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Chemical compositions, fine structure and physicochemical properties of kudzu (*Pueraria lobata*) starches from different regions

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Abstract

Three commercial kudzu starches from Vietnam, Japan and Korea were used to determine chemical compositions, isoflavone compounds, fine structure and physicochemical properties. The kudzu starch from Vietnam had polygonal granules, whereas the kudzu starches from Japan and Korea contained both polygonal and spherical granules. Total protein, lipid, ash and phosphorus contents present in these kudzu starches were less than 1% (starch basis). The kudzu starch from Vietnam and Korea contained both daidzein and daidzin, whereas the kudzu starch from Japan had only daidzein. These starches had similar actual amylose contents (22.2–22.9%). However, λ_{max}, blue value and apparent amylose contents of the kudzu starch from Vietnam were lower than those from Japan and Korea. Amylose molecules of the kudzu starch from Vietnam had the largest average degree of polymerization (DP_n) and number of chains (NC), followed by the kudzu starches from Japan and Korea. Amylopectin molecules of the kudzu starch from Vietnam also had the largest DP_n and NC, followed by the kudzu starches from Korea and Japan. X-ray diffraction patterns of the kudzu starches from Vietnam, Japan and Korea were A-type, C-type and B-type, respectively. The kudzu starch from Vietnam was found to have the specific characteristics such as significantly high gelatinization temperature, transition enthalpy and degree of crystallinity as compared to the kudzu starch from Korea and Japan.

Keywords: Kudzu starch; *Pueraria lobata*; Starch structure; Isoflavone; X-ray diffraction

1. Introduction

Kudzu (*Pueraria lobata*) is a perennial leguminous vine of the genus *Pueraria* native to East Asia. It is believed to have originated in China and is one of the earliest medicinal plants used in traditional Chinese medicine (Keung & Vallee, 1998). The Chinese use primarily the diced and dried root of kudzu as the key ingredient in the medicinal kudzu root tea and have also used it to treat influenza, fever, dysentery, and even snake and insect bites since the earliest times (Shurtleff & Aoyagi, 1977). The root of kudzu (*Radix puerariae*, RP) is reported to contain a number of bioactive isoflavones, e.g. daidzein, daidzin and puerarin (Chen, Zhang, & Ye, 2001; Hirakura et al., 1997; Jiang et al., 2005; Miyazawa, Sakano, Nakamura, & Kosaka, 2001). These isoflavones from *R. puerariae* not only have many important physiological activities such as anti-cancer activity but also have been used to treat alcohol abuse safely and effectively. Starch is also a main composition of the root of kudzu. The yield of starch is about 15–34.2% of the fresh roots (Soni & Agarwal, 1983). The kudzu starch comes in crumbled white clots and has been used in Japan since the ancient times as an indispensable ingredient to make good quality cuisine and as an effective natural medicine. Kudzu starch extracted from tuberous roots in Japan is sold as a health

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food worldwide. In Vietnam, kudzu starch has been traditionally used as a kind of nutritious and natural medicinal drink after suspended with water and sugar without cooking. Because of high physiologically effective values, kudzu starch is more expensive than the other starches. However, until now there are few researches on the chemical and isoflavone compositions, and fine structure as well as on the physicochemical properties of the kudzu starches (Hizukuri, Takeda, Yasuda, & Suzuki, 1981; Kirakosyan et al., 2003; Suzuki, Hizukuri, & Takeda, 1981). The kudzu starch is reported to have 20.8–21% of amylose content and 20.5 of chain length of amylopectin (Suzuki et al., 1981). In addition, Kirakosyan et al. (2003) reported that the commercial kudzu starch, a pure root starch produced in Japan, does not contain any isoflavonoid except very low levels of daidzein. These results were studied on a single cultivar grown in Japan and might not be representative of kudzu starches as a whole because the chemical compositions and starch structure were different depending on each cultivar, growing conditions and isolating methods. Also, although kudzu starch has been sold and consumed throughout the world for both cooking and non-cooking, physicochemical properties of kudzu starch is not yet well understood because very few studies have been carried out so far (Soni & Agarwal, 1983; Suzuki et al., 1981). The objective of this study is to determine and characterize the chemical and isoflavone compositions, fine structure and physicochemical properties of kudzu starches from different regions, which were purely isolated using traditional methods and sold as the commercial products in Vietnam, Japan and Korea. This information is useful to understand well the specific characteristics of kudzu starches.

