Physicochemical properties of potato starches manufactured in Hokkaido factories

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Revised: 15 March 2019 / Accepted: 18 March 2019 / Published online: 30 March 2019
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Abstract Potato starch is an important agricultural product in Hokkaido, the northernmost island of Japan, with output of around 0.18 million tons/year. The present investigation was conducted to evaluate the physicochemical properties of potato starch samples manufactured in 10 factories in Hokkaido. The starch samples were analyzed for pasting properties by rapid visco analyzer (RVA), gelatinization properties by differential scanning calorimetry (DSC), color components, and minerals, amylose, and resistant starch (RS) contents. The phosphorus and potassium contents of potato starches averaged 746 ppm and 681 ppm, ranging from 669 to 835 ppm and from 481 to 803 ppm, respectively. Relatively wide ranges were noted in the contents of sodium (35–134 ppm), magnesium (50–121 ppm), and calcium (34–164 ppm). RVA analysis revealed clear differences in peak viscosity (PV) and breakdown (BD) among starch samples examined. Higher contents of divalent cations, magnesium, and calcium, were associated with lower values of PV and BD, whereas the phosphorus content did not affect PV and BD. The differences in amylose content, DSC gelatinization properties and color components as well as RS content in raw starch were not large.

Keywords Potato starch · Pasting properties · Gelatinization properties · Resistant starch

Introduction

The potato (*Solanum tuberosum* L.) is a critical root and tuber crop that is highly cultivated worldwide as a food source. Starch is the most abundant constituent of potato tubers. Japan produce approximately 2.4 million tons of potatoes annually, with about 80% of the total production concentrated in Hokkaido, the northernmost and second-largest island of Japan. Potato cultivars grown in Japan are grown for table use, food processing, and starch production. Only in Hokkaido is potato starch manufactured mainly in large-scale modern factories, with output of around 0.18 million tons/year. The old leading cultivar for starch production in Hokkaido was ‘Benimaru,’ until it was replaced by ‘Konafubuki’ in 1996 (Shimoda et al. 2018). Root and tuber starches have significant amounts of phosphate monoesters covalently bound to starch. Among the commercially available root and tuber starches, potato starch has the highest concentration of covalently bound phosphates (Hizukuri et al. 1970), which confers the highest viscosity (Hoover 2001). Thus, as potato starch exhibits unique traits, it can be utilized as an ingredient in foodstuffs. In relation to the application of potato starch produced in Hokkaido, the majority (60–65%) are used for noodles, fish paste products, confectioneries, thickening agents for cooking, etc. The rest (30–35%) are used in the saccharification industry to manufacture sugar products, such as glucose and fructose syrup (isosyrup), and in the production of chemically modified starch. It is well known that the cultivar and environmental factors affect starch characteristics in many crops. Several research groups have studied the differences in starch characteristics among potato cultivars (Ezekiel et al. 2010; Kim et al. 1995; Šimková et al. 2013; Singh et al. 2018; Wiesenborn et al. 1994). Additionally, our previous studies revealed that the

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cultivar (Karim et al. 2007; Noda et al. 2004a, 2007, 2008), harvest date (Noda et al. 2004b), and environmental temperature (Noda et al. 2012) affected starch properties in potatoes grown in Hokkaido. However, very little data regarding variability in starch properties at the factory level are currently available. It is vital to examine the difference in starch properties among different factories with the aim of preventing the occurrence of extreme variations in the quality of the final products, such as noodles, fish paste products, and confectioneries. Thus, the current study was carried out to compare the quality parameters of potato starch samples manufactured in 10 large-scale factories in Hokkaido.

Materials and methods

Materials

Potato starch samples manufactured in 10 large-scale factories (referred to as factory 1 through factory 10) in Hokkaido were used in this study. The operations of potato starch production were similar for all factories and involved starch extraction, separation, dewatering, and drying after potato tuber washing and rasping.

