J Food Sci Technol (March–April 2010) 47(2):195–201
DOI: 10.1007/s13197-010-0025-1

ORIGINAL ARTICLE

Physico-chemical and pasting properties of starch from stored potato tubers

Ezekiel R. · Rana G. · Singh N. · Singh S.

Revised: 10 August 2009 / Accepted: 14 August 2009

Abstract Starch was separated from tubers of four potato (*Solanum tuberosum* L.) cultivars, viz. 'Kufri Jyoti', 'Kufri Sindhuri', 'Kufri Chipsona-1' and 'Kufri Chipsona-2' before and after 90 days of storage at 4, 8, 12 and 16°C and, morphological, physico-chemical and pasting properties were studied. Scanning electron microscopy showed oval and irregular shaped starch granules with average diameter of 15 μm, and the granule diameter increased after storage. Peak viscosity was lower after storage at 8°C and higher at 16°C. Hot paste viscosity decreased while breakdown viscosity and set back viscosity increased after storage, and there was no significant change in cold paste viscosity. A significant decrease in pasting time and increase in pasting temperature was observed after storage. Phosphorus content showed significant positive correlation with peak viscosity ($r = 0.452$, $p < 0.05$) and breakdown viscosity ($r = 0.685$, $p < 0.01$), and a negative correlation with amylose content ($r = -0.674$, $p < 0.01$). 'Kufri Sindhuri' starch showed significantly ($p < 0.05$) higher peak, hot paste, breakdown and cold paste viscosity. The X-ray diffraction pattern of starch showed a distinctive maximum peak at around 17°, 2 θ and it was not affected by the cultivar or storage temperature.

Keywords Potato starch · Storage · Temperature · Granule size · Physicochemical properties · Pasting properties

Ezekiel R.[1] · Rana G.[1] · Singh N.[2] · Singh S.[2]
[1]Division of Crop Physiology and Post-harvest Technology,
Central Potato Research Institute,
Shimla - 171 001, India
[2]Department of Food Science and Technology,
Guru Nanak Dev University,
Amritsar - 143 005, India

Ezekiel R. (✉)
E-mail: rajarathnamezekiel@yahoo.co.in

Introduction

Starch is the major component of dry matter in potato (*Solanum tuberosum* L.) tubers and its content is influenced by a number of cultural and environmental factors (Smith 1987). Fresh potatoes are available only for a few months in a year and potatoes need to be stored properly to make them available to the starch processing industry throughout the year. During storage starch is converted into sugars (Smith 1987) and this conversion is more at lower temperatures of 4°C or less (Van Es and Hartmans 1987, Burton 1989) resulting in quantitative loss of starch in stored potatoes. Storage temperature affects not only the quantity but also the quality of potato starch (Leszczynski 1989). Jhonston et al. (1968) observed an increase in amylose content after storage while Golachowski (1985) reported a decrease. There are conflicting reports about the effect of storage on the viscosity of starch. Golachowski (1985) reported an increase in viscosity of starch separated from potatoes stored for 12 weeks at 8 and 12°C whereas, Ridley and Hogan (1976) observed a decrease in viscosity of starch separated from potatoes stored for 3 months at 1.7 and 7.2°C. P, K and Ca contents of starch are also affected by storage conditions (Mica 1976). The results of many of these studies are not comparable because of the differences in materials used and storage conditions (Golachowski 1985). Brabender viscoamylograph and rapid visco-analyzer have been used extensively for measuring starch paste viscosity (Wiesenborn et al. 1994) and starch exhibits unique viscosity behaviour with change of temperature (Nurul et al. 1989). Starch has a definite crystalline nature due to the well ordered structure of amylopectin molecules inside the granules. Starches show characteristic X-ray diffraction patterns and potato starch shows B-type pattern (Leszczynski 1989). The aim of this investigation was to determine physico-chemical and pasting properties of starch separated from 2 old and 2 new Indian potato cultivars stored for 90 days at 4, 8, 12 and 16°C.

