

Physicochemical properties of Venezuelan breadfruit (*Artocarpus altilis*) starch

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SUMMARY. *Artocarpus altilis*, seedless variety, is a fruit-producing plant which is cultivated in Margarita Island, Venezuela, and is consumed by the inhabitants of the region. Its chemical composition and physical characteristics were determined. The chemical (AOAC and AACC methods), physicochemical, morphometric characteristics, viscoamylographic properties and digestibility *in vitro* of starch from *Artocarpus* were studied. The starch yield was 18.5 g/100 g (dw)w with a purity of 98.86%, 27.68 and 72.32% of amylose and amylopectin, respectively. Scanning electron microscopy showed irregular-rounded granules. Swelling power, water absorption and solubility values were determined and found to be higher than that of corn and amaranth starch. The amylographic study showed a gelatinization temperature at 73.3°C, with high stability during heating and cooling cycles. *Artocarpus* starch could also be categorized in the group of mixed short chain branched/long chain branched glucan starches, this agrees with digestibility results that showed a high degree of digestibility *in vitro*. These results might be advantageous in medical and food use.

Keywords: *Artocarpus altilis* starch, chemical composition, physicochemical properties, pasting characteristic.

RESUMEN. Propiedades fisicoquímicas del almidón de *Artocarpus altilis* (pan de año) cultivado en Venezuela. *Artocarpus altilis*, variedad sin semilla, es un fruto cultivado en la isla de Margarita, Venezuela, y consumido por los habitantes de la región. El objetivo de este estudio fue evaluar la composición química y características físicas del fruto (Métodos del AOAC y AACC), y la composición química, características fisicoquímicas, morfométricas, propiedades reológicas y la digestibilidad *in vitro* del almidón aislado de *Artocarpus*. El rendimiento del almidón fue de 18,3 g/100g (bs), con una pureza de 98,86% y un contenido de 27,68% amilosa y 72,32% amilopectina. La microscopía de barrido electrónico mostró gránulos redondeados e irregulares. Los resultados muestran valores de poder de hinchamiento, solubilidad y absorción de agua más elevados que los de almidones de maíz y amaranto. El estudio amilográfico mostró una temperatura de gelatinización de 73,3°C, con una gran estabilidad durante los ciclos de calentamiento y enfriamiento. Asimismo, permite clasificar al almidón en el grupo de glucanos mixtos con ramificaciones de cadena corta y cadena larga; que concuerda con el alto grado de digestibilidad del almidón *in vitro*. Estos resultados podrían ser de utilidad para uso farmacéutico y alimentario.

Palabras clave: Almidón de *Artocarpus altilis*, composición química, propiedades fisicoquímicas, características de "pasting".

INTRODUCTION

The breadfruit (*Artocarpus altilis*), which is native to Polynesia, is a large, round, starchy fruit borne by a tree. The plant belongs to the Moraceae, a family of about 50 general and over 1000 species (1), and was introduced in Venezuela in 1780 as a food for slaves. Breadfruit is also widely distributed in Central and South America including Colombia, Guatemala, Costa Rica and Brasil, the Virgin Islands, Jamaica, St. Vincent, and Pto Rico. There are two varieties, with either seeded or seedless fruits. The seedless fruits are considered a non-conventional food product, consumed and cultivated only in the central and northeastern Venezuela regions, where is known as "pan de año", "pan de name or "topan", in other regions is called "panapen". The seeded fruits are brown and chestnut like. Seedless fruits harvested before complete maturity are consumed boiled or deep-fried as chips. Although many people in other parts of the world have heard of breadfruit, few have eaten it.