Determination of starch characteristics

For all starch samples studied, RVA pasting and DSC gelatinization properties, color, and amylose, resistant starch, and mineral contents were measured. The paste viscosity at 4% (w/w) starch suspension (dry-weight basis, w/w) was determined using an RVA-4 (Newport Scientific Pvt., Ltd., Warriewood, NSW, Australia), as previously reported (Noda et al. 2004b). The thermal properties at 30% starch suspension (dry-weight basis, w/w) were determined using a DSC 6100 (Seiko Instruments, Tokyo, Japan), in accordance with the procedures of Noda et al. (2004b). The color of the starch was measured using color meter NE 4000 (Nippon Denshoku Industries Co., Ltd., Tokyo, Japan), as described elsewhere (Noda et al. 2018). The resistant starch (RS) content, which corresponds to the ratio of RS to total starch, of native starches was analyzed using a Megazyme Resistant Starch Assay Kit, 05/2008 (Megazyme International Ireland Ltd., Co., County Wicklow, Ireland) in accordance with AOAC method 2002.02 (McCleary and Monaghan 2002). The contents of amylose and five minerals—phosphorus, sodium, potassium, magnesium, and calcium—were analyzed. The contents of amylose and phosphorus was analyzed as described previously (Noda et al. 2004b), whereas the sodium, potassium, magnesium, and calcium contents were determined according to the method reported previously (Noda et al.

2005). Measurements of amylose, mineral and RS contents, RVA pasting properties, DSC thermal properties, and color components were carried out in triplicate.

Statistical analysis

Averages of the RVA pasting property parameters, DSC gelatinization parameters, color parameters, and amylose, mineral, and RS contents were computed, and Tukey's range tests were conducted to measure variations in these parameters among starch factories. Correlation coefficients between the contents of five minerals and nine parameters of other physicochemical properties were calculated.

Results and discussion

Table 1 shows the contents of five minerals—phosphorus, sodium, potassium, magnesium, and calcium—of the potato starches produced in different factories. The contents of five minerals were altered significantly due to the differences in factories. The phosphorus content ranged from 669 to 835 ppm with a mean value of 747 ppm. The highest phosphorus content was observed for factory 9 and the lowest for factory 7. The cultivars have a manifest influence on the phosphorus content in potato starches. For example, starch from 'Konafubuki,' the present leading cultivar for starch production, has a higher phosphorus content than does 'Benimaru,' the old leading cultivar for starch production (Noda et al. 2004a, b, 2012). The potato starch samples examined in this study were derived mostly from 'Konafubuki.' Our research group previously found the average values of the phosphorus content for 'Konafubuki' to be 773 ppm (Noda et al. 2004a), 777 ppm (Noda et al. 2004b), and 788 ppm (Noda et al. 2012). These average values were in line with that obtained in this study (747 ppm). Among four cations examined, the potassium content showed the highest average value (681 ppm), ranging from 481 to 803 ppm. In contrast, the average values of the contents of sodium, magnesium, and calcium were 85, 76, and 83 ppm, respectively. Relatively large variations were found in the contents of sodium (35–134 ppm), magnesium (50–121 ppm), and calcium (34–164 ppm). Among factories for cations, factory 10 showed the lowest potassium content (481 ppm) and highest contents of magnesium (121 ppm) and calcium (164 ppm). This implied that a higher ratio of divalent cations to monovalent cations in the starch samples was produced in factory 10 than in those produced in other factories. It has been established that, in potato starches, metal cations are attached to the phosphate ester groups by ion forces (Kainuma et al. 1976; Md. Zaidul et al. 2007; Noda et al. 2005; Wiesenborn et al. 1994). Commonly,

Table 1 Mineral and amylose contents of the potato starches produced in different factories

