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Food Chemistry 91 (2005) 69–77
Food Chemistry
www.elsevier.com/locate/foodchem

Properties of starches from cocoyam (*Xanthosoma sagittifolium*) tubers planted in different seasons

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Received 23 February 2004; received in revised form 25 May 2004; accepted 25 May 2004

Abstract

Starch was extracted from the tubers of two cocoyam (*Xanthosoma sagittifolium*) cultivars (KCX01 and KCX02) planted in three different seasons (summer, winter and spring). Physicochemical properties of the starch were determined in order to investigate the seasonal effect on cocoyam starch. Cocoyam tubers planted in the summer showed higher contents of total starch than tubers planted in other seasons. Starches from both cultivars of cocoyam tubers planted in the summer season had significantly ($p < 0.05$) higher average granule sizes, higher contents of amylose, higher ratios of short-to-long chains of amylopectin, and lower values of the average degree of polymerization (DP) of the chain length distribution profiles. The distinct properties of the fine structure of cocoyam starch from tubers planted in summer season were associated with lower values of onset and peak temperatures and enthalpies of gelatinization.

Keywords: Cocoyam starch; Planting season; Gelatinization thermal properties; Amylose content; HPSEC

1. Introduction

The edible aroid tuber crops, belonging to the family Araceae, are grown throughout the humid tropics for their edible corms and leaves. Traditionally, the Araceae crops planted in Taiwan belong to the *Colocassia* genus and are called taro. *Xanthosoma sagittifolium* (L) Schoot, generally considered to be the main planting species in West Africa, has recently been introduced to Taiwan. The *Xanthosoma* species are collectively known as cocoyam (Hoover, 2001). With starch as its major solid content (Hoover, 2001), cocoyam is a potential source of food and industrial starch that has not been exploited in Taiwan. Cocoyam starch was found to have the typical "A" type X-ray diffraction pattern (Lauzon et al., 1995) with higher pasting temperatures and lower paste viscosity than those of other starches, such as Peruvian carrot and potato starches (Perez, Breene, & Bahnassey, 1998). The average granule size of cocoyam starch from different cultivars of *X. sagittifolium* was reported to range from 12.5 to 14.2 μm, and the amylose content from 21.3% to 25.4% (Lauzon et al., 1995).

Starch properties of many tuber species are affected by environmental factors; Hizukuri (1969) and Nikuni et al. (1969) indicated that starches extracted from tubers grown at higher temperatures had a consistent amylose content but higher pasting temperature. Haase and Plate (1996) found that the total starch and starch phosphorus contents, as well as granule size distributions of starch from different varieties of potato, showed significant

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doi:10.1016/j.foodchem.2004.05.048

variation due to genotype and environment factors, while amylose contents of starch were very consistent. The starch extracted from four varieties of cassava roots, which were harvested on four different occasions, showed granules sizes varying with the seasons and minor differences in the X-ray crystallinity, the amylose content, the proximate composition and the time course of digestion by glucoamylase (Asaoka, Blanshard, & Rickard, 1991). Furthermore, both the genetic variation and environmental condition induced differences in gelatinization temperature, pasting properties and viscoelastic characteristics of cassava starch (Asaoka, Blanshard, & Rickard, 1992). Starch extracted from late-harvested cassava showed a higher peak viscosity, and the dry season had an impact on starch properties as did the immediate onset of the rainy season (Sriroth, Santisopasri, Petchalanuwat, Kurotanawong, & Piyachomkwan, 1999). Noda, Takahata, Sato, Ikoma, and Mochida (1997) found that late planting and late harvesting led to a higher gelatinization temperature and higher peak viscosity of sweet potato starch. Increasing soil temperature from 15 to 33 °C resulted in an increase of amylose content of sweet potato starch and higher onset and peak gelatinization temperature, as well as higher enthalpy of gelatinization. In a comprehensive survey, Tester and Karkalas (2001) indicated that the environmental factors had a very significant influence on the physicochemical properties of starch and, in many cases, these influences were greater than varietal differences or even differences between different species.

Although variability has been reported in the morphological and tuber characteristics (Chang, Yang, & Wang, 1999) and in the physicochemical properties of flour (Chang et al., 1999; Jane et al., 1992) and starch (Jane et al., 1992; Moorthy, Pillai, & Unnikrishnan, 1993; Wang, Wang, & Chang, 1997) from different varieties of cocoyam, compared to other tubers, much less is known about how environmental factors affect starch properties of cocoyam. Therefore, the purpose of this study was to elucidate the effect of planting season on the physicochemical properties of starch. To that end, starches extracted from cocoyam tubers differing in planting seasons were analyzed for purity, amylose content, and their granular, pasting, and molecular properties.