Some varieties have been studied and are appreciated for their nutritional properties because they are rich in carbohydrates, lipids and proteins (2-5). Variation in carbohydrate composition (starch content and free sugar) of the fruit of the soft and firm varieties of *Artocarpus heterophyllus* Lam have been reported (5). Free sugars and fatty acid of different parts of jack fruit (*A. heterophyllus*) have been isolated (6). Functional properties (*A. heterophyllus*) seed flour, and the baking properties of *A. altilis* flours have been studied (1-7). Studies on the chemical composition for the seedless and seeded varieties have shown a protein content of 15.10 and 1.70 g/100 g, fat 29.0 and 0.30 g/100 g and moisture 20.20 and 70.80 g/100g respectively (2,7).

Bread prepared with 30 % of *A. altilis* flour did not show any significant difference with bread made with 100 % wheat flour, and a substitution of 10 % gave the best pasting characteristics (1). Nutritional value of composite flours and of the dried meal were evaluated (8), and some of the starch properties obtained from immature fruits have been studied (3).

Although the major commercial sources of starch are cereal grains seeds (maize, wheat, rice), tubers (potato) and certain roots (sweet potato, cassava), several potential non conventional sources have been reported (9-11). One of the potential alternative sources of commercial starch could be the seedless fruit of *A. attilis* due to its high yield.

Literature survey reveals little work on the physical characteristics, chemical properties and digestibility *in vitro* of *A. attilis* starch. Since the chemical composition and physical characteristics of a given starch are typical of its biological origin (12), the purpose of the present study was to characterize this starch and provide information on its composition, morphology, selected physico-chemical characteristics, and assessment of its pasting properties and *in vitro* digestibility.

MATERIALS AND METHODS

Materials

Fifty two samples of immature fruits of *Artocarpus*, seedless variety, were collected in Margarita Island, Venezuela. All analyses were performed with analytical grade reagents, and results expressed as mean \pm standard deviation (SD) of $n=3$.

Morphology, chemical composition and physical characteristics of fruits samples

Fruits of *A. attilis* were analyzed for their physical attributes: morphology, size and weight. Size was evaluated on a representative sample of fruits (100), by measuring length and width using a measuring tape. Fruits were peeled manually and the peeled material (edible portion) was weighed. Yield was calculated from the following equation:

$$\text{Yield} = (\text{wt of edible portion}) / (\text{wt of whole fruit}) \times 100$$

$$\text{Peel fraction} = 100 - \text{Yield}$$

Peeled fruits were sliced and dried in a Labline Imperial oven at 45 °C for 24 h, followed by milling in a Braun food processor to obtain a flour or meal which was sifted through a 60 mesh sieve and stored at room temperature in plastic bags.

Chemical composition of the flour was determined by the AOAC official methods (13). Soluble and insoluble fiber by Mañas and Saura-Calixto method (14).

Starch extraction and chemical composition

Starch extraction was based on that described by Rincón *et al* (10). Briefly, the seedless fruits of *Artocarpus* were washed, peeled and pulp suspended in large quantities of distilled water, blended for 1 min in a Oster blender, at medium speed. The homogenate was filtered through a muslin bag. The filtrate was centrifuged and the supernatant was decanted. The starch was washed several times with distilled water and

dried at 45°C for 24 h, and stored at room temperature in plastic bags. Quantitative evaluation of moisture, ash and nitrogen were performed by the standard methods of the AACC (15). Total lipids were determined by Schoch method (16), and the pH and acidity using Smith method (17).

Apparent amylose content

Quantitative estimation of apparent amylose was determined by the method of Ratnayake *et al* (18), slightly modified. Starch (20 mg, db) was dissolved in 90% dimethylsulfoxide (3 ml) in 10 ml screw-cap reaction vials. The content of the vials was vigorously mixed for 2 min and then heated in a water bath (with intermittent shaking) at 85°C for 15 min. The vials were then cooled to ambient temperature, and the content diluted with water to 25 ml in a volumetric flask and sonicated for 10 min. 1.0 ml of the diluted solution was mixed with 40 ml of water and 5 ml I₂/KI solution (0.0025 M I₂ and 0.0065M KI) and then adjusted to a final volume of 50 ml. The contents were allowed to stand for 15 min at ambient temperature, before absorbance measurements at 600 nm. The amylopectin content was obtained by difference.

