Unequal distribution of sugar and starch contents within Japanese processing potatoes during storage

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Two potato cultivars, Toyoshiro and Norin-ichigo, which are commonly used in Japan for processing, were stored at 7 ℃ for 3 months, and the sugar (glucose, fructose and sucrose) and starch contents within the potatoes were measured at intervals during storage. The aim of this study was to examine sugar distribution within the potatoes. Regarding reducing sugar (glucose + fructose) or starch contents, a linear relationship was found between that in stem and bud areas of both processing potatoes; the significant ($p<0.01$) relations indicated that the stem end of both cultivars had 2.5 and 1.1 times higher reducing sugar and starch contents, respectively than the bud end during storage.

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Potato tubers are often stored for several months at temperatures between 4.4 and 7.2℃ to extend the processing season[1]. Reducing sugar content increases during this storage period. The magnitude of increase is dependent upon the variety of potato and the storage temperature. To make acceptable light-colored French fries or chips, the reducing sugar content must be lowered prior to frying. This can usually be accomplished by holding (reconditioning) the cold-stored tubers at 21℃ for periods of 1 ~ 3 weeks[2,3].

French fries and chips are produced mainly from Toyoshiro and Norin-ichigo potatoes in Japan[4]. The potato processors point out that there are some parts within these potato tubers where sugars are not easily reduced during reconditioning. Thus, they want to better understand the changes in sugar content and distribution within Japanese processing tubers during storage and subsequent reconditioning in order to produce uniform light-colored products.

Several studies have been conducted on sugar change of Japanese potatoes for fresh consumption during storage. MURATA *et al.*[5] reported increase in sugar contents of 'Danshaku' and 'May Queen' potatoes stored at 1 and 5 ℃. KEVIN *et al.*[6] and MURATA *et al.*[7,8] found the increase of 'Danshaku' tubers stored at 0 ℃. However, for the processing potatoes, relatively little research has been conducted[9),10]. In addition, no reports were found on the sugar distribution of Japanese potatoes during storage. Thus, this study was initiated to investigate changes in sugar content, and its distribution within Toyoshiro and Norin-ichigo potatoes during storage.

Materials and methods

1. Source and tuber storage

Tubers of mid-early (Toyoshiro) and late (Norin-ichigo) cultivars grown in Hokkaido, Japan were harvested on Sep. 17, 1996, and Oct. 9, 1996, respectively. After harvesting, these potatoes were cured for two weeks at 15℃ and 90~95% RH, and then stored at 7 ℃ and 90~95% RH. Both cultivars approximately 150g in size were used for the experiment.

2. Sample preparation

Eight potatoes were selected at random from each

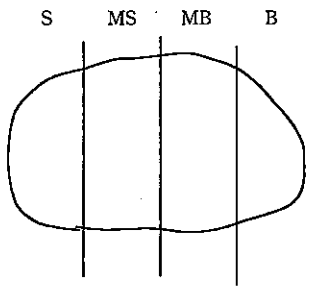
cultivar, washed, and four pieces were cut from stem end to bud end of the tuber for analysis (Fig. 1). Then the potatoes were peeled and diced into approximately 5 ㎜ cubes.

3. Moisture content

The moisture content was measured by placing approximately 10g of potato cubes in an oven at 70 ℃ for 24 hours and then drying them at 70℃ for 2 hours in a vacuum oven[11].

4. Sugars

Sugars was extracted from tubers using the method described by WILSON *et al.*[12] ; 50g of potato cubes were homogenized in a waring blender in 50 ㎖ of distilled water for 150sec. The homogenate was centrifuged at 1,710×g for 5 min at 4 ℃. The supernatant was filtered through Toyo No. 5 filter paper and then analyzed using high-performance liquid chromatography (HPLC) (Model BIP-1, Nihon Bunko Co.) as described previously[13].



S: stem end, MS: middle toward the stem end, MB: middle toward the bud end, B: bud end.

Fig. 1 The four potato tuber areas

5. Starch

The dehydrated samples after the measurement of moisture content were used[14]. The tissues were ground to 40-mesh size, and starch concentration in the desiccated tuber powder was determined as previously described by SASAKI[15]. This procedure utilized : (a)DMSO (dimethyl sulfoxide) extraction of starch from 80% ethanol washed precipates ; (a) a digestion with glucoamylase and α-amylase enzymes; and (c) the determination of glucose by the Somogyi method[16]. A factor of 0.9 was used to convert glucose to starch equivalents[17].