2. Materials and methods

2.1. Materials

Freshly harvested cocoyam (*X. sagittifolium*) tubers from cultivars KCX01 and KCX02 were used in this study. The cocoyam tubers were planted in three seasons (summer, winter and spring) and were raised for 10 months in the Kaohsiung District Agricultural Improvement Station, Kaohsiung, Taiwan.

2.2. Starch isolation

Cocoyam tubers were peeled, weighed, sliced and ground in a commercial blender with triple weight of 0.1% NaOH solution. The homogenate was passed through a 250-mesh sieve, and the filtrate slurry was centrifuged at 3500*g* for 10 min. The sediment was suspended in 0.1% NaOH solution, neutralized with 0.1 N HCl solution, and centrifuged again. The sediment was then suspended in 0.1 M NaCl solution with 10% toluene, stirred overnight at room temperature, and centrifuged to remove the protein. The collected starch was purified by washing with distilled water to completely remove the NaCl, washed with ethanol and air-dried at 40 °C.

2.3. Chemical composition

Total starch content of cocoyam tuber and the crude protein ($N \times 6.25$) and lipid contents of starch were measured according to the AACC methods (2000). Amylose content of starch was determined by iodine potentiometric titration (IPT) (Schoch, 1964). Before evaluation of iodine affinity, the starch was thoroughly defatted for 48 h with 85% methanol by Soxhlet extraction and the sample was dried and pulverized to pass a 60-mesh screen.

2.4. Granule size distribution

The granule size distribution of starch was determined by use of a laser light scattering-based particle size analyzer (Mastersizer Micro, Malvern Instruments, Malvern, UK).

2.5. Pasting properties

Pasting properties of starch was determined by use of a rapid viscoanalyzer (Model 3D$^+$, Newport Scientific, Warriewood, Australia). Each starch suspension (7% w/w, dry basis), with 28 g total weight, was equilibrated at 50 °C for 1 min, heated to 95 °C at a rate of 12 °C/min, maintained at 95 °C for 2.5 min, and then cooled to 50 °C at the same rate. Paddle speed was set at 960 rpm for the first 10 s and then 160 rpm for the rest of the analysis.

2.6. Gelatinization thermal properties

Thermal properties of starch during heating were determined by use of a differential scanning calorimeter (DSC, Micro DSC VII, Setaram, Leon, France). Starch was weighed into the stainless steel sample pan, mixed with distilled water (three times of dry starch weight), sealed and equilibrated at room temperature for 1 h. The samples were heated from 25 to 115 °C at a heating rate of 1.2 °C/min. Onset (T_o), peak (T_p) and conclusion (T_c) temperatures, together with gelatinization enthalpy (ΔH), were quantified.

2.7. Molecular weight distribution

The molecular weight distribution of starch was determined according to the previously reported method (Lin, Lee, & Chang, 2003). Starch (0.75 mg, dry-weight basis) was mixed with 15 ml of 90% dimethyl sulfoxide (DMSO) solution in a boiling water bath for 1 h with constant stirring, and then continuously stirred for 24 h at room temperature. Starch was precipitated from an aliquot of DMSO solution (2.1 ml) with excess absolute ethyl alcohol and centrifuged at 4000*g* for 10 min. The precipitated amorphous starch pellet was solubilized in deionized water (15 ml, 95 °C) and stirred with a magnetic stirrer in a boiling water bath for 30 min. Starch solutions were then filtered through a 5.0 μm syringe filter. The filtrate was injected (100 μl) into a high-performance size exclusion chromatography (HPSEC) system. The system consisted of an HP G1310A isocratic pump (Hewlett Packard, Wilmington, DE), a refractive index (RI) detector (HP 1047A), and a multi-angle laser light-scattering (MALLS) detector (Dawn DSP, Wyatt Tech., Santa Barbara, CA). The columns used were G5000PW and G4000PW (TSK-Gel, Tosoh, Tokyo, Japan) columns connected in series and kept at 70 °C. The mobile phase was 100 mM $NaNO_3$ containing 0.02% sodium azide at a flow rate of 0.5 ml/min.

