Food Chemistry 114 (2009) 1396–1404

Contents lists available at ScienceDirect

Food Chemistry

journal homepage: www.elsevier.com/locate/foodchem

Properties of starches separated from potatoes stored under different conditions

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A R T I C L E I N F O

Article history:
Received 18 March 2008
Received in revised form 30 September 2008
Accepted 10 November 2008

Keywords:
Potato starch
Storage temperatures
Amylose
Thermal
Rapid visco analysis
Swelling
Gel texture
Granule size distribution
Morphology

A B S T R A C T

Starches from 11 potato cultivars stored at five temperatures (4, 8, 12, 16 and 20 °C) for 120 days were evaluated for physicochemical, thermal and pasting properties. Amylose content and swelling power increased with increase in storage temperatures. The proportion of small size granules was higher in starches from potatoes stored at 4 °C. The starch granules of stored potatoes were slightly rough-surfaced and pitted; the effect was pronounced in those stored at 4 °C. Starches from potatoes stored at 4 °C showed lower onset gelatinization temperature and conclusion temperature than did starches from potatoes stored between 8 and 20 °C. Starches from potatoes stored at higher temperature (20 °C) showed higher peak viscosity, set back, as well as gel hardness, chewiness and gumminess than did starches from those stored between 4 and 16 °C. Amylose content showed significant positive correlation with gumminess and setback while swelling power showed significant positive correlation with peak viscosity and hot-paste viscosity.

1. Introduction

In most countries, only one potato crop can be grown in one year and, therefore, fresh potatoes are available only for a few months. Storage of potatoes is essential to meet the requirements during the rest of the year. Good storage environment should maintain the stored potatoes in good condition by preventing excessive weight loss, spoilage by pathogens, sprout growth and deterioration in quality. Storage conditions depend on the purpose for which potatoes are stored. Seed potatoes are stored at lower temperatures (4 °C or less) whereas potatoes meant for processing are stored at above 8 °C (Van Es & Hartmans, 1987). Storage conditions bring about different changes in chemical composition of tubers (McCay, McCay, & Smith, 1987) and texture (Sowokinos, Orr, Knoper, & Varns, 1987; Kazami, Tsuchiya, Kobayashsi, & Ogura, 2000), depending upon the temperature employed. Inter-relationships of physical and biochemical quality characteristics of potatoes have been reported, involving texture, starch and reducing sugars. Storage of potatoes is very important for the starch processing industry, as it has to depend on stored potatoes for a large part of the year. Sugar and starch are the two components, which are affected most by the storage temperature and the mechanisms of changes that occur during storage at higher temperatures, are different from those at lower temperatures (Sowokinos et al., 1987; Kazami et al., 2000). Storage affects, not only starch content, but also its properties. Effects of storage temperature on starch granule number and size, amylose content and viscosity have been studied (Golachowski, 1985). The results of many of these studies are not comparable because of the differences in materials used and storage conditions (Golachowski, 1985). This study was undertaken with an aim of evaluating the changes in physicochemical, thermal and pasting properties of starches from potato cultivars stored at different temperatures.

2. Material and methods

2.1. Materials

The tubers of 11 potato (*Solanum tuberosum* L.) cultivars, namely Kufri Badshah, Kufri Lauvkar, Kufri Anand, Kufri Bahar, Kufri Chandarmukhi, Kufri Chipsona-1, Kufri Chipsona-2, Kufri Jyoti, Kufri Lalima, Kufri Pukraj and Kufri Sindhuri, grown at two locations, Jalandhar and Modipuram, during 2004 and stored at different temperatures (4, 8, 12, 16 and 20 °C) for 120 days, were studied. The RH was kept between 85% and 90%. CIPC (isopropyl N-3-chlorophenyl carbamate) fog was used twice at 35 ml per tonne of potatoes (the commercial preparation manufactured by United Phosphorus Limited, Mumbai, contains 50% a.i.) to suppress

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0308-8146/$ - see front matter © 2008 Published by Elsevier Ltd.
doi:10.1016/j.foodchem.2008.11.025

sprout growth. Uniform tubers were selected from each cultivar and washed thoroughly.

2.2. Methods

2.2.1. Starch isolation

Starch was isolated from different potato cultivars stored at different temperatures as described previously (Singh & Singh, 2001).

2.2.2. Morphological properties

Scanning electron micrographs of starches separated from tubers of Kufri Chipsona-2, unstored and stored at different temperatures, 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 15 kV was used during micrography.

2.2.3. Physicochemical properties of starches

2.2.3.1. Ash content (%). Ash content was determined in triplicate by the standard AACC method (1995).

2.2.3.2. Amylose content (%). Amylose content was determined in triplicate by the method of Williams, Kuzina, and Hlynka (1970).

2.2.3.3. Swelling power (g/g) and solubility index (%). Swelling power (g/g) and solubility (%) were determined using a 2% (w/v) aqueous suspension of starch at 90 °C, following the method of Leach, McCowen, and Schoch (1959).

2.2.3.4. Transmittance (%). Light transmittances were measured by the method of Craig, Maningat, Seib, and Hoseney (1989). An aqueous suspension 1(%) of starch near neutral pH from each potato cultivar was heated in a water bath at 90 °C for 1 h with constant stirring. The suspension was cooled and held for 1 h at 30 °C. The sample was then stored for 5 days at 4 °C in a refrigerator and transmittance was determined every 24 h by measuring the absorbance at 640 nm with UV–vis spectrometer lambda 25 (Perkin–Elmer, Switzerland).

2.2.4. Thermal properties

Thermal properties of potato starches were analyzed using a DSC-822^e (Mettler Toledo, Greifensee, Switzerland) equipped with a thermal analysis data station. Starch samples (3.5 mg, dwb) was weighed into a 40 µl capacity aluminium pan (Mettler, ME-27331) and distilled water was added with the help of a Hamilton micro syringe to achieve a starch–water suspension containing 70% water. Pans were hermetically sealed and allowed to stand for 1 h at room temperature before heating in a DSC. The analyzer was calibrated using indium and an empty aluminium pan was used as reference. Sample pans were heated at a rate of 10 °C/min from 20 to 100 °C. Onset temperature (T_o), peak temperature (T_p), conclusion temperature (T_c), enthalpy of gelatinization (ΔH_{gel}) and gelatinization temperature range (R) were calculated.