Materials and methods

Tubers of 2 old potato cultivars viz. 'Kufri Sindhuri' and 'Kufri Jyoti', released in 1967 and 1968, respectively, and 2 new potato cultivars viz. 'Kufri Chipsona-1' and 'Kufri Chipsona-2', released in 1998, were used in this experiment. 'Kufri Jyoti', 'Kufri Chipsona-1' and 'Kufri Chipsona-2' are medium (90–110 days) duration cultivars, while 'Kufri Sindhuri' (more than 110 days) is a late duration cultivar. The crop was raised at the Central Potato Research Institute Campus, Modipuram, India (29° 4'N, 77° 46'E, 237M above MSL) during 2004–05 following recommended package of practices. Planting was done in October 2004. Haulms were cut after full maturity had been reached and the crop was harvested 15 days later. The harvested tubers were brought to Central Potato Research Institute, Shimla, India, cured at room temperature for 3 weeks and 500 kg of tubers of each variety were stored in walk-in-chambers at 4, 8, 12 and 16°C for 90 days. The temperature was brought down by 0.5°C/day until the desired temperature was reached. The relative humidity was maintained at 90–95% at 4°C and at 85–90% at other temperatures. Normally potatoes are stored at 4°C in cold stores in India, therefore, 4°C was taken as one of the treatments. But potatoes stored at 4°C are not suitable for processing, therefore, higher storage temperatures of 8, 12 and 16°C were used in this experiment. When stored at these temperatures, potato tubers sprout and to check sprout growth a chemical sprout suppressant was used. Isopropyl N-(3 chlorophenyl) carbamate (CIPC) commonly known as chlorpropham was applied as a fog, using a fogger (Dyna-Fog, Curtis Dyna-Fog, Westfield IN, USA). A commercial preparation of CIPC called 'Oorja' (United Phosphorus, Mumbai, India) which contains 50% a.i. was applied at 35 ml/1000 kg of potatoes, which resulted in a final concentration of 17.5 ppm. After CIPC application, the walk-in-chamber was kept airtight for 48 h, and then ventilated. There were 2 applications of CIPC, the first application at the first sign of sprouting and the second at 45 days after the first application.

Starch isolation: Tubers were selected from each variety before and after 90 days of storage. There were 3 samples (representing 3 replications) for each variety at each observation and each sample consisted of 5 kg of tubers (individual tuber weight 75–125 g) taken randomly from a lot of 500 kg. The tubers were washed thoroughly, peeled and sliced into 2 mm thick slices using a rotary slicer and the slices were kept immersed in water containing 0.5% potassium metabisulphite to avoid browning. Defective slices were removed. The slices were ground thoroughly in a laboratory scale grinder (Lumix, Ambala, India) at 12,000 rpm, 450 W, to get a fine slurry. The slurry was filtered through a muslin cloth and the residue washed repeatedly to recover maximum amount of starch. The filtrate was collected in a tub and left overnight for the starch to settle. The supernatant liquid was decanted and the starch layer was washed repeatedly (4–5 times) with distilled water until the supernatant became transparent. The starch cake was dried in a hot-air oven at 40°C until it was dry. The dried starch was ground to a fine powder and kept in an airtight container at room temperature (16–24°C) for further analysis. Physicochemical and pasting properties were determined in all the cultivars. For X-ray diffraction studies, 'Kufri Jyoti' and 'Kufri Chipsona-2,' and for electron microscopy, 'Kufri Jyoti' were used.

Morphological properties: Scanning electron micrographs of starch samples isolated from tubers of potato cultivar 'Kufri Jyoti' before and after 90 days storage at 4, 8, 12 and 16°C were taken with a scanning electron microscope (Jeol JSM-6100, Jeol Ltd., Tokyo, Japan). Starch suspension (1%) in ethanol was prepared and one drop of the suspension was taken on an aluminium stub and the starch was coated with gold palladium (60: 40). An accelerating potential of 10 kV was used during micrography.

Physicochemical properties of starch: Swelling volume using 2% (w/v) aqueous suspension of starch following the method of Schoch (1964) and amylose content of starch samples by the method given by Williams et al. (1970) were determined. Optical density was measured for determining clarity of starch following the procedure described in Ezekiel et al. (2007). Phosphorus content was determined by the method of Smith and Caruso (1964).

