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Physico-chemical properties of native and cross-linked banana starches

(Ciri fizikokimia kanji pisang asli dan kanji pisang rangkaian silang)

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Key words: banana, starch, native, cross-linked, properties

Abstrak

Ekstrak kanji pisang varieti Awak, Embun dan Nangka dirangkai silang dengan menggunakan natrium trimetafosfat. Ciri fizikokimia kanji asli dan kanji rangkaian silang ditentukan. Cirinya dibandingkan dengan ciri kanji pisang yang dikaji di tempat lain. Perbezaannya dengan kanji pisang varieti lain juga dikenal pasti. Keluk viskositi pes kanji tersebut didapati serupa dengan keluk kanji jagung terubahsuai komersial yang disyorkan untuk sos. Viskositi pes kanji asli dan kanji rangkaian silang Embun lebih tinggi daripada viskositi pes kanji varieti Awak dan Nangka. Pengasingan air (sineresis) kanji asli dan kanji rangkaian silang Embun terendah manakala sineresis bagi kanji Nangka tertinggi.

Kanji asli pisang mengandungi lembapan, protein, lemak, abu dan serabut kasar yang rendah. Kandungan amilosanya berjulat antara 33.6% hingga 40.9%. Kandungan sisa fosforus dan fosfat kanji rangkaian silang lebih rendah daripada tahap yang dibenarkan oleh FAO/WHO dan EEC. Kedua-dua kanji asli dan kanji rangkaian silang boleh digunakan sebagai pemekat bagi makanan yang berasid. Akan tetapi kanji rangkaian silang lebih stabil terhadap haba, pH dan ricih.

Abstract

The extracted starches of banana varieties Awak, Cavendish and Nangka were cross-linked with sodium trimetaphosphate. Their physico-chemical properties were determined and compared with banana varieties studied elsewhere. The pasting viscosity curves of banana starches were similar to that of a commercial modified corn starch recommended for sauces. The pasting viscosities of native and cross-linked Cavendish starches were higher than those of the other two varieties. The water separation in native and cross-linked Cavendish starches was the lowest while that of Nangka was the highest.

The native banana starches had low moisture, protein, fat, ash and crude fibre contents. The amylose contents of banana starches were between 33.6% and 40.9%. The residual phosphorus and phosphate contents were lower than the permitted levels specified by FAO/WHO and EEC. Both native and cross-linked banana starches can be used as thickener in acidic foods such as sauces but the cross-linked ones are more stable to heat, pH and shear.

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Introduction

Banana (*Musa* sp.) is the most important Malaysian fruit in terms of production and it ranks second to durian in terms of acreage. In 1996, the total area under banana cultivation in Peninsular Malaysia was 29 214 ha. The production of banana had increased gradually from 231 725 t in 1989 to 372 700 t in 1995 (Anon. 1996). The production is largely for the local market. The popular local dessert cultivars are Pisang Mas, Pisang Embun (Cavendish), Pisang Rastali and Pisang Berangan while the cooking varieties include Pisang Tanduk, Pisang Raja, Pisang Nangka, Pisang Awak and Pisang Abu (Abdullah et al. 1990). The Cavendish, an export variety, is gaining popularity in the country.

Several products can be processed from ripe and green banana. These include puree, juice, powder, flour, starch, flake, alcohol and vinegar (Ling et al. 1982; Jonas 1994; Zainun and Zainon 1994; Chin et al. 1996). Enzymatic processing leads to glucose and fructose syrups.

Very few studies have been carried out on banana starch. Kayisu et al. (1981) found that both the Brabender amylograph and the two-stage swelling patterns of banana starch (*Musa* sp. var. Valery) were similar to those reported for mungbean starch. Ling et al. (1982) determined the physical properties of starch from Cavendish banana *(Musa cavendishii)* and compared it with corn, waxy corn, potato and tapioca starches. Lii and Chang (1991) reviewed banana starch studies in Taiwan. Perez (1997) characterized the starch isolated from plantain *(Musa paradisiaca normalis)* and discovered that the reducing sugar value, gel strength and all the rheological parameters except for the initial gelatinization temperature of the plantain starch were higher than those of corn starch.