2.2.5. Pasting properties

The pasting properties of potato starches were evaluated with a rapid visco analyzer (RVA-4, Newport Scientific, Warriewood, Australia) using material from different potato starch cultivars. Starch (3 g, 14% mb) was weighed directly into the aluminium RVA sample canister, and distilled water was added to a total constant sample weight of 28 g. A programmed heating and cooling was used where samples were held at 50 °C for 1 min, heated to 95 °C in 3.7 min, held at 95 °C for 2.5 min and held at 50 °C for 2 min. Parameters recorded were pasting-temperature (P_{temp}), peak viscosity (PV), hot-paste viscosity (minimum viscosity at 95 °C), cool-paste viscosity (CPV) (final viscosity at 50 °C), breakdown (BD) (=PV − HPV) and setback (SB) (=CPV − HPV).

2.2.6. Textural properties of gels

Textural properties of RVA gels (Bhattacharya, Zee, & Corke, 1999) were evaluated on an Instron Universal Testing Machine (Model 44464, Instron, Buckinghamshire, England). The starch-paste formed in the canister, after RVA testing, was covered and kept at room temperature (≈25 °C) overnight and allowed to gel. The gel formed in the can (37 mm diam., 20 mm height) was used directly for texture analysis. The gel was compressed to a distance of 10 mm using a flat cylindrical probe (6 mm diam.) at a crosshead speed of 30 mm/min, twice in two cycles. The textural parameters of hardness, cohesiveness, springiness, gumminess, and chewiness were computed using textural profile analysis (TPA), as described by Bourne (1978).

2.2.7. Granule size distribution

Granule size analysis was done using a coulter small module model L S230 laser particle size analyser.

2.2.8. Statistical analysis

The data reported are averages of triplicate observations. The data were subjected to two-way analysis of variance (ANOVA). Pearson correlation coefficients (r) for relationships between various starch properties and principal component analysis were calculated and statistical analysis was done using Minitab Release 14 Statistical Software (Minitab Inc., State College, PA).

3. Results and discussion

3.1. Morphological properties

Starch from unstored potatoes showed granule diameters between 14 and 50 µm while starch separated from potatoes stored at 4, 8, 12, 16 and 20 °C had granule diameters from 9 to 36, 13 to 40, 20 to 40, 23 to 54 and 26 to 56 µm, respectively. Starch from potatoes stored at a lower temperature (4 °C) showed a higher proportion of small size granules, while the reverse was observed in starches from potatoes stored at a higher temperature (20 °C). A decrease in the proportion of small size granules in starches separated from tubers stored at 20 °C has also been reported (Golachowski, 1985). Storage temperatures affected the surface morphology of starch granules. The granules of starches separated from unstored potatoes had smooth surfaces while granules of starches from stored potatoes had slightly rough and pitted surfaces. Cottrell, Duffus, Mackay, and Allison (1993) reported that surfaces of granules became progressively more pitted and less smooth during storage of potatoes at low temperatures (4 and 10 °C).

3.2. Physicochemical properties of starch

Among various cultivars, Kufri Chipsona-2 starch showed the highest ash content, followed by Kufri Sindhuri, Kufri Chipsona-1, Kufri Jyoti, Kufri Chandharmukhi, Kufri Bahar, Kufri Anand, Kufri Lalima, Kufri Lauvkar and Kufri Pukraj, while Kufri Badshah showed the lowest (Table 1). Starches separated from potatoes stored at different temperatures showed significant variations in swelling power. Starches from potatoes stored at 20 °C showed higher swelling power than did starches from potatoes stored between 4 and 16 °C. Swelling power of starches ranged from 16.8 to 33.0 g/g. Among cultivars studied, Kufri Chipsona-1 starch showed the highest swelling power. The differences in swelling power among the starches from different cultivars may be attributed to differences in phosphorus content, as well as variation in

Table 1
Physicochemical properties of starches from various potato cultivars stored at different temperatures.

Cultivar	Location	Temperature (°C)	Ash (%)	Amylose (%)	Swelling power (g/g)	Solubility index
K. Badshah	Jalandhar	4	0.39	16.1	19.1	16.2
K. Lauvkar	Jalandhar	4	0.70	16.1	20.9	12.5
K. Anand	Modipuram	4	0.58	17.5	16.8	10.2
K. Bahar	Modipuram	4	0.67	15.9	21.7	10.2
K. Chandarmukhi	Modipuram	4	0.50	15.1	25.2	18.7
K. Chipsona-1	Modipuram	4	0.74	16.8	23.7	12.7
K. Chipsona-2	Modipuram	4	1.18	15.9	19.7	9.6
K. Jyoti	Modipuram	4	0.52	17.3	22.0	12.9
K. Lalima	Modipuram	4	0.57	18.9	20.0	14.6
K. Pukraj	Modipuram	4	0.34	23.5	19.6	9.8
K. Sindhuri	Modipuram	4	0.68	15.6	25.3	10.5
K. Badshah	Jalandhar	8	0.20	18.8	19.1	16.2
K. Lauvkar	Jalandhar	8	0.02	19.7	20.0	12.5
K. Anand	Modipuram	8	0.95	15.9	16.8	10.2
K. Bahar	Modipuram	8	0.85	13.4	21.7	14.2
K. Chandarmukhi	Modipuram	8	0.45	14.2	25.2	18.7
K. Chipsona-1	Modipuram	8	0.20	23.4	23.7	12.7
K. Chipsona-2	Modipuram	8	1.11	20.4	19.7	9.6
K. Jyoti	Modipuram	8	1.22	15.8	22.0	12.7
K. Lalima	Modipuram	8	0.13	15.0	20.0	14.6
K. Pukraj	Modipuram	8	1.09	23.2	19.6	9.8
K. Sindhuri	Modipuram	8	1.10	15.5	25.3	19.5
K. Badshah	Jalandhar	12	0.36	20.1	32.3	11.3
K. Lauvkar	Jalandhar	12	1.01	16.2	23.6	19.3
K. Anand	Modipuram	12	0.88	16.0	27.9	12.5
K. Bahar	Modipuram	12	0.74	17.5	24.4	12.3
K. Chandarmukhi	Modipuram	12	0.13	14.5	26.5	23.7
K. Chipsona-1	Modipuram	12	1.63	17.3	30.8	18.6
K. Chipsona-2	Modipuram	12	1.73	18.9	22.8	6.4
K. Jyoti	Modipuram	12	0.60	18.2	26.5	11.9
K. Lalima	Modipuram	12	1.10	18.3	25.4	20.0
K. Pukraj	Modipuram	12	0.02	27.3	21.9	14.6
K. Sindhuri	Modipuram	12	0.95	18.7	23.1	15.4
K. Badshah	Jalandhar	16	0.92	13.8	27.0	17.6
K. Lauvkar	Jalandhar	16	0.83	16.8	27.7	16.5
K. Anand	Modipuram	16	0.43	16.8	20.8	22.3
K. Bahar	Modipuram	16	0.85	16.9	19.6	27.8
K. Chandarmukhi	Modipuram	16	1.54	26.0	29.6	16.0
K. Chipsona-1	Modipuram	16	0.58	22.8	37.1	18.6
K. Chipsona-2	Modipuram	16	0.85	20.4	29.2	14.9
K. Jyoti	Modipuram	16	0.72	19.7	29.9	16.0
K. Lalima	Modipuram	16	0.13	14.5	27.0	21.8
K. Pukraj	Modipuram	16	0.32	19.8	26.2	15.4
K. Sindhuri	Modipuram	16	1.10	19.4	28.6	11.2
K. Badshah	Jalandhar	20	0.54	23.7	28.4	19.3
K. Lauvkar	Jalandhar	20	0.62	20.3	22.6	22.1
K. Anand	Modipuram	20	0.67	17.7	33.0	17.7
K. Bahar	Modipuram	20	0.46	13.4	29.5	26.0
K. Chandarmukhi	Modipuram	20	0.93	17.6	27.3	23.3
K. Chipsona-1	Modipuram	20	0.75	20.1	29.6	20.2
K. Chipsona-2	Modipuram	20	0.82	20.4	26.5	22.1
K. Jyoti	Modipuram	20	0.82	21.2	25.5	11.7
K. Lalima	Modipuram	20	1.54	18.8	26.1	35.7
K. Pukraj	Modipuram	20	0.80	27.6	29.7	15.8
K. Sindhuri	Modipuram	20	0.95	19.7	27.7	29.8
LSD ($p \leqslant 0.05$) temperature			0.3	2.2	2.5	3.9
LSD ($p \leqslant 0.05$) cultivar			0.5	3.4	3.8	5.8