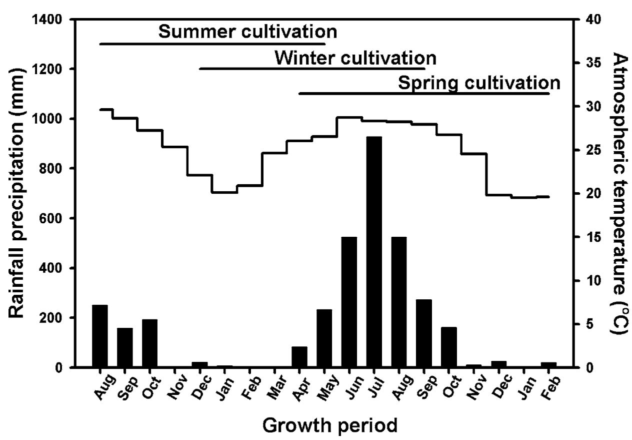

Fig. 1. The rainfall precipitation (vertical bar chart) and the atmospheric temperatures (line plot) during the growth periods of cocoyam tubers.

2.8. Chain-length distribution

Starch debranched with *Pseudomonas* isoamylase (Suzuki, Hizukuri, & Takeda, 1981) was filtered through a 0.45 μm nylon syringe filter, and the chain length distribution of the debranched starch was determined by using the HPSEC system described above, except that the columns used were one G3000PW$_{XL}$ and two G2500PW$_{XL}$ columns (TSK-Gel, Tosoh) (Lin et al., 2003) and the mobile phase was 100 mM phosphate buffer (pH 6.2) containing 0.02% sodium azide solution.

2.9. Statistical analysis

Statistical comparison of means was conducted using the Student's *t* test in a general linear model (GLM) procedure on an SAS system (release 8.2, SAS Institute, Cary, NC).

3. Results and discussion

3.1. Growth

Rainfall precipitation and atmospheric temperatures during the growth periods of cocoyam tubers are shown in Fig. 1. The average atmospheric temperatures were 24.6, 26.4 and 24.8 °C for the summer, winter and spring cultivations, respectively. And the total rainfall of the growth period from the fourth to the tenth months was 344, 2560 and 1920 mm for the planting seasons of summer, winter and spring, respectively. Compared to the substantially constant atmospheric temperature, there was a pronounced difference in the total rainfall

Table 1
Total starch contents of cocoyam tubers and amylose contents of cocoyam starches

Cultivar	Planting season	Total starch (%)	Iodine affinity (%)	Amylose (%)[a]
KCX01	Summer	87.1 ± 0.3a[b]	4.57 ± 0.01a	22.9 ± 0.1a
	Winter	82.1 ± 1.0b	4.24 ± 0.02c	21.2 ± 0.1c
	Spring	78.9 ± 0.8c	4.41 ± 0.03b	22.1 ± 0.2b
KCX02	Summer	87.7 ± 1.5a	4.27 ± 0.08a	21.4 ± 0.5a
	Winter	85.3 ± 1.0b	3.84 ± 0.06b	19.2 ± 0.3b
	Spring	81.1 ± 0.7c	3.62 ± 0.04c	18.1 ± 0.2c

[a] Based on starch. Calculated as: $C = 100 \times IA_S/IA_{amylose}$, where C is the percentage of apparent amylose content and IA_S is the iodine affinity of the whole defatted starch. Iodine affinity for pure amylose was assigned as 20.0%.
[b] Means with different letters in the same column within the same cultivar differ significantly ($p < 0.05$), $n = 3$.

for the growth period from the fourth to the tenth months. The variation in rainfall could lead to significant differences in soil temperature and the immediate environment of the growing tubers (Asaoka et al., 1992).

3.2. Chemical composition

Total starch contents of cocoyam tubers studied ranged from 78.9% to 87.1% and from 81.1% to 87.7% (on dry matter) for KCX01 and KCX02, respectively (Table 1). For both varieties, the total starch contents of cocoyam tubers planted in the summer season were significantly higher than those planted in other seasons ($p < 0.05$). Protein and lipid contents of the isolated starches ranged from 0.04% to 0.06% and from 0.08% to 0.09% (dry-weight basis), respectively.