This paper relates the physico-chemical properties of native and cross-linked banana starches. These characteristics will determine the suitability of the starches as food ingredient.

Materials and methods

Starch extraction

Three commercially available banana varieties (Awak, Cavendish and Nangka) were used to produce starch. The starches were prepared from green unriped bananas by peeling, chopping, wet grinding, washing several times with water, drying in an oven at 45–50 °C and grinding to 150 µm in size.

Starch modification

The modified or cross-linked starch was prepared by reacting the native starch with sodium trimetaphosphate (0.4% dry weight of native starch) for 8 h at 45 °C and at pH 10.0 *(Figure 1* and *Figure 2).*

Analytical

The colour of the native and modified starches was measured by Chroma Meter CR200 (Minolta Camera Co.) based on the

50% (w/v) aqueous starch suspension
↓
Stir
↓
Heat to 45 °C
↓
Add sodium trimetaphosphate
(0.4% dry weight of starch)
↓
Adjust to pH 10.0 with 1*N* sodium hydroxide
↓
Continue stirring for 8 h
↓
Adjust to pH 6.5 with 1*N* hydrochloric acid
↓
Filter
↓
Wash with distilled water
↓
Filter
↓
Wash with distilled water
↓
Dry at 50 °C
↓
Grind and sieve
↓
Cross-linked starch

Figure 1. Preparation of cross-linked starch

$$2StOH + Na_3P_3O_9 \xrightarrow{\text{Catalyst}} StO\text{-}\overset{\overset{\text{O}}{\text{II}}}{\underset{\underset{\text{ONa}}{\text{I}}}{\text{P}}}\text{-}OSt + Na_2H_2PO_7$$

(Starch) (Sodium tri-metaphosphate) (Phosphate di-starch ester)

Figure 2. Cross-linking of starch with sodium trimetaphosphate

Hunter's system (*L*, *a*, and *b* values). The standard white plate used has the *L*, *a*, and *b* values of 97.83, –0.38 and +1.94 respectively. Chroma was calculated using the formula, $C = \sqrt{[a^2 + b^2]}$ where *a* and *b* are colour values from the Chroma Meter CR200.

The particle size was measured according to the Malaysian Standard (Anon. 1994). The size of the sieve used was 125 µm or 120 mesh.

The starch pasting characteristic was measured using a Brabender amylograph (700 cm-g and at 75 rpm). A 6% (d.b.) starch suspension was used and the cycle involved a heating period from 30 °C to 95 °C, a holding period at 95 °C for 30 min followed by a cooling period to 50 °C. In the determination of pasting characteristic of starches at different pH, the pH of the starch paste was initially adjusted to the desired pH before it was measured by the amylograph.

The moisture, protein, fat, ash, crude fibre and starch contents of the starches were determined according to the AOAC methods (1984). The amylose content was determined using a simplified assay for milled rice amylose (Juliano 1971).

The phosphorus or phosphate residue was determined spectro-photometrically using the Smith and Caruso method (1964). The swelling power of the starch granules at 75, 85 and 95 °C was determined as described by Petersen (1975).

The freeze-thaw cycle of the gelatinized starches was determined as described by Wu and Seib (1990). The starch paste (6% d.b., pH 6.5) which had undergone the heating-cooling cycle in the amylograph was used in the determination. The cooked starches in sealed tubes were held first at 4 °C for 24 h and then subjected to freeze-thaw cycles (–18 °C for 48 h and thawed at 30 °C in a water-bath for 2 h).

Results and discussion

The native and cross-linked banana starches exhibited high degree of whiteness *(Table 1)*. The cross-linked starches of Awak and Nangka varieties were not as white as their native starches while the cross-linked starch of Cavendish variety was whiter than its native starch. The banana starch *(M. paradisiaca normalis)* reported by Perez (1997) was not as white as those in this study.

