced by the analytical process as well as the source of the materials (i.e. geographic distribution, material origin, growing habitat and collection site) [21].

Table 2. Approximate composition of starch samples.

| Parameters    | Jackfruit seed starch | Corn starch | Tapioca starch |
|---------------|-----------------------|-------------|----------------|
| Moisture      | 8.99 ± 0.24           | 8.66 ± 0.30 | 9.74 ± 0.25   |
| Ash           | 0.8 ± 0.11            | 0.69 ± 0.04 | 0.80 ± 0.05   |
| Lipid         | 0.215 ± 0.02          | 0.173 ± 0.01| 0.27 ± 0.01   |
| Total protein | 3.79 ± 0.18           | 2.14 ± 0.25 | 0.67 ± 0.13   |
| Carbohydrate  | 86.21 ± 0.26          | 88.33 ± 0.02| 88.52 ± 0.20  |

3.2. Color of starches
The color parameter of starches include L*, a*, b* and whiteness index (WI%) were presented in Table 3. This L*, a* and b* color space scale is a more visual color scale for measuring color of samples. Lightness value (L*) have ranged from 0 -100 and is characteristic parameter for bright and dark of the sample. L* value of the jackfruit seed starch (96.09±0.04) was lower than corn starch (96.39±0.89) and tapioca starch (97.78±0.45). However, the whiteness index of jackfruit seed starch (89.65±0.08) was higher than corn starch (87.01±0.13) and nearly equal to tapioca starch (90.56±0.12). Due to the difference in genetic, climate, agronomic factors as well as purification in extract starch process [22]. The high whiteness index is an advantage to apply food products such as cakes, edible films and pudding. Based on this result, jackfruit seed starch meets the sensory requirements to become a commercial products.

Table 3. Color parameter of starches.

| Sample              | L*      | a*    | b*    | WI(%)  |
|---------------------|---------|-------|-------|--------|
| Jackfruit seed starch | 96.09±0.04 | -5.33±0.005 | 7.95±0.10 | 89.65±0.08 |
| Corn starch          | 96.93±0.89 | -6.30±0.02 | 10.90±0.16 | 87.01±0.13 |
| Tapioca starch       | 97.78±0.45 | -5.31±0.02 | 7.47±0.02 | 90.56±0.12 |

3.3. Viscosity of starches
Figure 1 presents that the viscosity of starch based on stirring speed and temperature. This result showed that the temperature and the stirring speed of starch increased, the viscosity value decreased. Viscosity value is one of starch's important parameters, because it affects many products' structure and quality. Jackfruit starch had a higher viscosity than corn starch and tapioca starch. This may be explained that the jackfruit seed starch molecules had many hydroxyl group so they can hold more water so their viscosity value was higher [23]. High viscosity is an inherent advantage of starch but it also causes disadvantage. For example, high viscosity and ductility are favorable for textile sizing but it is also difficult to desizing. Therefore, the use of high or low viscosity starches depend on the requirements of the products.
Figure 1. The effect of (a) stirring speed (rpm) and (b) temperature (°C) on starch viscosity.

3.4. Surface morphology and particle size distribution

Figure 2 shows the jackfruit starch, tapioca starch, and corn starch scanning electron micrographs. The tapioca starch and the jackfruit seed starch had the similar grain shape. They had a spheroid form or half-oval with smooth surface. However, the average particle size of tapioca starch (11-13 µm) was larger than the jackfruit seed starch (7–9 µm). Meanwhile, corn starch granules are very triangular in form and have a rough surface with many slight depressions or pores. The average diameter of corn starch was 13-15 µm. Starch has different origins so they have different shape and size of grain which lead to different chemical properties and physical such as viscosity, gelatinization temperature, solubility, methylene blue absorption capacity. The SEM images of this studies was similar to previous reports such as Manchun [24] for tapioca starch, Monika Sujka et al [25] for corn starch and Nisit Kittipongpatana [26] for jackfruit seed starch.

Figure 2. Scanning electron microscopic analysis of (A1-A2) jackfruit seed starch, (B1-B2) tapioca starch and (C1-C2) corn starch at ×5000 and ×1000 magnification
3.5. **Structural evaluation by XRD methods**

The X-ray diffraction (XRD) diagram was presented in Figure 3. According to previous research results, the pattern of crystal structure consist mainly of A-type pattern and B-type pattern and a small V-type pattern [27-29]. Meanwhile, the pattern of A-type starch has theta degree (Θ) is about 15°, 17°, 18° and 26° and a few extra peaks are 9°, 11°, 22°, 23° [30]. The main theta degree (Θ) of B-type is about 50, 140 and 160 and the V-type is 19.80 [31]. The result of Figure 3 noticed that the strong peak theta (Θ) of the jackfruit seed starch was all about 17°, 18° and 23°. Therefore, the crystal structure pattern of these starches was all type A. This is consistent with results of Rengsutthi and Charoenrein showed that the jackfruit seed starch had a type-A crystallinity pattern [32].