All analyses were performed eight times.

6. Data analysis

The results were averaged to obtain mean values. The data was processed using analysis of variance (ANOVA). Duncan's multiple range test of SPSS[18] was used to determine differences between area means over storage time.

Results and discussion

As shown in Table 1, moisture contents of Norin-ichigo and Toyoshiro potatoes varied between 71~76 and 72~76, respectively, during storage. However, the mean moisture contents over storage time were not different among pieces from the same tuber.

Fig. 2~4 show changes in sugar content of the cultivars during storage. As shown in these figures,

Table 1 Moisture content (%) of two processing potatoes during storage

Cultivar	Area*	Storage time (days)										Mean over storage
		0	14	28	42	56	70	84	98	112	123	
Norin-ichigo	S	71.60	73.56	74.28	72.19	75.12	74.20	71.42	71.12	70.63		72.68a**
	MS	71.56	74.91	75.46	72.03	74.32	75.07	71.34	72.72	70.59		73.33a
	MB	73.92	75.05	76.25	75.36	72.60	73.84	72.53	73.17	72.83		73.78a
	B	73.70	76.18	75.67	75.06	75.45	73.02	73.76	73.08	74.09		74.04a
Toyoshiro	S	73.72	73.12	73.91	73.17	74.62	76.46	73.86	75.35	73.32	76.62	74.17a**
	MS	74.55	74.15	73.22	73.16	73.71	77.52	74.5	75.68	73.52	72.75	74.29a
	MB	75.26	75.39	73.44	74.03	74.51	76.64	73.53	74.85	72.65	73.22	74.09a
	B	75.19	74.98	73.20	73.96	74.53	76.70	75.03	73.56	73.56	74.21	74.19a

* Area codes are presented in Fig. 1.

** Means in each column with same letter are not significantly different ($p>0.05$).

the glucose, fructose and reducing sugar (glucose+ fructose) contents of both potatoes increased, followed by a slight decrease. IRITANI *et al.*[19] reported that at a low storage temperature (6 ℃) the flush of sugar accumulation occurred within the first month after storage, and that after approximately that first month, the amount of sugars gradually decreased with storage. Thus, these results were in agreement with those of IRITANI *et al.*[19]. However, KOWATA *et al.*[9] found the consistent increase in reducing sugar contents of Japanese cultivars, 'Danshaku', 'Kita-akari', 'May Queen', 'Hokkai-kogane' and 'Konahubuki', at storage of 2 ℃ for 8 months. Thus, the difference in increase behavior may be attributed to variety of potato and storage temperature[20]. With respect to the reducing sugar content of potatoes to have acceptable color for processed products, SMITH[21],[22] found that potatoes with less than 0.25% reducing sugar on fresh weight gave acceptable color for chips. In Fig. 4a, "Norin-ichigo" potatoes exceeded the level of reducing sugar content during storage