Factory	Sodium (ppm)	Potassium (ppm)	Magnesium (ppm)	Calcium (ppm)	Phosphorus (ppm)	Amylose (%)
1	58 ± 2 ^f	668 ± 3 ^d	82 ± 1 ^{bc}	108 ± 3 ^b	755 ± 5 ^b	20.5 ± 1.3 ^a
2	76 ± 2 ^{de}	718 ± 3 ^c	74 ± 1 ^{cd}	75 ± 1 ^d	748 ± 5 ^b	20.9 ± 0.5 ^a
3	85 ± 1 ^d	803 ± 3 ^a	70 ± 4 ^{de}	50 ± 2 ^e	765 ± 7 ^b	20.7 ± 0.6 ^a
4	134 ± 3 ^a	663 ± 5 ^d	88 ± 2 ^b	68 ± 2 ^d	756 ± 3 ^b	20.3 ± 0.8 ^a
5	72 ± 3 ^e	738 ± 2 ^{bc}	60 ± 2 ^{ef}	34 ± 1 ^f	749 ± 5 ^b	20.9 ± 0.7 ^a
6	128 ± 2 ^b	636 ± 3 ^e	74 ± 2 ^{cd}	92 ± 3 ^c	754 ± 3 ^b	20.5 ± 0.3 ^a
7	35 ± 1 ^g	760 ± 3 ^b	50 ± 2 ^f	37 ± 1 ^{ef}	669 ± 6 ^c	21.2 ± 0.3 ^a
8	84 ± 3 ^d	588 ± 8 ^f	61 ± 2 ^{ef}	118 ± 2 ^b	680 ± 6 ^c	21.4 ± 0.2 ^a
9	73 ± 3 ^e	750 ± 6 ^b	81 ± 3 ^{bcd}	81 ± 2 ^{cd}	835 ± 8 ^a	21.8 ± 0.5 ^a
10	105 ± 1 ^c	481 ± 9 ^g	121 ± 3 ^a	164 ± 5 ^a	764 ± 5 ^b	21.4 ± 0.7 ^a
Mean (n = 10)	85	681	76	83	747	21.0

The data are mean ± standard deviation of three determinations, and the same letter does not show significant difference among samples at $p < 0.05$

potato starches produced in local factories in Hokkaido contain high levels of potassium (500–900 ppm) and low levels of other metal cations, sodium (< 100 ppm), magnesium (< 150 ppm), and calcium (< 200 ppm) (Md. Zaidul et al. 2007). The result agrees with the data obtained in this study. When potato starch is treated with a solution containing high amounts of magnesium and/or calcium, potassium, the major cation in potato starch, is displaced by magnesium and/or calcium through an ion-exchange process (Noda et al. 2014, 2015; Wiesenborn et al. 1994). Thus, it was assumed that the tap water used to extract the starch in factory 10 contained higher levels of magnesium and calcium than those in other factories. The amylose content was calculated from the absorbance at 680 nm (blue value), and the results are also shown in Table 1. Unlike the contents of five minerals, there were no significant differences in the amylose content, with a range between 20.3 and 21.8%. Singh et al. (2018) found that the amylose content varied widely from 6.5 to 32.2% among diverse Indian potato cultivars. Other researchers revealed the amylose content was changeable to some extent due to the difference in potato cultivars (Ezekiel et al. 2010; Kim et al. 1995; Šimková et al. 2013; Wiesenborn et al. 1994). As all the potato starches used in this study were manufactured mostly from “Konafubuki”, we attempted to compare the present data to the previous ones for “Konafubuki”. According to our previous reports (Karim et al. 2007; Noda et al. 2004a, b), the amylose content for “Konafubuki” was 19.8–20.5%, which was almost in agreement with our data. The pasting properties of the potato starches were analyzed by RVA, which measures the viscosity of starch suspension during a standard heating–cooling cycle with continuous agitation; the results are presented in Table 2. The results show that RVA

Table 2 RVA pasting properties of the potato starches produced in different factories