Scanning electron microscopy (SEM)

Granule morphology was determined by scanning electron microscopy (SEM), using a Hitachi electron microscope, model S 2400 at 20 kV. Samples were mounted, and the sample holder was sealed with silver paint and coated with gold/palladium at 8-10mA for 10 min, under low pressure less than 10 torr.

Swelling power, solubility and water absorption

Swelling, water absorption, and solubility determinations were carried out at a temperature range of 60 ° to 90 °C. An appropriate amount of the starch (2 g, db) was accurately weighed and quantitatively transferred with distilled water into a dry, 500 ml Pyrex flat bottom flask with three angle necks and t-joints. Sufficient distilled water was added to give 200 ml total suspension volume. A magnetic stir bar was placed inside the flask. The central neck was connected to a reflux condenser, which in turn was attached to a support stand by a single clamp. In the right neck a thermometer was placed attached to a rubber stopper and the left neck was covered with a rubber stopper. The system was placed on a hot, porcelain top, magnetic stirrer and heated from 65 °C up to 95 °C at a uniform rate (1.5 °C/min increments) under constant stirring (75 rpm). At each 10 °C temperature increment, an aliquot of 10 ml was taken and placed into a tared centrifuge tube, and centrifuged 15 minutes at 2200 rpm. Using a glass tube attached to a clean dry suction flask, all supernatant was removed from settled paste. Each solution was transferred to a tared, 50-ml nickel evaporating dish and evaporated to dryness on a steam bath. The dishes were dried for 4 hours in a

vacuum oven at 65 °C, cooled in a desiccator, and weighed. The centrifuge tubes with settled paste were weighed. The following calculations were used:

$$W_1 = [\text{Starch weight (dw)} / \text{Starch weight (fw)} + 200] \times 100$$

$$W_2 = [A \times W_1] / 100$$

$$W_3 = W_2 - b$$

$$\%SS = \text{Soluble Solids} = [b / W_2] \times 100$$

$$WA = \text{Water Absorption (g water/g starch)} = [a - W_3] / W_3$$

$$SP = \text{Swelling Power} = [a \times 100] / W_2 \times (100 - \% S.S.)$$

$$W_1 = \% \text{ Starch (dw) in suspension}$$

$$W_2 = \text{Starch content in each aliquot}$$

$$W_3 = \text{Residual starch in each aliquot (settled paste)}$$

$$A = \text{Weight of aliquot (g)}$$

$$a = \text{Weight of settled paste}$$

$$b = \text{Weight of dry residue}$$

$$dw = \text{Dry weight}$$

$$fw = \text{fresh weight}$$

Results used for calculations were means of triplicate measurements.

Brabender viscosography

A Brabender viscosographic amylogram of a 6.0 g/100 mL slurry was obtained on a Brabender Micro visco-amylograph following the procedure and condition described by the manufacturer. The aqueous starch suspension was heated from 50°C to 95°C, kept at this temperature for 5 min and then cooled to 50 °C and held at this temperature for 1 min. Speed rotor was fixed at 75 rpm and the rate of heating and cooling was 7.5°C.min⁻¹ throughout the range of gelatinization, holding and cooling steps. Amylogram parameters and determination of breakdown and setback points were calculated by the viscosograph program for Windows N° 72300 (software) and analyzed according to Rasper (19). The peak of viscosity (P), hot paste viscosity (H, viscosity after 5 min stirring at 95 °C) and cold paste viscosity (C, viscosity after cooling to 50°C) were recorded. Breakdown (BD) is the viscosity difference between the maximum viscosity (P) and the hot paste viscosity (H). Setback (SB) is the viscosity difference between viscosity at 50°C (C) and viscosity at 95°C (P). Additionally, in order to monitor disintegration behavior upon controlled energy input and accompanied tendencies to reconstitute super molecular glucan structures, Brabender viscosity was determined for 10 % (w/v) aqueous starch suspensions, according to Praznik method (20), with some modification as follows: a heating program from 30 to 90°C, kept at this temperature for 5 min, and then the cooling period started and maintained till the end of the study (22min).