The pasting viscosity curves of native banana starches (var. Awak, Cavendish and Nangka) resemble the characteristic restricted swelling that is typical of chemically cross-linked starches *(Figure 3)* (Emiola and Delarosa 1981). Unlike native sago, tapioca and sweet potato starches, native banana starches did not have peak viscosities at 6% (d.b.) and were stable during heating and holding period (Khatijah and Patimah 1997a, b). Kayisu et al. (1981) stated that green and ripe banana starch granules (*Musa* sp. var. Valery) swelled very little and resisted mechanical fragmentation at low concentration leading to the absence of peak viscosity. At higher concentration, it demonstrated a pronounced peak viscosity followed by a moderate decrease in viscosity. They found that the peak viscosity at 8% starch concentration was similar to that of tapioca and sago starches, lower than potato and sweet potato starches, but higher than waxy cereal starches.

The pasting viscosities of native and cross-linked Cavendish starches were higher than those of the other two varieties. The pasting viscosities of the cross-linked banana starches increased more gradually than those of their native starches implying that they possess stronger type of bonding forces that are not easily disrupted by shear. The high overall pasting viscosity of banana

Table 1. Colour and particle size of native and cross-linked banana starches*

Variety	Colour				Starch (%) passed through 125 µm sieve
	L (white)	*a (pinkish)*	*b (yellowish)*	*C (chroma)*	
Native starch					
Awak	97.75 ± 0.05	0.20 ± 0.02	1.50 ± 0.02	1.51 ± 0.03	88.1 ± 0.2
Cavendish	88.39 ± 0.08	1.64 ± 0.04	5.91 ± 0.08	6.13 ± 0.08	99.6 ± 0.3
Nangka	97.05 ± 0.11	0.18 ± 0.02	2.57 ± 0.05	2.58 ± 0.05	99.8 ± 0.2
*Musa paradisiaca normalis****	80.0	1.3	13.2		
Cross-linked starch					
Awak	87.72 ± 0.03	1.60 ± 0.02	7.93 ± 0.03	8.09 ± 0.04	–
Cavendish	95.97 ± 0.04	0.23 ± 0.01	2.52 ± 0.03	2.53 ± 0	–
Nangka	86.56 ± 0.04	1.56 ± 0.02	7.32 ± 0.02	8.09 ± 0.02	–

*Mean of two replicates
***Perez (1997)