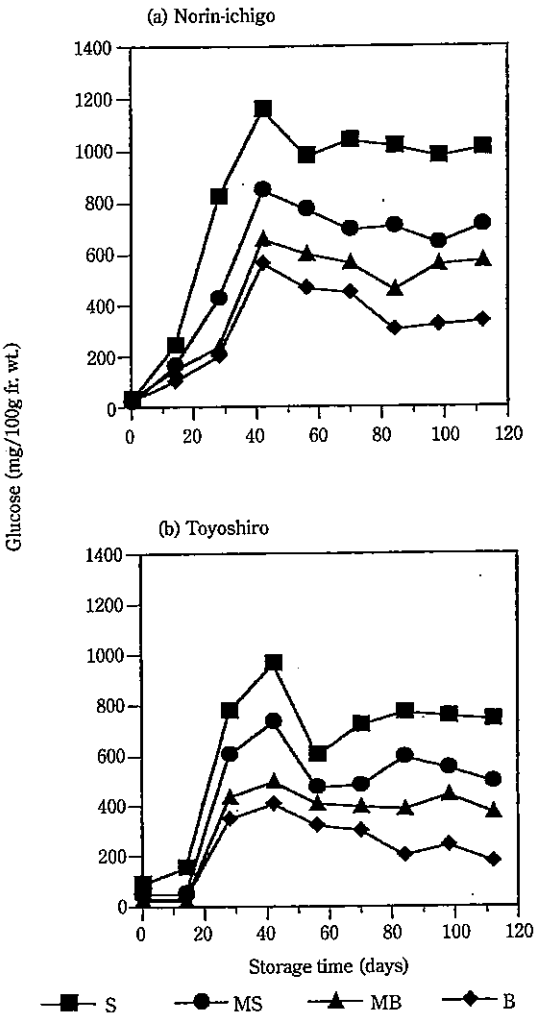


Fig. 2 Changes in glucose content of potatoes during storage at 7 ℃ (tuber area codes are presented in Fig. 1)

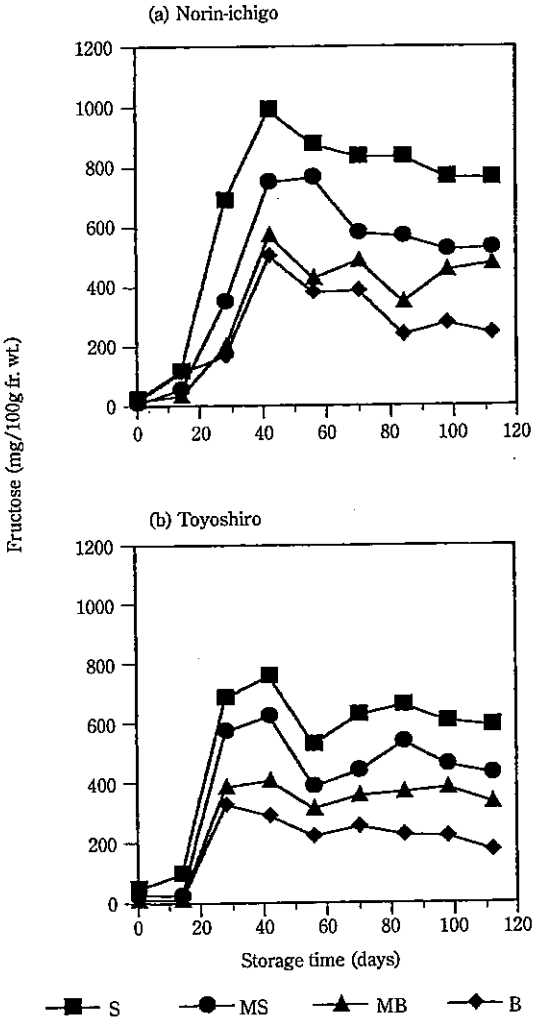


Fig. 3 Changes in fructose content of potatoes during storage at 7 ℃ (tuber area codes are presented in Fig. 1)

except the initial samples. For "Toyoshiro" cultivar (Fig. 4b), the amount of reducing sugar content of samples exceeded the acceptability level after 14 days of storage. Therefor, stored tubers for both cultivars need reconditioning in order to obtain acceptable color for processed products. For French fries, the upper limit is reported to be as high as 0.5% (BURTON and WILSON[23]). Hence, the stored tubers for both cultivars when processed into French fries still need reconditioning to have acceptable color products. In Fig. 5, sucrose contents gradually increased during storage. CHRISTOPHER and REES[20] also reported a gradual increase in sucrose content at 2 ℃ storage. MURATA *et al.*[8] also found that the sucrose content of 'Danshaku' tubers rapidly increased at 0 ℃ storage although the content was almost constant at 10℃. In contrast to the sugar increase, starch contents gradually decreased during storage (Fig. 6). SOWOKINOS *et*