2. Materials and methods

2.1. Materials

Kudzus (*P. lobata*) grown in Thanh Hoa province of Vietnam, in Nara Prefecture of Japan and in Seoul of Korea were used. All samples were commercial pure products purchased at markets of these regions. Cassava starch was isolated and purified from raw materials at Laboratory of Post-harvest Technology, Hanoi University of Technology, Vietnam.

2.2. Scanning electron microscopy (SEM) of starch granules

Native starch granules were observed using a scanning electron microscope (SEM) according to the procedure of Hung and Morita (2005a). Native kudzu starches were suspended in 95% ethanol and then sprinkled on a double-sided adhesive tape mounted on an aluminum stub. The sample was coated with Pt/Pd and photographs were taken using a SEM apparatus (Hitachi model S-800, Tokyo, Japan) at an accelerating potential of 10 kV.

2.3. Chemical and isoflavone compositions

Protein contents of kudzu starches were determined using a Buchi analysis system (Units B-324 and K-435, Buchi Labortechnik AG, Switzerland) according to the Kjeldahl method. Moisture, lipid and ash contents were determined using the standard AACC International approved methods 44-15A, 08-01 and 30-10, respectively (American Association of Cereal Chemists, 2000). Phosphorus content was determined according to the method of Joint FAO/WHO Expert Committee as previously described by Hung and Morita (2005b).

Isoflavone compounds of kudzu starches were isolated with 10 ml of 80% methanol at 40 °C for 12 h with continuously stirring in a water bath. Daidzein and Daidzin in the extract were analyzed using a Hitachi HPLC system equipped with a L-4200 UV–VIS detector and a L-6200 intelligent pump. The chromatographic separation was carried out on a column of YMC-Pack ODS-AM-303 (YMC Co., Ltd., Japan) using a gradient solvent system comprising of CH_3CN (solvent A) and 0.1% of CH_3COOH (solvent B). Gradient was run from 15%A to 35%A during a 50 min period at a flow rate of 1.0 ml/min. The column was set up on an oven temperature controller at 35 °C. Authentic daidzein and daidzin purchased from Fujicco Co., Ltd. (Kobe, Japan) were used as standards.

2.4. Measurements of iodine absorption, amylose and amylopectin structure

Amylose and amylopectin of starch were fractionated according to the method of Klucinec and Thompson (1998). Iodine absorption spectra of starches, amylose and amylopectin fractions were determined based on the method of Takeda, Takeda, and Hizukuri (1983) with a slight modification as described previously (Hung & Morita, 2005a). Blue values (B.V.) were measured at 680 nm according to the method of Takeda et al. (1983) and amylose contents of starches were calculated as follows: Amylose content (%) = [Blue value (starch−amylopectin)/Blue value (amylose−amylopectin)] × 100; Apparent amylose content (%) = [Blue value (starch)/1.2] × 100. Isoamylolysis of amylose and amylopectin was done according to the procedure of Hizukuri (1985). The number-average degrees of polymerization (DP_n) and the average chain length (CL) after isoamylolysis were determined by the method of Hizukuri et al. (1981). The average number of chains per molecule was calculated as follows: (NC) = $[(DP_n/CL)-1]$ (Hizukuri et al., 1981; Suzuki et al., 1981).

2.5. X-ray diffractions of starches

X-ray diffraction analysis was performed using an X-ray diffractometer (Rigaku Co., Ltd., Rint-2000 type, Tokyo, Japan) operated at 40 kV and 80 mA. Diffractograms were obtained from 4° 2θ to 40° 2θ with a scanning speed of 8°/min and scanning step of 0.02°. The degree of crystallinity (%) of starches was quantitatively estimated according to the method of Nara and Komiya (1983). The crystallinity and amorphous areas on the diffractograms were measured using a Tamaya digital planimeter (Planix 6, Tamaya Technics, Inc., Tokyo, Japan). The ratio of the crystallinity area to the total diffraction area was calculated as the degree of crystallinity (%).

