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RESEARCH ARTICLE

Effect of time and temperature on the functional and textural characteristics of starch isolated, from pigmented traditional rice cultivars of Kashmir

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ABSTRACT

The research was to done to determine the effect of amylose content, temperature and time periods on the functional, textural and rheological properties of starch isolated from five different rice cultivars. The water solubility and swelling power was found to increase with every 10ºC increase in temperature with *Samarkand* exhibiting highest values of water solubility. The syneresis between starches of different rice cultivars during storage showed a significant difference with starch gel of *Shel Kew* exhibiting highest syneresis ranging from 16.715 to 4.873 % during storage period of 120h. The turbidity values estimated from gelatinized starch suspensions from different rice cultivars was found to increase progressively during the storage periods. The fluctuating trends in turbidity values of starches from *Gull zag* and *Kaw kareed* could be attributed to the amylose aggregation and crystallization that are not completed during first 4 days of during storage periods. The texture profile analysis of starch gels of the analysed rice cultivars revealed a significant difference in their textural characteristics with *Kaw kareed* exhibiting the highest value of hardness, gumminess and chewiness. The rheological analysis revealed that starch of *Gull zag* was found to depict the highest peaks values of $G^{/}$ (7550Pa) and $G^{//}$ (630Pa).

Keywords: Rice starch, amylose content, syneresis, turbidity, TPA, rheological characteristics

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INTRODUCTION

Starch is mainly determines the physicochemical, textural and cooking characteristic of rice and thus has the main role in measuring the acceptability of rice. The applications of rice starch are diverse in food, pharmaceutical and non-food sectors. The starch production from rice is much cheaper as compared to other cereal starches due to bulk availability of broken rice at cheaper rates (Sodhi and Singh, 2003). In modern times, rice starch is preferred over other starch sources isolated from several conventional sources due to its novel properties including non-allergenicity, easy digestibility, bland flavour, white colour and a wide range of amylose/amylopectin ratios. Rice starch has property of having bland taste, creamy in appearance and easy spreadable in its gelatinized form (Bhat and Riar, 2016).

The starch granules of rice are the smallest than other cereal starches that imparts it texture perception similar to that of fat globules, retention of excess amount of water, lower syneresis and a substitute for fats in various food formulations (Labell,

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1991). These unique properties of rice starch together with their large diversity makes rice as one of the best source of producing starch in different food and non-food industries (Vandeputte and Delcour, 2004).

Heating of starch beyond gelatinization temperature causes pasting of starch granules, which include swelling of starch granules that caused leaching of molecular components and finally disruption of the starch granules (Tester and Morrison, 1990). The viscosity parameters during heating of starch are largely controlled by the swelling power and solubility of starch granules (Sandhu and Singh, 2007). The starch properties turbidity, syneresis, gel texture have been explored by researchers in order to select the desired starches for specific product end uses and to avoid different modification techniques (Correja et al., 2012). Rice starch with desirable rheological properties is used in number of food products possessing specific characteristics. A rheological property of starch is determined by amylose content, lipid contents and branch chain length distribution of amylopectin (Wani et al., 2012). The purpose of this research was also to analyze the effect of storage time and temperature on textural and rheological properties of starches isolated from these rice cultivars.

MATERIALS AND METHODS

Procurement of raw materials

The different rice cultivars to be explored for the research work were procured from the rice research centres and different breeding station of Sher-e-Kashmir Agricultural University of Science and Technology, Kashmir (India). These cultivars were cleaned from various impurities including dust, dirt, straw, immature kernels, stones and then subjected to milling using in a pilot scale grinding mill (Agrosa India,Pvt. Ltd.). The bran was removed from the rice kernels by abrasive action of the emery roller and the white rice obtained was ground in a disc mill (M/s. Perten, Huddinge, Sweden) to get flour. The flour recovered was passed through 100 mesh sieve and stored at 4^{o}C in air tight containers for further analysis.