Pasting properties: The pasting properties of starch samples were determined with Rapid Visco Analyzer (RVA-4, Newport Scientific, Warriewood, Australia). Viscosity profiles of starch samples were recorded using starch suspensions (6% w/w; 28 g total weight). A programmed heating and cooling cycle was used where the samples were held at 50°C for 1 min, heated to 95°C at 6°C/min, held at 95°C for 2.7 min, before cooling from 95 to 50°C at 6°C/min and holding at 50°C for 2 min. Parameters recorded were pasting temperature, peak viscosity, hot paste viscosity (minimum viscosity at 95°C), cold paste viscosity (viscosity at 50°C), breakdown viscosity (peak viscosity – hot-paste viscosity) and setback viscosity (cold-paste viscosity – hot-paste viscosity). All measurements were replicated thrice.

X-ray diffraction: X-ray diffraction pattern of starch samples separated from 'Kufri Jyoti' and 'Kufri Chipsona-2' before and after 90 days storage at 4, 8, 12 and 16°C was taken using a Philips PW 1710 diffractometer (Eindhoven, The Netherlands) equipped with a Cu anode. The samples were scanned from 5° to 60° (2 θ) with a step width of 0.05 nm. The generator current was 20 mA, divergence slit was 1º and receiving slit was 0.1 mm (Gebre – Mariam and Schmidt 1996) .

Statistical analysis: All determinations were done in triplicate and a completely randomized design was followed. The data were analysed using MSTAT (4.0 C) software with LSD at significance level of 5%.

Results and discussion

Morphological properties: The starch granules were oval and irregular shaped and the granule surface generally appeared smooth (Fig. 1). The mean granule diameter of starch before storage was 15 µm. After 90 days of storage at 4, 8, 12 and 16°C, it was 19, 22, 25 and 24 µm, respectively. We observed a decrease in the number of small granules and increase in large granules after storage. But Golachowski (1985) observed a decrease in the proportion of granules with more than 35 µm diameter and an increase in smaller granules (20–30 µm and less than 20 µm) after storage at 4, 8 and 20°C.

Physicochemical properties of starch: Amylose content was higher in starch from 'Kufri Jyoti' and was least in the starch from 'Kufri Sindhuri' (Table 1). Higher amylose content in 'Kufri Jyoti' starch has been observed in freshly harvested potatoes (Singh and Singh 2003). A significant decrease in amylose content was observed in starch from tubers stored for 90 days at 8, 12, and 16°C but not at 4°C. Golachowski (1985) also observed less amylose content in starch from potato stored at 8 or 20°C for 12 weeks but observed no significant change at 4ºC. Similar results were obtained by Schwimmer et al. (1954) and Ezekiel et al. (2007). After 90 days, significant decrease in swelling volume was observed in starch from tubers stored at 4°C, but not at 8, 12 and 16°C (Table 1). Potato starch is known to have higher swelling volume compared to other starches and a high swelling power, which is 10–100 times higher than that of starches of cereal grains (Leszczynski 1989). The amylopectin fraction of starch is believed to be primarily responsible for swelling (Tester and Morrison 1990) and the higher swelling power of potato starch could also be due to a higher content of phosphate groups on amylopectin (Galliard and Bowler 1987). After 90 days, there was no significant difference in P content of starch from tubers stored at 4 or 8°C but was higher ($p < 0.05$) in starch from tubers stored at 12 or 16°C, compared to that before storage (Table 1). Among the cultivars, the P content of starch was higher ($p < 0.05$) in 'Kufri Sindhuri' and 'Kufri Chipsona-1', and lower in 'Kufri Jyoti'. The P content varied from 0.07 to 0.13% and these values are closer to the values of 0.063 to 0.115% reported by Veselovsky (1940) for starch

