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Combined effects of planting and harvesting dates on starch properties of sweet potato roots

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Starch was extracted from sweet potato roots differing in planting and harvesting dates. The physicochemical properties of the isolated starches were analyzed. Amylose content was found to be almost independent of both planting and harvesting dates. The proportions of the short chains of amylopectin were lower at the earliest harvesting, while the planting date had little influence on the chain length distribution of amylopectin. Not only the harvesting date but also the planting date were confirmed to have a profound effect on pasting and gelatinization properties determined by rapid viscoanalyzer (RVA) and differential scanning calorimetry (DSC), respectively. Earlier planting and harvesting apparently enhanced the onset and peak temperatures for gelatinization determined by DSC and the pasting temperature determined by RVA. Furthermore, earlier planting and harvesting dates were generally associated with lower peak viscosity determined by RVA. The effect of planting and harvesting dates on the mean size of starch granules, starch granule digestibility by glucoamylases and X-ray diffractograms of starch was also investigated. © 1997 Elsevier Science Ltd

INTRODUCTION

It is important for breeders, farmers and starch users to understand the factors that affect starch characteristics. In general, starch characteristics alter according to the stage of development of the plant of origin. For example, amylose content was lower at an early stage of development of the grains in cereals (Inouchi *et al.*, 1984; Asaoka *et al.*, 1985). Also, in potato, a significant increase in amylose content was found with enlargement of the tubers (Geddes *et al.*, 1965). Contrary to these findings, there was little difference in amylose content during development of tuberous roots in the case of cassava (Asaoka *et al.*, 1991) and sweet potato (Noda *et al.*, 1992c). A decrease in starch granule digestibility by amylase was observed during the development of sweet potato roots (Noda *et al.*, 1992c) and maize grains (Inouchi *et al.*, 1984). The X-ray diffraction pattern and gelatinization temperature were found to be sensitive to environmental temperature during the starch accumulation period (Hizukuri, 1969). Starches exhibiting the C type (a mixture of A and B types) X-ray diffraction pattern (i.e. sweet potato and soybean) changed with decreasing environmental temperature, shifting toward the B type, while those exhibiting A or B type were independent of environmental temperature. The gelatinization temperature was found to increase with elevation of the environmental temperature. Thus, information on the change in starch properties during development of the various plant organs has been accumulated to some extent. However, most of these research studies were carried out using plant materials that were planted on a single date and harvested on a different date. A few reports have been published concerning the effect of planting date on starch properties. According to the report of Helm *et al.* (1968), later planted high-amylose maize showed a slightly increased amylose content. A recent study by Campbell *et al.* (1994) revealed significant increases in peak temperature (T_p) and gelatinization heat (ΔH), determined by differential scanning calorimetry (DSC), with later planting dates. They also found that later planting dates had no influence on amylose content and starch granule size. However, the relationship between starch characteristics and planting date have not been elucidated to date, especially in root crops.

This investigation focuses on the combined effect of planting and harvesting date on starch properties from sweet potato roots. We have extensively surveyed the starches extracted from sweet potato roots differing in planting and harvesting dates in relation to their granular, molecular and pasting properties.

MATERIALS AND METHODS

Starch samples

The purple fleshed cultivar, Ayamurasaki, and the orange fleshed candidate cultivar, Kyushu No. 120, were used in this study. The cultivars were grown at the Kyushu National Agricultural Experiment Station at Miyakonojo, Miyazaki. The plant materials were planted and harvested on the dates listed in Table 1. A compound fertilizer (60 kg per 10a, $N:P_2O_5:K_2O = 2:3:5$) and compost (1 t per 10a) were applied before transplanting. At least 20 plants were sampled at each sampling. Each plant had about five roots. The weight of all roots was measured. A composite sample of 8–12 medium sized roots was used for starch extraction and determination of starch content. Each root was peeled and cut into small pieces for freeze drying. The freeze dried samples were milled until they passed through a 500 μm sieve. Starch was extracted from each sample as follows. The sweet potato floury samples were suspended in distilled water and passed through a 62μm sieve. The filtrate, a starch suspension, was allowed to stand. Starch granules were recovered from the extract by decantation. The starch was washed successively with distilled water twice, with ethanol and acetone, and air dried.

