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Effect of Storage Period and Temperature on Some Properties of Potato Starch

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ABSTRACT

The effect of temperature on the properties of potato starch during storage at 1, 5 and 10℃ for 6 months were determined. The Brabender peak viscosity, final viscosity at 92.5℃ breakdown, swelling power, solubility and phosphorus content decreased while initial pasting temperature, temperature at peak viscosity and blue value of the starches increased during storage. Phosphorus content was highly correlated with Brabender peak viscosity and breakdown ($r=0.92$ and 0.82, respectively, $p<0.01$). Higher rates of decrease in viscosity and phosphorus content occurred at 1 and 10℃ during storage.

Keywords: potato storage, potato starch, Brabender viscosity, swelling power, solubility, phosphorus, blue value.

INTRODUCTION

Many reports have indicated that potato starch properties change during storage. This include changes in the size and appearance of starch granules, amylose content, phosphorus content, viscosity and in other properties and chemical composition (Golachowsky, 1985; Johnston et al., 1968; Mica, 1975 and 1976; Winkler, 1971; Yamamoto, 1989) during potato storage. Basically, the chemical composition of potato starch and subsequently its properties are dependent on genetic, climatic, soil, meteorological and technological factors which include technologies used for starch preparation, quality of industrial water, parameters of the drying process (Lisinska and Lesczczynski, 1989) as well as the time and temperature of storage (Golachowsky, 1985) prior to starch extraction. Observations on the changes in starch properties are very significant in terms of the consistent quality of products utilizing potato starch. However, potato producers' knowledge of the effect of the different factors on potato starch properties are generally meager (Lisinska and Lesczczynski, 1989). In Japan, where potato starch is incorporated into various products, no substantial study on the effect of storage on potato starch properties has been done. Additional knowledge on this aspect was therefore deemed necessary since the factors affecting starch properties vary in every country and in a particular period of time. Thus, this study was initiated to determine the effect of storage period and temperature on the properties of starch from potatoes specifically that of Benimaru variety which is the primary source of starch in Japan.

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MATERIALS & METHODS

1. Potato variety, storage period and temperature

The potatoes (Benimaru variety) which were part of the October, 1991 harvest were obtained from Kawanishi District, Obihiro, Hokkaido, Japan. The tubers were cured for 2 weeks before storage for 6 months at carefully controlled temperatures of 1, 5, and 10℃ and at relative humidity of about 90%. Unstored potatoes served as the control.

2. Starch Preparation

Starches were prepared according to the method of Yamamoto (1984) with modifications. The potato tubers (2 kg) were washed thoroughly, cut into about 25.4 mm cubes and crushed using a high speed juicer. The crushed potatoes were suspended in 20 L distilled water, mixed well and sieved through 20, 100, 165 and 200 meshes, respectively. The filtered solution was allowed to stand for 3 hr before decantation. Distilled water (4 L) was added to the precipitate, mixed, mechanically stirred for 2 hr, allowed to stand for 3 hr and decanted. This series of adding water, stirring, standing and decanting was repeated six times. Finally, 4 L of water was added and the solution was stirred again for 2 hr before filtering in a glass filter (G 4). The recovered starch was placed in stainless steel trays and dried at 38℃ to approximately 20% (w.b.) moisture content using a forced-draft cabinet dryer. Isolated starches were kept in polyethylene bottles until analyses.

3. Chemical composition and physicochemical properties

Moisture, crude protein and ash contents of isolated starches were determined by AOAC (1984) methods. Fat content of the starch was analyzed after extraction with a 2 : 1 (volume ratio) mixture of chloroform/methanol under reflux at 60℃ for 1 hr, twice (Tsutsumi, 1969). Amylose content was determined according to the method of Williams, et al. (1970). Known amylose/amylopectin mixtures were used to obtain a standard curve. Blue value was measured as the absorbance of 4 mg starch in 100 ml dilute I_2-KI solution at 680 nm according to the method of Kobayashi (1961). Phosphorus content was measured using the Vanado-Molybdate method of Takagi (1964). Swelling power and solubility patterns were determined over the pasting range of 60, 70 and 80℃ (±1℃). Swelling power index was computed with correction for solubles (Leach, et al., 1959).

The behavior of starch during heating was analyzed using a Brabender Viscograph AM−3 (C. W. Brabender Co., W. Germany). The bowl speed was 75 rpm with the 700 gcm torsion spring. The starch suspension (4%, d. b.) was heated at the rate of 1.5℃ per min until 92.5℃, held at this temperature and viscosity determination was continued for 30 min.