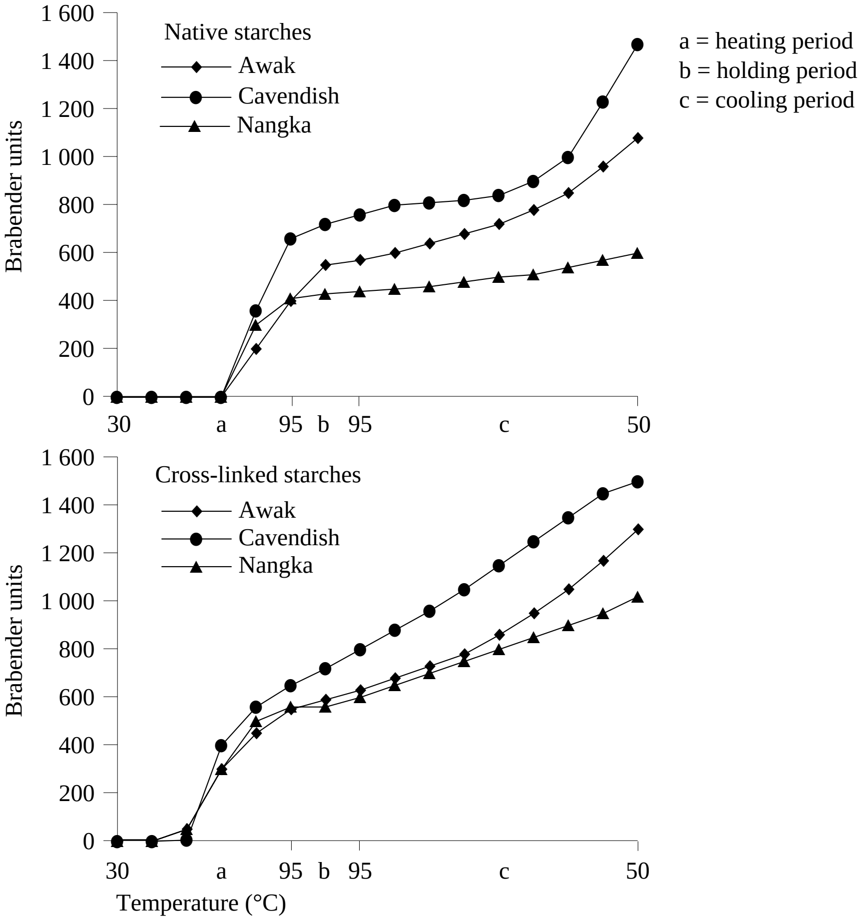

Figure 3. Pasting characteristics of native and cross-linked banana starches (var. Awak, Cavendish and Nangka)

starches is similar to that reported by Perez (1997). Ling et al. (1982) also reported high overall pasting viscosity of banana starch (var. Cavendish) but its pasting viscosity curve differed from those in this study.

The pasting viscosity pattern of a commercial modified corn starch for sauces is similar to that of the banana starches *(Figure 4)*. The gelatinization temperatures of the banana starches ranged from 76.5 °C to 79.1 °C and the time taken for them to gel ranged from 31.0 min to 32.7 min *(Table 2)*. Kayisu et al. (1981) reported that the gelatinization temperature of green and ripe banana starches (*Musa* sp. var. Valery) was 67–70 °C while Perez (1997) reported the initial gelatinization temperature of 59.3 °C and final being 95 °C for banana starch *(M. paradisiaca normalis)*.

The viscosities of native and modified banana starches decreased with a decrease in pH *(Figure 5* and *Figure 6)*. The viscosities of both native Cavendish and Nangka starches increased steadily at pH ≥4.0 indicating absence of a viscosity drop, whereas in the case of native Awak starch, there was no viscosity drop even at pH 3.8. In the case of cross-linked banana starches, the viscosity drop was absent in Awak at pH ≥4.0, Cavendish at pH ≥3.8 and Nangka at pH ≥3.7. This implies that the starches are suitable for acidic foods such as sauces.