Analytical methods

The starch content was determined using the modified method of McCready *et al.* (1950), as described previously (Noda *et al.*, 1992b). Starch granule size was measured by an image analyzer (Excel-II, Nippon Avionics Co., Tokyo) attached to a light microscope (Microphot-FXA, Nikon Co., Tokyo), as described elsewhere (Noda *et al.*, 1992a). Amylose content was calculated from the blue value at 680 nm according to the method reported previously (Noda *et al.*, 1992a). The enzymatic digestibility of raw starch by crude glucoamylase of *Rhizopus* sp. and crystalline glucoamylase of *Rhizopus niveus* was studied as described elsewhere (Noda *et al.*, 1992b). X-ray diffraction patterns of the starches were recorded on a Mini Flex X-ray diffractometer (Rigaku-denki Co., Tokyo), as reported previously (Noda *et al.*, 1995b). Rapid viscoanalyzer (RVA) measurements were conducted using the RVA-3D (Newport Scientific Pty. Ltd, Australia), as reported previously (Noda *et al.*, 1995b). Each starch was hydrolyzed with *Pseudomonas amyloderamosa* isoamylase, as described earlier (Noda *et al.*, 1995a), and the fractionation of linear maltosaccharides was performed by high performance anion exchange chromatography (HPAEC) using a Dionex BioLC system (Dionex Co., Sunnyvale, CA) equipped with pulsed amperometric detection (PAD) and a CarboPac PA1 Column (4×250 mm), as Koizumi *et al.* (1991) reported. Differential scanning calorimetry (DSC) measurements were carried out using a Perkin-Elmer DSC-7 analyzer (Perkin-Elmer Co., Norwalk, CT). Approximately 3 mg of starch (dry weight basis) was weighed into an aluminum sample pan. Distilled water was added to give a starch concentration of 30% (dry weight basis). The pan was hermetically sealed with a sample sealer. An empty pan was used as the reference. Samples were heated from 30 to 100°C at a rate of 10°C/min. The onset (T_o) and peak (T_p) temperatures and gelatinization heat (ΔH) were computed automatically. The gelatinization range (R) was calculated as $2(T_p - T_o)$, as previously described by Krueger *et al.* (1987).

RESULTS

Table 2 shows the effects of planting and harvesting dates on mean root weight and some fundamental

Table 1. Sweet potato samples used in this study

Cultivar	Planting date	Harvesting date	Abbreviation
Ayamurasaki	20 May	5 September	AM May–Sep
Ayamurasaki	20 May	3 October	AM May–Oct
Ayamurasaki	20 May	1 November	AM May–Nov
Ayamurasaki	10 June	1 November	AM Jun–Nov
Ayamurasaki	4 July	1 November	AM Jul–Nov
Kyushu No. 120	20 May	5 September	K120 May–Sep
Kyushu No. 120	20 May	3 October	K120 May–Oct
Kyushu No. 120	20 May	1 November	K120 May–Nov
Kyushu No. 120	10 June	1 November	K120 Jun–Nov
Kyushu No. 120	4 July	1 November	K120 Jul–Nov

Table 2. Analysis data of starches from sweet potato roots differing in planting and harvesting dates

