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Rheological study of starch extracted from germinated and non-germinated maize vis-a-vis printing

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ABSTRACT

Due to the untimely rains and inadequate storage facility, a lot of wheat, maize, jowar, rice, etc. often get dampened and start germinating becoming unacceptable for edible consumption. In the current study the starches are extracted from germinated as well as non-germinated maize grains by alkali steeping method and their employability as printing thickener is studied. The study of rheology of these starches and their blends is also carried out. The effect of solid content and the shearing time on the viscosity of the paste has been studied and the shear thinning index (STI) and the values of viscosity at 1 rpm shear rate (i.e. *K* value) are used to compare the behaviour of both the starches. The effect of rheological behaviour of starch paste on the printing properties is confirmed in printing of vat dyes on cotton, using these starches as thickener paste.

1. Introduction

In India untimely rains and hail storms at harvest time and inadequate storage facility for the food-grains cause dampening of a lot of cereal grains such as wheat, sorghum, maize and rice. The subsequent germination and microbial growth make them unacceptable for edible consumption (Pandey & Raja, 1992). The percentage of such waste is quite alarming i.e. 10–15%. Germinated grains which are normally dumped as waste can be effectively utilized for extraction of starch which in turn can find applications in textile printing as well as in sizing. Suitability of germinated wheat starch to substitute sound or virgin wheat starch in printing of vat dyes on cotton has been reported earlier from our laboratory (Shanbhag V.S., M.Sc. Tech. Thesis 1994, TH 2296, I.C.T. Mumbai).

Rheology plays an important role in optimization and control of the textile printing process (Bandyopadhyay & Bhattacharya, 1998; Sostar, 1997). The rheological properties determine the amount of the printing paste applied as well as its spread on the surface and into the structure of textile material. The viscosity of most of the thickener pastes does not remain constant, but decreases with shear rate. Such substances are called non-Newtonian, pseudoplastic, or shear thinning and the viscosity values of pseudoplastic materials are termed as "apparent" viscosities, meaning that they correspond to a given shear rate. Since pseudoplastic material has as many apparent viscosities as there are shear rates, only a viscosity profile can thus display the wide range of attainable viscosities. Hence, to characterize a non-Newtonian fluid, it is necessary to make shear stress–shear rate determinations at many points. The pseudoplastic nature of printing pastes can best be studied by the Ostwald-de-Waele equation, which is also called a 'power law', and it is denoted as follows:

$$\zeta = KD^n$$

where, ζ is shear stress, D is shear rate, K is constant, n is power, having value between 0 and 1 (Teli & Vyas, 1990). Many researchers have studied influence of electrolytes and investigated some of the relationships between the rheological behaviour of printing pastes and the performance of resulting prints (Dang & Prasil, 2001). The influence of temperature, concentration of dyes and thickeners on the rheological behaviour of printing pastes both experimentally and mathematically has also been studied (Prasil & Dang, 1996). However, so far no detailed identification of rheological properties of printing thickeners and printing pastes has been made during the process of textile printing (Sostar, 1997).

By studying the rheological properties of the printing pastes based on different thickening agents, the contribution of the nature of the thickening agent in the flow properties of print paste can be understood. The rheological properties of Amaranthus starch vis-a-vis wheat starch is already reported from our laboratory (Teli, Shanbag, Dhande, & Singhal, 2007). Application of starch extracted from germinated maize in textile printing as replacement of normal maize starch is also reported from our laboratory (Teli, Shanbag, Rohera, Sheikh, & Singhal, 2009).

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In the present study an attempt is made to study the effect of germination on the rheological properties of the starch pastes extracted from germinated and sound maize grains. The effect of changes in rheology on the properties of the fabrics printed using these starches, is also subject of this study. This study is further extended to blends of starch pastes to look into the possibility of partial replacement of normal starch with that obtained from germinated variety.