the strength of associative bonding forces with granules (Leach et al., 1959). The higher swelling power of potato starch has been attributed to the presence of negatively charged phosphate groups (Singh, Singh, Kaur, Sodhi, & Gill, 2003; Swinkels, 1985). Starch swelling occurs concomitantly with loss of birefringence and precedes solubilization (Sandhu, Singh, & Kaur, 2004). Swelling power and solubility can be used to assess the extent of interaction between starch chains, within the amorphous and crystalline domains of the starch granule (Ratnayake, Hoover, & Warkentin, 2002). Solubility of various potato starches ranged from 6.4% to 32.7%. Among various cultivars studied, Kufri Lalima and Kufri Chandharmukhi starches showed higher solubility than did other cultivars. Starches from potatoes stored at lower temperatures showed lower solubility than did starches from potatoes stored at higher temperatures. Amylose content of starches ranged between 13.4% and 27.6%. Kufri Pukraj starch had a higher amylose content than had other cultivars. The results are consistent with those reported by Kaur, Singh, and Sodhi (2002), Singh and Kaur (2004), Singh and Singh (2001), and Wiesenborn, Orr, Casper, and Tacke (1994). The differences in amylose content among starches from different potato cultivars may be due to different factors, such as genotype, environmental conditions and cultural practice (Cottrell, Duffus, Paterson, & George, 1995; Kim & Wiesenborn, 1995).

3.3. Thermal properties

The results of DSC analysis of starches separated from various potato cultivars and stored at different temperatures are shown in Table 2. The onset gelatinization temperature (T_o), peak temperature (T_p) and conclusion temperature (T_c) of starches from different storage temperatures ranged from 53.6 to 68.8 °C, 53.2 to 72.1 °C, and 55.3 to 77.0 °C, respectively. Kufri Sindhuri starches showed higher T_o, T_p and T_c than did other cultivars. Kufri Chipsona-2 starch showed lower transition temperatures, possibly due to the lower crystallinity. Starches from potatoes stored at different temperatures showed significant differences in transition temperatures. Starches from potatoes stored at 4 °C showed lower T_o, T_c and ΔH_{gel} than did starches from potatoes stored at 8, 12, 16 and 20 °C. Myllarinen, Schulman, Salovaara, and Poutanen (1998) found that gelatinization peak temperature, measured by DSC, was lower for barley stored at low temperatures. Maize starches, indicating the presence of more amorphous regions, had lower transition temperatures (Singh, Inouchi, & Nishinari, 2006), while starches with higher crystallinity have been observed to have higher transition temperatures, as well as higher gelatinization enthalpy. Barichello, Yada, and Coffin (1991) also reported that higher transition temperatures resulted from higher degrees of crystallinity, which provide structural stability and make the granules more resistant to gelatinization. Their results also revealed that starches with long branch chain length amylopectin had higher gelatinization enthalpy, indicating that more energy was required to gelatinize the crystallites of long chain length. The differences in ΔT

Table 2
Thermal properties of starches from various potato cultivars stored at different temperatures.