Sample	Mean weight of roots (g)[a]	Starch content (%)[b]	Mean granule size (μm)[c]	Amylose content (%)[d]
AM May–Sep	109	24.2	12.5	16.5
AM May–Oct	130	32.0	12.8	16.6
AM May–Nov	174	31.4	14.0	15.7
AM Jun–Nov	152	30.2	13.7	16.1
AM Jul–Nov	107	30.8	12.1	15.4
K120 May–Sep	106	21.9	11.0	21.6
K120 May–Oct	173	17.3	12.4	21.1
K120 May–Nov	158	17.7	12.4	20.1
K120 Jun–Nov	164	19.7	12.4	19.7
K120 Jul–Nov	144	18.9	12.0	19.0

[a] Values are means of approximately 100 roots.
[b] Values are means of four determinations. Standard deviation ±1.3%.
[c] Measured by an image analyzer attached to a light microscope on approximately 1200 granules.
[d] Values are means of three determinations. Standard deviation ±0.7%.

starch characteristics for the two sweet potatoes, Ayamurasaki and Kyushu No. 120. Harvesting date had a significant effect on mean root weight, which increased with a later harvesting date. Compared to the samples planted on a single date (20 May), the mean weight of the root harvested on 5 September was 37.4% and 32.9% lower than the mean weight of that harvested on 1 November for Ayamurasaki and Kyushu No. 120, respectively. Early planting increased the mean root weight significantly for Ayamurasaki, while such a tendency was not clearly observed for Kyushu. No. 120. Ayamurasaki contained about a 1.7-fold greater amount of starch (24.2–32.0%) than Kyushu No.120 (17.3–21.9%). The starch content of Ayamurasaki was lowest for the earliest harvesting and was independent of the planting date. The lowest content (24.2%) was about 0.8 times those of others (30.2–32.6%). In contrast, early harvesting reduced the starch content for Kyushu No. 120. The distributions of the mean granule size of the Ayamurasaki and Kyushu No. 120 starches were found to be respectively 12.1–14.0 μm and 11.0–12.4 μm. Mean granule size increased with a later harvesting date. Later planting led to a reduction in mean granule size for Ayamurasaki, while such a reduction was not detected for Kyushu No. 120. The amylose content was apparently higher in Kyushu No. 120 (19.0–21.6%) than in Ayamurasaki (15.4–16.6%). Differences in amylose content from altering planting and harvesting dates were not significant.

Digestibility of starch granules by crude glucoamylase of *Rhizopus* sp. and crystalline glucoamylase of *Rhizopus niveus* is presented in Fig. 1. Both glucoamylases used are well known for their higher affinity for starch granules. Crude glucoamylase preparation of *Rhizopus* sp. contained α-amylase, which stimulates raw starch digestion by glucoamylase (Noda *et al.*, 1992a). Raw starch hydrolysis was conducted at 40°C for 4 h with a substrate concentration of 2.0%. In the case of digestion of crude glucoamylase, earlier harvesting and later planting resulted in a higher hydrolysis rate for Kyushu No. 120. On the other hand, the hydrolysis rate of starch granules from Ayamurasaki remained almost constant, irrespective of planting and harvesting dates.

When crystalline glucoamylase was used, Ayamurasaki exhibited a somewhat higher hydrolysis rate (4.29–4.65%) than Kyushu No. 120 (3.83–4.31%).