Factory	PV (RVU)	BD (RVU)	SV (RVU)	PVT (°C)
1	290 ± 1 ^a	175 ± 1 ^a	15 ± 1 ^a	79.6 ± 0.5 ^{bc}
2	291 ± 4 ^a	169 ± 5 ^a	15 ± 1 ^a	80.7 ± 0.9 ^{bc}
3	288 ± 14 ^a	158 ± 12 ^a	13 ± 3 ^a	82.8 ± 1.2 ^{ab}
4	295 ± 2 ^a	186 ± 2 ^a	17 ± 1 ^a	77.7 ± 0.0 ^c
5	307 ± 10 ^a	194 ± 10 ^a	16 ± 1 ^a	77.4 ± 0.0 ^c
6	288 ± 14 ^a	176 ± 13 ^a	13 ± 0 ^a	78.5 ± 0.0 ^{bc}
7	294 ± 5 ^a	185 ± 4 ^a	13 ± 2 ^a	76.8 ± 0.0 ^c
8	269 ± 2 ^{ab}	164 ± 3 ^a	13 ± 1 ^a	78.7 ± 0.5 ^{bc}
9	295 ± 1 ^a	169 ± 1 ^a	15 ± 0 ^a	80.9 ± 0.0 ^{bc}
10	236 ± 7 ^b	115 ± 5 ^b	15 ± 1 ^a	85.2 ± 0.9 ^a
Mean (n = 10)	285	169	14	79.8

The data are mean ± standard deviation of three determinations, and the same letter does not show significant difference among samples at $p < 0.05$

parameters—peak viscosity (PV), breakdown (BD), and peak viscosity temperature (PVT)—were altered manifestly by the different starch factories. PV, BD, and PVT varied in the range from 236 to 307 RVU, from 115 to 194 RVU, and from 76.8 to 85.2 °C, respectively. The average values of PV, BD, and PVT were 285 RVU, 169 RVU, and 79.8 °C, respectively. Interestingly, the significantly lowest values of PV and BD and highest value of PVT were detected in factory 10. Factories 4, 5, and 7 showed lower PVT (76.8–77.7 °C). No significant differences in PV and BD were observed among factory-made potato starches, except for factory 10. We previously reported that the average values of PV, BD, and PVT for ‘Konafubuki’ were 275 RVU, 153 RVU, and 83.6 °C, respectively (Noda et al.

2004a). This coincides with the present data on PV, BD, and PVT. Setback viscosity (SV) ranged from 13 to 17 RVU, showing no significant differences among the potato starches examined. The thermal properties of the potato starches were measured by DSC, and gelatinization parameters, which include onset temperature (To), peak temperature (Tp), and enthalpy (ΔH), are presented in Table 3. Significant but minor variations in To and Tp were noted among the potato starches examined. To and Tp ranged from 60.0 to 61.4 °C and from 63.7 to 65.2 °C with mean values of 60.6 and 64.4 °C, respectively. Factory 3 showed the highest To and Tp, whereas the lowest values of To and Tp were observed in factory 7. Significant differences were not observed in ΔH , with a range between 15.2 and 15.9 J/g. RS is a form of starch that is not degraded by amylases in the small intestine and enters the large intestine (Englyst et al. 1992; McCleary and Monaghan 2002; Raigond et al. 2015). In common with dietary fiber, RS appears to be desirable in human health. As raw potato starch is well known to be extremely difficult to digest by amylase among different raw starch samples (Englyst et al. 1992; McCleary and Monaghan 2002; Noda et al. 2008; Raigond et al. 2015), it is regarded as a promising source of RS. A recent study in mice has revealed that consuming raw potato starch controls postprandial blood glucose levels (Lee et al. 2018). Potato starch manufactured in Hokkaido is frequently utilized as an ingredient in processed foods such as egg boro, called “eisei boro,” where the potato starch has been scarcely gelatinized (Suzuki et al. 2002). Therefore, it is important to estimate the RS content in raw potato starch. To measure RS content, each raw potato starch was digested with pancreatic α -amylase and amyloglucosidase, and the RS content results are also shown in Table 3. As expected,