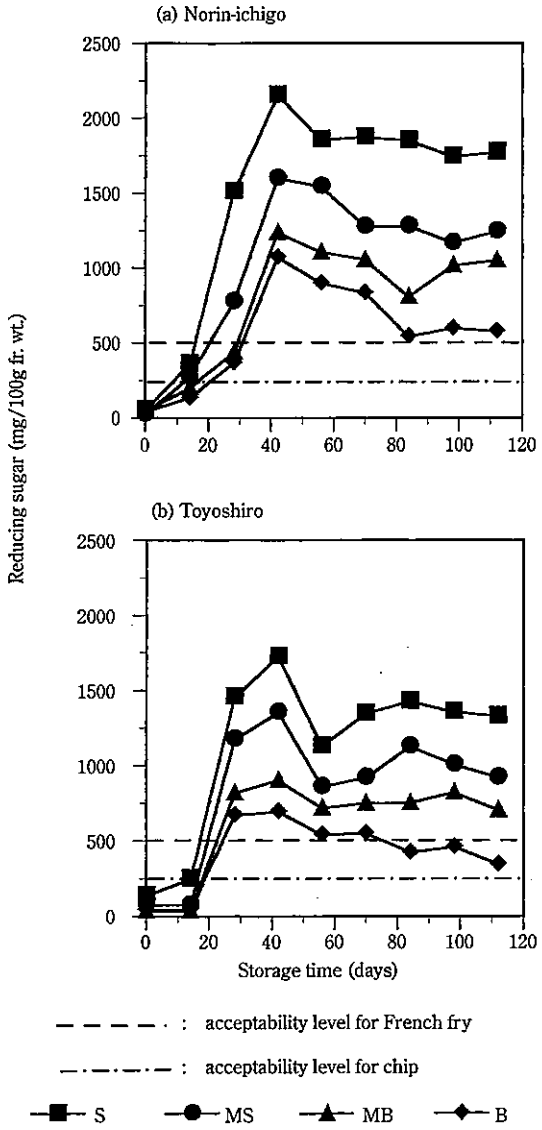


Fig. 4 Changes in reducing sugar content of potatoes during storage at 7 ℃ (tuber area codes are presented in Fig. 1)

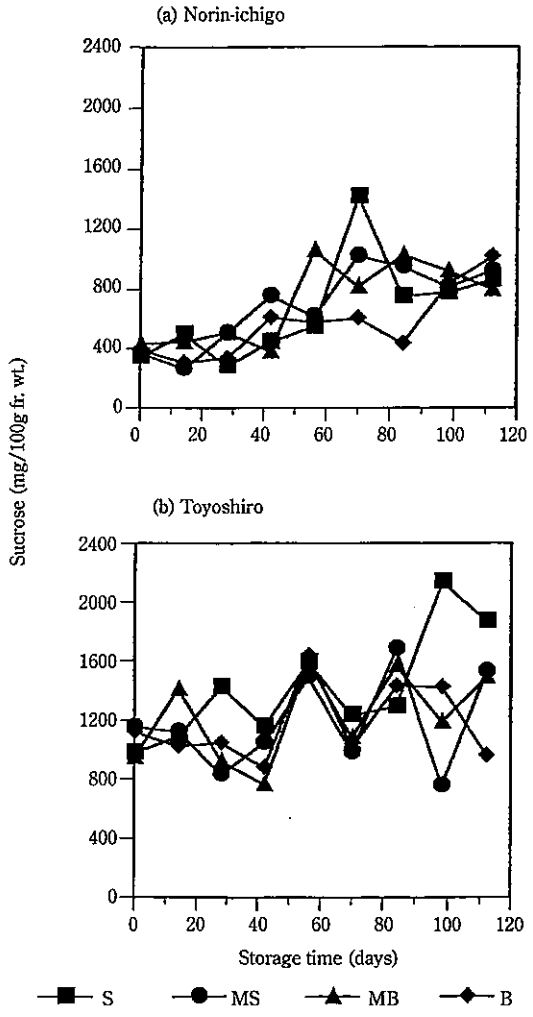


Fig. 5 Changes in sucrose content of potatoes during storage at 7 ℃ (tuber area codes are presented in Fig. 1)

al.[25] found starch content reductions of from 14 to 12% at 10℃ for 8 months, and OHAD *et al.*[14] also reported starch reductions of from 17 to 11% at 4 ℃ storage for 10 weeks. MURATA *et al.*[8] also reported starch reductions of 'Danshaku' cultivar at 0 ℃ storage. In potato chipping industry, potatoes with high starch content are desirable because they : (a) have good cooked texture, (b)have relative less water to be driven off - thus potentially reducing energy costs, and (c) absorb less cooking oil - a cost item[26]. Hence, research concerning the mechanism of starch degradation and sugar increases is important, but the mechanism is not evident from the present study. However, it is possible that starch degradation and sugar increases are induced by a break in the amyloplast membrane[27] or the elevated enzyme activity of invertase[28] and other enzymes[29]. Thus, continued work on the above enzymes and on morphological changes in the membrane is required to further understand these events.