Isolation of rice starch

Isolation of rice starch was done by means of alkali extraction method followed by Yamamoto (1973), with little modification. Rice flour obtained after sieving through 100 mesh sieve was steeped in 0.05M NaOH solution for 5h at room temperature. The alkali solution resulted in the separation of proteins adhering to rice starch along with fibres and lipid present in endosperm. The steeped alkaline solution was drained fallowed by diluting the crude starch sediments. The slurry prepared by diluting the crude starch was mixed thoroughly in a mixer grinder and then filtered through a No. 200 wire mesh sieve. The filtered starch slurry was then centrifuged at 3000rpm and the starch settled in the bottom of centrifuge tubes after centrifugation was scraped off at its surface to remove the dark trailing layer adhering at its upper surface. The starch recovered was again dissolved and centrifuged continuously until no dark layer appears on its surface. The final purified white coloured starch was washed continuously by distilled water until the supernatant attains pH 7. The starch recovered was dried in a hot air oven at 40^{o}C for 48 h to remove moisture and then grounded in a mortar pestle fallowed by sieving through 100 mesh sieve. The final powdered starch was stored in air tight containers at 4^{o}C.

Determination of amylose Content

Amylose content of the isolated starches was determined by the colorimetric method of Morrison and Laignel et al. (1988). The starch (70 mg dry basis) was poured in a test tube followed by addition of 10 ml of urea (6M)-DMSO solution in the ratio of (1:9) ml with continuous shaking. The solution was kept in boiling water for 10 minutes and then in an oven at 100^{o}C for 1 hour. After cooling at room temperature, 0.5 ml of the solution was pipette out into a volumetric flask containing 25 ml distilled water along with 1 ml of I_2 and KI (100mg I_2 and 1000 mg KI in 50 ml distilled water). The final volume was made up to 50 ml with distilled water and mixed completely. Absorbance of the samples was measured at 635nm in a spectrophotometer against a blank (prepared by allowing chemicals and distilled water to stabilize for a period of 15 minutes).

$$\%(Amylose) = \left(\frac{Absorbance \times 100}{2 \times g\ solution \times mg\ starch}\right) \times 100 \times 28.414$$

Swelling power and solubility

Swelling power (SP) and solubility (SOL) of rice starch was determined by following the procedure given by Adebooye and Singh (2008), with slight modification. Starch (500 mg dry basis) was dissolved in 20 ml distilled water and then subjected to the different temperatures for 30 min each, starting from 55^{o}C to 95^{o}C with an interval of 10^{o}C. The gelatinised starch suspensions were centrifuged at 3000 rpm after cooling at room temperature. The supernatant of the starch suspensions were poured into petriplates and dried at 105^{o}C in a hot air oven for 24 hr to determine the solids content present in the supernatant.

$$\%SOL = \frac{A}{S} \times 100$$

$$SP = {(B \times 100)}\Big/{S(100 - \%SOL)}$$

Where % SOL=Percent solubility; SP=swelling power; A=weight of dissolved solids in supernatant; B=weight of sediment paste; S=weight of sample.

Turbidity

Turbidity of starches was determined by following the method of Perera and Hoover (1999). An aqueous starch suspension of 1% was heated at 90^{o}C in a water bath for 1 hr with constant stirring. The suspension of the samples were cooled for 1 h at room temperature and stored for under refrigeration for 5 days at 4^{o}C. The transmittance of the samples were determined every 24 h by measuring the absorbance at 640 nm against distilled water with a UV Spectrophotometer.

Syneresis

Syneresis was different rice starches was determined according to method of Sodhi and Singh (2003), by heating 5 % aqueous starch solution in a screw capped centrifuge tubes by heating in a boiling water bath for 30 min with continuous stirring followed by cooling in an ice bath. The starch pastes were weighed and then placed in freezer at 4^{o}C for 48, 72, 96 and 168 h. Syneresis was measured as amount of water released (%) by centrifugation at 5000 rpm for 15 min.

$$Syneresis(\%) = \left(\frac{wt\ of\ water\ released\ after\ centrifugation}{wt\ of\ starch\ gel}\right) \times 100$$

Textural properties of starch gel

Texture profile analysis (TPA) of the starch gels were done according to the method of Hormdok and Noomhorm (2007), with slight modification. The gelatinized starch samples prepared from 3g of starch in a beaker were kept at 4 °C for 24 h for formation of solid gel formation. The gels were evaluated for textural analysis using TA-XT2 texture analyzer (M/s. Stable Microsystems, Surrey, UK). The gel sample was compressed to a distance of 10.0 mm at rate of 0.5 mm/s using cylindrical plunger (P-5, 5 mm diameter). Textural properties measured were hardness, adhesiveness, cohesiveness, springiness, gumminess and chewiness.