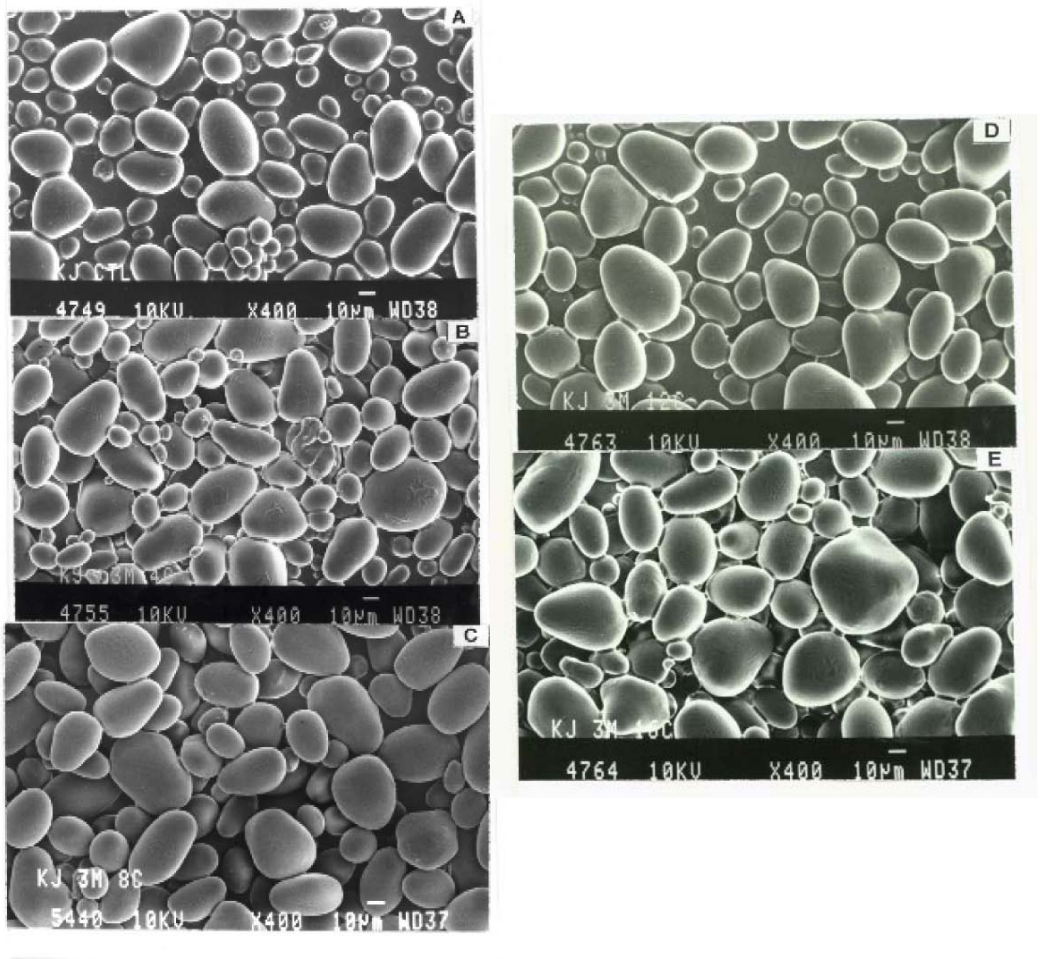

Fig. 1 Scanning electron micrographs (SEM) of starch separated from tubers of 'Kufri Jyoti' before storage (A) and after 90 days of storage at 4ºC (B), 8ºC (C), 12ºC (D) and 16ºC (E)

Table 1 Physicochemical and pasting properties of starch from potato cultivars (C) stored for 90 days at different temperatures (T)