Light transmittance of starch pastes

The light transmittance of starch pastes was carried out

according Hoover *et al* method (21). Starch pastes were prepared at 1% (w/v) by weighing 50mg (db) and suspended in 5ml of water in screw cap tubes and the pH was adjusted by addition of 0.1N HCl or NaOH as required between pH 2 and 14. The tubes were heated in a boiling water bath, with occasional shaking, for 30 min. After cooling to ambient temperature, the transmittance percentage (%T) at 650 nm was determined against a water blank in a Genesis 2 spectrophotometer.

In vitro starch digestibility

Estimation of *in vitro* digestibility by pancreatic α -amylase of *A. altilis* starch was assessed by a colorimetric assay method (22). Percentage of starch hydrolysis was calculated as follows:

$$\% \text{ starch hydrolysis} = \frac{\text{mg glucose}}{\text{mg starch (dry basis)}} \times 0,90 \times 100$$

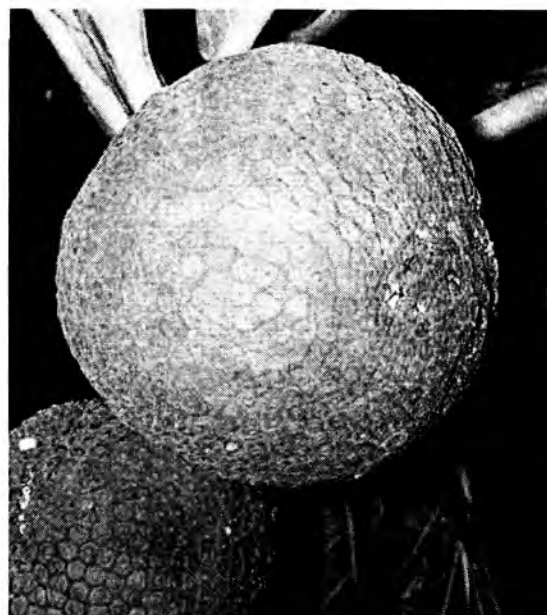
RESULTS AND DISCUSSION

Morphology and physical characteristics of fruits

Breadfruit (*A. altilis*) fruits are round with a smooth surface and a diameter between 12 to 35 cm Figure 1. The whitish to pale yellow pulp presented a weight range of 233.7- 656.6 g. The edible portion was 88.64 g/100 g, and a waste (peel) of 11.36g/100 g.

FIGURE 1

Morphological appearance of *Artocarpus altilis*, seedless variety



Proximal composition

The results are shown in Table 1. The moisture content of the fresh fruits, and the chemical composition of the flour. Carbohydrate content as well as its composition in starch, and fiber: insoluble (lignin, resistant starch, and resistant protein), and soluble (as neutral sugars and uronic acid) are comparable to the results reported for *A. Heterophyllus* (5). Protein content (15.09 g/100 g) is similar to one reported for *A. Heterophyllus* (7), but much higher than the one reported for the same specie (1), and for *A. communis* (8). The soluble and insoluble dietary fiber as well as the starch content were comparable to values reported in different varieties of *A. heterophyllus* (5). The low starch content is probably due to the maturity stage, variety, different climatic and agronomic conditions. Results for protein and soluble and insoluble dietary fiber are likely to make this fruit of nutritional and physiological importance.