Variety	Location	Temperature (°C)	T_o (°C)	T_p (°C)	T_c (°C)	ΔH_{gel} (J/g)	R
K. Badshah	Jalandhar	4	53.6	67.2	68.3	3.4	14.6
K. Lauvkar	Jalandhar	4	62.6	66.0	69.8	3.1	7.1
K. Anand	Modipurarm	4	60.7	62.8	65.7	14.8	4.4
K. Bahar	Modipurarm	4	62.6	66.0	70.3	15.5	7.7
K. Chandarmukhi	Modipurarm	4	58.9	63.6	68.6	10.5	9.7
K. Chipsona-1	Modipurarm	4	63.1	65.7	68.7	15.6	5.6
K. Chipsona-2	Modipurarm	4	50.5	53.2	55.3	5.5	4.5
K. Jyoti	Modipurarm	4	67.3	70.3	72.1	16.9	4.8
K. Lalima	Modipurarm	4	60.8	64.7	69.0	14.6	8.1
K. Pukraj	Modipurarm	4	61.1	64.4	68.2	4.0	7.1
K. Sindhuri	Modipurarm	4	68.8	70.7	72.0	12.5	3.2
K. Badshah	Jalandhar	8	56.1	64.0	72.5	1.5	16.3
K. Lauvkar	Jalandhar	8	59.3	66.4	74.1	2.0	14.8
K. Anand	Modipurarm	8	64.3	68.3	76.0	9.6	11.4
K. Bahar	Modipurarm	8	59.3	63.1	67.6	10.8	8.3
K. Chandarmukhi	Modipurarm	8	54.4	68.2	73.5	3.9	18.7
K. Chipsona-1	Modipurarm	8	61.7	64.5	67.9	5.0	6.2
K. Chipsona-2	Modipurarm	8	63.6	65.1	67.5	16.5	3.8
K. Jyoti	Modipurarm	8	60.8	67.6	71.7	2.9	10.8
K. Lalima	Modipurarm	8	62.4	65.2	68.1	5.3	5.7
K. Pukraj	Modipurarm	8	61.2	65.1	68.9	7.1	7.6
K. Sindhuri	Modipurarm	8	68.8	70.7	72.0	12.5	3.2
K. Badshah	Jalandhar	12	59.9	64.5	70.2	16.4	12.3
K. Lauvkar	Jalandhar	12	63.0	67.0	72.0	14.9	9.0
K. Anand	Modipurarm	12	62.3	65.9	70.3	13.1	8.0
K. Bahar	Modipurarm	12	60.4	64.3	68.9	15.6	8.5
K. Chandarmukhi	Modipurarm	12	60.0	63.5	68.3	13.8	8.2
K. Chipsona-1	Modipurarm	12	63.9	66.0	68.2	3.6	4.2
K. Chipsona-2	Modipurarm	12	61.2	64.8	69.7	12.2	8.4
K. Jyoti	Modipurarm	12	58.5	71.5	76.8	10.3	18.3
K. Lalima	Modipurarm	12	62.1	65.7	70.4	15.0	8.3
K. Pukraj	Modipurarm	12	61.0	64.8	69.8	14.9	8.7
K. Sindhuri	Modipurarm	12	62.2	65.8	70.5	13.0	8.2
K. Badshah	Jalandhar	16	61.9	65.9	71.0	14.5	9.0
K. Lauvkar	Jalandhar	16	63.9	67.4	71.8	10.5	7.9
K. Anand	Modipurarm	16	62.3	65.9	70.3	13.1	8.0
K. Bahar	Modipurarm	16	62.1	66.7	71.6	16.0	9.5
K. Chandarmukhi	Modipurarm	16	60.3	63.9	68.7	13.3	8.3
K. Chipsona-1	Modipurarm	16	61.3	64.6	68.5	10.8	7.1
K. Chipsona-2	Modipurarm	16	61.8	65.9	70.7	11.2	8.8
K. Jyoti	Modipurarm	16	60.9	67.2	72.2	9.7	11.2
K. Lalima	Modipurarm	16	62.4	65.6	69.4	10.6	7.0
K. Pukraj	Modipurarm	16	62.7	67.0	71.7	8.5	8.9
K. Sindhuri	Modipurarm	16	62.6	67.4	72.6	16.5	10.0
K. Badshah	Jalandhar	20	62.0	66.3	71.6	14.9	9.5
K. Lauvkar	Jalandhar	20	62.5	66.1	70.7	13.5	8.2
K. Anand	Modipurarm	20	61.4	64.3	68.2	14.5	6.8
K. Bahar	Modipurarm	20	61.4	64.8	69.5	14.3	8.1
K. Chandarmukhi	Modipurarm	20	60.7	64.1	69.2	15.6	8.4
K. Chipsona-1	Modipurarm	20	61.6	64.9	69.2	15.5	7.5
K. Chipsona-2	Modipurarm	20	61.5	65.5	70.1	15.0	8.6
K. Jyoti	Modipurarm	20	62.1	66.1	70.9	14.7	8.7
K. Lalima	Modipurarm	20	67.6	72.1	77.0	12.0	12.3
K. Pukraj	Modipurarm	20	61.9	65.5	70.0	13.6	8.1
K. Sindhuri	Modipurarm	20	62.7	66.0	70.4	14.7	7.7
LSD ($p \leqslant 0.05$) temperature			2.8	3.5	3.7	2.4	1.7
LSD ($p \leqslant 0.05$) cultivar			4.8	4.8	5.6	3.5	2.6

T_o = onset temperature; T_p = peak temperature; T_c = conclusion temperature; R = gelatinization range ($T_c - T_o$); and ΔH_{gel} = enthalpy of gelatinization.

among the starches from different potato cultivars may be due to the presence of crystalline regions of different strength in the granules (Banks & Greenwood, 1975). Gunaratne and Hoover (2002) also reported that variability in ΔT values in the starches was due to the difference in the degree of heterogeneous crystal strengths.

3.4. Transmittance

A decrease in transmittance of suspension from starches separated from all the cultivars after storage duration was greatest for Kufri Jyoti starch while Kufri Lalima was the least. This may be due to less variation in granule remnants in starch-paste that, in turn, depends on the morphological structure of the starch granules. The lower light transmittance may be due to high refraction of light by swollen granule remnants (Craig et al., 1989). Starches separated from potatoes stored at 4 °C showed lower transmittance values than did starches from potatoes stored at 8, 12, 16 and 20 °C. The lower transmittance values in starches separated from potatoes stored at 4 °C may be attributed to increase in the proportion of small size granules. Lim, Jane, Rajagopalan, and Seib (1992) linearly correlated starch granule size with light transmittance in potato starch film. Granule swelling, granule remnants, leached amylose and amylopectin and molecular weights and

Table 3
Pasting properties of starches from different potato cultivars stored at different temperatures.