The amylose content of starch determined by IPT varied from 21.2% to 22.9% and from 18.1% to 21.4% for KCX01 and KCX02, respectively. For both KCX01 and KCX02 cultivars, tubers planted in the summer had the highest amylose content among the three planting seasons studied. Tester, Debon, Davies, and Gidley (1999) reported that the amylose content of potato starch decreased as the growth temperature increased from 10 to 20 °C. However, the amylose content of sweet potato starch increased as the soil temperature changed from 15 to 33 °C (Noda, Kobayashi, & Suda, 2001). Besides the effect of environmental temperature, the amylose content of sweet potato starch was reported significantly higher for wet season crops (Noda et al., 1997); this result was in agreement with the study on cassava starch (Sriroth et al., 1999). The amylose content of cassava starch was also found to be affected by the planting season (Asaoka et al., 1991); however, Defloor, Leuven, and Delcour (1998) indicated that the planting season was apparently not an important parameter in determining the amylose content of cassava starch. The discrepancy of the results implies that influences of environmental factors on the amylose content of starch are complicated.

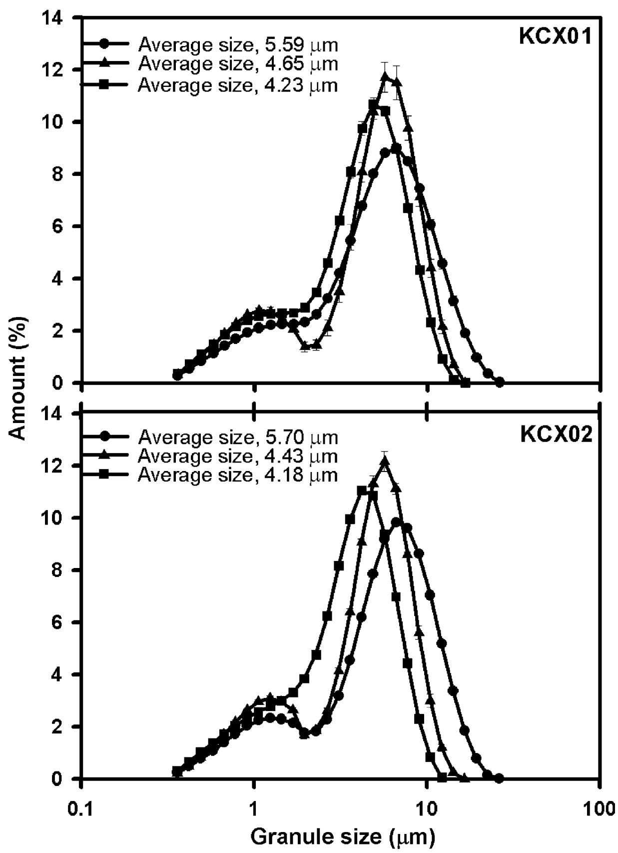

Fig. 2. Granule size distributions of starches from cocoyam tubers planted in summer (●), winter (■), and spring (▲) seasons, respectively.

3.3. Granule size distribution

Fig. 2 shows the granule size distribution of starch. For both KCX01 and KCX02, the starch granule size showed bimodal distributions. The average granule size ranged from 4.23 to 5.59 and 4.18–5.70 µm for KCX01 and KCX02, respectively. The result was consistent with a previous report (Wang et al., 1997); however, it was different from the results of a study on the starch of red and white cocoyam which were reported to have average granule sizes of 14.2 and 12.5 µm, respectively (Lauzon et al., 1995). This discrepancy indicated that

Table 2
Pasting properties of cocoyam starches

Starch	Planting season	Viscosity (cP)				
		Peak	Hot paste	Final	Breakdown	Setback
KCX01	Summer	883 ± 6b[a]	757 ± 4b	1540 ± 10b	126 ± 4b	783 ± 10b
	Winter	917 ± 31b	786 ± 35b	1567 ± 17b	131 ± 4b	781 ± 18b
	Spring	1360 ± 6a	1174 ± 13a	2001 ± 13a	186 ± 10a	827 ± 0a
KCX02	Summer	1508 ± 70b	1111 ± 39a	1749 ± 46a	397 ± 30b	638 ± 7a
	Winter	1171 ± 24c	938 ± 6b	1464 ± 11c	232 ± 30c	526 ± 4b
	Spring	1974 ± 33a	1134 ± 14a	1661 ± 2b	840 ± 30a	527 ± 13b

[a] Means with different letters in the same column within the same cultivar differ significantly ($p < 0.05$), $n = 3$.

the average granule size of cocoyam starch varied with plant species.

Fig. 2 also shows that there was no significant difference between KCX01 and KCX02 in the average granule size of starch from tubers planted in the same season, but there were significant differences ($p < 0.05$) in average granule size among the starches of the same cultivars planted in different seasons. The summer season samples were characterized by a higher population of larger starch granules than those of samples from other seasons. The average granule sizes of the starches from the cocoyam tubers planted in different seasons were in the order: summer > spring > winter.