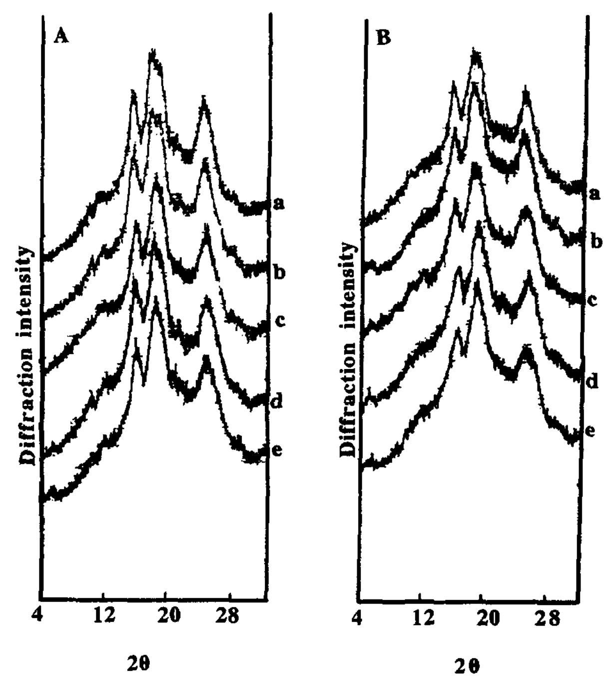

Fig. 1. X-ray diffraction patterns of starches from sweet potato roots differing in planting and harvesting dates. (A) Ayamurasaki; (B) Kyushu No. 120; (a) planted on 20 May and harvested on 5 September; (b) planted on 20 May and harvested on 3 October; (c) planted on 20 May and harvested on 1 November; (d) planted on 10 June and harvested on 1 November; (e) planted on 4 July and harvested on 1 November.

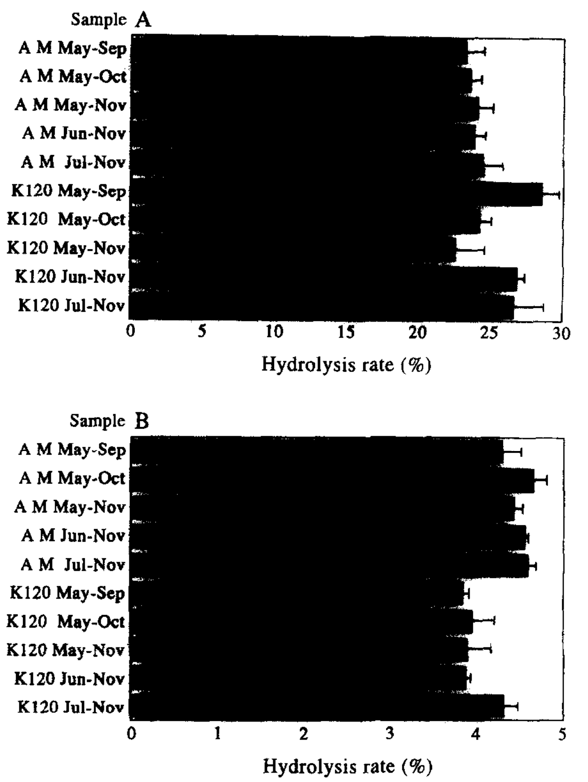

Fig. 2. Enzymatic digestibility of starch granules from sweet potato roots differing in planting and harvesting dates, by crude (A) and crystalline (B) glucoamylases. Results are expressed as means±standard errors of four determinations.

The effect of harvesting date on the hydrolysis rate was not important. Except in the case of Kyushu No. 120, the hydrolysis rate was highest for the latest planting.

Figure 2 shows the X-ray diffraction patterns of these starch granules. The starches from Ayamurasaki gave a C type pattern, having a small reflection at a 2θ value of 5.6 except for the sample harvested on the earliest date, which displayed a Ca type (C near to A type). X-ray diffraction patterns of the starches from Kyushu No. 120 were of the Ca type in almost all cases, and were of the C type for the samples planted on 10 June or 4 July and harvested on 1 November. The starches from Ayamurasaki tended to shift somewhat to the A type, compared to those from Kyushu No. 120. In addition, later planting or harvesting made X-ray diffraction patterns of these starch granules shift somewhat to the B type.