Variety	Location	Temperature (°C)	Peak viscosity (cP)	Hot-paste viscosity (cP)	Cold-paste viscosity (cP)	Set-back (cP)	Breakdown (cP)	Pasting-temperature (°C)	Pasting-time (min)
K. Badshah	Jalandhar	4	1462	1200	981	480	218	71.85	7.00
K. Lauvkar	Jalandhar	4	1748	1384	1193	552	198	71.85	7.00
K. Anand	Modipuram	4	1651	1328	1177	475	151	71.85	7.00
K. Bahar	Modipuram	4	1358	1174	968	390	202	71.85	7.00
K. Chandarmukhi	Modipuram	4	2079	1685	1351	707	313	67.65	6.60
K. Chipsona-1	Modipuram	4	2450	1975	1222	122	750	71.15	5.93
K. Chipsona-2	Modipuram	4	1867	1394	1255	480	139	68.89	6.87
K. Jyoti	Modipuram	4	1798	1532	1249	549	283	68.88	6.67
K. Lalima	Modipuram	4	2274	1538	1428	853	117	68.85	6.73
K. Pukraj	Modipuram	4	2925	2151	1860	1065	291	68.60	4.97
K. Sindhuri	Modipuram	4	2750	2131	1577	390	554	66.60	6.40
K. Badshah	Jalandhar	8	3801	3158	2723	1078	435	69.45	4.80
K. Lauvkar	Jalandhar	8	1827	1475	1150	677	325	71.00	5.07
K. Anand	Modipuram	8	2347	2203	1615	732	588	67.05	4.60
K. Bahar	Modipuram	8	3116	2336	2010	1106	326	68.65	4.73
K. Chandarmukhi	Modipuram	8	2657	2407	1970	687	437	67.00	4.87
K. Chipsona-1	Modipuram	8	2136	1842	1348	788	494	68.60	4.33
K. Chipsona-2	Modipuram	8	2948	2362	1894	1054	468	67.80	5.07
K. Jyoti	Modipuram	8	2994	2634	2017	977	617	69.45	4.73
K. Lalima	Modipuram	8	2925	2151	1860	1065	291	68.60	4.97
K. Pukraj	Modipuram	8	3486	2645	2363	1123	282	68.60	4.93
K. Sindhuri	Modipuram	8	2609	2047	1619	990	428	68.65	4.73
K. Badshah	Jalandhar	12	3658	3334	2665	993	669	68.50	4.93
K. Lauvkar	Jalandhar	12	3160	2193	1870	1290	323	70.30	5.40
K. Anand	Modipuram	12	3001	2912	2257	744	655	67.75	4.93
K. Bahar	Modipuram	12	3111	2798	2229	882	569	67.80	4.93
K. Chandarmukhi	Modipuram	12	2587	2140	1807	780	333	67.00	5.00
K. Chipsona-1	Modipuram	12	3090	2868	2414	676	454	68.60	5.20
K. Chipsona-2	Modipuram	12	2813	2026	1721	1092	305	68.60	5.20
K. Jyoti	Modipuram	12	3307	2957	2269	1038	688	68.50	4.80
K. Lalima	Modipuram	12	3316	3347	2675	641	672	67.75	5.00
K. Pukraj	Modipuram	12	3364	2611	2217	1147	394	69.45	5.07
K. Sindhuri	Modipuram	12	3345	2714	2210	1135	504	68.50	5.40
K. Badshah	Jalandhar	16	3161	2534	2031	1130	503	67.80	4.47
K. Lauvkar	Jalandhar	16	2861	2239	1793	1068	446	69.45	5.20
K. Anand	Modipuram	16	3050	2757	2378	672	379	68.50	5.40
K. Bahar	Modipuram	16	3146	2334	2063	1083	271	68.65	4.87
K. Chandarmukhi	Modipuram	16	1468	1361	980	488	381	67.10	3.80
K. Chipsona-1	Modipuram	16	2982	3042	2292	690	750	67.80	5.13
K. Chipsona-2	Modipuram	16	2675	1966	163	1036	327	68.50	5.20
K. Jyoti	Modipuram	16	3218	2679	2150	1068	529	69.45	4.93
K. Lalima	Modipuram	16	1855	1705	1231	624	474	70.20	5.13
K. Pukraj	Modipuram	16	4216	2879	2771	1445	108	70.20	5.13
K. Sindhuri	Modipuram	16	3345	2714	2210	1135	504	68.50	5.40
K. Badshah	Jalandhar	20	3542	2893	2350	1192	543	69.35	4.67
K. Lauvkar	Jalandhar	20	3674	2098	1969	1705	129	71.10	5.67
K. Anand	Modipuram	20	1792	1464	1170	622	294	69.35	4.13
K. Bahar	Modipuram	20	3588	2195	2118	147	77	70.20	5.53
K. Chandarmukhi	Modipuram	20	1915	1519	1208	707	383	66.95	4.47
K. Chipsona-1	Modipuram	20	3175	2756	245	725	306	67.65	6.07
K. Chipsona-2	Modipuram	20	3504	2162	2113	1391	49	70.25	6.07
K. Jyoti	Modipuram	20	4122	2467	2442	1680	25	71.85	5.53
K. Lalima	Modipuram	20	3061	2047	1845	1216	202	68.60	4.80
K. Pukraj	Modipuram	20	4122	2467	2442	1680	25	71.85	5.53
K. Sindhuri	Modipuram	20	4723	2841	2717	2006	124	71.85	7.00
LSD ($p \leqslant 0.05$) temperature			688.4	337.2	2091	243.1	122.1	3.7	0.41
LSD ($p \leqslant 0.05$) cultivar			464.4	500.6	3102	360.6	182.4	5.6	0.62

chain lengths of amylose and amylopectin have been reported to vary with granule size, which ultimately leads to the development of turbidity and decreased light transmittance in starch-pastes during refrigerated storage (Perera & Hoover, 1999).

3.5. Pasting properties of starches

Significant differences were observed in pasting properties of starches separated from potatoes stored at different temperatures (Table 3). Among various cultivars studied, Kufri Pukraj starch showed higher peak viscosity, cold-paste viscosity and setback than did other cultivars. Peak viscosity and setback of starches separated from potatoes stored at higher temperature (20 °C) were higher than those of starches from potatoes stored at lower temperature (4 °C). Peak viscosity and pasting-temperature of starches from potatoes stored at different temperatures ranged from 1358 to 4723 cP and 66.6 to 71.95 °C, respectively. The results of pasting-temperatures are consistent with those reported earlier by Noda et al. (2004). The increase in viscosity with increase in temperature during heating has been attributed to the removal of water from the exuded amylose by the granules on swelling of starches (Ghiasi, Varriano-Marston, & Hoseney, 1982). Cold-paste viscosity and set back of starches from potatoes stored at different temperatures varied from 163 to 2723 cP and 122 to 2006 cP, respectively. Set back was higher in starches from potatoes stored at 20 °C. Cold-paste viscosity increased upon cooling which may be

Table 4
Textural properties of starch gels from various potato cultivars stored at different temperatures.