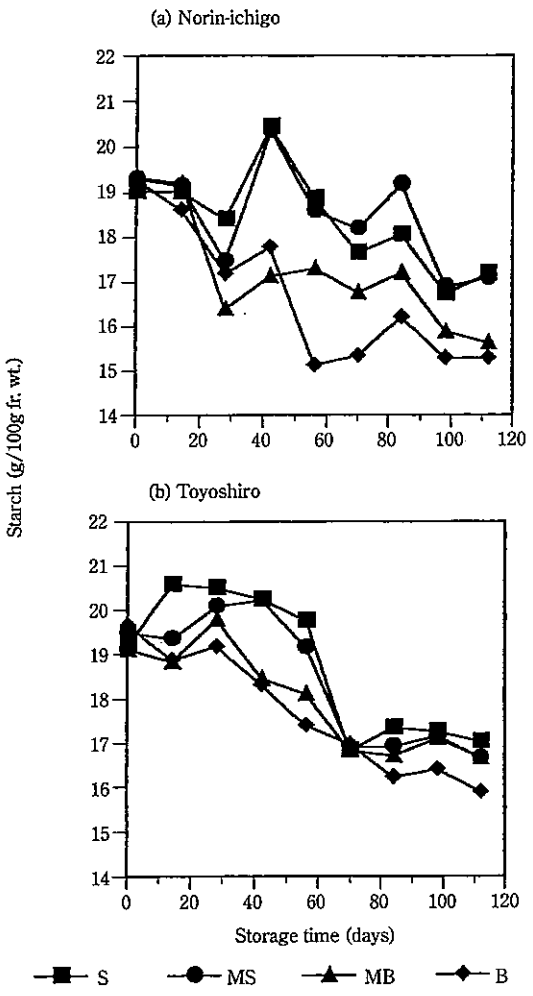


Fig. 6 Changes in starch content of potatoes during storage at 7 ℃ (tuber area codes are presented in Fig. 1)

Tables 2 ~ 5 show differences in sugar and starch contents among tuber areas. These tables revealed that, except for sucrose content, the stem area had a higher sugar and starch content than the bud end. Then, we attempted to determine a relationship between reducing sugar contents in stem and bud areas of two processing cultivars. Fig. 7 indicates the significant ($p < 0.01$) linear relationship. The relationship was described by the equation :

$$Y = 2.48x;\ r = 0.907^{**}$$

Where Y = reducing sugar content in the stem area and x = that in bud one.

Fig. 8 also shows a significant ($p < 0.01$) linear relationship between starch contents in the stem and bud areas :

$$Y = 1.08x;\ r = 0.618^{**}$$

Where Y = starch content in the stem area and x

Table 2 Mean glucose content (mg/100 g fr.wt.) of two processing potatoes over storage period

Cultivar	Area*			
	S	MS	MB	B
Norin-ichigo	807a**	553bd	425cd	307c
Toyoshiro	619a	447bd	330cd	228c

* Area codes are presented in Fig. 1.
** Means in each row with same letter are not significantly different ($p > 0.05$).

Table 3 Mean fructose content (mg/100g fr.wt.) of two processing potatoes over storage period

Cultivar	Area*			
	S	MS	MB	B
Norin-ichigo	655a**	466bd	347cd	255c
Toyoshiro	509a	387ab	284bc	190c

* Area codes are presented in Fig. 1.
** Means in each row with same letter are not significantly different ($p > 0.05$).

= that in bud one.

These equations indicate stem area of both cultivars have 2.5 and 1.1 times higher reducing sugar and starch contents, respectively, throughout storage time than bud one.

There are two methods to reduce the content of reducing sugars: reconditioning room temperature (20℃) over 1 ~ 3 wk/ or water blanching to leach out soluble solids of potatoes without reconditioning[30]. Thus, the equation of reducing sugar may be of practical value for Japanese processors to determine blanching time and slice thickness of French fry or chips in blanching operation. Blanching time[31] and slice thickness[32] depend on reducing sugar content, since as reducing sugar content increases, slice thickness needs to decrease, or blanching time to increase. Consequently, the thickness of stem area is needed to be thinner than that of bud one. In addition, followed by the blanching, frying operation is performed. Frying time of potato chip varies with potato starch content[33]. As the starch content decrease, frying time needs to be longer. Thus, the equation of starch content also may be useful to determine frying time of chips. Developments during subsequent reconditioning will be reported in a future paper.