TABLE 1

Chemical composition (g/100 g) and some physical characteristics of seedless variety of *Artocarpus altilis* fruit, flour, and starch ¹

Characteristics	Fruit	Flour	Native Starch
Yield			18.50
Moisture	61.08 ± 0.06	10.43 ± 0.06	13.59 ± 0.56
Ash		7.17 ± 0.04	0.47 ± 0.04
Protein (N x 6.25)		15.09 ± 1.58	0.61 ± 0.01
Total lipids		3.04 ± 0.12	0.06 ± 0.01
Insoluble fiber ²		43.67 ± 0.47	
Soluble fiber ³		4.70 ± 0.26	
Total carbohydrates (by difference)			98.86
Apparent amylose			27.68 ± 0.75
Amylopectin (by difference)			72.32
pH			5.51
Titrateable acidity (meq.g ⁻¹)			2.77 x 10 ⁻³
Granule: shape			Irregular, rounded
Diameter (µm) n = 12			3.03 – 7.88

¹ Dry basis and represent means ± standard deviation of n= 3

² Include dietetic fiber, lignin, resistant starch and protein resistant

³ Determined like neutral sugars and uronic acid

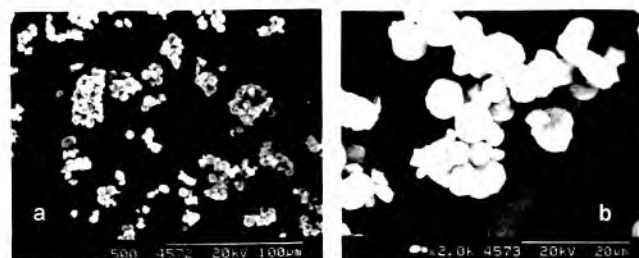
Scanning Electron Microscopy (SEM)

Scanning electron microscopy of *A. altilis* starch granules is presented in Figure 2 (a, b). The starch granules have a rounded irregular shape, with some surface indentations, and a width and length diameter range of 4.24 – 6.67 µm and 3.03 – 7.88 µm, respectively. Indentations might be caused by

compression of small starch granules or protein bodies during the early development stages in the amyloplast. Fissures suggest that the extraction and purification procedure were somewhat drastic.

FIGURE 2

Artocarpus altilis starch granules photomicrographs



Starch chemical composition

Proximate analysis and yield are shown in Table 1, as well as some of the physical properties of the breadfruit starch. 18.50 g/100 g (dw) yield is somewhat low, nevertheless one has to consider that during the extraction and purification procedure there is some loss. The purity of the starch (98.86 g/100) was judged on the basis of composition and microscopic observation. A low protein content of 0.06 g/100 g corroborates this, which is similar to values reported (3). Amylose content was higher than the results presented in the literature (3) for two different varieties of *Artocarpus* (16.4 and 18.2).

Swelling, water absorption and solubility

The results are presented in Table 2. Swelling of starch granules is the first stage in the initiation of changes in hydration related properties. The swelling power of the *A. altilis* starch increased with temperature. This increase was more pronounced within 70 – 80°C, and values are higher than the ones previously reported (3). The swelling power have been related to the associative binding within the starch granule, and apparently, the strength and character of the micellar network is related to the amylose content of the starch; low amylose content, produces high swelling power(23). However, these results are much higher when compared with the ones reported for amaranth (6.57 g/100 g amylose) and corn (17.00 g/100 g amylose) (24). As a result of swelling there is an increment in solubility, showing the highest value at 90°C. These results are also similar to the ones reported for African breadfruit (4). Increased solubility could be

attributed to the amylose content, since the solubilized amylose molecules leach from the swelled starch granules.

TABLE 2
Physicochemical properties of native starch from *A. altilis*
(seedless variety)

Temperature (°C)	Swelling power	Solubility (g/100 g)dw	Water absorption (g/100 g)dw
60	35.7 ± 0.11	2.31 ± 0.17	2.70 ± 0.11
70	46.9 ± 0.35	2.75 ± 0.26	3.69 ± 0.36
80	144.9 ± 0.12	5.28 ± 0.24	13.49 ± 0.13
90	238.1 ± 2.17	8.93 ± 2.8	22.81 ± 2.18

All data represent mean ± standard deviation n = 3

Water absorption capacity and gelatinization temperature are specific for each type of starch, and they depend on several factors such as size of granules, amylose/amylopectin ratio, and intra and inter molecular forces. The breadfruit starch presented a lower absorption of water below 70°C; this can be explained by the slow dispersion that polymers show when they are added to a solvent and the separation and absorption of moisture by particles do not take place before the swelling occurs. This is due to the degree of intermolecular association within the starch granule. Water absorption is also dependent on the size of the starch granule: the smaller the size of the granules, the higher the absorption capacity.