Although the precise mechanism affecting the size of starch granules is not well understood, Noda et al. (2001) reported that an increase of the average granule size of sweet potato starch occured as soil temperature rose from 15 to 27 °C. However, the average granule size of potato starch decreased from 26.9 to 18.4 μm as growth temperature increased from 16 to 25 °C (Tester et al., 1999). As shown in Fig. 1, in this study, the atmospheric temperature was more or less constant from season to season, but the variation in precipitation might lead to significant differences in soil temperature (Asaoka et al., 1992), which could consequently result in differences of starch granule size.

3.4. Pasting properties

The pasting properties of starches examined by RVA are summarized in Table 2. Peak viscosity of starch ranged from 883 to 1360 and from 1171 to 1974 cP for KCX01 and KCX02, respectively. And the breakdown of KCX01 and KCX02 starches varied within the ranges 126–186 and 232–840 cP, respectively. Among the three planting seasons, starches from both KCX01 and KCX02 tubers planted in the spring were observed to have significantly higher values of peak and breakdown viscosity ($p < 0.05$). The KCX01 starch from tubers planted in the spring also showed higher values of hot paste, final and setback viscosity than those grown in the other seasons. However, a similar trend was not found for the KCX02 starch sample, which had the highest values of final and setback viscosity for starch from tubers planted in the summer.

3.5. Gelatinization thermal properties

Table 3 shows the gelatinization thermal properties of starch determined by DSC. Planting season was found to have a significant effect ($p < 0.05$) on the values of

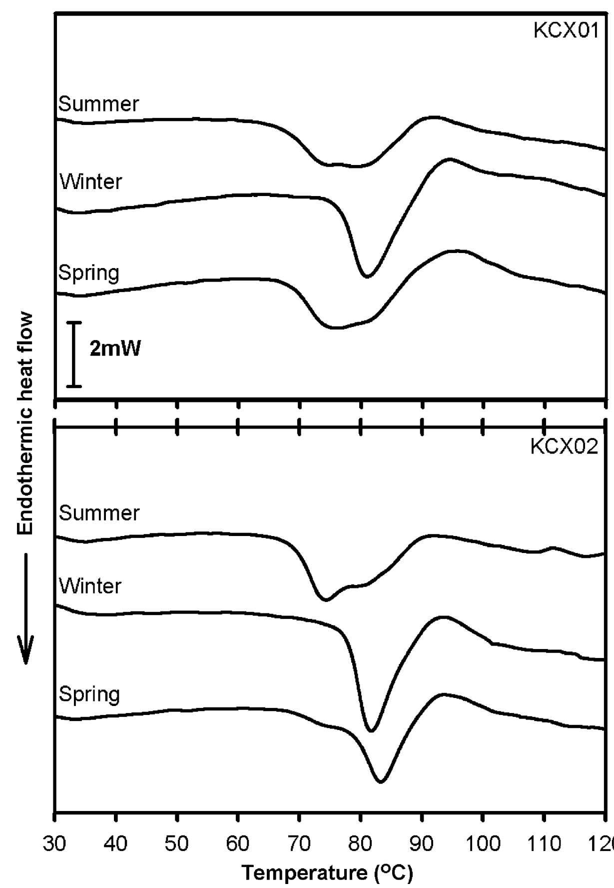

Fig. 3. DSC thermograms of starches from cocoyam tubers planted in different seasons.

Table 3
Gelatinization thermal properties of cocoyam starches

Starch	Planting season	Gelatinization temperature (°C)[a]			T_c–T_o (°C)	ΔH (J/g)[b]
		T_o	T_p	T_c		
KCX01	Summer	68.1 ± 0.0c[c]	76.0 ± 0.1c	88.7 ± 0.2a	20.6 ± 0.2a	16.1 ± 0.0c
	Winter	76.1 ± 0.0a	81.5 ± 0.0a	88.0 ± 0.0b	11.9 ± 0.0b	17.8 ± 0.1a
	Spring	68.3 ± 0.1b	78.5 ± 0.5b	88.7 ± 0.3a	20.4 ± 0.4a	16.5 ± 0.1b
KCX02	Summer	68.7 ± 0.0c	73.8 ± 0.0c	86.6 ± 0.2c	17.9 ± 0.2a	16.3 ± 0.0c
	Winter	77.1 ± 0.1a	81.3 ± 0.4b	87.3 ± 0.3b	10.2 ± 0.3c	18.1 ± 0.1a
	Spring	75.6 ± 0.1b	82.8 ± 0.0a	88.4 ± 0.1a	12.9 ± 0.2b	16.8 ± 0.0b