higher RS content was noted, ranging from 81.1% for factory 8 to 85.5% for factory 9 with a mean value of 84.1%. A significant but relatively small difference was observed in the RS content amongst potato starches examined. Color components of the potato starches were measured by using a color meter; the results are shown in Table 4. L*-values, an indicator of lightness, ranged from 95.51 to 96.44 with a mean value of 96.13; they were lowest for factory 10 and highest for factory 5. Among the potato starches examined, a*-(redness–greenness) and b*-(blueness–yellowness) values ranged from – 0.17 to 0.19 and from 1.31 to 1.98, respectively. Average a*- and b*-values were – 0.04 and 1.65, respectively. Factory 10 had the highest a*-value, whereas factory 1 had the lowest. The highest b*-value was found in factory 3, while factory 5 had the lowest. Thus, significant differences in L*, a*, and b*-values were observed among the potato starches examined, but the differences were not so large. It was concluded that all potato starches manufactured in the 10 factories in Hokkaido are satisfactorily white. Correlation analysis was performed to examine the contribution of the contents of five minerals to RVA pasting properties, DSC thermal properties, color components, and RS content in 10 potato starches examined in this study. Since no significant differences were noted among starch samples examined for SV and ΔH , their correlation analysis was avoided. The results of correlation analysis are presented in Table 5. It is generally recognized that the phosphorus content in potato starch is the principal factor contributing to pasting properties. For example, previous reports indicated that the phosphorus content was positively correlated with PV and BD (Ezekiel et al. 2010; Karim et al. 2007; Noda et al. 2004a, b). Our previous report indicated that the phosphorus content was significantly and negatively correlated

Table 3 DSC gelatinization properties and RS content of the potato starches produced in different factories

Factory	DSC parameters			RS content (%)
	To (°C)	Tp (°C)	ΔH (J/g)	
1	60.4 ± 0.3 ^{abc}	64.3 ± 0.2 ^{abc}	15.7 ± 0.4 ^a	84.0 ± 0.1 ^a
2	61.1 ± 0.1 ^{ab}	64.8 ± 0.2 ^{ab}	15.7 ± 0.2 ^a	84.3 ± 0.1 ^a
3	61.4 ± 0.1 ^a	65.2 ± 0.2 ^a	15.5 ± 0.2 ^a	85.4 ± 0.1 ^a
4	60.4 ± 0.3 ^{abc}	64.2 ± 0.3 ^{bc}	15.8 ± 0.2 ^a	85.2 ± 1.2 ^a
5	60.2 ± 0.3 ^{bc}	64.1 ± 0.1 ^{bc}	15.3 ± 0.2 ^a	84.2 ± 0.3 ^a
6	60.9 ± 0.1 ^{abc}	64.5 ± 0.1 ^{abc}	15.3 ± 0.3 ^a	83.2 ± 0.5 ^{ab}
7	60.0 ± 0.1 ^c	63.7 ± 0.2 ^c	15.3 ± 0.3 ^a	83.6 ± 0.1 ^{ab}
8	60.3 ± 0.1 ^{bc}	64.0 ± 0.1 ^{bc}	15.3 ± 0.1 ^a	81.1 ± 0.4 ^b
9	60.7 ± 0.2 ^{abc}	64.9 ± 0.2 ^{ab}	15.9 ± 0.2 ^a	85.5 ± 0.1 ^a
10	60.9 ± 0.1 ^{abc}	64.6 ± 0.2 ^{abc}	15.2 ± 0.4 ^a	84.7 ± 0.3 ^a
Mean (n = 10)	60.6	64.4	15.5	84.1

The data are mean ± standard deviation of three determinations, and the same letter does not show significant difference among samples at $p < 0.05$

Table 4 The color components of the potato starches produced in different factories