Variety	Location	Temperature (°C)	Hardness (g)	Cohesiveness	Springiness (mm)	Gumminess (g)	Chewiness (g mm)
K. Badshah	Jalandhar	4	22.8	0.27	2.8	6.1	17.5
K. Lauvkar	Jalandhar	4	24.9	0.13	1.4	3.4	5.0
K. Anand	Modipuram	4	11.5	0.18	3.0	2.1	6.6
K. Bahar	Modipuram	4	20.6	0.23	3.8	5.6	21.8
K. Chandarmukhi	Modipuram	4	12.6	0.30	3.9	3.8	15.2
K. Chipsona-1	Modipuram	4	23.3	0.02	3.0	5.6	17.4
K. Chipsona-2	Modipuram	4	23.6	0.22	3.8	5.3	20.7
K. Jyoti	Modipuram	4	26.6	0.17	2.3	4.5	10.7
K. Lalima	Modipuram	4	18.2	0.12	1.6	2.2	3.8
K. Pukraj	Modipuram	4	17.7	0.18	3.0	3.2	9.6
K. Sindhuri	Modipuram	4	21.7	0.23	3.2	5.1	16.9
K. Badshah	Jalandhar	8	28.4	0.05	1.5	1.4	2.2
K. Lauvkar	Jalandhar	8	24.8	0.10	1.2	0.5	0.6
K. Anand	Modipuram	8	10.7	0.26	2.3	2.8	6.6
K. Bahar	Modipuram	8	22.3	0.18	2.7	4.0	11.1
K. Chandarmukhi	Modipuram	8	15.8	0.22	2.6	3.4	9.3
K. Chipsona-1	Modipuram	8	18.8	0.01	2.0	0.3	0.6
K. Chipsona-2	Modipuram	8	13.1	0.01	1.5	0.1	0.2
K. Jyoti	Modipuram	8	18.8	0.26	2.5	4.9	12.7
K. Lalima	Modipuram	8	16.8	0.17	2.3	2.8	6.7
K. Pukraj	Modipuram	8	18.8	0.19	3.0	3.3	9.8
K. Sindhuri	Modipuram	8	13.1	0.02	2.9	0.3	0.7
K. Badshah	Jalandhar	12	32.2	0.19	2.1	6.3	13.4
K. Lauvkar	Jalandhar	12	24.1	0.21	0.3	5.3	1.7
K. Anand	Modipuram	12	15.3	0.10	3.8	1.5	6.1
K. Bahar	Modipuram	12	14.5	0.17	3.6	2.5	9.3
K. Chandarmukhi	Modipuram	12	19.8	0.02	2.6	0.5	1.4
K. Chipsona-1	Modipuram	12	18.8	0.16	2.0	3.0	6.3
K. Chipsona-2	Modipuram	12	11.8	0.32	3.5	3.7	13.6
K. Jyoti	Modipuram	12	18.8	0.23	3.1	4.4	7.2
K. Lalima	Modipuram	12	15.9	0.17	2.3	2.8	6.5
K. Pukraj	Modipuram	12	21.5	0.17	2.6	3.8	10.2
K. Sindhuri	Modipuram	12	22.3	0.14	2.2	3.2	7.2
K. Badshah	Jalandhar	16	32.2	0.14	1.9	4.6	9.2
K. Lauvkar	Jalandhar	16	30.6	0.17	1.7	5.2	8.9
K. Anand	Modipuram	16	23.1	0.16	3.8	3.7	12.6
K. Bahar	Modipuram	16	25.2	0.17	2.4	4.4	10.6
K. Chandarmukhi	Modipuram	16	16.1	0.24	3.0	3.9	11.8
K. Chipsona-1	Modipuram	16	26.6	0.27	3.1	7.2	22.7
K. Chipsona-2	Modipuram	16	23.9	0.25	2.8	6.1	17.2
K. Jyoti	Modipuram	16	25.8	0.33	3.1	8.6	27.4
K. Lalima	Modipuram	16	25.2	0.10	1.2	2.5	3.1
K. Pukraj	Modipuram	16	33.5	0.41	3.1	13.1	43.1
K. Sindhuri	Modipuram	16	11.2	0.19	2.1	2.2	4.8
K. Badshah	Jalandhar	20	34.4	0.21	2.9	7.4	21.8
K. Lauvkar	Jalandhar	20	44.6	0.28	3.3	12.0	42.5
K. Anand	Modipuram	20	33.8	0.13	1.8	4.6	8.6
K. Bahar	Modipuram	20	28.0	0.04	1.7	0.3	0.6
K. Chandarmukhi	Modipuram	20	23.3	0.19	2.9	4.6	13.4
K. Chipsona-1	Modipuram	20	51.0	0.27	2.6	14.5	37.6
K. Chipsona-2	Modipuram	20	30.9	0.20	3.1	6.2	19.5
K. Jyoti	Modipuram	20	36.0	0.11	3.6	3.9	14.5
K. Lalima	Modipuram	20	20.4	0.23	3.3	4.8	16.3
K. Pukraj	Modipuram	20	55.6	0.25	3.4	14.2	49.3
K. Sindhuri	Modipuram	20	19.6	0.13	2.1	2.5	5.5
LSD ($p \leqslant 0.05$) temperature			5.8	0.07	0.6	2.3	6.2
LSD ($p \leqslant 0.05$) cultivar			8.7	0.1	0.8	3.4	9.2

due to aggregation of amylose molecules (Miles, Morris, Orford, & Ring, 1985).

3.6. Gel textural properties of starch gels

The textural properties of gels from starches separated from potato cultivars stored at different temperatures are listed in Table 4. The starch gels from potatoes showed hardness, springiness and gumminess in ranges from 10.75 to 55.62 g, 0.32 to 3.85 mm, and 0.26 to 14.29 g, respectively. Kufri Badshah and Kufri Lauvkar starch showed higher hardness and lower springiness, than did other cultivars. Kufri Pukraj starch showed higher cohesiveness, chewiness and gumminess than did starches from potatoes of other cultivars. The starch gels prepared from potatoes stored at 20 °C showed higher hardness, chewiness and gumminess than did gels prepared from starches of potatoes stored between 4 and 16 °C. The gel firmness is mainly caused by retrogradation of starch gels, which is associated with syneresis of water and crystallization of amylopectin, leading to harder gels (Miles et al., 1985). Starches that exhibit harder gels tend to have higher amylose content and longer amylopectin chains (Mua & Jackson, 1998). The mechanical properties of starches gels depend upon various factors, including the rheological characteristics of the amylose matrix, the volume fraction and the rigidity of the gelatinized starch granules, as well as the interactions between dispersed and continuous phase of the gel (Biliaderis, 1998).

Table 5
Granule size distribution of starches separated from potatoes stored at different temperatures.