4. Statistical Analysis

Each determination was done in duplicate. Data were analyzed by analysis of variance and Duncan's Multiple Range Test was used to determine significant differences among treatment means at 1% level.

RESULTS AND DISCUSSION

The starch from unstored potato tubers had a lower level of crude protein (0.01%) but almost the same crude fat (0.05%), ash (0.24%) and amylose (24.52%) contents compared with the literature values (Lisinska and Lesczczynski, 1989 ; Swinkels, 1985 ; Yamamoto, 1989).

Storage of potatoes up to 6 months at 1, 5, and 10 ℃ showed significant changes in the Brabender viscosity pattern of the starches ($p<0.01$) (Table 1). Initial pasting temperature tended to increase on storage period but little change was observed at 5℃ compared with 1 and 10℃. The temperature at peak viscosity was not significantly affected by storage temperature but it tended to increase during storage. Final viscosity at 92.5℃ decreased on storage period but the effect of temperature was not significant. Peak viscosity decreased with increase in storage period at all storage temperatures employed with slower change at 5℃. Golachowski (1985) also observed a decrease in the peak viscosity and an increase in the temperature at peak viscosity of starches from potato tubers stored at 0℃. However, starches from potato tubers stored at 8℃ for 12 weeks (Golachowsky, 1985) and at 6℃ for 6 months (Yamamoto, 1989) reached maximum viscosity at a

Table 1. Brabender viscoamylograms of potato starches stored at different temperatures for 6 months.

Storage condition		Pasting	Peak visco.	Viscosity (BU)		Breakdown
Period (month)	Temp. (℃)	temp. (℃)	temp (℃)	Peak (P)	92.5℃ (F)	(BU) (P-F)
0		60.0 Aa	72.5 Aa	1528 Ed	290 Ba	1238 Ed
1	1	61.0 Aa	73.5 Aa	1323 Ba	270 Aa	1053 Ba
4	1	61.5 Bb	75.5 Bb	1285 Aa	270 Aa	1015 Aa
6	1	60.5 Aa	75.0 Bb	1255 Aa	255 Aa	1000 Aa
1	5	60.0 Aa	74.5 Aa	1375 Dc	280 Aa	1095 Dc
4	5	60.0 Aa	74.5 Aa	1340 Cb	270 Aa	1070 Db
6	5	61.0 Aa	74.0 Aa	1330 Ca	265 Aa	1065 Cb
1	10	61.0 Aa	75.5 Bb	1370 Dc	280 Aa	1090 Dc
4	10	61.0 Aa	74.0 Aa	1280 Aa	275 Aa	1005 Aa
6	10	61.5 Bb	73.5 Aa	1260 Aa	250 Aa	1010 Aa

Means within each column not followed a common superscript are significantly different ($p<0.01$). Values are means of two replications.