Temp,°C	Amylose content, %	Swelling volume, ml/g	Phos-phorus content, %	Optical density	Peak visco sity, cP	Hot paste visco sity, cP	Break down visco sity, cP	Cold paste viscosity, cP	Setback viscosity, cP	Pasting time, min	Pasting temp, °C
Kufri Chipsona-1											
BS	20.0	35	0.09	1.538	3661	2689	972	2985	296	5.23	64.6
4	18.0	39	0.09	1.570	3768	2567	1201	3018	451	5.07	68.4
8	18.6	40	0.08	1.594	3151	2436	715	2922	486	5.13	68.6
12	19.0	35	0.11	1.636	3636	2474	1162	2854	380	4.93	67.0
16	19.0	46	0.12	1.274	4612	2425	2187	2706	281	4.60	67.9
Kufri Chipsona-2											
BS	19.6	42	0.07	1.415	3672	2879	793	3271	392	5.53	66.1
4	18.7	40	0.08	1.538	4007	2680	1327	3102	422	5.20	67.7
8	18.8	40	0.10	1.587	3293	2156	1137	2568	412	4.80	67.1
12	18.6	45	0.10	1.621	3504	2418	1086	2865	447	5.07	68.5
16	17.9	40	0.10	1.419	3790	2467	1323	2725	258	4.87	68.5
Kufri Jyoti											
BS	22.0	43	0.07	1.621	3847	2643	1204	3021	378	5.00	67.7
4	22.2	36	0.07	1.613	3331	2293	1038	2628	335	5.07	69.4
8	20.9	39	0.08	1.654	3368	2483	885	2939	456	4.80	68.4
12	19.7	41	0.08	1.683	3577	2584	993	3000	416	5.07	67.8
16	21.0	39	0.08	1.466	3843	2589	1254	3094	505	4.93	67.0
Kufri Sindhuri											
BS	19.1	43	0.09	1.559	4341	2976	1365	3307	331	5.20	67.0
4	18.0	38	0.11	1.596	4231	2661	1570	3234	573	5.00	66.9
8	17.2	41	0.10	1.684	4379	2588	1791	2931	343	4.60	68.5
12	18.0	42	0.11	1.624	3972	2580	1392	3007	427	4.87	67.7
16	17.8	40	0.10	1.333	4372	2860	1512	3230	370	5.07	68.5
LSD ($p \leq 0.05$)											
T	1.1	1.5	0.008	0.026	270	147	160	NS	41	0.13	1.4
C	0.9	1.2	0.007	0.021	250	203	248	225	NS	NS	NS
TxC	2.2	3.0	0.022	0.052	579	421	547	NS	NS	NS	NS

BS: Before storage, NS: Not significant

in European and North American potato varieties. Starch from potato tubers stored at 4 or 8°C contained less P than starch from tubers before storage (Golachowski 1985). But in the present study there was no significant difference in P content before and after storage at 4 or 8°C. However, an increase was observed in the P content of starch from tubers stored at 12 or 16°C, when compared to starch from tubers before storage. The optical density of starch from tubers of 'Kufri Jyoti' was higher indicating that starch of this cultivar was less clear compared to 'Kufri Chipsona-2' and 'Kufri Chipsona-1'. The optical density of starch from tubers before storage varied from 1.415 to 1.621 and it increased ($p < 0.05$) after 90 days of storage at 4, 8 and 12°C and decreased significantly ($p < 0.05$) at 16°C (Table 1). Generally the starch clarity was lower after storage at lower temperatures of 4 or 8°C and increased after storage at higher temperature of 16°C. Potato starch which is of B – type is known to have higher clarity than A – type starches from cassava and sweet potato (Moorthy 2002) and the higher transmittance of potato starch has been attributed to the higher phosphate monoester content (Singh et al. 2002). Swelling volume showed a non-significant, negative correlation ($r = –0.392$) with amylose content (Table 2). Collado et al. (1999) also did not observe a significant correlation between amylose content and swelling volume. Higher swelling of potato starch has been attributed to the presence of phosphate groups which are responsible for the swelling of starch granules (Swinkels 1985, Galliard and Bowler 1987). In this study, a positive but non-significant correlation ($r = 0.282$) was observed between swelling

volume and P content. Amylose content showed a significant ($p < 0.01$) negative correlation with P content ($r = –0.674$) (Table 2).

Pasting properties: Pasting temperature of starch separated from potato varied from 64.6 to 67.7°C before storage and, it varied from 66.9 to 69.4°C after 90 days storage at different temperatures (Table 1). Pasting temperature ranging from 66.7 to 70.3°C has been reported for different potato cultivars (Noda et al. 2004). 'Kufri Sindhuri' starch showed higher ($p < 0.05$) peak, hot paste, and break down and cold paste viscosity, while there was no significant cultivar differences in set back viscosity, pasting time and temperature. Compared to that before storage, peak viscosity was lower ($p < 0.05$) after 90 days of storage at 8°C and higher ($p<0.05$) at 16°C, with no significant difference at 4 or 12°C. Sugimoto et al. (1988) observed a decrease in viscosity after storage. Hot paste viscosity decreased ($p<0.05$) after storage and the decrease was maximum at 8°C. Significant increase ($p\leq0.05$) in breakdown viscosity was observed after storage at 4 or 16°C but not at the other 2 temperatures. Cold paste viscosity increased upon cooling, which may be due to aggregation of amylose molecules (Miles et al. 1985). It decreased after storage but the differences were non-significant. Setback viscosity increased ($p<0.05$) after storage at 4, 8 and 12°C but not at 16°C. There was a decrease ($p<0.05$) in pasting time and increase in pasting temperature in starch from tubers after storage. Golachowski (1985) did not observe significant difference in the viscosity of starch from tubers stored at 4°C compared to that before storage. However, he observed a higher viscosity at 8°C and it was attributed to changes in chemical composition and starch granularity. He also observed an increase in viscosity at 20°C but the increase was lower than the increase at 8°C and this difference was attributed to the decreased quantity of amylose, decreased reducing power and increased contribution of small granules during potato storage. P content showed, positive correlation with peak viscosity ($r = 0.452$, $p \leq 0.05$) and breakdown viscosity ($r = 0.685$, $p < 0.01$) (Table 2). There was a highly positive correlation between peak viscosity and breakdown viscosity ($r = 0.831$, $p \leq 0.01$).