2.6. Thermal characteristics of starches

Thermal characteristics of starch were determined using a differential scanning calorimeter (DSC) (DSC-60, Shimadzu, Japan) (Hung & Morita, 2005a). The sample (3 ± 0.1 mg) was directly weighed into an aluminum vessel and then 10 μl of distilled water was added. The vessel was sealed and kept at room temperature for more than 30 min for equilibration. Then the sample-containing vessel was heated from 30 to 120 °C at a rate of 10 °C/min. An empty vessel was used as a reference. The initial, peak and recovery temperatures and transition enthalpy were determined.

2.7. Pasting properties of starches

Pasting properties of starch suspension (8%, w/v) were tested using an amylograph (Brabender, Germany) as described previously (Hung & Morita, 2005a). The starch slurries were heated from 30 to 93 °C at the rate of 1.5 °C/min. After keeping at 93 °C for 15 min, the starch pastes were cooled to 30 °C at the same rate of 1.5 °C/min and also kept at this temperature for 15 min. The amylograms of the pastes were recorded.

2.8. Statistical analysis

All tests were performed at least in triplicate. Analysis of variance (ANOVA) was performed using Duncan's multiple-range test to compare treatment means at $P < 0.05$ using SPSS software (SPSS Inc., USA).

3. Results and discussion

3.1. Appearances of kudzu starches

The appearances of native kudzu starches from the different regions are shown in Fig. 1. The surfaces of the granules of all samples were smooth with no evidence of cracks. The granules of kudzu starch from Vietnam had the polygonal shapes, whereas the kudzu starches from Japan and Korea had both polygonal- and spherical-shaped granules. Thus, the shape of kudzu starch was different from most of tuber and root starches except only elephant yam and taro starches as reported in a review of Hoover (2001). The kudzu starches exhibited the granular sizes of 2–20 μm. Among them, the kudzu starch from Japan showed the presence of many large-sized granules, followed by that from Vietnam and finally from Korea. Thus, the results showed that the kudzu starches from the different regions had different appearances of granules. The different sizes and shapes of starch granules affect their physicochemical characteristics such as amylose content, gelatinization temperature and pasting properties.

3.2. General compositions

Data of general analysis are shown in Table 1. Moisture contents of the kudzu starches were not significantly different and in a range of 13.4–14.2% of total sample weight. Also, protein and lipid contents (0.14–0.18% and 0.22–0.25%, db, respectively) were not significantly different among the samples. However, kudzu starch from Vietnam showed significantly higher ash content than those from Japan and Korea. Root and tuber starches were found to contain significant amounts of mono phosphate esters covalently bound to starch (Lim, Kasemsuwan, & Jane, 1994; Kasemsuwan & Jane, 1995). Among the tuber and root starches, potato starches contain the largest quantity of organic phosphate followed by taro starch (Hoover, 2001). In this study, levels of phosphorus were similar for kudzu starches from Vietnam and Japan (0.021% and 0.023%, db), which were higher than that from Korea (0.015%, db). Thus, the chemical compositions of kudzu

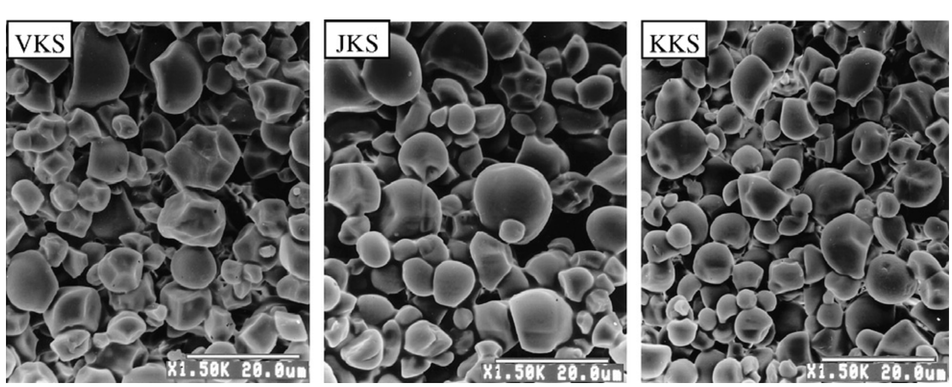

Fig. 1. Scanning electron microscope (SEM) of kudzu starches. VKS, Vietnamese kudzu starch; JKS, Japanese kudzu starch, KKS, Korean kudzu starch.