Rheological properties

Rheological properties of starches isolated from different rice cultivars were measured according to procedure of Sodhi and Singh (2003), with some modification. Dynamic rheology of different rice starches gel was analyzed by means of temperature sweep oscillatory experiment as done with Modular Compact Rheometer (MCR-102, M/s. Anton Paar, Austria), equipped with parallel plate system having diameter of 50 mm. The probe was set at 0.5mm diameter, while strain and frequency were set at 0.5 % and 1 Hz, respectively. A starch suspension of uniform particle size (20 % (w/w) of 2ml was kept on the ram of Rheometer and the starch sample was subjected to temperature sweep at a temperature ranging from 50 to 90 °C at a heating rate of 2 °C/min. The dynamic rheological properties of rice starch gel from different rice cultivars was determined in terms of storage modulus ($G^{/}$), loss modulus ($G^{//}$) and loss factor (tan δ) as a function of temperature. $TG^{/}$ was calculated by measuring the temperature at peak value of storage modulus ($G^{/}$) or Loss modulus ($G^{//}$) and have an important role in determining the rheological behavior of different rice starches.

Statistical analysis

All the experiments performed were done in triplicate and the results expressed as mean values ± standard deviation. Data were statistically analysed by analysis of variance (ANOVA) and Duncan's Multiple Range test (p<0.05) was done to determine significant differences among the results.

RESULTS AND DISCUSSION

Water solubility and swelling power

The starch of different rice cultivars showed a significant (p ≤ 0.05) difference for water solubility and swelling power, when heated from 55ºC to 95ºC as depicted in Table 1 and 2. The increase in water solubility and swelling power after interval of 10ºC increase could be attributed to the swelling and solubilisation of starch granules. The maximum amount of water solubility was displayed by Samarkand with its values ranging from 0.751% at 55ºC to 13.784% at 95ºC. The higher water solubility of starch from different rice cultivars could be attributed to length range of its starch granules and starch with higher length and width had been found to possess higher water solubility (Bhat and Riar, 2016). The swelling power among the analysed starch samples was found to be highest in *Kaw quder* (2.432 to 12.275%) and lowest in Shel kew (2.755-7.682%). The greater the size of starch granules, the higher will be the leaching of solids due to the more contact of granule surface with the water as confirmed earlier by Lindeboom et al. (2004). The water solubility and swelling power of the given starches were found to correlate with the values determined for starch from different Indica and Japonica rice varieties as reported earlier by Lii et al. (1995). The amylose content in starch had been reported by Ratnayake et al. (2002) to be responsible for water solubility and that of amylopectin for swelling power. The higher amylose content in starch maintains the compactness of the starch granule and thus reduces the leaching of starch fractions from the granules thus resulting in lowering solubility (Seguchi et al., 2003). The variations in water solubility and swelling power of different rice starches may be attributed to different degrees of bonding and starch chain interactions within their granules (Leach et al., 1959). Swelling power depict the capacity of starch granules to hold water by means of hydrogen bond and thus gives measure of amorphous and crystalline domains starch granules (Ratnayake et al., 2002).

Syneresis

The syneresis between starches of different rice cultivars during storage showed a significant difference as illustrated in Table 3. The starch gel of *Shel kew* showed the highest syneresis values with storage periods ranging from 16.715 to 4.873 %, while the least values of syneresis was depicted by the starch gel of *Samarkand* (18.457-2.937%). Syneresis considered an undesirable property gives the measure of the degree of retrogradation in starch during storage periods at lower temperature. Syneresis is due to the contraction of gelatinized starch at lower temperature that occurs by association of amylase chains resulting in loss of water (Hermansson and Svegmark, 1996).