Table 4 Mean sucrose content (mg/100g fr.wt.) of two processing potatoes over storage period

Cultivar	Area*			
	S	MS	MB	B
Norin-ichigo	660a**	705a	691a	731a
Toyoshiro	1418a	1241a	1461a	1277a

* Area codes are presented in Fig. 1.
* * Means in each row with same letter are not significantly different ($p>0.05$).

Table 5 Mean starch content (g/100g fr.wt.) of two processing potatoes over storage period

Cultivar	Area*			
	S	MS	MB	B
Norin-ichigo	18.37a**	18.46a	17.20b	16.68b
Toyoshiro	18.74a	18.43b	18.06b	17.57b

* Area codes are presented in Fig. 1.
* * Means in each row with same letter are not significantly different ($p>0.05$).

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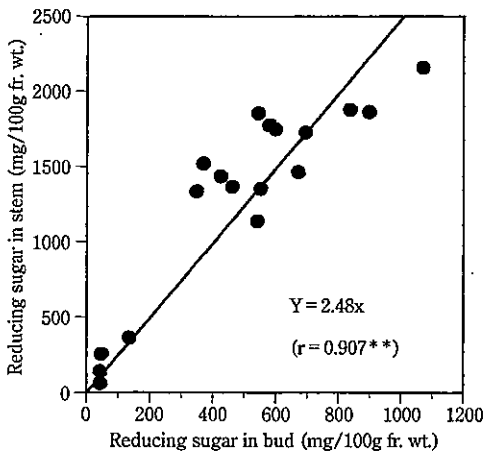

Fig. 7 Relation between reducing suger contents in stem and bud areas of potatoes including two cultivars stored at 7 ℃

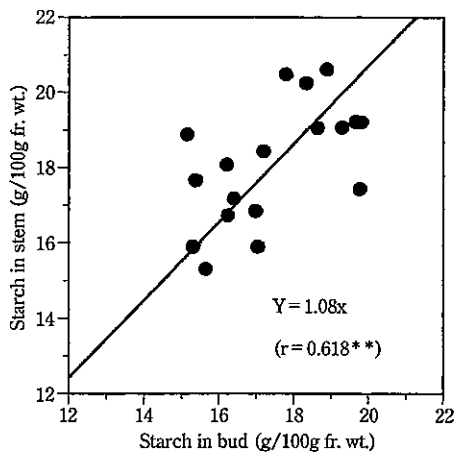

Fig. 8 Relation between starch contents in stem and bud areas of potatoes including two cultivars stored at 7 ℃

References

1) WEAVER, M.L., HAUTALA, E., MONAKA, M. and IRITANI, W.M.: *Amer. Potato J.*, **49**, 376～382 (1972)

2) WEAVER, M.L. and HAUTALA, E.: *Amer. Potato J.*, **48**, 199～205 (1971)

3) LAMMERINK, J.P.: *New Zealand J. Crop Hort. Sci.*, **17**, 61～65 (1989)

4) IWAHUNE, O.: *Hokkaido no nogyo* (Hokkaido Kyodokumi-ai Tushinsha, Sapporo, Japan), p. 28 (1993)

5) MURATA, T. and ISHIHARA, R.: *Nippon Shokuhin Kogyo Gakkaishi*, **34**, 443～447 (1987)

6) KEVIN, F.Y., SATO, H., SUZUKI, T., TAKANO, K. and KOZIMA, T.T.: *Food Preser. Sci.*, **26**, 103～107 (2000)

7) MURATA, Y., KEVIN, F.Y., NOGUCHI, T., SUZUKI, T., SATO, H., MATSUMOTO, S. and TAKANO, K.: *Food Preser. Sci.*, **26**, 153～160 (2000)

8) MURATA, Y., NOGUCHI, T., KEVIN, F.Y., SATO, H., MATSUMOTO, S., TAKANO, K. and SUZUKI, T.: *Food Preser. Sci.*, **26**, 281～287 (2000)

9) KOWATA, H., SATO, Y. and ISHII, G.: *J. Soc. Agr. Struc.*, **27**, 173～180 (1996)