The restricted granule swelling power which is usually exhibited by cross-linked

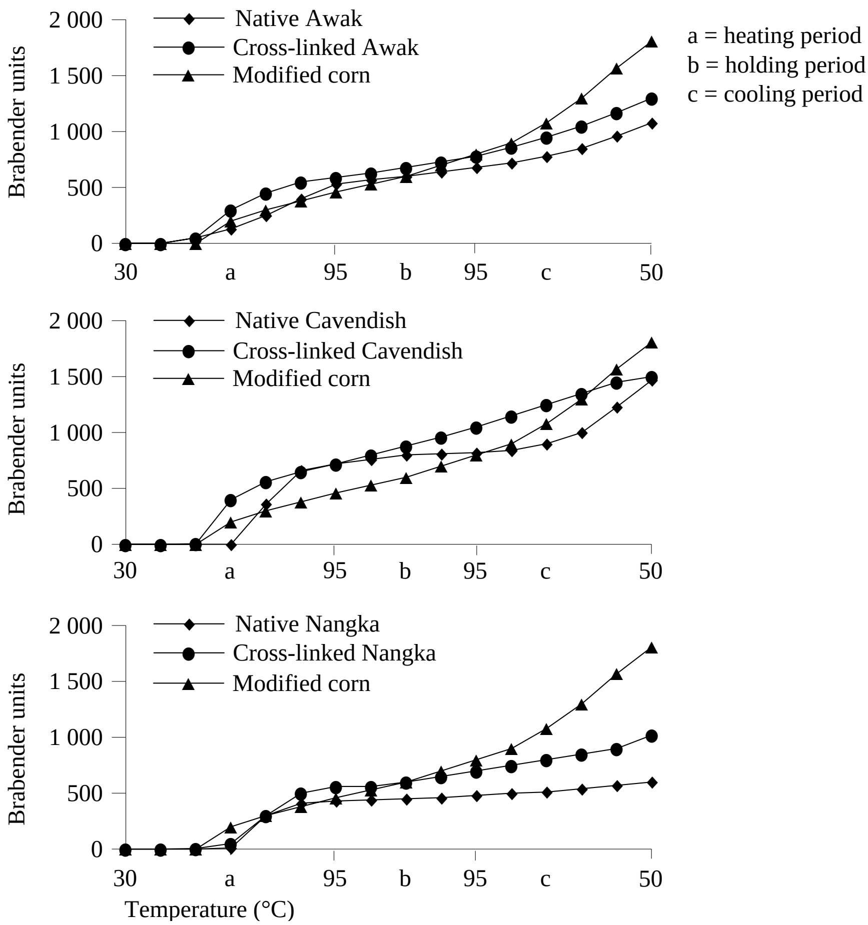

Figure 4. Pasting characteristics of banana (var. Awak, Cavendish and Nangka) and modified corn starches

Table 2. Pasting characteristics of 6% (d.b.) native and cross-linked banana starches*

Variety	Gelatinization temperature (°C)	Time taken to gel (min)	Peak viscosity (B.U.)	Time taken to reach peak viscosity (min)	Viscosity at the end of holding period (B.U.)	Viscosity at 50 °C (B.U.)	Set back (B.U.)	Consistency (B.U.)	Breakdown (B.U.)
Native starch									
Awak	77.4 ± 0.2	31.6 ± 0.1	None	None	610 ± 2	1 080 ± 2	–	470 ± 1	–
Cavendish	76.5 ± 0.3	31.0 ± 0.2	None	None	805 ± 1	1 470 ± 2	–	665 ± 1	–
Nangka	79.1 ± 0.4	32.7 ± 0.2	None	None	463 ± 3	610 ± 4	–	147 ± 3	–
*Musa paradisiaca normalis***	59.3 – 95	–	860	–	860	1 000	140	140	0
Cross-linked starch									
Awak	78.0 ± 0.1	32.0 ± 0.2	None	None	670 ± 3	1 300 ± 3	–	630 ± 1	–
Cavendish	76.5 ± 0.2	31.0 ± 0.1	None	None	840 ± 2	1 500 ± 2	–	660 ± 2	–
Nangka	77.3 ± 0.2	31.5 ± 0.1	None	None	610 ± 2	1 110 ± 2	–	500 ± 2	–

*Mean of two replicates
**Perez (1997)
d.b. = dry basis

Set back = viscosity at 50 °C – peak viscosity
Consistency = viscosity at 50 °C – viscosity at the end of holding period
Breakdown = peak viscosity – viscosity at the end of holding period

Table 3. Chemical properties of three native banana starches*

Variety	pH of aqueous extract	Amylose (%)**	Moisture (%)	Protein (%)	Fat (%)	Ash(%)	Crude fibre (%)
Awak	5.20 ± 0.06	40.9 ± 0.3	4.78 ± 0.2	0.24 ± 0.05	0.12 ± 0.05	0.13 ± 0.04	0.08 ± 0.003
Cavendish	4.82 ± 0.08	33.6 ± 0.5	8.30 ± 0.3	0.49 ± 0.03	1.20 ± 0.03	0.12 ± 0.02	0.04 ± 0
Nangka	4.60 ± 0.05	40.1 ± 0.4	3.00 ± 0.2	–	0.12 ± 0.02	0.12 ± 0.03	0.59 ± 0.001

*Mean of two replicates
**Ajimilah, N. H., Food Technology Centre, MARDI, Serdang, pers. comm. (1996)