X-ray diffraction: X- ray diffraction analysis of starch samples revealed B-type pattern, which is characteristic of potato starch (Leszczynski 1989). X-ray diffraction pattern of starch separated from tubers of 'Kufri Jyoti' and 'Kufri Chipsona-2', before and after storage showed a distinctive maximum peak at around 17°, 2 θ (Fig. 2). Gebre – Mariam and Schmidt (1996) also reported B-type X-ray diffraction pattern for potato starch with a major peak at 17°. There was little difference in X-ray diffraction pattern of starches of 'Kufri Jyoti' and 'Kufri Chipsona-2'. Barichello et al. (1990) and Hoover and Sosulski (1985) also did not observe any difference in the X-ray diffraction pattern of potato and common bean (*Phaseolus vulgaris* L.*)* genotypes, respectively. The major peak in starch from tubers before storage was at 17.3° in 'Kufri Jyoti' and 17° in 'Kufri Chipsona-2', which corresponded to interplanar spacings of 5.12 and 5.20 Å, respectively. In starch from tubers after 90 days of storage at 4, 8, 12 and 16°C, the major peak was observed at 17°, 16.8°, 16.9°, and 17°, respectively in 'Kufri Jyoti', which corresponded, respectively, to interplanar spacings of 5.20, 5.27, 5.24 and 5.20 Å. In 'Kufri Chipsona-2', the major peak was at 17°, 16.9°, 17.3° and 17°, respectively, which corresponded to interplanar spacings of 5.20, 5.24, 5.12 and 5.20 Å, respectively (Fig. 2). The above results indicate that storage temperature did not alter the X-ray diffraction pattern of starch from stored potato tubers.

Conclusion

Changes in physico-chemical and pasting properties of potato starch varied with the storage temperature. Pasting time decreased while pasting temperature increased. Among the cultivars, 'Kufri Sindhuri' starch showed significantly higher peak, hot paste, breakdown and cold paste viscosity, while there was no significant cultivar differences in setback viscosity, pasting time and temperature. The results indicated that cultivar and storage temperature had significant effects on physicochemical and pasting properties of potato starch but not on the X-ray diffraction pattern.

Table 2 Pearson's correlation coefficients for the physicochemical and pasting properties of starch separated from four potato cultivars stored for 90 days at four temperatures

	AC	SV	PC	PV	HPV	CPV	BDV
SV	–0.392						
PC	–0.674**	0.282					
PV	–0.423	0.374	0.452*				
HPV	–0.125	0.264	–0.167	0.606			
CPV	–0.000	–0.030	–0.044	0.140	0.505		
BDV	–0.405	0.322	0.685**	0.831**	0.079	–0.123	
SBV	–0.019	0.001	–0.121	–0.220	–0.019	–0.013	–0.312

AC=Amylose content, SV= Swelling volume, PC= Phosphorus content, PV= Peak viscosity, HPV=Hot paste viscosity, CPV=Cold paste viscosity, BDV=Breakdown viscosity, SBV= Setback viscosity, *= $p < 0.05$, ** = $p < 0.01$