Variety	Location	Temperature (°C)	0–20 (μm)		20–40 (μm)		40–60 (μm)		60–80 (μm)		Above 80 (μm)	
			%	AD	%	AD	%	AD	%	AD	%	AD
K. Badshah	Jalandhar	4	37.9	8.4	32.9	30.5	19.0	49.1	7.5	70.4	3.2	82.5
K. Lauvkar	Jalandhar	4	35.3	11.1	31.2	29.9	22.6	48.4	8.1	69.7	2.9	83.0
K. Anand	Modipuram	4	34.1	10.8	37.9	30.0	17.2	48.3	8.6	70.0	2.2	81.9
K. Bahar	Modipuram	4	33.8	10.6	37.6	30.0	16.7	48.5	9.3	70.1	2.9	83.0
K. Chandarmukhi	Modipuram	4	34.4	11.7	37.3	29.9	12.7	47.7	10.5	69.6	4.1	82.9
K. Chipsona-1	Modipuram	4	37.6	10.8	34.9	30.5	14.4	48.7	9.5	74.8	2.9	83.5
K. Chipsona-2	Modipuram	4	35.4	12.5	36.1	31.5	17.9	48.8	9.2	77.2	1.2	83.3
K. Jyoti	Modipuram	4	35.9	7.6	31.4	34.0	20.1	50.0	10.1	61.3	2.5	82.5
K. Lalima	Modipuram	4	31.5	10.0	36.6	30.4	19.9	48.7	9.6	73.7	2.4	85.4
K. Pukraj	Modipuram	4	37.6	7.1	34.6	30.7	17.2	48.8	9.0	74.0	1.2	82.7
K. Sindhuri	Modipuram	4	35.7	11.9	33.9	30.2	15.6	48.5	10.5	74.0	2.4	82.7
K. Badshah	Jalandhar	8	36.6	10.5	29.9	30.2	21.8	48.6	9.5	74.3	1.8	87.1
K. Lauvkar	Jalandhar	8	34.9	6.4	30.2	29.8	22.9	48.5	9.5	75.5	1.9	88.0
K. Anand	Modipuram	8	33.1	10.4	36.7	30.2	18.1	48.5	10	74.1	1.8	86.8
K. Bahar	Modipuram	8	32.8	10.7	35.6	30.0	19.2	48.3	9.8	75.6	2.1	87.1
K. Chandarmukhi	Modipuram	8	33.7	10.6	36.5	30.1	15.9	48.6	10.6	74.3	2.9	88.5
K. Chipsona-1	Modipuram	8	36.5	8.1	34.8	30.8	16.2	48.9	10.4	75.3	2.8	85.9
K. Chipsona-2	Modipuram	8	35.4	10.6	35.1	30.0	16.9	48.9	10.2	75.1	2.2	85.2
K. Jyoti	Modipuram	8	34.6	10.1	30.8	30.3	21.7	48.5	10.0	74.6	2.8	86.8
K. Lalima	Modipuram	8	31.3	10.1	35.6	30.2	20.5	48.9	10.2	75.1	2.1	87.0
K. Pukraj	Modipuram	8	36.1	9.6	32.2	30.3	19.2	48.9	10.1	75.9	1.9	88.5
K. Sindhuri	Modipuram	8	34.3	9.9	32.6	30.3	19.5	48.7	10.7	75.1	2.6	85.9
K. Badshah	Jalandhar	12	35.7	12.1	28.1	29.7	22.8	47.8	10.9	71.6	2	92.9
K. Lauvkar	Jalandhar	12	34.1	12.1	29.4	29.7	23.3	48.2	11.1	73.6	2	93.0
K. Anand	Modipuram	12	33.0	8.7	33.5	30.7	20.1	48.8	10.8	74.4	1.9	93.5
K. Bahar	Modipuram	12	30.4	10.9	34.0	30.0	21.2	48.5	11.9	74.4	2.1	93.8
K. Chandarmukhi	Modipuram	12	31.9	11.1	34.5	29.7	18.9	48.4	11.6	74.5	2.2	97.0
K. Chipsona-1	Modipuram	12	34.8	9.4	31.8	30.5	19.2	48.8	12.0	74.8	2.1	92.1
K. Chipsona-2	Modipuram	12	33.0	10.4	32.8	30.1	19.8	48.7	12.2	74.7	2	92.8
K. Jyoti	Modipuram	12	34.1	12.7	30.5	29.1	22.6	48.1	10.8	74.2	2.1	95.1
K. Lalima	Modipuram	12	30.3	9.9	33.6	30.2	21.2	48.6	12.8	74.9	1.8	96.2
K. Pukraj	Modipuram	12	34.1	11.3	31.2	30.1	21.2	48.2	11.5	73.4	1.4	95.8
K. Sindhuri	Modipuram	12	33.5	10.4	30.5	30.2	21.5	48.6	12.7	74.1	1.5	93.1
K. Badshah	Jalandhar	16	31.8	8.9	24.2	30.4	24.5	49.1	16.1	74.7	2.8	103
K. Lauvkar	Jalandhar	16	32.1	11.9	25.4	29.7	23.3	48.3	16.2	74	2.7	104
K. Anand	Modipuram	16	31.1	10.1	28.5	30.2	22.1	48.7	15.8	74.4	2.1	102
K. Bahar	Modipuram	16	29.2	11.1	31.0	30.0	20.7	48.2	16.9	73.6	2.1	105
K. Chandarmukhi	Modipuram	16	30.1	10.7	31.5	30.4	19.2	47.6	17.0	74.2	2.0	100
K. Chipsona-1	Modipuram	16	31.8	10.7	29.8	30.0	19.7	48.7	15.0	74.8	2.1	99.5
K. Chipsona-2	Modipuram	16	31.0	9.7	29.8	30.4	20.1	49.0	16.8	74.5	1.9	100
K. Jyoti	Modipuram	16	30.5	11.2	28.1	29.9	22.9	48.4	16.4	74.9	2.0	105
K. Lalima	Modipuram	16	30.1	10.6	29.6	30.1	21.5	48.8	16.2	74.6	2.2	105
K. Pukraj	Modipuram	16	30.5	10.2	29.2	30.2	21.2	48.7	16.9	74.2	1.9	103
K. Sindhuri	Modipuram	16	30.3	10.3	28.5	30.5	21.8	47.6	16.8	72.6	1.9	103
K. Badshah	Jalandhar	20	29.9	11.9	23.8	30.2	25.1	48.0	18.8	73.0	2.5	110
K. Lauvkar	Jalandhar	20	29.2	11.4	22.8	29.8	25.4	47.8	19.1	73.3	2.7	110
K. Anand	Modipuram	20	29.6	12.3	23.9	29.4	24.1	48.1	19.1	73.8	2.3	108
K. Bahar	Modipuram	20	29.2	11.2	25.0	29.9	24.4	48.0	19.3	73.4	2.0	107
K. Chandarmukhi	Modipuram	20	29.2	10.9	26.9	30.0	24.2	48.4	18.5	73.7	2.0	110
K. Chipsona-1	Modipuram	20	29.5	10.8	25.8	29.9	23.7	48.8	18.0	74.3	2.5	108
K. Chipsona-2	Modipuram	20	29.0	10.4	25.5	30.1	23.1	48.9	19.4	74.7	2.0	106
K. Jyoti	Modipuram	20	29.1	10.5	24.8	30.1	24.9	48.5	19.4	73.8	2.1	110
K. Lalima	Modipuram	20	28.8	10.1	24.6	30.0	24.1	48.5	19.2	73.7	2.2	110
K. Pukraj	Modipuram	20	29.8	10.5	23.7	30.1	24.2	48.6	19.7	74.0	2.0	108
K. Sindhuri	Modipuram	20	29.0	10.3	24.7	30.3	24.5	48.6	19.1	73.5	2.0	108

AD = average diameter.