10) KAZAMI, D., TSUCHIYA, T., KOBAYASHI, Y. and OGURA, N.: *Nippon Shokuhin Kogyo Gakkaishi*, **47**, 851～856 (2000)

11) The Association of Official Analytical Chemists: Official Method of Analysis of the Assoc. Offic. Anal. Chemists, 11th ed., p. 539 (1970)

12) WILSON, A.M., WORK, T.M., BUSHWAY, A.A. and BUSHWAY, R.J.: *J. Food Sci.*, **46**, 300～301 (1981)

13) HIRONAKA, K., TAKADA, K. and ISHIBASHI, K.: *Nippon Shokuhin Kogyo Gakkaishi*, **37**, 48～51 (1990)

14) OHAD, I., FRIEDBERG, I., NE'EMAN, Z. and SCHRAMM, M.: *Plant Physiol.*, **47**, 465～477 (1971)

15) SASAKI, T.: Denpun oyobi sono seibun no bunri-teiryo, in Methods in Starch (NAKAMURA, M. and SUZUKI, S., eds.) (Asakura Shoten, Tokyo), pp. 1～40 (1979)

16) NELSON, N.: *J. Biol. Chem.*, **153**, 375～380 (1944)

17) PUCHER, G.W., LEAVENWORTH, C.S. and VICKERY, H.B.: *Anal. Chem.*, **20**, 850～853 (1948)

18) SPSS Inc.: SPSS for windows Base System User's Guide Release5.0 (SPSS Inc., Chicago, IL.), pp. 269～270 (1992)

19) IRITANI, W.M., WELLER, L. and RUSSELL, T.S.: *Amer. Potato J.*, **50**, 24～31 (1973)

20) BURTON, W.G., van ES, A. and HARTMANS, K.J.: The Physics and physiology of storage, in The Potato Crop, 2 th ed. (PAUL, M.H., ed.) (Chapman & Hall, London), pp. 685～688 (1992)

21) SMITH, O.: Nat. Potato chip Inst., Proc. Prod. Tech. Div. Meetings, 1955, pp. 2～5 (1955)

22) SMITH, O.: Nat. Potato chip Inst., Proc. Prod. Tech. Div. Meetings, 1956, pp. 2～5 (1956)

23) BURTON, W.G. and WILSON, A.R.: *Potato Res.*, **13**, 269 (1970)

24) CHRISTOPHER, J.P. and ap REES, T.: *Phytochem.*, **14**, 613～617 (1975)

25) SOWOKINOS, J.R., LULAI, E.C. and KNOPER, J.A.: *Plant Physiol.*, **78**, 489～484 (1985)

26) ORR, P.H. and GRAHAM, C.K.: *Transactions of the ASAE*, **26**, 297～304 (1983)

27) ISHEWOOD, F.: *Phytochem.*, **15**, 33～41 (1976)

28) PRESSEY, R.: *Amer. Potato J.*, **46**, 291～297 (1969)

29) SOWOKINOS, J.R.: *Amer. Potato J.*, **67**, 849～857 (1990)

30) RAUL, L.G., ENRIQUE, R.S. and RICARDO, A.B.: *J. Food Sci.*, **54**, 1090～1091 (1989)

31) SMITH, O.: Potato chips in Potato Processing, in Potato Processing, 4 th ed. (TALBURT, W.F., ed.) (AVI Book, New York), p. 449 (1987)

32) TALBURT, W.F., WEAVER, M.L., REEVE, R.M. and KUENEMAN, R.W.: Frozen French fries and other frozen potato products, in Potato Processing, 4 th ed. (TALBURT, W.F., ed.) (AVI Book, New York), pp. 508～509 (1987)

33) BURTON, W.G.: The potato, 3 rd ed. (Longman Scientific & Tecnical, London), p. 420 (1989)

加工用貯蔵ジャガイモの塊茎内の糖およびデンプン含量の不均一分布

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加工用品種の農林１号およびトヨシロを用いて７℃で３カ月の貯蔵実験を行い，塊茎内の糖（グルコース，フルクトースおよびスクロース）およびデンプン含量の分布を検討した。その結果，還元糖（グルコース＋フルクトース）およびデンプン含量について，基部および頂芽の含量間に直線関係が認められ，両品種とも，塊茎基部は頂芽部よりも2.5倍多い還元糖および1.1倍高いデンプン含量を貯蔵中，有することが明らかとなった。

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