[a] T_o, onset temperature; T_p, peak temperature; T_c, conclusion temperature.
[b] Enthalpy of gelatinization.
[c] Means with different letters in the same column within the same cultivar differ significantly ($p < 0.05$), $n = 3$.

both T_o and T_p. The starches from the cocoyam tubers planted in the summer had the lowest T_o and T_p and the broadest temperature range (T_c–T_o) among the starches from tubers planted in different seasons. Table 3 also shows that KCX02 starch had higher T_o and narrower temperature range than KCX01 starch of cocoyam tubers planted in the same season. Sriroth et al. (1999) reported that the gelatinization temperature of cassava starch was affected by environmental temperature during growth. However, growth temperature was probably not a key issue in this study as the temperature varied very little during the growth of cocoyam tubers.

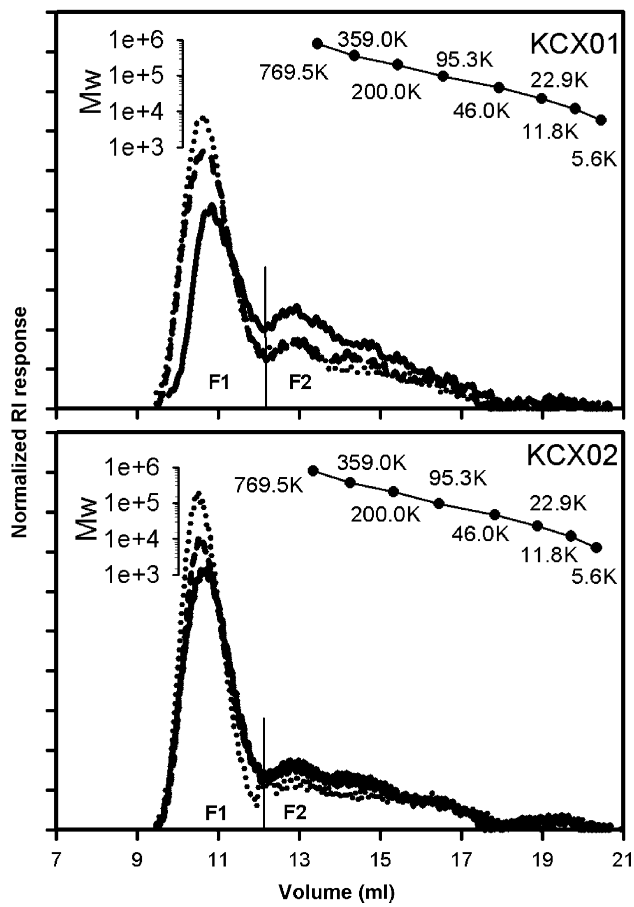

Fig. 4. HPSEC profiles of starches from cocoyam tubers planted in summer (—), winter (---), and spring (···) seasons, respectively.

The gelatinization curve of the starches from the cocoyam tubers planted in the summer and spring showed broad endothermic peaks (Fig. 3), which might have resulted from the presence of two populations of granules or from the existence of two types of molecules within the granules (Yuan, Thompson, & Boyer, 1993). Gelatinization enthalpies (ΔH) of starches varied from 16.1 to 17.8 and from 16.3 to 18.1 J/g for KCX01 and KCX02, respectively. There were significant ($p < 0.05$) differences in the gelatinization enthalpy among the starches from tubers planted in different seasons. The gelatinization enthalpies of the starches from the cocoyam planted in different seasons were in the order: winter > spring > summer. A later planting date was found to enhance the values of gelatinization enthalpies for maize starch (Campbell, Pollak, & White, 1994); conversely, early planting and harvesting generally tended to enhance the gelatinization enthalpy values of sweet potato starch (Noda et al., 1997). The opposite results, that indicate influences of environmental factors on the gelatinization enthalpy of starch, are complicated. Nevertheless, this study provides evidence that manipulating the planting season could control the gelatinization temperature and gelatinization enthalpy of starches from cocoyam.