Table 1: Effect of storage temperature on the water solubility (%) of starches from different rice cultivars

Cultivars	55°C	65°C	75°C	85°C	95°C
Gull Zag	0.376 ± 0.005^{e}	2.537 ± 0.048^{cd}	4.685 ± 0.013^{d}	8.754 ± 0.065^{b}	12.453 ± 0.017^{b}
Kaw quder	0.822 ± 0.020^{a}	2.476 ± 0.019^{ce}	4.452 ± 0.005^{e}	8.573 ± 0.013^{b}	11.385 ± 0.003^{c}
Kaw kareed	0.825 ± 0.015^{b}	2.534 ± 0.048^{de}	4.673 ± 0.065^{d}	8.378 ± 0.015^{b}	11.424 ± 0.174^{c}
Shel kew	0.435 ± 0.006^{d}	3.787 ± 0.013^{ab}	5.254 ± 0.013^{b}	11.253 ± 0.013^{a}	13.241 ± 0.013^{a}
Samarkand	0.751 ± 0.017^{b}	3.775 ± 0.017^{a}	5.646 ± 0.005^{a}	11.417 ± 0.015^{a}	13.784 ± 0.060^{a}

Results are expressed as mean values ± standard deviations. Means in a column with different superscripts are significantly different ($P<0.05$)

Table 2: Effect of storage temperature on the swelling power (%) of starches from different rice cultivars

Cultivars	55°C	65°C	75°C	85°C	95°C
Gull Zag	3.587 ± 0.157^{a}	6.267 ± 0.015^{c}	7.573 ± 0.065^{f}	9.351 ± 0.012^{e}	10.676 ± 0.118^{b}
Kaw quder	2.432 ± 0.050^{cd}	4.428 ± 0.082^{e}	8.828 ± 0.032^{d}	10.743 ± 0.065^{b}	12.275 ± 0.052^{a}
Kaw kareed	2.417 ± 0.050^{c}	5.375 ± 0.157^{d}	10.453 ± 0.013^{a}	10.756 ± 0.011^{a}	9.756 ± 0.032^{d}
Shel kew	2.755 ± 0.320^{b}	6.738 ± 0.015^{b}	9.265 ± 0.060^{c}	10.376 ± 0.030^{d}	7.682 ± 0.061^{f}
Samarkand	3.086 ± 0.157^{a}	7.253 ± 0.082^{a}	8.687 ± 0.085^{d}	9.683 ± 0.013^{e}	10.322 ± 0.112^{c}

Results are expressed as mean values ± standard deviations. Means in a column with different superscripts are significantly different ($P<0.05$)

Table 3: Effect of storage on the syneresis (%) of starches from different rice cultivars

Cultivars	24h	48h	72h	96 h	120h
Gull Zag	15.135 ± 0.074^{e}	4.535 ± 0.015^{f}	5.653 ± 0.015^{a}	4.576 ± 0.011^{a}	4.853 ± 0.05^{b}
Kaw quder	16.766 ± 0.011^{f}	8.616 ± 0.023^{a}	3.538 ± 0.118^{d}	2.275 ± 0.017^{e}	2.353 ± 0.11^{e}
Kaw kareed	17.175 ± 0.073^{c}	3.475 ± 0.012^{g}	2.675 ± 0.015^{f}	2.653 ± 0.015^{c}	2.873 ± 0.02^{d}
Shel kew	16.715 ± 0.081^{a}	5.674 ± 0.015^{c}	4.736 ± 0.023^{b}	4.657 ± 0.013^{b}	4.873 ± 0.12^{a}
Samarkand	18.457 ± 0.061^{b}	6.575 ± 0.011^{b}	3.531 ± 0.011^{c}	2.573 ± 0.112^{d}	2.937 ± 0.01^{c}

Results are expressed as mean values ± standard deviations. Means in a column with different superscripts are significantly different ($P<0.05$)