Table 1
Chemical compositions of kudzu starches[a,b]

Sample	Moisture (% total weight)	Total starch (%, d.b.)	Protein (%, d.b.)	Lipid (%, d.b.)	Ash (%, d.b.)	Phosphorus (mg/100 g starch)	Daidzein (mg/100 g starch)	Daidzin (mg/100 g starch)
VKS	13.4 ± 0.2	99.46 ± 0.09	0.18 ± 0.07	0.25 ± 0.02	0.087 ± 0.002	21 ± 0.1	2.36 ± 0.03	0.21 ± 0.01
JKS	14.2 ± 0.1	99.57 ± 0.08	0.14 ± 0.07	0.22 ± 0.01	0.045 ± 0.007	23 ± 0.1	2.18 ± 0.02	0.00 ± 0.00
KKS	13.7 ± 0.2	99.58 ± 0.06	0.16 ± 0.04	0.20 ± 0.02	0.043 ± 0.006	15 ± 0.1	16.35 ± 0.05	0.06 ± 0.01

[a] VKS, Vietnamese kudzu starch; JKS, Japanese kudzu starch, KKS, Korean kudzu starch.
[b] Values are the mean ± s.d. of duplicate.

starches were different depending on the growing regions and isolating procedures. However, levels of these components were small (<1%) in all kudzu starches. Protein, lipid, ash and phosphorus contents in the commercial kudzu starches may affect the physicochemical properties of the starches.

3.3. Isoflavone contents

Amounts of daidzein and daidzin in the commercial kudzu starches from different regions were determined (Table 1). Amounts of daidzein in the kudzu starches from Vietnam and Japan were similar (2.36 and 2.18 mg/100 g starch, db), while that in the kudzu starch from Korea was significantly higher (16.35 mg/100 g starch). The kudzu starch from Vietnam contained higher level of daidzin (0.21 mg/100 g starch), while the kudzu starch from Korea had lower amount of daidzin (0.06 mg/100 g starch) and the kudzu starch from Japan did not contain any daidzin. The presence of isoflavone compounds contributed to higher nutrition of the kudzu starches rather than other kinds of starches. Daidzein and daidzin were reported to have been used to treat alcohol abuse safely and effectively. In Vietnam, kudzu starch is usually used as a kind of nutritious and natural medicinal drink after suspended with water and sugar without cooking because of its health benefits. Isoflavone compounds (daidzein, genistein, daidzin, genistin and puerarin) were found to exist in all kudzu organs (root, leaf and seed), whereas commercial kudzu starch from Japan contained only low level of daidzein (Kirakosyan et al., 2003). The different levels of isoflavone compounds in the kudzu starches might be caused by the loss of these compounds during isolation of starches from fresh roots. Therefore, it is necessary to improve the isolation method for enhancing the levels of isoflavone compounds in the isolated kudzu starches.

3.4. Iodine absorption spectra, blue value and amylose content

The λ_{max} and blue values of the kudzu starch from Vietnam were significantly lower than those of the kudzu starches from Japan and Korea (Table 2). Actual amylose contents of all kudzu starches were similar (22.2–22.9%) to each other. However, the kudzu starch from Vietnam had lower apparent amylose content than the others. Suzuki et al. (1981) reported that amylose content of kudzu starch was 21%, whereas another study (Soni & Agarwal, 1983) indicated that amylose content of kudzu starch was lower (15.1%). These results might be due to the different cultivars and growing conditions of these starches.