3.6. Molecular weight distribution

Two fractions, named F1 and F2, were observed in the HPSEC profiles of the cocoyam starches (Fig. 4). The F1 fraction corresponded with the amylopectin, and the F2 to the amylose and low molecular weight molecules of starch. The weight percentage of F1 fraction ranged from 56.4% to 69.6% and from 58.2% to 71.4% for KCX01 and KCX02, respectively (Table 4). Both KCX01 and KCX02 starches from summer cultivations showed significantly ($p < 0.05$) lower values of

Table 4
Distributions and weight-average molecular weight (M_w) of cocoyam starches

Starch	Planting season	Distribution (%, w/w)		M_w	
		F1	F2	F1 ($\times 10^4$ kDa)[a]	F2 ($\times 10^2$ kDa)[b]
KCX01	Summer	56.4 ± 1.3c[c]	43.9 ± 1.0a	7.32 ± 0.19a	6.44 ± 0.27b
	Winter	59.7 ± 1.6b	40.1 ± 2.0b	7.88 ± 0.22a	6.87 ± 0.43ab
	Spring	69.6 ± 0.5a	30.8 ± 2.0c	7.68 ± 1.04a	7.38 ± 0.50a
KCX02	Summer	58.2 ± 2.1c	41.7 ± 1.5a	8.67 ± 1.55a	7.54 ± 0.73a
	Winter	64.1 ± 1.1b	35.9 ± 1.1b	7.99 ± 0.69a	7.27 ± 0.20a
	Spring	71.4 ± 2.3a	28.7 ± 2.1c	8.20 ± 0.72a	8.50 ± 1.24a

[a] Molecular weight determined by light scattering and refractive index detectors.
[b] Molecular weight determined by pullulan standard curve with refractive index detectors.
[c] Means with different letters in the same column within the same cultivar differ significantly ($p < 0.05$), $n = 3$.

the weight percentage of the F1 fraction than did starches from tubers planted in other seasons. Consequently, the weight percentage of the F2 fraction for both starches, ranging from 30.8% to 43.9% and from 28.7% to 41.7% for KCX01 and KCX02, respectively, showed the highest value of starch from tubers planted in the summer.

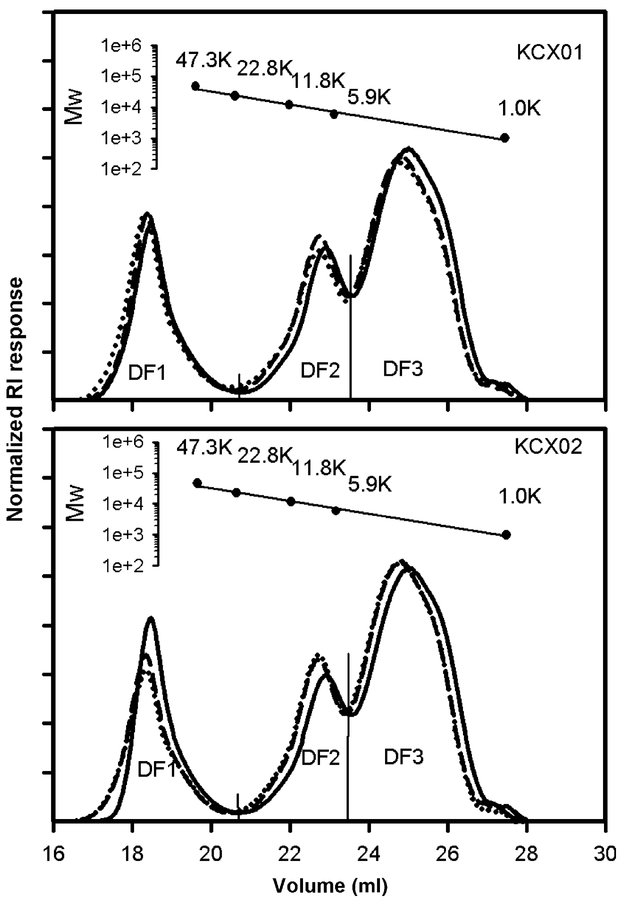

Fig. 5. HPSEC profiles of isoamylase-debranched starches. The starches were from cocoyam tubers planted in summer (—), winter (- - -), and spring (· · ·) seasons, respectively.

Compared to the discrepancy found for the weight percentages of HPSEC fractions of starch planted in different seasons, the average molecular weight of HPSEC fractions of starch, from both KCX01 and KCX02 cocoyams grown in different seasons, were not significantly different (Table 4). It is proposed that the gelatinization properties of starch are controlled in part by the molecular structure, composition and granule architecture (Tester, 1997). As shown in Table 3, the starches from both KCX01 and KCX02 cocoyams planted in the summer, had the lowest values of T_o, T_p and ΔH, which also showed the lowest value of the weight percentage of the F1 fraction and the highest value of the F2 fraction.