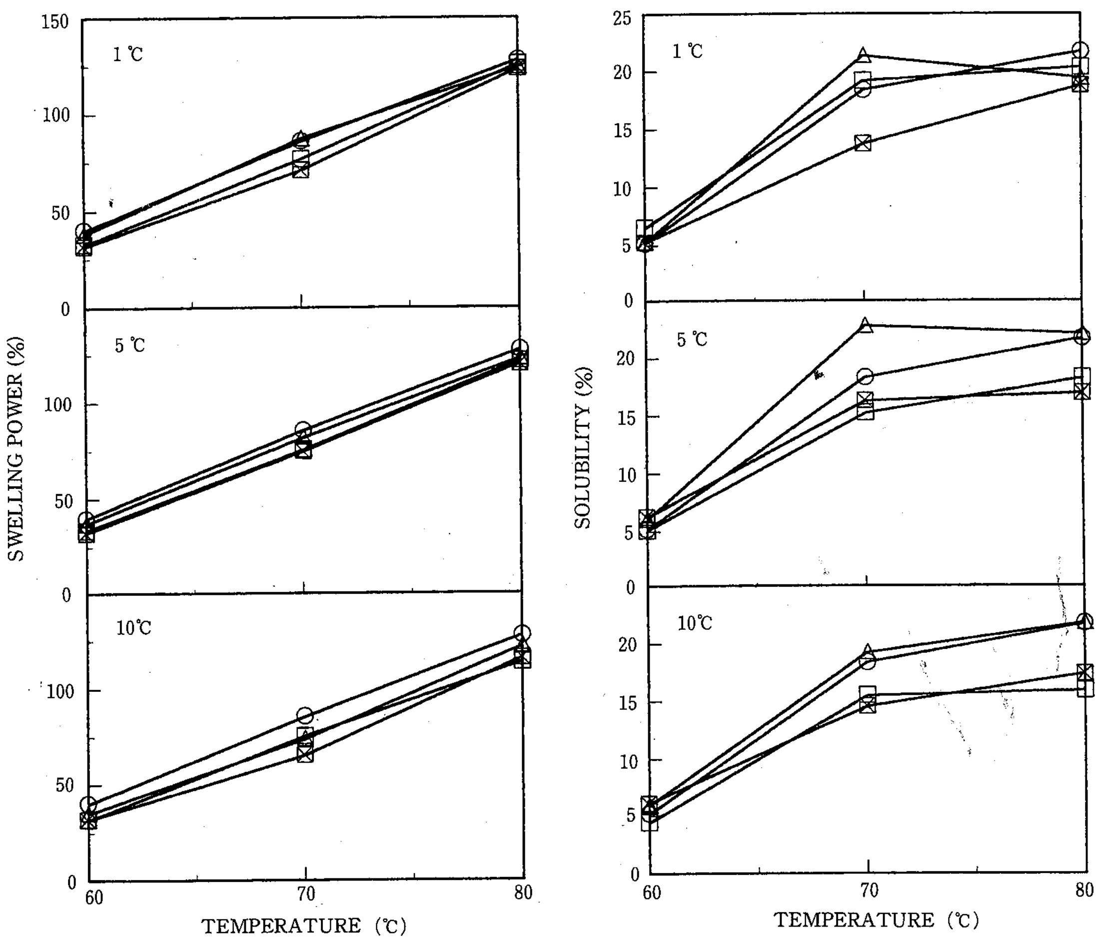

Fig. 1. Swelling power and solubility patterns of potato starches from tubers stored at different temperatures for 1 (△), 4 (⊠), 6 (□) months; (○) control. Values are means of two replicates.

lower temperature though their maximum viscosities were lower than that of the starch from unstored tubers.

The swelling power of the starches decreased with increase in storage period while the amount of solubles generally increased after 1 month storage and decreased afterwards (Fig. 1). The effect of storage period at 1, 5 and 10℃ on the swelling power and solubility pattern was not clear. The decrease in swelling power supports the decrease in Brabender viscosity since this viscosity is said to be primarily dependent on the extent of swelling of the starch granules and the resistance of the swollen granule to dissolution by heat or fragmentation by shear (Schoch and Maywald, 1968).

Potato starch is known to undergo a very rapid and exceptionally high swelling at relatively low temperatures indicating weak internal bonding which is partly due to the presence of ionizable esterified phosphate groups (Whistler and Paschall, 1965). In this study, the phosphorus content of the starches from stored tubers decreased with increase in the storage period with slower rates of decrease at 5℃ than at 1 and 10℃ compared with the control (Fig. 2). A decrease in the phosphorus content during storage at 20, 8, 4, 0 and −15℃ for 12 weeks was also observed by Golachowski (1985). However, Mica (1976) observed an increase in the phosphorus content of starch from tubers stored for 6 months at 10℃. On the other hand, Schwimmer, et al. (1954) did not find any change in the phosphorus content of starch from tubers stored at 4.4 and 10℃ for 18 weeks. Phosphorus content was positively correlated with viscosity of the starch pastes (Winkler, 1961). This relationship is due to the close orientation of phosphate ions in potato starch which gives rise to electrostatic repulsions that help expand the amylopectin molecules promoting their hydration and the consequent high viscosity (Nutting, 1951). Thus, the decrease in viscosity and swelling of starches stored at 1, 5 and 10℃ could be attributed to the decrease in phosphorus content. A high correlation of phosphorus content with peak viscosity ($r=0.92$, $p<0.01$) and breakdown viscosity ($r=0.82$, $p<0.01$) was also observed in this study.

Blue value and percentage amylose have an excellent linear correlation (Morrison and Laignelet, 1983). The blue value of the starches from stored tubers increased as storage time increased (Fig. 3). At 5℃, the blue value of the starches was higher than that of the starches from tubers stored at 1 and 10℃. Golachowski (1985) found no change in the amylose content during potato storage at 4℃ but storage at 8, 20 and 0℃ caused a decrease in the amylose content. Schwimmer, et al. (1954) reported that storage time

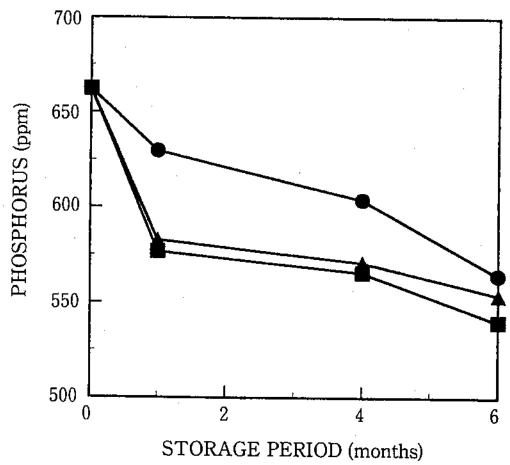

Fig. 2. Phosphorus content of potato starches from tubers stored for 6 months at 1℃ (■), 5℃ (●) and 10℃ (▲). Values are means of two replicates.