3.7. Granule size distribution

The granule size distribution in starches separated from potatoes of various cultivars stored at different temperatures is shown in Table 5. The proportion of granules of size 0–20 μm and 20–40 μm in starches separated from potatoes stored at 4 °C ranged from 31.5% to 37.9% and 31.3% to 37.9%, respectively against 28.8% to 29.6% and 22.8% to 26.9%, respectively for those stored at 20 °C. The proportions of granules of size 0–20 μm and 20–40 μm decreased with increase in storage temperatures from 4 to 20 °C. Among various cultivars stored at 4 °C, Kufri Badshah (Jalandhar) showed a higher proportion of granule size range from 0 to 20 μm (37.9%), followed by Kufri Pukraj (Modipuram), Kufri Chipsona-1 (Modipuram), while Kufri Lalima (Modipuram) showed the lowest (37.6%, 37.5% and 31.5%, respectively). Kufri Badshah (Jalandhar) stored at 20 °C showed a lower proportion of granule size range from 0 to 20 μm (29.9%), followed by Kufri Pukraj (Modipuram) and Kufri Chipsona-1 (Modipuram), while Kufri Lalima (Modipuram) showed the lowest (29.8%, 29.5% and 28.8%, respectively). The proportion of granule of size 20–40 μm decreased with increase in storage temperatures from 4 to 20 °C. Kufri Chandharmukhi (Modipuram) stored at 4 °C showed a higher proportion of granule size from 20 to 40 μm (37.9%), and Kufri Lauvkar (Jalandhar) showed the lowest (31.2%). Kufri Chandharmukhi (Modipuram) stored at 20 °C showed a higher proportion of granule of size from 20 to 40 μm (26.9%), while Kufri Lalima (Jalandhar) showed the lowest (22.8%). Johnston, Urbas and Khanzada (1968) reported that the number of granules of size <22 μm diameter increased after 80 days of storage at 4 °C. By contrast, Golachowski (1985) observed a decrease in the proportion of granules with >35 μm diameter and an increase in smaller granules (<20 μm) after 12 weeks of storage at 8 and 20 °C.

3.8. Pearson correlation between different properties of starches

Ash content, which mainly represents the phosphorus content in potato starch, showed negative correlation with gelatinization range ($r = -0.269$, $p \leqslant 0.05$) and positive correlation with T_o ($r = 0.305$, $p \leqslant 0.05$). Amylose content showed positive correlation with gumminess, set back, chewiness and %granules of 60–80 μm size ($r = 0.319$, 0.383, 0.370 and 0.305, $p \leqslant 0.05$). Swelling power showed positive correlation with peak viscosity, hot-paste viscosity, gel hardness and gel gumminess ($r = 0.299$, 0.335, 0.376 and 0.0.318, $p \leqslant 0.005$, respectively) and was negatively correlated with pasting-time ($r = -0.271$, $p \leqslant 0.05$). Solubility showed positive correlation with peak viscosity ($r = 0.309$, $p \leqslant 0.05$). Peak viscosity showed positive correlation with hot-paste viscosity, cold-paste viscosity, set back and %granules of 40–60 μm size ($r = 0.818$, 0.719, 0.719 and 0.270, $p \leqslant 0.005$, respectively) and was negatively correlated with %granules of 0–20 μm size and %granules of 20–40 μm size ($r = -0.353$ and -0.309, $p \leqslant 0.05$, respectively). Hot-paste viscosity showed positive correlation with cold-paste viscosity, set back, breakdown viscosity ($r = 0.779$, 0.404 and 0.429, $p \leqslant 0.005$, respectively) and was negatively correlated with pasting-time and granule size of 40–60 μm ($r = -0.323$ and -0.283, $p \leqslant 0.05$, respectively). Breakdown had negative correlation with set back, pasting-time, gel hardness, gel chewiness and pasting-temperature ($r = -0.278$, -0.397, -0.304, -0.260 and -0.472, $p \leqslant 0.05$, respectively). Pasting-temperature showed positive correlation with T_c, gel hardness and granule size of 20–40 μm ($r = 0.243$, 0.324 and 0.258, $p \leqslant 0.05$, respectively). T_o showed positive correlation with T_p, ΔH_{gel}, %granules of 60–80 μm size and granules of size above 80 μm ($r = 0.626$, 0.386, 0.383 and 0.357, $p \leqslant 0.005$, respectively). T_p showed positive correlation with %granules of 60–80 μm size ($r = 0.314$, $\leqslant 0.05$). T_c showed positive correlation with set back ($r = 0.857$, $p \leqslant 0.005$). Gelatinization range showed positive correlation with %granules of 0–20 μm size ($r = 0.733$, $p \leqslant 0.05$) and negative correlated with %granules of 40–60 μm size ($r = -0.301$, $p \leqslant 0.05$).

3.9. Principal component analysis

A principal component analysis was carried out to obtain the main variables describing the potato starch diversity and to find relationships between the different variables. The first five factors accounted for 71% of the total variance. Factors 1, 2, 3, 4 and 5, explained variances of 19.6%, 14.9%, 12.2%, 10.8% and 8.5%, respectively. Factor 1 was mainly associated with pasting-time, cohesiveness, hardness, gumminess and chewiness, which were most closely associated parameters, with correlation coefficients from -0.564 to -0.862. Peak viscosity and hot-paste viscosity, on the other, were associated with Factor 2. Factor 3 explained 12.2% of variance and was negatively influenced by pasting-temperature, T_c and $T_{p.}$ Factor 4, which explained 10.8% of variance, was negatively influenced by breakdown and swelling index. Factor 5 was mainly associated with springiness and ΔH_{gel}.

4. Conclusion

The present study demonstrated the effect of storage temperatures on properties of starches from different potato cultivars. Surface morphology of starch granules was affected by storage temperatures. Solubility, thermal properties, pasting properties and textural properties seem to be more altered than are other starch properties. In contrast, slight differences in amylose content and swelling power were observed.

Acknowledgment

The financial support from the Department of Science and Technology (DST), New Delhi to N.S. is gratefully acknowledged.

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