![Figure 3](image)

**Figure 3.** X-ray diffraction (XRD) images of jackfruit seed starch, corn starch and tapioca starch.

3.6. **FT-IR spectra**

The results of FTIR infrared spectroscopy of the starch samples within the range from 400 to 4000 cm⁻¹ is presented in Figure 4. This result showed that the typical peaks of starches was not much different, including O-H Alcohol (H-bonded), C-H aldehydes, C-O amide, C-O ester. The stretching vibration of C-O, -OH, -CH group was about 1000-1100 cm⁻¹, 2800-3000 cm⁻¹ and 3000-3500 cm⁻¹, respectively. The presence of the OH group linked to hydrogen, the stretching of C-H alkanes, the stretching of C = O amide and the stretching of C-O ether represented the amylose and amylopectin content of starch and reduced glucose (C₆H₁₀O₅)ₙ [33].

![Figure 4](image)

**Figure 4.** FTIR spectra of jackfruit seed starch, corn starch and tapioca starch.
3.7. Application of jackfruit seed starch on cupcake

The image of cupcake with different starch content of jackfruit seed was presented in Table 4. According to the result of Table 4, the color and texture of cupcake did not differ significantly between ratio of 5% and 15% when comparing to the control cupcake. However, the color of cupcake became darker and it was harder to form the structure of cake at the rate of 20% and 25% of jackfruit seed starch. The interactions of between starch and lipid/protein would affect the batter formulations. The ability of jackfruit seed starch to absorb water and swelling powder was worse than the wheat flour, resulting in lower hydration of the microstructure forming hydrocolloids and thus weakening the batter [34]. Therefore, the texture characteristics of cupcake decreased monotonously with increasing the jackfruit seed starch. This result was identical to that of Guadarrama-Lezama determining the features of sponge cake with native corn in partial or complete substitution of what starch [35].

Table 4. Cupcake with different starch concentration.

|        | Control | 5%    | 10%   | 15%   | 20%   | 25%   |
|--------|---------|-------|-------|-------|-------|-------|
| FIGURE 5 shows the assessment level of cupcake with different starch content of jackfruit seeds. In 15 untrained panelists, evaluate the form, taste, scent and overall requirements. This result showed that the score acceptance of volunteers were tended to decrease when the jackfruit seed starch increased. There was not difference significant about the flavor and aroma when replacing a quantity of wheat flour with jackfruit seed starch. However, the texture was influenced strongly by decreased the wheat flour so it affect the sensory of panelists. These experimental results are analogous to Guadarrma-Lezama et al substitute with corn starch for a partial or whole of wheat flour [36]. The overall and texture score of control sample was similar to sample of 5% and 10%. Therefore, replacing 5-10% of wheat flour into jackfruit seed starch did not affect the quality of cupcake.

| Starch concentration | 0 | 0.5 | 1 | 1.5 | 2 | 2.5 | 3 | 3.5 | 4 | 4.5 | 5 |
|----------------------|---|-----|---|-----|---|-----|---|-----|---|-----|---|
| control              | a |     | c | d   | c |     | d |     | e |     | f |
| 5%                   | a | c   | d |     | c |     | d |     | e |     | f |
| 10%                  | ab| c   | d |     | ef|     | d |     | e |     | f |
| 15%                  | b | c   | d |     | f |     | d |     | e |     | f |
| 20%                  | c |     | d |     | d |     | d |     | e |     | f |
| 25%                  | c |     | d |     | d |     | d |     | e |     | f |

Figure 5. Cupcake Sensory evaluation Chart survey with different jackfruit seed starch content.
4. Conclusion

Jackfruit seed starch has all the essential properties like as commercial starch, it can be impetus to their selection and application in food industry. Any one of the physicochemical properties of seed starch from jackfruit were similar to starch from corn and starch from tapioca. Each type of starch will have its own properties because of their shape of characteristics granules. Their properties may be advantage or disadvantage depending on demand on products. Jackfruit seed starch can used in cupcake formulation. However, addition of higher jackfruit seed starch content (more than 10%) can affect the quality of cupcakes. The color and texture will be changed, resulting in a reduced sensory value of the cupcake. Therefore, it can be suggested that jackfruit seed starch may be used in the production of cupcake at maximum level of 10% without any significantly undesirable effect on the cake overall sensory properties.

Acknowledgments

This study was supported by Tien Giang Department of Science and Technology, Tien Giang province, Vietnam.