The syneresis due to retrogradation of starch occurs due to the reassociation of starch molecules in an ordered structure (Atwell et al., 1988). The higher syneresis in starch of *Shel kew* could be attributed to its widely spaced granules with rounded granule morphology which are more susceptible to release of water upon cooling due to its loose three dimensional structure of gel as depicted by its comparatively higher value of springiness and lowest hardness value. Similar values of textural characteristics found in *Gull zag* depicted higher synersis percentage (4.853%) which validated the above statement. The percentage increase in syneresis during storage periods had been attributed to the association between leached amylose and amylopectin chains resulting in the formation of functional zones, that lead to shrinkage and oozing of water from the starch gels (Perera and Hoover, 1999). Syneresis of starch gels leads to the formation of harder gels and starch with higher amylose content and longer amylopectin chains had been reported to be responsible for harder gel formation (Mua and Jackson, 1997). The starch chains that had been disintegrated and taken up a random configuration due to swelling and rupturing of starch granules during gelatinization tends to recrystallize upon cooling. During storage at low temperature amylose crystallization occurs during the first few hours and that of amylopectin during later stages as reported previously by Singh et al. (2008).

Turbidity

The values of turbidity from different gelatinized starch suspensions of rice cultivars are summarized in Table 4. The lowest turbidity value among the given rice starches was shown by *Kaw kareed* upon storage possessing the least value of 1.37 on the 6th day, while the highest turbidity value was depicted by Gull zag with values ranging from 1.45 to 1.57 during the storage period. The turbidity values estimated from gelatinized starch suspensions from different rice cultivars was found to increase progressively during storage periods. The fluctuating trends in turbidity values of starches from *Gull zag* and *Kaw kareed* could be attributed to the amylose aggregation and crystallization that are not completed during first 4 days of during storage periods thereby leading increasing turbidity as reported earlier by Miles et al. (1985). The increasing turbidity on various starches from diverse sources during first 4 days of storage had been reported by Maninder et al. (2004). The turbidity values for these two cultivars were found to decrease on the 5th days followed by a slightly increasing value on the 6th day. The increase in turbidity with storage had been found to be due to the swelling of starch granules coupled with repulsion between the negatively charged phosphate groups, which are attached with amylopectin chains by covalent bonds (Perera and Hoover, 1999). The derivatives of phosphate monoester and phospholipids content in starches of different rice cultivars had been found to contribute variations in the turbidity values of rice starches (Jane et al., 1996). The phosphate-monoester derivatives in starch are associated with increasing paste clarity and phospholipids have been found in determining the opaqueness of starch pastes (Kasemsuwan and Jane, 1996). The swelling of starch granules, granule remnants and association between leached amylose and amylopectin chains had been reported to account for the turbidity of gelatinised starch during storage (Jacobson et al., 1997). The interaction between leached amylose and amylopectin chains during storage of gelatinised starch leads to the development of function zones that are having a significant effect on the reflection or scattering of light and thus contributing to turbidity (Yu et al., 2012**)**.

Table 4: Effect of storage on the turbidity of different starch samples

	Absorbance at 640nm						
Cultivars	**0 Day**	**1 Day**	**2 Day**	**3 Day**	**4 Day**	**5 Day**	**6 Day**
Gull Zag	1.45±0.015^{a}	1.46±0.002^{a}	1.48±0.003^{a}	1.52±0.002^{a}	1.50±0.001^{a}	1.54±0.001^{a}	1.57±0.001^{a}
Kaw quder	1.34±0.001^{b}	1.36±0.015^{b}	1.39±0.002^{b}	1.43±0.001^{b}	1.46±0.002^{b}	1.48±0.002^{b}	1.51±0.002^{b}
Kaw kareed	1.25±0.002^{d}	1.27±0.001^{e}	1.30±0.015^{d}	1.33±0.002^{e}	1.31±0.010^{e}	1.35±0.002^{d}	1.37±0.001^{d}
Shel kew	1.28±0.002^{c}	1.30±0.002^{c}	1.32±0.002^{c}	1.35±0.001^{c}	1.38±0.015^{c}	1.40±0.001^{c}	1.43±0.001^{c}
Samarkand	1.25±0.015^{d}	1.28±0.002^{cd}	1.30±0.002^{d}	1.34±0.002^{d}	1.37±0.001^{f}	1.40±0.002^{c}	1.43±0.010^{c}