Table 2
Amylose content and fine structure of kudzu starches[a,b]

	VKS	JKS	KKS
Starch			
λ_{max}	583.5 ± 2.2	598.2 ± 2.3	599.8 ± 0.3
Blue value	0.305 ± 0.006	0.384 ± 0.015	0.380 ± 0.018
Amylose (%)	22.2 ± 0.5	22.9 ± 0.0	22.4 ± 1.0
Apparent amylose (%)	25.4 ± 0.5	32.0 ± 1.2	31.7 ± 1.5
Amylose properties			
λ_{max}	623 ± 1.0	627 ± 1.0	628 ± 1.0
Blue value	0.99 ± 0.02	1.19 ± 0.04	1.23 ± 0.02
DP_n	2686 ± 122	2228 ± 108	1906 ± 169
CL	130 ± 9	162 ± 8	236 ± 18
NC	19.7 ± 2.3	12.8 ± 1.1	7.1 ± 0.2
Amylopectin properties			
λ_{max}	531 ± 1.5	534 ± 0.5	531 ± 1.0
Blue value	0.11 ± 0.00	0.14 ± 0.01	0.13 ± 0.00
DP_n	4189 ± 177	2955 ± 84	3424 ± 73
CL	29 ± 2	30 ± 1	28 ± 1
NC	146.1 ± 4.5	98.4 ± 1.8	119.6 ± 7

[a] VKS, Vietnamese kudzu starch; JKS, Japanese kudzu starch; KKS, Korean kudzu starch; DPn, degree of polymerization; CL, chain length; NC, number of chain.
[b] Values are the mean ± s.d., $n = 3$.

3.5. Fine structure of amylose and amylopectin of kudzu starches

Characteristics of amylose molecules fractionated from the kudzu starches are shown in Table 2. The λ_{max} and blue values of amylose molecules of the kudzu starch from Vietnam were lower than those from Japan and Korea. The lower blue value of amylose molecules of kudzu starch from Vietnam was due to the larger number of chains per molecule than the kudzu starches from Japan and Korea. In addition, amylose molecules of kudzu starch from Vietnam had larger degree of polymerization and shorter chain length than the others. The amylose molecules of kudzu starches from Japan and Korea had similar λ_{max} (627–628 nm) and blue value (1.19–1.23). However, the kudzu starch from Korea exhibited lower degree of polymerization, longer chain length and smaller number of chains in the amylose molecules than the kudzu starch from Japan.

Hizukuri et al. (1981) reported that numbers of chains in amylose molecule of potato, tapioca and kudzu starches were 9.5–12.2, 20 and 9.1, respectively. Later, Takeda, Hizukuri, and Juliano (1986) reported that amylose molecules of rice starches were also branched with 2–5 chains per molecule on average. Thus, the kudzu starches had less numbers of chains than potato and cassava starches but more than rice starches. Also, degree of polymerization of the kudzu starches was lower than potato and cassava starches but larger than rice starches. The different fine structures of amylose molecules of the kudzu starches might affect their physicochemical properties as discussion takes place in the next parts.

The fine structure of amylopectin molecules of the kudzu starches is shown in Table 2. The λ_{max} and blue values of amylopectin molecules of the kudzu starches ranged from 531 nm to 534 nm and 0.11 to 0.14, respectively, which were not significantly different among all samples. Degree of polymerization of amylopectin molecules of the kudzu starch from Vietnam was significantly larger than the others, followed by the kudzu starches from Korea and Japan. Amylopectin molecules of the kudzu starch from Vietnam also had more numbers of chains (146.1 chains/molecule) than the others, whereas amylopectin of the kudzu starch from Japan had less numbers of chains (98.4 chains/molecule) than the kudzu starch from Korea (119.6 chains/molecule). The higher degree of polymerization and larger number of chains indicate that the amylopectin molecules of the kudzu starch from Vietnam were larger and more complex than other kinds of kudzu starches. Average chain lengths of amylopectin of the kudzu starches were similar among all samples and in a range of 28–30. Hizukuri (1996) also reported that tuber and root starches had average chain length in a range of 19–44. These results indicate that Vietnamese kudzu starch contained fewer A and B-1 chains and more B-2 and B-3 chains than other kudzu starches.