2. Materials and methods

2.1. Materials

Maize cereals and jute sack used for extraction of starch were obtained from local grocery shop. 100% cotton fabric was used for printing with the fabric construction of E.P.I – 76 & P.P.I – 70. GSM of fabric used was 123.5 g/m^2. Nylon bolting cloth of 200 mesh was used for the extraction of starch. All chemicals used were of laboratory grade. Vat dyes used were supplied by Atul (P) Ltd., India.

2.2. Methods

2.2.1. Germination

Germination of maize was done by imitating the actual poor conditions during storage. Maize grains were packed and allowed to suffocate in a jute sack. Sprinkling of water was done every 2 h for 24 h to keep it in a damp condition. After 24 h the grains were removed and without rinsing, they were completely dried in an oven at 50 °C.

2.2.2. Extraction of starch

Extraction of starch was done by alkali steeping method (Yanez & Walker, 1986). The grains were ground to coarse flour which was then treated with 5 times the volume of 0.25% NaOH for 4 h followed by draining. The treatment was repeated again for 3 h, which was followed by washing it thoroughly until free of NaOH. The grains were ground in a waring blender and the slurry obtained was then passed through a 200 mesh bolting cloth and squeezed to extract the crude starch. The extract obtained was kept overnight until separation of two layers. Upper layer was drained and lower layer was centrifuged at 4000 rpm for 10 min. The upper proteinous portion was then scrapped and starch obtained was dried in an oven at 50 °C. The starch was then ground to 60 mesh and stored in an air tight container under refrigeration to avoid microbial or fungal attack.

2.2.3. Analysis of starch

Analysis of germinated and non germinated starch was done for comparison.

2.2.3.1. Estimation of colour of starch powders. The starch powder samples were taken in a small plastic sacks and placed against the measuring slit of spectrophotometer. Kubelka Munk function K/S and L^*, a^*, b^* values were measured using Spectraflash SF300, to determine its colour using 10° observer taking the mean of 3 readings at different interval after every time shaking the sample in the sack.

2.2.3.2. Swelling power. Swelling power was determined by the method reported by Subramanian, Hoseney, and Bramel-Cox (1994). Starch (0.6 g) was heated with 30 ml of distilled water at 95 °C for 30 min. Lump formation was prevented by stirring this mixture at every 5 min interval. The mixture was then cooled and centrifuged (using CRU-5000 centrifuge) at 5000 rpm for 15 min. The supernatant liquid was carefully removed and the swollen starch sediment was weighed. Swelling power (g/g) was calculated as the ratio of the weight of the wet sediment to the initial weight of the dry starch.

2.2.3.3. Paste clarity. Measurement of paste clarity was carried out by method of Craig, Maningat, Seib and Hoseney (1989). 250 mg of starch sample was suspended in 20 ml of distilled water in a 40 ml test tube with plastic cap. The tubes were then placed in a boiling water bath for 30 min, shaken thoroughly every 5 min and then cooled to room temperature (25–30 °C) for about 10 min. The percent transmittance (% *T*) was determined at 650 nm against water as blank on a UV-1201 spectrophotometer (Shimadzu, Japan).

2.2.3.4. Estimation of iodine binding. The amylose content of starch was measured colorimetrically using the iodine method (Juliano, 1971). The sample (100 mg) was weighed accurately and placed into a 50 ml Erlenmeyer flask, to which 1 ml of 95% ethanol and 9 ml of 1 N NaOH were added. The sample was heated for 10 min in boiling water to geletanize the starch. After cooling the gelatinized sample to room temperature, it was transferred to 100 ml volumetric flask; then the total volume made to 100 ml by adding distilled water. The starch solution (5 ml) was pipetted into a 100 ml volumetric flask and 1 ml of 1 N acetic acid and 2 ml of iodine solution (0.2 g of iodine and 2.0 g of potassium iodide in 100 ml of aqueous solution) were added. The solution was diluted to 100 ml with distilled water, shaken and then allowed to stand for 20 min. The absorbance was then measured at 620 nm using spectrophotometer (UV-1201 Shimadzu, Japan).