Results are expressed as mean values ± standard deviations. Means in a column with different superscripts are significantly different (P<0.05)

Texture profile analysis of starch gel

The values of different parameters obtained from TPA analysis of starch are illustrated in Table 5. The TPA values of different starch gels revealed a significant difference in their textural parameters including hardness, adhesiveness, springiness, gumminess and chewiness. Among the starch gels, *Kaw kareed* showed the highest value of hardness (0.635N), gumminess (35.263) and chewiness (30.553). Which could be attributed to its higher amylose content and greater amylopectin chain length as reported earlier by Mua and Jackson (1997). The textural attributes of starch gel as determined by TPA analyser had been found to be highly correlated with amylose content (Kohyama et al., 2015). The lowest hardness (0.345N) and chewiness (17.163) was found in *Samarkand*.

The value of adhesiveness was found lowest in *Shel Kew* (0.067) and highest in *Gull zag* (0.215). Springiness that measures the recovery of starch gel from deformation was found to be higher in *Kaw quder with* value of 90.576. The retrogradation in starch gels accompanied by water loss due to syneresis resulted in firmness of gels, which causes crystallization of amylopectin and thus hardness of starch gels (Miles et al., 1985**)**. Starch gels of rice had been found to be very sensitive to fracture due to its inherent defects with their size ranging to that of swollen starch granules (Luyten and Van Vliet, 1995). The textural characteristics of rice starch gel had been found to be determined by the amylose to amylopectin ratio and temperature of storage (Yu et al., 2012). The retrogradation of starch gels at frozen temperatures are retarded which in turn maintains its textural characteristics for longer periods.

Table 5: Texture profile analysis (TPA) of starch gel from different rice cultivars

Cultivars	Hardness	Adhesiveness	Springiness	Gumminess	Chewiness
Gull Zag	0.345±0.002^{d}	-0.215±0.002^{a}	85.376±0.001^{c}	21.055±0.003^{c}	17.163±0.002^{d}
Kaw quder	0.583±0.002^{b}	-0.205±0.002^{a}	90.576±0.002^{a}	33.513±0.002^{b}	30.515±0.003^{b}
Kaw kareed	0.635±0.001^{a}	-0.135±0.002^{b}	84.635±0.002^{d}	35.263±0.002^{a}	30.553±0.002^{a}
Shel kew	0.347±0.002^{d}	-0.067±0.003^{d}	86.465±0.002^{b}	20.273±0.002^{d}	17.635±0.001^{c}
Samarkand	0.354±0.002^{c}	-0.131±0.001^{c}	83.435±0.003^{e}	19.537±0.002^{e}	16.432±0.001^{e}

Results are expressed as mean values ± standard deviations. Means in a column with different superscripts are significantly different (P<0.05)

Table 6: Rheological characteristics of starch gels from different rice cultivars

Cultivars	Peak $G^{/}$ (Pa)	Peak $G^{//}$ (Pa)	$TG^{/}$ (°C)	Peak tanδ	Breakdown in $G^{/}$ (Pa)
Gull zag	7550±0.57^{a}	630±1.00^{a}	75.85±0.01^{a}	0.0735±0.0001^{d}	7325±1.52^{a}
Kaw quder	3740±1.00^{d}	510±1.15^{c}	74.36±0.01^{c}	0.1235±0.0002^{a}	3124±1.00^{c}
Kaw kareed	4385±1.15^{c}	348.5±1.53^{d}	75.43±0.01^{b}	0.0713±0.0002^{e}	3454±1.15^{b}
Shel kew	4875±0.57^{b}	515.7±0.57^{b}	75.41±0.01^{b}	0.1035±0.0001^{c}	2738±0.57^{d}
Samarkand	2353±1.00^{e}	240.7±1.53^{e}	74.30±0.02^{c}	0.1043±0.0002^{b}	875±1.15^{e}