To analyze changes in the molecular structure of amylopectin of sweet potato roots caused by altering the planting and harvesting dates, starch samples were hydrolyzed with *Pseudomonas* isoamylase and the resulting α-1,4-glucans were separated into individual fragments using Dionex BioLC anion exchange chromatography equipped with PAD. Maltosaccharides up to DP 45 could be divided into individual peaks. Based on the area per cent of each peak, the distributions of amylopectin chain length (DP 6-45) were determined and the results are summarized in Table 3. The starches from sweet potato roots harvested at the earliest date were characteristic in having a low proportion of short chains between DP 6 and 10 and a slightly higher proportion of long chains between DP 16 and 45, suggesting a lower degree of branching of amylopectin. The values of relative PAD responses of malto-oligosaccharides (DP 6-17) were determined by Koizumi *et al.* (1991); therefore, we estimated the molar distributions of amylopectin chain length (DP 6-17) using these values. As shown in Fig. 3, a peak at DP 12 and a trough at DP 8 were detected in all cases, which agrees with previous data on sweet potato amylopectin (Koizumi *et al.*, 1991; Noda *et al.*, 1995a). The most striking point was that the contents of DP 6 and 7 were apparently lower at the earliest harvesting. Thus, earlier harvesting was found to have a noticeable effect on the chain length of amylopectin. On the other hand, the contribution of planting date to the chain length of amylopectin was small.

To detect differences in pasting properties among starches from sweet potato roots differing in planting

Table 3. **Areas (% of total) of groups of unit chains between DP 6 and 45 of amylopectins from sweet potato roots differing in planting and harvesting dates**[a]

Sample	Chain length (DP)				
	6–10	11–15	16–20	21–30	31–45
AM May–Sep	12.4	33.6	24.6	22.9	6.5
AM May–Oct	13.4	33.7	24.2	22.2	6.5
AM May–Nov	14.3	33.8	23.8	21.7	6.4
AM Jun–Nov	14.1	33.5	24.0	22.1	6.3
AM Jul–Nov	14.2	33.2	23.7	22.3	6.6
K120 May–Sep	12.8	33.4	23.7	23.0	7.1
K120 May–Oct	14.2	33.5	23.1	22.5	6.7
K120 May–Nov	14.6	33.7	23.1	22.1	6.7
K120 Jun–Nov	15.1	33.7	22.9	21.7	6.6
K120 Jul–Nov	15.2	33.7	22.9	21.7	6.5

[a] Values are means of two determinations.

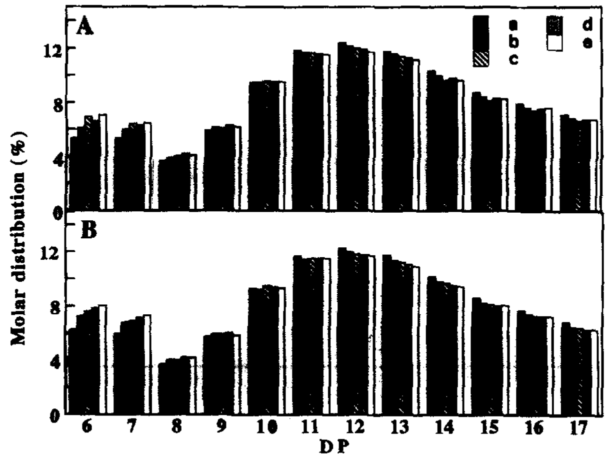

Fig. 3. Molar distributions (% of total) of unit-chains between DP 6 and 17 of amylopectins from sweet potato roots differing in planting and harvesting dates. (A) Ayamurasaki; (B) Kyushu No. 120; (a) planted on 20 May and harvested on 5 September; (b) planted on 20 May and harvested on 3 October; (c) planted on 20 May and harvested on 1 November; (d) planted on 10 June and harvested on 1 November; (e) planted on 4 July and harvested on 1 November. Results are means of two determinations.