Viscoelastic behavior

In the presence of water and heat, starch granules swell by imbibing water. As the temperature is increased the gelatinization temperature is reached after which a paste is formed. Pasting properties of *Artocarpus* starch are given in Figure 3 and Table 3. According to Brabender viscoamylograph, the gelatinization temperature of a 6.0 g/100 g of *Artocarpus* starch paste was found to be 73.3 °C. This value is higher than that of potato starch (61.6 °C) but much lower than that of maize starch (83.3 °C)(24). The gelatinization temperature depends on the size of the starch granule; small granules are more resistant to rupture and loss of molecular order, so this might explain the relatively high gelatinization temperature. After gelatinization, the viscosity of starch increases markedly, mainly because of lack of water which acts as a lubricant between the swollen granules. The peak viscosity (P) at any concentration is an important distinguishing feature of a given starch from other species of starch. *Artocarpus* starch shows a peak viscosity value of 790 BU. Peak viscosity (P) of *Artocarpus* starch is similar that of *Dioscorea* starch (781 BU)(25) but higher than that of maize starch (302 BU). Viscosities of maize and potato starches decrease during the isothermal holding (24), while for

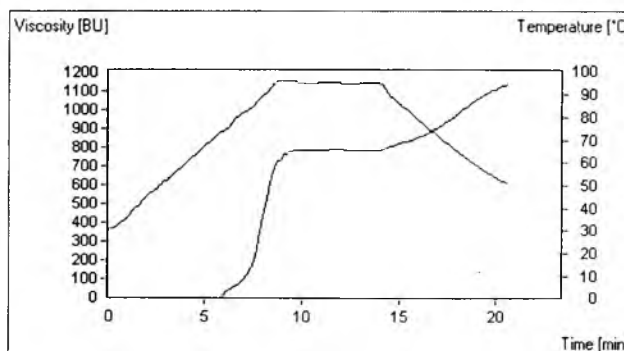
Artocarpus starch viscosity increases during this period. The hot paste viscosity (H) has been attributed to the mixed effect of swollen starch granules, granule fragments, dispersed colloidal starch molecules, molecularly dispersed starch molecules, rate of amylose exudation, and competition between exuded amylose and remaining granules for free water (25). *Artocarpus* starch maintains its structural integrity under shear and heat as the breakdown in hot paste viscosity is only 4 BU, compared to other starches (24,25). *Artocarpus* starch could be used in food products that will require continuous heating like those for children and the elderly. When hot starch paste is cooled, the extent of viscosity increase is governed by the starch retrogradation tendency. This behaviour is largely determined by the affinity of hydroxyl groups of one molecule for another. Amylose molecules being randomly dispersed can orient themselves in parallel fashion to form aggregates of low solubility, leading to gel formation (25). The cold paste viscosity (C: 1091 BU) of *Artocarpus* starch was greater than its corresponding peak of viscosity (P:790 BU). Hence, it may be assumed that on cooling the viscosity of *Artocarpus* starch rises due to the high retrogradation tendency of the amylose fraction.