3.6. X-ray diffractions of starch

The X-ray diffraction patterns of the kudzu and cassava starches are given in Fig. 2. The kudzu starch from Vietnam exhibited A-type crystal as classified by Zobel (1988) with the major peaks 3b (5.8 Å), 4a (5.2 Å), 4b (4.8 Å) and 6a (3.8 Å), while the kudzu starch from Japan exhibited C-type crystal, which is the same as A-type crystal except for the presence of the medium peak 1 (15.8 Å) and lower peak 4b. A previous study also reported that the kudzu starch from Japan had C-type crystal close to A-type crystal (Suzuki et al., 1981). In contrast, the kudzu starch from Korea had the high and sharp peak 4a, no presence of peak 4b, medium peak 1, and medium peaks 6a and 6b (4.0 and 3.7 Å, respectively), which is characteristic of B-type crystal. However, this starch seems to exhibit C-type crystal quite close to B-type crystal because the peak 3a was absent. These results showed the differences in crystallinity of the kudzu starches obtained from the different regions. These differences were due to the weight-average chain length of amylopectin with short, long and medium chains which gives A, B and C patterns, respectively (Zobel, 1988). The kudzu starch from Vietnam was found to have higher degree of polymerization and larger number of chains of amylose and amylopectin molecules, which made the kudzu starch granules more complicated crystallization. In contrast, the kudzu starches from Japan and Korea had less number of chains of amylose molecules and smaller degree of polymerization of amylopectin molecules, which showed C-type crystallization of starch. The results of degree of crystallinity in Table 3 showed the highest degree of crystallinity for the kudzu starch from Vietnam (38.6%) and similar degrees of crystallinity for the kudzu starches from Japan and Korea (35.9% and 35.7%, respectively). Thus, the fine structure of amylose and amylopectin molecules and crystallization of starch granules are different depending on the cultivars and growing conditions. The X-ray diffraction characteristic of the kudzu

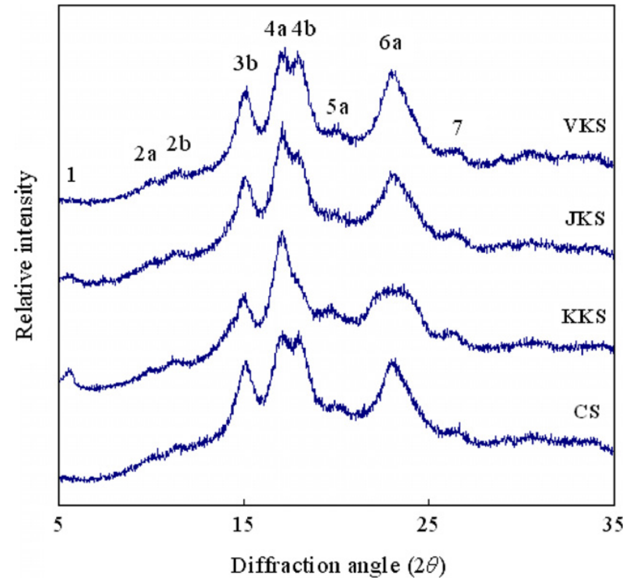

Fig. 2. X-ray diffraction patterns of kudzu starches. VKS, Vietnamese kudzu starch; JKS, Japanese kudzu starch; KKS, Korean kudzu starch; CS, cassava starch.

Table 3
Degree of crystallinity (%) and thermal characteristics of kudzu and cassava starches[a,b]

Sample	Degree of crystallinity (%)[c]	Transition temperature (°C)			Enthalpy (J/g)
		Onset	Peak	Completion	
VKS	38.6 ± 0.5	78.9d	83.4d	88.6d	14.56b
JKS	35.9 ± 0.7	65.3b	72.7c	83.4c	12.03a
KKS	35.7 ± 0.2	57.5a	64.3a	73.0a	11.74a
CS	32.5 ± 0.3	66.2c	71.0b	75.7b	12.44a

[a] VKS, Vietnamese kudzu starch; JKS, Japanese kudzu starch, KKS, Korean kudzu starch; CS, cassava starch.
[b] Means by the same letter in the same column are not significantly different ($P < 0.05$).
[c] Values are the mean ± s.d., $n = 3$.