3.7. Chain-length distribution

Fig. 5 shows the chain length distribution profiles of starches determined by HPSEC. Each profile showed three peaks and was divided into three fractions accordingly. The fractions of the profiles from low to high elution volume corresponded to amylose (DF1), and long chains (DF2) and short chains (DF3) of amylopectin, respectively. The weight-average degree of polymerization (DP_W) and the weight percentage of each fraction of the samples are summarized in Table 5. The weight percentages of DF1, DF2 and DF3 among the samples were 20.0–23.7%, 19.9–22.3% and 55.0–57.9%, respectively. Starches from both KCX01 and KCX02 cocoyam tubers, planted in the summer, showed a significantly ($p < 0.05$) higher value for the weight percentage of DF1 and lower value for that of DF2 than did those of starches from tubers planted in other seasons, while the planting season was found to have no significant effect on the weight percentage of DF3 among starches from tubers planted in various seasons. The amylose contents of starches from tubers planted in different seasons determined by the HPSEC (Table 5) were greater than those obtained by the IPT method (Table 1). The difference can be attributed to the intermediate components, molecules with branched structures and molecular size smaller than amylopectin, which might elute at

Table 5
Distributions and weight-average degrees of polymerization (DP_W) of debranched cocoyam starches

Starch	Planting season	Distribution (%, w/w)				DP_W		
		DF1	DF2	DF3	DF3/DF2	DF1[a]	DF2[b]	DF3[b]
KCX01	Summer	23.7±0.3a[c]	20.9±0.5b	55.5±0.6a	2.65±0.08a	4053±116b	58.9±1.5b	18.3±0.2b
	Winter	22.4±0.5b	22.3±0.6a	55.3±0.8a	2.48±0.10b	4322±045a	62.7±0.3a	19.6±0.2a
	Spring	22.8±0.3b	22.2±0.5a	55.0±0.8a	2.47±0.10b	4403±138a	64.6±1.1a	19.6±0.1a
KCX02	Summer	22.5±0.3a	19.9±0.3b	57.6±0.2a	2.89±0.04a	3321±017c	57.9±0.4b	18.0±0.2b
	Winter	20.7±0.4b	21.8±0.1a	57.5±0.4a	2.64±0.03b	4150±123b	62.8±0.3a	19.7±0.2a
	Spring	20.0±0.9b	22.0±1.0a	57.9±0.8a	2.64±0.14b	4671±188a	63.9±1.3a	19.8±0.4a

[a] Molecular weight determined by light scattering and refractive index detectors.
[b] Molecular weight determined by pullulan standard curve with refractive index detectors.
[c] Means with different letters in the same column within the same cultivar differ significantly ($p < 0.05$), $n = 3$.

the same time as amylose (Jane et al., 1992). However, results of the two different methods showed the same trend, in that cocoyam tubers planted in the summer had the highest amylose content.

The ratio of DF3/DF2, reflecting the ratio of short-to-long chains of amylopectin, ranged from 2.47 to 2.65 and from 2.64 to 2.89 for KCX01 and KCX02, respectively (Table 5). Starches from both KCX01 and KCX02 cocoyam tubers, planted in the summer, showed higher values of DF3/DF2 and lower DP_W values for all three fractions than did starches planted in other seasons. The distribution of amylopectin chain length was thought to be the primary factor that influenced the starch gelatinization properties (Noda et al., 1998). In this study, the higher DF3/DF2 values of starches planted in the summer did correspond to lower values of T_o, T_p and ΔH (Table 3).

4. Conclusion

Planting season affects the properties of cocoyam tuber starch. Both KCX01 and KCX02 cocoyam tubers planted in summer had higher total starch and amylose contents and larger average granular size of starch than did tubers planted in winter and spring seasons. Among the three planting seasons studied, starches from the cocoyam tubers planted in the summer also had the lowest values of T_o, T_p, and ΔH. The fine structure of starch was also affected by the planting season. Starches planted in the summer showed a significantly higher ratio of DF3/DF2 (short-to-long chains of amylopectin), and lower DP values for the chain length distribution profiles determined by HPSEC. The precise mechanism explaining the seasonal effects on the starch properties remains to be elucidated; however, differences might be due to differences in total rainfall during the growth period (from the fourth to the tenth months) of the tubers.

Acknowledgments

The authors thank the National Science Council, Taiwan, for financial support (NSC 89-2313-B-126-017-A23) and the Kaohsiung District Agricultural Improvement Station, Kaohsiung, Taiwan, for kindly providing cocoyam tubers.

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