TABLE 3
Viscographic characteristics of 6.0 g/100 ml *A. altilis*
(seedless variety) native starch. n = 3

Parameter	BU
Gelatinization temperature	73.3 °C
Peak viscosity (P)	790
Hot paste viscosity (H)	786
Cold paste viscosity (C)	1091
Breakdown (P-H)	4
Setback (C-P)	305

BU = Brabender units

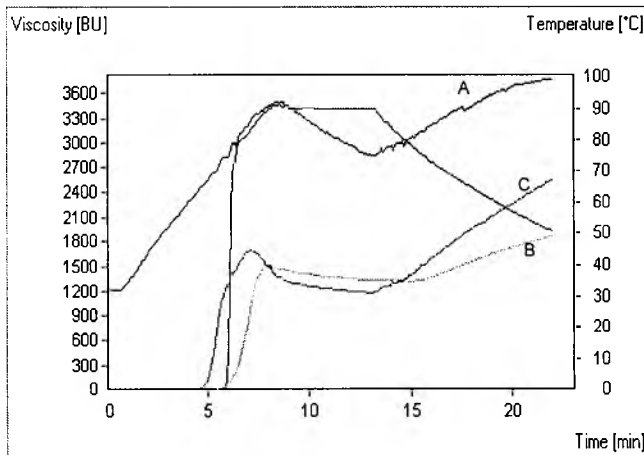
FIGURE 3
Brabender pasting curves for *A. altilis* starch
(seedless variety) at 6.0 % aqueous suspensions



Brabender viscosity was also determined for a 10% suspension, even though such a high concentration is atypical, but it was applied because, for wheat, a reasonable response could be achieved only at such concentration, and it was a way to compare *Artocarpus* starch behavior. This test was introduced to monitor disintegration behavior upon controlled energy input and accompanied tendencies to re-constitute supermolecular structures.

The amylograph (Figure 4) shows that maize starch has a similar disintegration in the initial temperature raising period as does wheat. At similar temperatures maize and wheat disintegrate in a similar way. Further increase in temperature reduced viscosity for wheat by increasing the mobility of disintegrated components. In the cooling period, mobility of glucans is reduced and thus, viscosity smoothly rises again for wheat and with less intensity for maize.

FIGURE 4
Brabender pasting curves for *A. altilis* starch (seedless variety)[A], maize [B], and wheat [C] at 10% aqueous suspensions



Artocarpus starch disintegrates much more strongly, which causes an enormous increase in viscosity. Further increase in temperature produces higher viscosity and disintegration takes place more slowly. Super molecular structures of *Artocarpus* starch are seriously disintegrated, but exhibited a high glucan/glucan interaction potential. In the cooling period viscosity increases indicating a tendency to re-constitute super molecular structures. Similar characteristics were observed for wheat but at lower temperatures.

When comparing these results with those of Praznik *et al.*(20), performance of *Artocarpus* starch could be similar to buckwheat starch, which is categorized on the group of mixed short chain branched/long chain branched glucan starches. When comparison is made taking in consideration [BU] ratio $T_{30^{\circ}\text{C}}/T_{90^{\circ}\text{C}}$ (Table 4) then *Artocarpus* starch (1.39) is similar to quinoa (*Chenopodium quinoa*) (1.5), which is considered by

Praznik *et al.*(20) a short chain branched glucan starch. Further studies should be performed in order to elucidate the real structure of *Artocarpus* starch glucans.

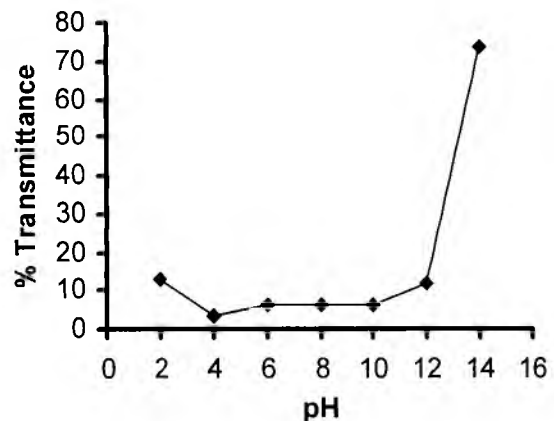
TABLE 4
Brabender viscograph characteristics of 10g/100 mL aqueous starch suspensions of wheat, maize and breadfruit