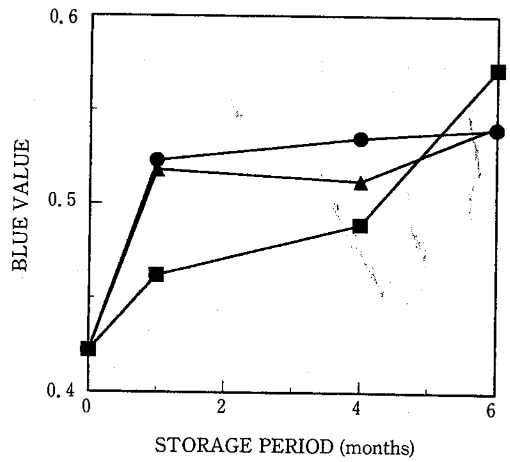

Fig. 3. Blue value of potato starches from tubers stored for 6 months at 1℃ (■), 5℃ (●), and 10℃ (▲). Values are means of two replicates.

and temperature had no effect on the amylose content of starches in stored potatoes nor on their amylose-amylopectin ratio while Johnston, et al. (1968) reported an increase in the amylose-amylopectin ratio during storage. An increase in amylose content would mean a decrease in the proportion of the amylopectin. The viscosity of the starch pastes is proportional to the quantity of amylopectin in starch (Golachowsky, 1985; Horiuchi, 1967). Thus, in this study, the decrease in the viscosity and swelling of the starches from stored potato tubers could be further explained by the decrease in the proportion of amylopectin as indicated by the increase in blue value.

Starches from potatoes stored at 1 and 10℃ had higher rates of decrease in viscosity and phosphorus content compared with the changes that occurred at 5 ℃. Golachowsky (1985) observed that changes in granularity during potato storage at 4 and 8℃ were remarkably smaller than those observed during storage at 0 and 20℃. He noted that during storage at 0 ℃ processes of starch to sugars transformation occur together with intensive respiration of the tubers while at 20℃, intensive biochemical processes occur mainly by the processes of starch changes accompanying the potato tuber germination. The same processes could explain the high rates of changes that occurred during storage at 1 and 10℃. Burton (1966) reported that in the range of 0−3℃, the respiration was higher gradually decreasing from 3−5℃ then gradually increasing again towards 10℃. Also, the rate of starch conversion to sugars was reported to be highest at 1 ℃, while storage at 10℃ for longer periods led to sprouting where there was a high requirement for energy (Lisinska and Lesczczynski, 1989). These results show that potatoes for starch manufacture should be stored at 5℃ where there is a slower rate of changes in starch properties.

Generally, the observations in this study were in accord with previous reports. Basic differences could also be attributed to factors other than varieties used and their natural conditions during growth. These factors include the analytical methods used as well as the experimental conditions (Golachowsky, 1985) especially in the determination of viscosity (Goto and Yokoo, 1969). Further studies are necessary in order to explain the changes that occurred in starch properties and identify the factors that specifically caused such changes.

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馬鈴薯デンプンの特性に及ぼす貯蔵期間と温度の影響

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要　旨

デンプン原料用馬鈴薯のベニマルを6ヵ月間貯蔵し，貯蔵温度と期間が馬鈴薯より調製したデンプンの品質に及ぼす影響を調べた。デンプンのアミログラム最高粘度，92.5℃における最終粘度，ブレークダウン，膨潤度，溶解度及びリン含量は馬鈴薯を貯蔵することによって減少したが，糊化開始温度，最高粘度到達時の温度と青価は逆に増加した。リン含量とアミログラム最高粘度及びブレークダウンとの間に，高い正の相関が認められた。1℃と10℃で貯蔵した馬鈴薯より調製したデンプンの粘度とリン含量は，5℃貯蔵のものより低下した。

キーワード：馬鈴薯貯蔵，馬鈴薯デンプン，ブラベンダー粘度，膨潤度，溶解度，リン含量，青価