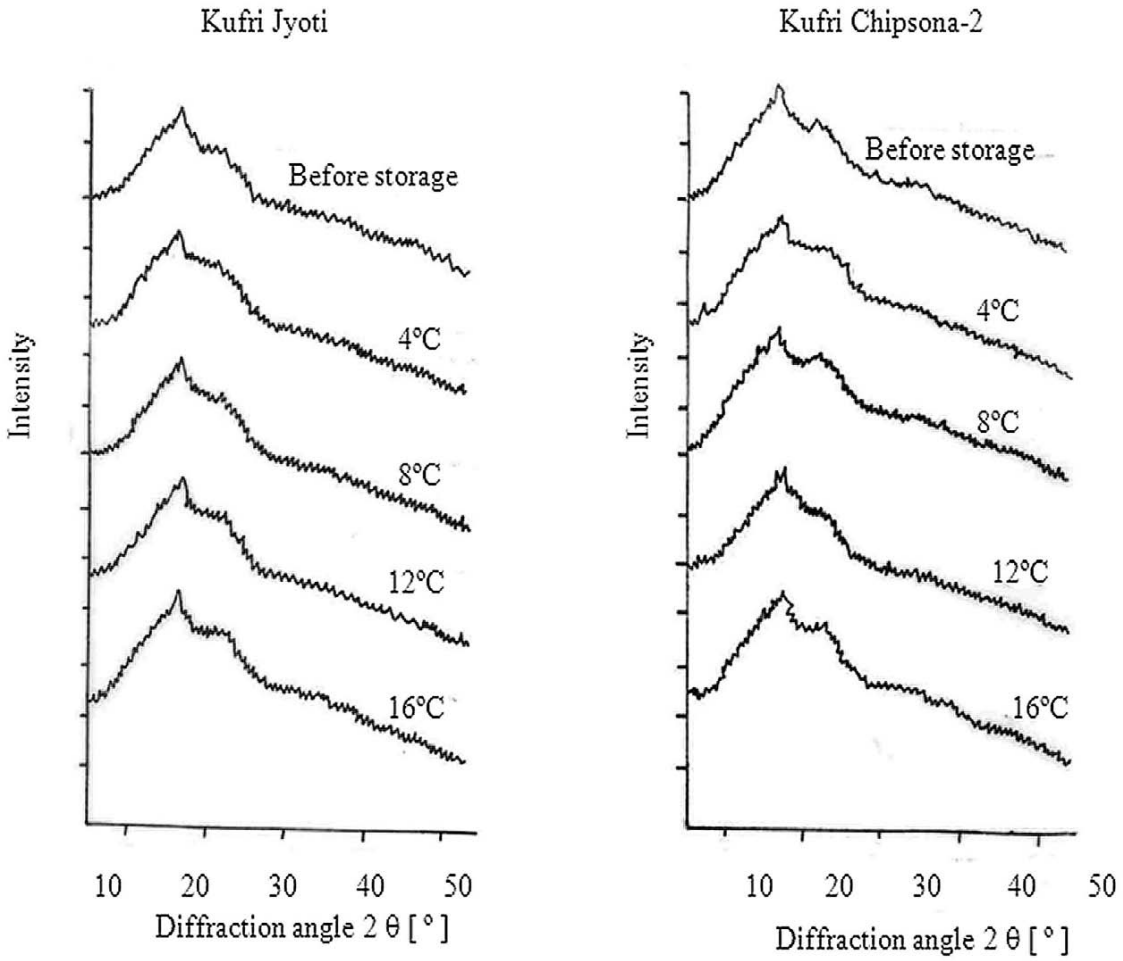

Fig. 2 X-ray diffraction patterns of potato starch extracted from tubers of 'Kufri Jyoti' and 'Kufri Chipsona-2' after 90 days of storage at 4, 8, 12 and 16°C

Acknowledgements Authors are thankful to Director, Central Potato Research Institute, Shimla for providing the facilities. Help received from Sharma ML and Jagtar Singh of Sophisticated Analytical Instrumentation Facility, Panjab University, Chandigarh, for scanning electron micrographs and XRD analysis is thankfully acknowledged.