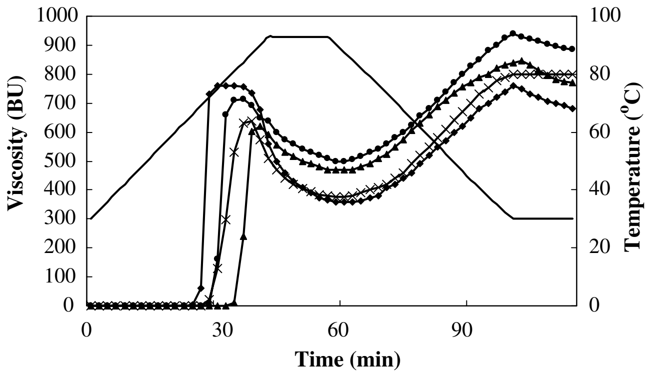

Fig. 3. Amylograms (8% starch, db) of kudzu starches. VKS, Vietnamese kudzu starch; JKS, Japanese kudzu starch, KKS, Korean kudzu starch; CS, cassava starch. –▲–, VKS; –●–, JKS; –×–, KKS; –◇–, CS.

starch from Vietnam is similar to that of cassava starch with A-type crystal. However, degree of crystallinity of the kudzu starches (35.7–38.6%) were higher than those of cassava starch (32.5%) (Table 3).

3.7. Thermal properties

The kudzu starch from Vietnam had specific characteristics such as significantly higher onset, peak and completion temperatures and enthalpy than the other kudzu starches as well as cassava starch (Table 3). These results were due to the difference in amylose and amylopectin structures between the kudzu starch from Vietnam and the other starches. The large number of chains of amylose and amylopectin molecules and the high degree of crystallization showed that the kudzu starch from Vietnam had a complicated structure of granules (both in amorphous and crystalline regions), which require higher energy to gelatinization. The kudzu starches from Japan also had significantly higher onset, peak and completion temperatures than kudzu starch from Korea, whereas the transition enthalpies of these starches were not significantly different. Thus, the different thermal characteristics were caused by the differences in molecular structure of amorphous and crystalline regions of granules, chain length distribution, etc. of these starches (Hoover, 2001; Jane et al., 1999; Sasaki & Matsuki, 1998).

3.8. Pasting properties

The pasting properties of the kudzu and cassava starches are shown in Fig. 3. The paste of the kudzu starch from Vietnam had lower peak viscosity and higher stability during heating and cooling than other kudzu starches. The kudzu starch from Korea had higher peak viscosity, but also had higher breakdown and lower final viscosity than the kudzu starch from Vietnam. The kudzu starch from Japan had the highest peak and final viscosities among all the kudzu starches. The different viscosities of the kudzu starches were affected by the structure and dimension of starch granules. The kudzu starch from Vietnam which had higher branching of amylose and amylopectin molecules and smaller starch granules exhibited lower viscosity than the others. All kudzu starches showed lower peak viscosity than cassava starch. Thus, the results obviously showed the significant differences in pasting properties between the kudzu starches and cassava starch. Therefore, pasting properties of starch are the important indices to distinguish between the pure kudzu starch and its adulterated ones.

4. Conclusion

In this study, the kudzu starches from different regions were characterized for chemical and isoflavone compositions, fine structure and physicochemical properties of starch. All the kudzu starches contained daidzein. In addition, the kudzu starches from Vietnam and Korea also contained daidzin. These compounds have many beneficial effects on health. The actual amylose contents of the kudzu starches were similar (22.2–22.9%). However, the kudzu starch from Vietnam had lower λ_{max}, blue value and apparent amylose contents and significantly higher gelatinization temperature, transition enthalpy and degree of crystallinity than those from Japan and Korea. In addition, X-ray diffraction patterns of the kudzu starches from Vietnam, Japan and Korea were A-type, C-type and B-type, respectively. These differences are inferred to be caused by the different fine structure of these starches. Amylose molecules of the kudzu starch from Vietnam had the largest average degree of polymerization (DP_n) and number of chain (NC), followed by the kudzu starches from Japan and Korea. Amylopectin molecules of the kudzu starch from Vietnam also had the largest DP_n and NC, followed by the kudzu starches from Korea and Japan. In this study, the kudzu starches were also found to have lower viscosity, higher gelatinization temperature and degree of crystallinity than cassava starch. The present findings of the existence of daidzein and daidzin in the kudzu starches and the unique characteristics of these starches would be helpful for practical application in food processing to improve the functionality of end-use products.

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