and harvesting dates, an RVA was used in this experiment. This instrument is useful because it needs a relatively small amount (1–3 g) for analysis. Important points, namely pasting temperature, peak viscosity, breakdown and setback were recorded, as reported previously (Noda *et al.*, 1995b). Pasting properties of these starches determined by RVA are given in Table 4 Peak viscosity varied from 477 to 534 SNU and from 512 to 645 SNU for Ayamurasaki and Kyushu No. 120, respectively. In general, later planting and harvesting dates were associated with higher peak viscosity. The value of the breakdown was slightly lower (310 SNU) at the earliest harvesting than those of others (321–328 SNU) for Ayamurasaki, whereas it was obviously lower (378SNU) at the earliest harvesting and higher (476SNU) at the latest planting for Kyushu No. 120. Late planting and harvesting enhanced the values of setback for Ayamurasaki, while such enhancement was not detected for Kyushu No. 120. Pasting temperature varied from 71.1 to 75.2°C and from 66.1 to 73.8°C for Ayamurasaki and Kyushu No. 120, respectively. In both cases, the pasting temperature clearly decreased with later planting and harvesting. This study revealed the distinct effects of both the planting and harvesting dates on pasting temperature measured by RVA for two types of sweet potatoes.

The thermal properties of these starches at the gelatinization were investigated by DSC, and the results are shown in Table 5. There were large differences in both T_o (Ayamurasaki, 64.5–73.1°C; Kyushu No. 120, 55.8–69.7°C) and T_p (Ayamurasaki, 71.0–76.0°C; Kyushu No. 120, 61.3–73.8°C) values among the starch samples from the same cultivar. In almost all cases, T_p values were equal to the values of pasting temperature determined by RVA. The starches from sweet potato roots whose planting and harvesting dates were earliest exhibited the highest T_o and T_p values, and the starches from those whose planting and harvesting dates were latest showed the lowest T_o and T_p values. Not only the harvesting date but also the planting date were found to have tremendous influence on T_o and T_p determined by DSC for the sweet potato. The values of R varied from 5.7 to 13.1°C and from 8.1 to 20.2°C for Ayamurasaki and Kyushu No. 120, respectively. In both cultivars, late harvesting resulted in higher values of R. Later planting led to an increase in the R values for Ayamurasaki. On the contrary, an evident decrease in the R values was detected for later planting with Kyushu No. 120. The values of ΔH ranged from 13.8 to 16.3 J/g and from 13.7 to 15.5 J/g for Ayamurasaki and Kyushu No. 120, respectively. Early planting and harvesting generally tended to enhance the ΔH values.

Table 4. Pasting properties by RVA of starches from sweet potato roots differing in planting and harvesting dates[a]

Sample	Peak viscosity (SNU)	Breakdown (SNU)	Setback (SNU)	Pasting temperature (°C)
AM May–Sep	477	310	87	75.2
AM May–Oct	509	326	88	73.9
AM May–Nov	500	327	116	73.0
AM Jun–Nov	521	328	121	72.8
AM Jul–Nov	534	321	126	71.1
K120 May–Sep	512	378	123	73.8
K120 May–Oct	548	411	118	71.1
K120 May–Nov	558	409	116	70.3
K120 Jun–Nov	562	418	114	69.5
K120 Jul–Nov	645	476	121	66.1

[a] Each starch was added to 25 ml of distilled water to create a 10% suspension on a dry weight basis. The suspension was heated from 30 to 95°C at a rate of 5°C/min, held at 95°C for 6 min, and cooled to 50°C at the same rate and held for 10 min. Values are means of two determinations.

Table 5. Gelatinization properties by DSC of starches from sweet potato roots differing in planting and harvesting dates[a]

Sample	T_o (°C) [b]	T_p (°C) [b]	R (°C)	ΔH (J/g) [c]
AM May–Sep	73.1	76.0	5.7	16.3
AM May–Oct	71.1	74.7	7.2	15.7
AM May–Nov	68.9	73.8	9.7	14.8
AM Jun–Nov	67.3	73.2	11.7	14.5
AM Jul–Nov	64.5	71.0	13.1	13.8
K120 May–Sep	69.7	73.8	8.1	15.5
K120 May–Oct	62.3	70.8	17.0	14.5
K120 May–Nov	59.8	70.0	20.2	14.6
K120 Jun–Nov	58.1	67.4	18.6	14.7
K120 Jul–Nov	55.8	61.3	11.1	13.7

[a] Values are means of three determinations.
[b] Standard deviation ±0.75°C.
[c] Standard deviation ±0.45 J/g.