References

Barichello V, Yada RY, Coffin RH, Stanley DW (1990) Low temperature sweetening in susceptible and resistant potatoes: Starch structure and composition. J Food Sci 55:1054–1059

Burton WG (1989) The potato. 2nd edn, Longman, Singapore, p 742

Collado LS, Mabesa RC, Corke H (1999) Genetic variation in the physical properties of sweet potato starch. J Agric Food Chem 39:1406–1410

Ezekiel R, Rana G, Singh N, Singh S (2007) Physicochemical, thermal and pasting properties of starch separated from γ-irradiated and stored potatoes. Food Chem 105:1420–1429

Galliard T, Bowler P (1987) Morphology and composition of starch. In: Starch properties and potential. Galliard T (ed), Wiley, Chichester, p 55–78

Gebre-Mariam T, Schmidt PC (1996) Isolation and physicochemical properties of Enset starch. Starch/Starke 48: 208–214

Golachowski A (1985) Properties of starch obtained from potato tubers influenced by various temperatures. Starch/Starke 37: 263–266

Hoover R, Sosulski F (1985) Studies on the functional characteristics and digestibility of starches from Phaseolus vulgaris biotypes. Starch/Starke 37:181–191

Jhonston FB, Urbas B, Khanzada J (1968) Effect of storage on the size distribution and amylose/amylopectin ratio in potato starch granules. Am Potato J 45:315–321

Leszczynski W (1989) Potato starch processing. In: Potato science and technology. Lisinska G, Leszczynski W (eds), Elsevier, London, p 281–348

Mica B (1976) Characteristics of starch of selected potato varieties. II. Phosphorus potassium and calcium content in the starch. Starch/Starke 28:410–413

Miles MJ, Morris VJ, Orford RD, Ringh SG (1985) The roles of amylose and amylopectin in the gelation and retrogradation of starch. Carbohydr Res 135:271–281

Moorthy SN (2002) Physicochemical and functional properties of tropical tuber starches: a review. Starch/Starke 54:559–592

Noda T, Tsuda S, Mori M, Takigawa S, Endo CM, Hashimoto N (2004) Properties of starches from potato varieties grown in Hokkaido. J Appl Glyco Sci 51:241–246

Nurul IM, Azemi BMNM, Manan DMA (1989) Rheological behaviour of sago (*Metroxylon sagu*) starch paste. Food Chem 64:501–505

Ridley SC, Hogan JM (1976) Effect of storage temperature on tuber composition, extrusion force and brabender viscosity. Am Potato J 53:343–353

Schoch TJ (1964) Swelling power and solubility of granular starches. In: Methods in carbohydrate chemistry, Vol IV. Whistler RL (ed), Academic Press, New York, p 42–46

Schwimmer S, Arthur B, William J, Potter AI (1954) Survey of major and minor sugar and starch components of the white potato. J Agric Food Chem 2:1284–1290

Singh J, Singh N (2003) Studies on the morphological and rheological properties of granular cold water soluble corn and potato starches. Food Hydrocoll 17:63–72

Singh N, Singh J, Kaur L, Sodhi NS, Gill BS (2002) Morphological, thermal and rheological properties of starches from different botanical sources-a review. Food Chem 79:1–13

Smith O (1987) Transport and storage of potatoes. In: Potato processing, Talburt WF, Smith O (eds), Van Nostrand Reinhold, New York, p 203–286

Smith RJ, Caruso JL (1964) Determination of phosphorus. In: Methods in carbohydrate chemistry. (Vol. IV), Whistler RL (ed), Academic press, New York, p 42–46

Sugimoto Y, Tokunou K, Yamamoto M (1988) Effects of temperature during storage on Brabender amylogram values of starch pastes. J Jap Soc Starch Sci 35:179–183

Swinkels JJM (1985) Composition and properties of commercial native starches. Starch/Starke 37:1–5

Tester RF, Morrison WR (1990) Swelling and gelatinization of cereal starches. I. Effects of amylopectin, amylose and lipids. Cereal Chem 67:551–557

Van Es A, Hartmans KJ (1987) Starch and sugars during tuberization, storage and sprouting. In: Storage of potatoes, Rastovski A, Van Es A (eds), Pudoc, Wageningen, p 114–132

Veselovsky IA (1940) Biochemical and anatomical properties of starch of different varieties of potatoes and their importance for industrial purposes. Am Potato J 17:330–339

Wiesenborn DP, Orr PH, Casper HH, Tacke BK (1994) Potato starch behaviour as related to some physical/chemical properties. J Food Sci 59:644–648

Williams PC, Kuzina FD, Hlynka I (1970) A rapid colorimetric procedure for estimating the amylose content of starches and flours. Cereal Chem 47:411–420