Reference

[1] El Halal S L M, Kringel D H, Zavareze E da R and Dias A R G 2019 Starch - Stärke 71 1900128
[2] Mason W R 2009 Starch (Elsevier) pp 745–95
[3] Santana A L, Angela M and Meireles A 2014 Food Public Heal. 4 229–41
[4] Shrinath M, Ramachandrayya A, Haniadka R, Dsouza J and Bhat H P 2011 FRIN 44 1800–11
[5] Tulyathan V, Tananuwong K, Songjinda P and Jaiboon N 2002 ScienceAsia 28 37–41
[6] Lan P, Hai D, Nguyen D, Ha V, Kim Y, Park S, Yoo S, Lee S and Kim Y 2015 Food Sci. Technol. 1–8
[7] Bobbio F O, El-Dash A A, Bobbio P A, and Rodrigues L R 1978 Cereal Chem 55 505 - 511.
[8] Omale J, and Emmanuel T F 2010 International Journal on Pharmaceutical and Biomedical Research 1 54–63
[9] Rossaporn J 2017 Food Research 15 56–62
[10] Williams P A 2009 Carbohydr. Polym. 78 462–8
[11] Prado H J, Matulewicz M C, Bonelli P R and Cukierman A L 2009 Carbohydr. Res. 344 1325–31
[12] Carmona-garcia R, Sanchez-rivera M M and Méndez-montealvo G 2009 Carbohydr. Polym. 76 117–22
[13] Pham T N, Le X T, Nguyen P T N, Tran T H, Dao T P, Nguyen D H, Danh V T and Anh H L T 2020 IOP Conf. Ser. Mater. Sci. Eng. 736 062005
[14] Nguyen N Q, Minh L V, Trieu L H, Bui L M, Lam T D, Hieu V Q, Khang T V and Trung L N Y 2020 IOP Conf. Ser. Mater. Sci. Eng. 736 062017
[15] Thanh V T, Tran N Y T, Linh N T V, Vy T A and Truc T T 2020 IOP Conf. Ser. Mater. Sci. Eng. 736 062015
[16] Nguyen N Q, Nguyen M T, Nguyen V T, Le V M , Trieu L H, Le X T, Khang T V, Giang N T L, Thach N Q and Hung T T 2020 IOP Conf. Ser. Mater. Sci. Eng. 736 022006
[17] Nguyen V T, Le V M, Vo T S, Bui L M, Anh H L T and Danh V T D 2020 IOP Conf. Ser. Mater. Sci. Eng. 736 022013
[18] Ratnayake W S, Wassinger A B and Jackson D S 2007 Cereal Chemistry Journal 84 415–22
[19] Tulyathan V, Tananuwong K, Songjinda P and Jaiboon N 2002 ScienceAsia 28 37
[20] Sobral A, Cristina I and Moraes F 2017 Starch/Stärke 69 11–2
[21] Madruga M S, de Albuquerque F S M, Silva I R A, do Amaral D S, Magnani M and Queiroga Neto V 2014 Food Chemistry 143 440–5
[22] L T, Spychaj T, Zdanowicz M, Kujawa J and Schmidt B 2013 Polimery 58 501–630
[23] Santana R F, Bonomo R C F, Gandolfi O R R, Rodrigues L B, Santos L S, dos Santos Pires A C, de Oliveira C P, da Costa Ilhéu Fontan R and Veloso C M 2018 J Food Sci Technol 55 278–86
[24] Abdel-Moemin A R 2016 Food Sci. Hum. Wellness 5 230–7
[25] Tongdang T 2008 Starch/Starke 60 199–207
[26] Manchun S, Nunthanid J, Limmatvapirat S and Srijamornsak P 2012 Adv. Mater. Res. 506 294–7
[27] Sujka M and Jamroz J 2009 a LWT - Food Sci. Technol. 42 1219–24
[28] Kittipongpatana N, Janta S and Kittipongpatana O 2014 Pharm. Sci. 24 415–20
[29] Taylor P, Chauhan G S, Sharma P and Bains G S 2007 Int. J. Food Prop. 6 37–41
[30] Zobel H F and Illinois U S A 1988 Starch/Starke 40 1–7
[31] Zobel H F, Young S N and Rocca L A 1988 Cereal Chem. 65 443–6
[32] Santana R F, Bonomo R C F, Gandolfi O R R, Rodrigues L B, Santos L S, dos Santos Pires A C, de Oliveira C P, da Costa Ilhéu Fontan R and Veloso C M 2018 J Food Sci Technol 55 278–8
[33] Lubis M, Gana A, Kartika T, Yudhistira B, Riyadi N H and Pangestika A D 2017 J. Phys. 801 0–6
[34] Jiamjariyatam R 2018 Walailak J Sci & Tech 15 879–92
[35] Vernon-carter E J 2016 Food Sci. Technol. 70 46–54
[36] Majzoobi M and S. Hedayati, M. Habibi1, F. Ghiasi and A F 2014 J. Agric. Sci. Technol. 16 569–76