Results are expressed as mean values ± standard deviations. Means in a column with different superscripts are significantly different (P<0.05)

Dynamic rheological characteristics of rice cultivars starch

The rheological properties of starch gels isolated from different rice cultivars are illustrated in Table 6. The starch from *Gull zag* have been found to possess the highest $TG^{/}$ with value of 75.85°C and *Samarkand* were found to depict the lowest value of $TG^{/}$ (74.30°C) during heating cycle. The rheological properties of starch are determined by the rigidity of starch granules along with their interaction during heating process. The starch of *Gull zag* was found to depict the highest peaks values of $G^{/}$ (7550Pa) and $G^{//}$ (630Pa), respectively, while starch isolated from *Samarkand* showed the lowest values of $G^{/}$ (2353Pa) and

$G^{//}$(240.7Pa)**.** The difference in the values of $G^{/}$, $G^{//}$ and tan β of starch upon heating have been found to be linked with amylose contents and its granular structure (Svegmark and Hermansson, 1993).

The transformation of starch suspension into gel with increasing temperature leading to increasing storage and loss modulus could be attributed to the conversion of amylose in the swollen starch granules to a 3-dimensional network formation (Hsu et al., 2000). The gelatinization of starch granules had been reported by Ring (1993) in reinforcing the 3- dimensional network formation in gel, which is determined mainly by the amylose content. The decrease in the values of $G^{/}$ and $G^{//}$ in the analyzed starch samples may be linked to the disentanglement of the amylopectin molecules in the gelatinized starch granules resulting in the destruction of formed gels (Keetels and Van Vliet, 1994). The leaching of amylose from starch gels along their changes in volume upon heating accounted for the differences in their values of $G^{/}$ and $G^{//}$ (Eliasson, 1986).

The peak tanδ, values in the analysed rice starches were found to be < 1 and ranged from 0.713 to 0.1235 with *Kaw quder* depicted the highest value and *Kaw kareed* showed the lowest value. The differences in the values of *tan d* could be attributed to the different values of $G^{//}$ and $G^{/}$. The loss factor (tanδ), calculated as the ratio of $G^{//}/G^{/}$ is gives the measure of the ratio of energy lost to the energy stored during a heating cycle of starch suspension (Ferry, 1970). The breakdown in $G^{/}$ that is the difference of peak $G^{/}$ at $TG^{/}$ and minimum $G^{/}$ at 90ºC was observed to be maximum in *Gull zag* (7325) and minimum in *Samarkand* (875) starch. The differences in the values peak $G^{/}$ and morphological characteristics of starch granules accounted for the variations in the breakdown values. It has been found that that the amylose content and peak $G^{/}$ and $G^{//}$ are inversely correlated to each other. Which is justified from the values of $G^{/}$ and $G^{//}$ in *Gull zag* with highest values but having lowest amylose content. Similar findings had been reported by Kaur et al. (2002); Sodhi and Singh (2003) in starches of potato and rice. The higher values of $G^{/}$ and $G^{//}$ in *Gull zag* may be due to its compact structure as validated from its swelling power capacity, that was lower than other starches samples analysed.

CONCLUSION

The effect of temperature and time was found to have a significant effect on the textural and rheological characteristics of the rice starch. The starches of the analysed traditional rice cultivars revealed desirable characteristic as compared to hybrid rice varieties as in terms of functional attributes including water solubility, swelling power, syneresis and turbidity values. The interaction between leached amylose and amylopectin chains during storage of gelatinised starch leads to the development of function zones that are having a significant effect on the reflection or scattering of light and thus contributing to turbidity. The higher syneresis in starch of *Shel kew* could be attributed to its widely spaced granules with rounded granule morphology which are more susceptible to release of water upon cooling due to its loose three dimensional structure of gel as depicted by its comparatively higher value of springiness and lowest hardness value. . It has been found that that the amylose content and peak $G^{/}$ and $G^{//}$ are inversely correlated to each other. Which is justified from the values of $G^{/}$ and $G^{//}$ in *Gull zag* with highest values but having lowest amylose content.

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