Factory	L*	a*	b*
1	96.27 ± 0.15 ^{abc}	− 0.17 ± 0.02 ^c	1.36 ± 0.06 ^f
2	96.03 ± 0.01 ^{bc}	− 0.09 ± 0.02 ^{bc}	1.80 ± 0.02 ^{bc}
3	96.01 ± 0.01 ^{bc}	0.01 ± 0.05 ^b	1.98 ± 0.02 ^a
4	96.29 ± 0.02 ^{abc}	− 0.12 ± 0.03 ^{bc}	1.56 ± 0.01 ^c
5	96.44 ± 0.06 ^a	− 0.12 ± 0.04 ^{bc}	1.31 ± 0.01 ^f
6	96.18 ± 0.07 ^{abc}	0.01 ± 0.01 ^b	1.75 ± 0.03 ^c
7	96.34 ± 0.01 ^{ab}	− 0.11 ± 0.02 ^{bc}	1.54 ± 0.02 ^e
8	96.26 ± 0.03 ^{abc}	− 0.05 ± 0.03 ^{bc}	1.58 ± 0.01 ^{de}
9	96.00 ± 0.04 ^c	0.02 ± 0.03 ^b	1.71 ± 0.03 ^{cd}
10	95.51 ± 0.07 ^d	0.19 ± 0.02 ^a	1.92 ± 0.02 ^{ab}
Mean (n = 10)	96.13	− 0.04	1.65

The data are mean ± standard deviation of three determinations, and the same letter does not show significant difference among samples at $p < 0.05$

with PVT (Noda et al. 2004a), whereas another study revealed no significant correlation between the phosphorus content and PVT (Karim et al. 2007). In this study, the phosphorus content was not significantly correlated with PV, BD, and PVT, which was unexpected. This was probably due to the relatively narrow range of phosphorus contents (669–835 ppm) of potato starch samples examined. The level of divalent cations, such as calcium and magnesium, appears to have an impact on starch pasting properties, presumably due to a cross-linking effect between divalent cations and phosphate groups on starch molecules. It has been reported that magnesium- and/or calcium-fortified potato starch has manifestly decreased values of PV and BD (Fortuna et al. 2013; Kainuma et al. 1976; Noda et al. 2014, 2015). Markedly higher PVT was noted in magnesium- and calcium-fortified potato starch containing no potassium and sodium (Noda et al. 2015). Conversely, increases in PV and BD were observed due to

Fig. 1 Relationships between the ratio of total divalent cations (magnesium plus calcium) to phosphorus and either PV (filled circle) or BD (open circle)

the fortification of potato starch with potassium (Fortuna et al. 2013; Kainuma et al. 1976). Our present study revealed that the contents of divalent cations magnesium and calcium were significantly and negatively correlated with PV (magnesium, $r = -0.692$, $p < 0.05$; calcium, $r = -0.865$, $p < 0.01$) and BD (magnesium, $r = -0.749$, $p < 0.05$; calcium, $r = -0.786$, $p < 0.01$), while the potassium content was significantly and positively correlated with PV ($r = 0.831$, $p < 0.01$). In addition, relationships between the cation contents and PVT were not found, with the exception of magnesium, which was significantly and positively correlated with PVT ($r = 0.731$, $p < 0.05$). Next, we attempted to calculate the correlation coefficients of the ratio of total divalent cations (magnesium plus calcium) to phosphorus on a molar basis with PV and BV. As shown in Fig. 1, the ratio of total divalent cations to phosphorus was significantly and negatively correlated with PV ($r = -0.884$, $p < 0.01$) and BV ($r = -0.815$, $p < 0.01$). Thus, the present data for the relationships between cation contents and RVA pasting properties were in line with the previous data, as mentioned above.