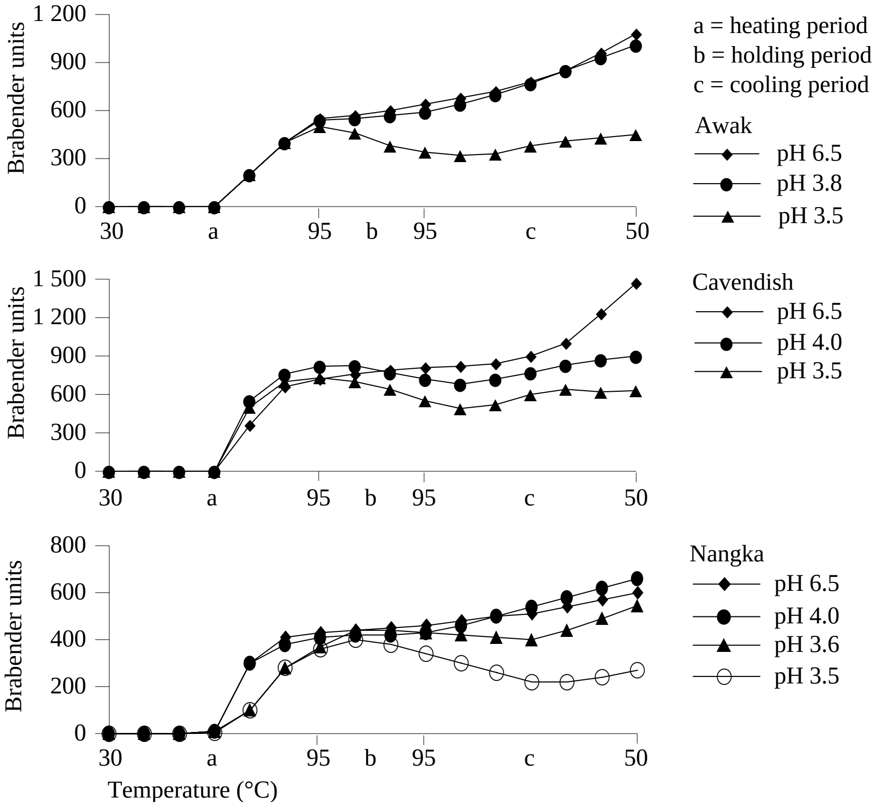

Figure 5. Pasting characteristics of native banana starches (var. Awak, Cavendish and Nangka) at different pH

starches was not well distinguished in the three banana varieties *(Figure 7)*. It could only be seen in the case of Awak.

Syneresis or water separation was observed throughout the freeze-thaw cycles *(Figure 8)*. The water separation in native and cross-linked Cavendish starches was the lowest while that of Nangka was the highest.

The native banana starches had low moisture, protein, fat, ash and crude fibre contents *(Table 3)*. Similar low values had been reported by Kayisu et al. (1981) and Perez (1997). The amylose contents of banana starches were higher than that reported by Ling et al. (1982) for Cavendish, i.e. 19.5%.

The residual phosphorus and phosphate contents of the prepared cross-linked banana starches *(Table 4)* were found to be lower than the permitted levels, i.e. 0.04% phosphorus or 0.11% phosphate, as specified by FAO/WHO and EEC (Trimble 1983; Wurzburg 1986).

Conclusion

The overall study indicates that native banana starches can be used as thickener in acidic foods such as sauces. However, cross-linked banana starches are more stable to heat, pH and shear. The properties exhibited by these starches have positive potential for industrial use. Thus, banana starch can be competitive with other commercial starches provided it has competitive production cost.

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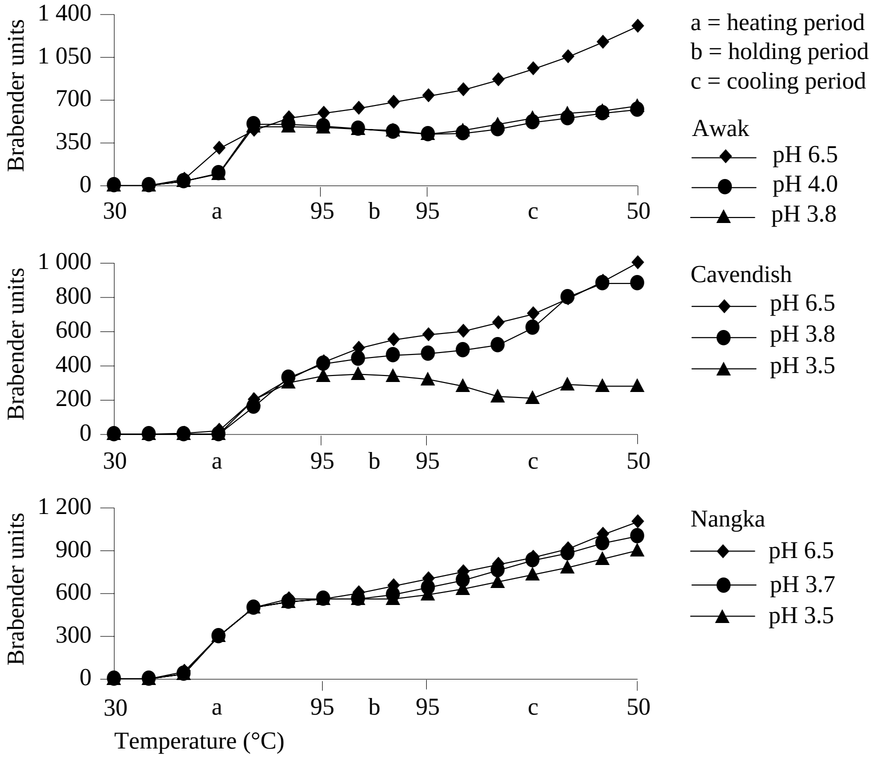