DISCUSSION

In previous papers (Noda *et al.*, 1992c, 1995a, b), we investigated the effects of an earlier harvesting date between 24 July and 7 October, respectively 62 and 137 days after planting (planting date, 23 May), on the properties of two major sweet potato cultivars, Koganesengan and Shiroyutaka. We tried to compare the present data for sweet potato samples planted on a single day, 20 May, and harvested on three dates, 5 September, 3 October and 1 November, to the previous data. From the previous results (Noda *et al.*, 1992c), the mean root weight and starch content at the last harvesting were found to be 6.17–14.2-fold and 1.63–1.68-fold higher, respectively, than those at the earliest harvesting. Such notable increases in mean root weight and starch content were not found in the present study. Therefore, it appears that starch accumulation was more active at the earlier developmental stage of the sweet potato root, when root formation was also more active. The previous study revealed a more notable increase in mean granule size than does the present one, and a decrease in the digestibility of raw starch by glucoamylases (Noda *et al.*, 1992c); namely, an increase of 23.5–3.3μm in mean granule size and 16.5–18.0% and 36.3–40.5% decreases in the hydrolysis rate of the raw starch from crude glucoamylase of *Rhizopus* sp. and crystalline glucoamylase of *Rhizopus niveus*, respectively, were observed from 24 July to 7 October. Our previous and present results suggest that the size and enzymatic digestibility of starch granules were affected more strongly at the earlier developmental stage of the sweet potato root. Much variation in amylose content at different stages of development (Koganesengan, 19.7–20.5%; Shiroyutaka, 21.9–23.1%) was not recognized previously (Noda *et al.*, 1992c), which is in good agreement with this study. Thus, it turned out that the amylose content remained almost constant in all stages, from the initial and later stages of development of the sweet potato root, whereas a significant increase in amylose content (12.5–20.0%) was detected during development of the potato tuber (Geddes *et al.*, 1965). Although the X-ray patterns of all starches were of the Ca type irrespective of harvesting date in our previous paper (Noda *et al.*, 1995b), the present data showed pattern changes (from Ca type to C type) with later harvesting for Kyushu No. 120. Furthermore, compared with the results obtained in this experiment, we previously observed relatively small decreases in T_o and T_p values by DSC (Noda *et al.*, 1992c) and pasting temperature by RVA (Noda *et al.*, 1995b) with later harvesting. Environmental temperature was reported to have large effects on the X-ray diffraction pattern and gelatinization temperature for sweet potato (Hizukuri, 1969). It was clearly shown that a change in crystalline structure from A type to B type and a decrease in gelatinization temperature occurred with decreasing environmental temperature. The environmental temperature range of the previous study was assumed to be so narrow that the X-ray diffraction pattern did not change and that the extent of decrease in gelatinization temperature with later harvesting was relatively small. The same evidence that peak viscosity and breakdown by RVA increase with later harvesting was obtained from our previous (Noda *et al.*, 1995b) and present studies. On the other hand, the values of setback by RVA were previously found to increase from 24 July to 2 September and remain constant after that (Noda *et al.*, 1995b). Such a tendency was not detected in our present results. As found in our present study, the mole fraction of short chains with DP 6 and 7 was apparently lowest and the per cent areas of chains longer than DP 16 were highest at the earliest harvesting. This suggested that the degree of branching of amylopectin became higher with later harvesting. From our previous results (Noda *et al.*, 1995a), the combined proportions of short chains of DP 6 and 7 were very slightly higher at the latest harvesting (Koganesengan, 13.2%; Shiroyutaka, 12.5%) than those at the earliest harvesting (Koganesengan, 12.8%; Shiroyutaka, 11.5%). The discrepancy could be because the chain length distributions of amylopectin were greatly influenced especially during the later developmental stage of the sweet potato root. Additionally, it might be that the degree of branching of amylopectin became higher with decreasing environmental temperature for sweet potato. Amylopectin chain length was related to the X-ray diffraction pattern, as demonstrated by Hizukuri (1985). He found that the relative order of proportions of short chains of amylopectin was B type starches < C type starches < A type starches. Our present data on X-ray diffraction and amylopectin chain length, especially for Kyushu No. 120, were inconsistent with his findings. Murugesan *et al.* (1992) used the HPAEC technique to indicate that chain length distributions of amylopectin from waxy rice were not significantly different during development of the grains unlike the present study. To attain a distinct conclusion regarding the relationship between the fine structure of amylopectin and the developmental stage of the plant, further investigation should be carried out using many kinds of plant materials.