	Wheat	Breadfruit	Maize
[BU] _{max}	1704	3509	1523
T at [BU] _{max} (°C)	82	90	89
[BU] at the end of T=const=90°C	1177	2860	1336
[BU] end of 90° ->30°C cooling	2550	3971	1874
[BU] ratio $T_{30^{\circ}\text{C}}/T_{90^{\circ}\text{C}}$	2.17	1.39	1.40
Increase in [BU] _{90^{\circ}\text{C} \rightarrow 30^{\circ}\text{C}} (%)	116.65	38.85	40.27

Light transmittance of starch pastes

The results of transmittance (%T) measurement differed at all pH levels. Figure 5. *Artocarpus* starch showed a lower %T at neutral pH compared to the alkaline pH. The starch chains increase their negative charges and association with increasing pH, this effect occurred rapidly between pH 10 and 14. This result is similar to the one reported by Craig *et al* (26). When a beam of light passes through native starch granules, a large proportion of the light is reflected back and the starch appears white and opaque due to the surface of the granule being larger than the wavelength of light (26). These authors proposed that the separation of starch chains during gelatinization decreases the reflection ability of starch granules and thus, increases the %T of starch paste. They also showed that amylose-lipid inclusion complexes decrease the %T of starch paste, and that %T increases with the degree of swelling. These results suggest that *A. altilis* starch might have lipid complexed amylose, since it shows a low %T

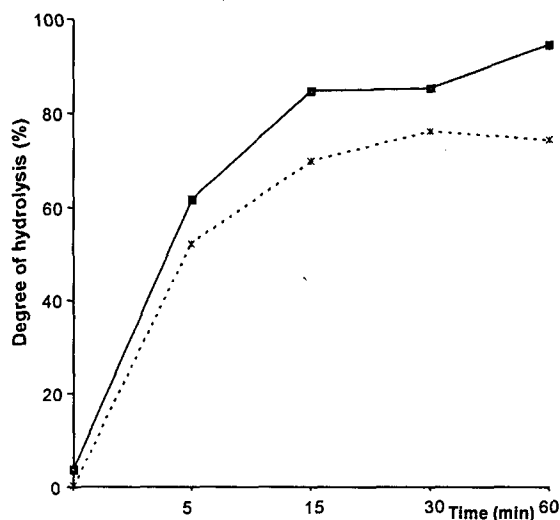
FIGURE 5
Effect of pH on light transmittance of *A. altilis* starch



In vitro digestibility studies

Digestion of starch samples was performed with α -amylase and the results are shown in Figure 6. Digestibility of *Artocarpus* and wheat starches, represented as percentage of hydrolysis at 60 min were 93 and 74% respectively. Digestibility of *Artocarpus* starch was higher than wheat starch. Literature shows that amylose rich starch is difficult to swell or to gelatinize, and it is digested slowly because of higher crystallinity in the structure due to extensive hydrogen bonding (27). Other studies report that retrogradation of amylose in starch generally suppresses the reaction with amylolytic enzymes (28). However, it is believed that the amylose content is not the only factor influencing digestibility and that digestion is a complicated procedure affected by many factors such as amylopectin structure, gelatinizing temperature and phosphorus content besides, the amylose content. A plausible reason for the high digestibility is that the amylopectin in *Artocarpus* starch might contain a larger amount of longer branched chains, which is suggested by the results of the amylo-viscographic study.

FIGURE 6
Artocarpus and wheat starch digestibility



CONCLUSIONS AND RECOMMENDATIONS

From these results it can be concluded that the *A. altilis* (Breadfruit) starch showed a high degree of purity, and has a tendency to retrogradation. The physicochemical and rheological characteristics suggest that this starch could be useful in products that require long heating processes. The excellent digestibility of *Artocarpus* starch might be advantageous for medical and food use.

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