Table 5 Correlation coefficients among starch properties for the potato starches produced in different factories

	Sodium	Potassium	Magnesium	Calcium	Phosphorus
PV	− 0.256	0.831**	− 0.692*	− 0.865**	0.078
BD	− 0.197	0.630	− 0.749*	− 0.786**	− 0.190
PVT	0.157	− 0.345	0.731*	0.596	0.469
To	0.392	0.020	0.413	0.207	0.537
Tp	0.254	0.162	0.408	0.159	0.758*
RS content	0.101	0.368	0.415	− 0.238	0.737*
L*	− 0.252	0.492	− 0.803**	− 0.674*	− 0.419
a*	0.368	− 0.511	0.643*	0.598	0.339
b*	0.346	− 0.129	0.422	0.301	0.287

** and * are significant at $p < 0.01$ and 0.05 , respectively

Literature is available on the influence of mineral contents in potato starch on DSC thermal properties. Several results, including ours, have shown that To and Tp remained constant or rose slightly as the phosphorus content increased (Karim et al. 2007; Kim et al. 1994; Noda et al. 2004b, 2007). Fortifying potato starch with calcium and/or magnesium did not play a large role in To or Tp (Fortuna et al. 2013; Noda et al. 2014). In this study, To and Tp showed no significant correlation coefficients with the contents of five minerals, except in the case of the positive correlation between the phosphorus content and Tp ($r = 0.758$, $p < 0.05$). It is currently accepted that the action of amylolytic enzymes is prevented by phosphate groups attached to the glucosyl residue of starch; phosphoryl-oligosaccharides are produced after the exhaustive degradation of potato starch by amylase (Kamasaka et al. 1995; Takeda et al. 1983). Supporting this, an enhancement in the phosphorus content led to a lower hydrolysis rate in raw starch for composites of potato and other root and tuber starches in our previous study (Noda et al. 2008). There was a significant positive correlation between the phosphorus content and RS content in this study ($r = 0.737$, $p < 0.05$). Thus, our results to date suggest that raw starches with higher phosphorus contents contain higher RS. We previously found no significant change in RS content in raw starch due to the magnesium- and calcium-fortification of potato starch (Noda et al. 2014). Consistently, no significant correlation coefficients were noted between cation contents, including magnesium and calcium contents, and RS content in this study. It has been reported that the compositional characteristics of starch, such as the contents of protein and minerals, are sensitive to L^{*}-, a^{*}-, and b^{*}-values of starch. As Singh et al. (2014) pointed out, L^{*}-value decreased and a^{*}- and b^{*}-values increased with the increase in protein content of maize starch. According to our previous report (Noda et al. 2018), the fortification of potato starch with iron slightly reduced L^{*}-value and enhanced b^{*}-value. However, as far as we know, the effects of the contents of phosphorus, sodium, potassium, magnesium, and calcium on color components in potato starch have not yet been elucidated. This study revealed no relationships between the contents of five minerals and color components, except significant negative correlation coefficients of the contents of magnesium ($r = -0.803$, $p < 0.01$) and calcium ($r = -0.674$, $p < 0.05$) with L^{*}-value and significant positive correlation coefficient of magnesium content with a^{*}-value ($r = 0.643$, $p < 0.05$). However, the contents of five minerals spanned limited ranges in this study; therefore, further investigation would be needed to clarify the precise relationship between mineral contents and color components using potato starches with widely varied mineral contents.

Conclusion

In the present investigation, we evaluated the physicochemical properties of potato starch samples manufactured in 10 Hokkaido factories. The results revealed that RVA pasting parameters, PV, BD, and PVT, differ greatly among factories. The contents of divalent cations magnesium and calcium showed significant negative correlation coefficients with PV and BD. In contrast, no or only small differences in DSC gelatinization properties, color components, and amylose and RS contents were found among starch samples. Consequently, this information would be useful for food industries that make use of potato starch manufactured in Hokkaido.

Acknowledgements This work was in part supported by a grant from Stabilization Fund Association of Hokkaido Potato Production.

Compliance with ethical standards

Conflict of interest All authors declare that they have no conflict of interest.

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