To examine the effects of planting date on the starch properties of sweet potato roots, we compared the data for sweet potato samples planted on three dates, 20 May, 10 June and 4 July, and harvested on a single day, 4 November. Except for the results in which later planting reduced the mean root weight and mean size of starch granules for Ayamurasaki, the planting date did not have significant effect on mean root weight, starch content, mean size of starch granules and amylose content. Amylose content was confirmed to be almost independent of the planting date as well as of the harvesting date for sweet potato. According to the report of Campbell *et al.* (1994), who studied the effects of planting date on maize starch properties, the amylose content and the mean size of starch granules remained almost constant irrespective of planting date. In another study, Helm *et al.* (1968) found that increased amylose content was associated with later planting for high-amylose maize. Starch granules at late planting were considered to be formed late. It was concluded by some reports (He and Suzuki, 1989; He *et al.*, 1989; Noda *et al.*, 1992b) that the late-formed starches were easily digested by amylase. In our present study, only in the case of Kyushu No. 120 did later planting result in higher digestibility of the starch granules by two types of glucoamylases. The environmental temperature throughout root formation was assumed to be lower with later planting. Therefore, the X-ray diffraction pattern would shift from the A type to the B type with later planting. This tendency was observed for Ayamurasaki, but not for Kyushu No. 120. No information on the relationship between the planting date of the crop and the fine structure of amylopectin has been acquired to date. Our present study revealed that the chain length distribution of amylopectin was not significantly affected by altering the planting date for sweet potato root as determined using the HPAEC technique. The planting date was found to have a profound effect on pasting and gelatinization properties determined by RVA and DSC, respectively; namely, an increase in peak viscosity and a decrease in pasting temperature were observed with later planting. Furthermore, distinct decreases in the values of T_o and T_p and a slight decrease in the values of ΔH were detected with later planting. Contrary to these results, breakdown and setback were not affected by altering the planting date, with the exception of the result in which Kyushu No. 120 had a higher value of breakdown for the latest planting. The data on DSC measurement suggested that the structure of the starch granules became less ordered with later planting. The fact that the environmental temperature throughout root formation for late planting was lower than that for early planting might lead to the present results in DSC measurement. In contrast to the results seen in this study, Campbell *et al.* (1994) reported that a later planting date enhanced the values of T_p and ΔH for maize (planting date, between 15 May and 6 June; harvesting date, 15 October). It was assumed that the environmental temperature during the earlier stages of the grain filling period, which was reported to be important for determining the values of T_p and ΔH for rice (Asaoka *et al.*, 1984), was higher for a later planting, resulting in higher values of T_p and ΔH.

This study provides evidence that the gelatinization temperature of starch from sweet potato can be easily controlled by manipulating the planting and/or harvesting dates. The range of planting and harvesting dates adopted in this study is optimum or suboptimum in Japan; therefore, the data obtained in this study would be useful to breeders, farmers and starch users.

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