Figure 6. Pasting characteristics of cross-linked banana starches (var. Awak, Cavendish and Nangka) at different pH

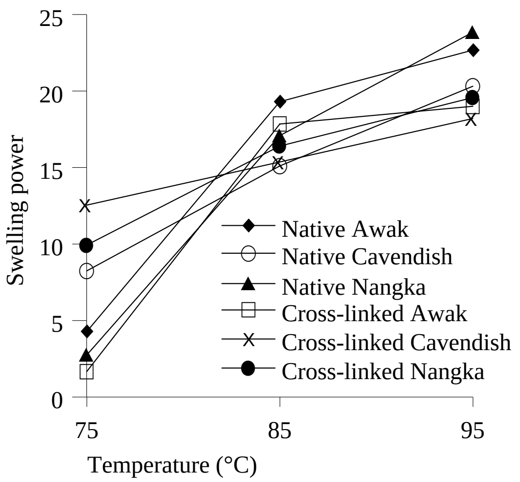

Figure 7. Granule swelling power of native and cross-linked banana starches (var. Awak Cavendish and Nangka) at three temperatures

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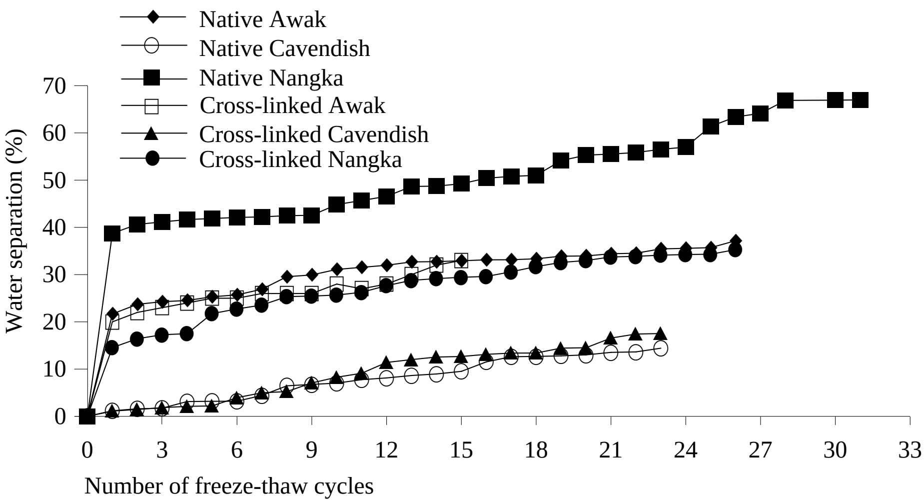

Figure 8. Freeze-thaw cycle of native and cross-linked banana starches (var. Awak, Cavendish and Nangka)

Table 4. Phosphorus and phosphate residues in three cross-linked banana starches

Variety	Residual phosphorus (%)	Residual phosphate (%)
Awak	0.015 ± 0	0.046 ± 0
Cavendish	0.008 ± 0.003	0.025 ± 0.003
Nangka	0.007 ± 0	0.022 ± 0

Values are mean of three replicates

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