2.2.4. Preparation of thickener paste

Non-germinated maize starch thickener (10%) was prepared by taking 10 parts of starch and 90 parts of water. In case of germinated maize starch, paste of 11% solid content was used as a thickener and it was prepared by taking 11 parts of germinated maize starch and 89 parts of water. Starch powder was first pasted with little amount of water followed by addition of the remaining water. The contents were then mixed and heated at boil for 30 min under continuous stirring so that starch gelatinizes, dissolves and paste is formed.

Similar procedure was used for thickener pastes of varying solid content as well as for preparing binary blends of germinated and non germinated thickener pastes, in the ratio of (w/w of the paste) of 70:30, 50:50, and 30:70, respectively.

2.2.5. Measurement of viscosity of thickener pastes

The various factors affecting the viscosity of these thickener pastes such as shear rate, solid content of thickener, time of shearing (shear sensitivity) were studied using a “Brookfield Synchrolectric Viscometer (Model RV)”. The thickener pastes were prepared of different solid contents and viscosity was measured by changing the shear rate at each concentration of the thickener. The readings were taken in triplicate and its mean is reported. Shear sensitivity was measured by shearing the thickener pastes over a period of time continuously.

2.2.5.1. Printing. Printing of vat dyes was done by pre-reduction method: (Potash Rongalite Method).

Formulation for printing using pre reduction method was made as follows:

Vat dye	2 parts
Glycerine + urea	5 parts
Solution salt B	3 parts
Potassium carbonate	12 parts
Sodium hydrosulphite	4 parts
Thickener paste	58 parts

The contents were then warmed at 60 °C and kept for 30 min at 60 °C. After cooling, 16 parts of Rongalite C was added to make a

Table 1
Analysis of starch extracted from germinated and sound maize grains.

Characteristics of starch		Germinated	Non-germinated
Colour values of starch powder	*K*/*S*	0.0148	0.0104
	L^*	90.80	91.82
	a^*	0.70	0.89
	b^*	7.59	7.75
Swelling power (g/g)		6.545	9.639
Transmittance (%)		2.13	2.83
Absorbence % (with iodine)		0.354	0.262

total of 100 parts. Samples were then printed with two strokes of squeeze, steamed at 102 °C for 4 min. This was followed by chemical oxidation using 2 g/l potassium dichromate and 5 g/l acetic acid (30%) solution. The samples were washed with non-ionic soap (Auxipon NP) in hot water followed by washing with water and then dried in air.

2.2.6. Analysis of printed fabrics

2.2.6.1. Colour value by reflectance method. The printed samples were evaluated for the depth of colour by reflectance method using 10° observer. The absorbance of the dyed samples was measured on Spectraflash SF 300 (Datacolor International, U.S.A.) equipped with reflectance accessories. The *K*/*S* values were determined using expression;

$$\frac{K}{S} = \frac{(1-R)^2}{2R}$$

where *R* is the reflectance at complete opacity; *K* is the absorption coefficient and *S* is the scattering coefficient.

2.2.6.2. Bending length. Bending length of printed samples, which is inversely proportional to the softness of the prints, was determined using a Shirley stiffness tester (Booth, 1983).

2.2.6.3. Washing fastness (ISO-III). The test for colour fastness to washing was carried out using ISO III methods (Trotmann, 1984).

2.2.6.4. Crocking fastness. The printed samples were tested for dry and wet crocking (rubbing). The colour fastness to dry crocking and wet crocking (cloth of the same sample impregnated in water with 70% expression) was measured using "crock-meter" with 50 strokes of crocking.

3. Results and discussion

3.1. Properties of starch extracted from germinated and non-germinated maize grains

Not much difference was observed in *K*/*S* and L^*, a^*, b^* values of both the starches (Table 1) and hence it is expected that the colour of starch would not play any role in affecting the final colour of prints.

Swelling power of non-germinated starch was about 1.473 times that of the germinated starch (Table 1). The major factor that controls the swelling behaviour of starch is the strength and character of the micellar network within the granule, which in turn is dependent on the degree and kind of association. Also at the molecular level, many factors influence the degree of association, as well as the size, shape, composition and distribution of the micellar areas in the internal lattice. These factors include the ratio of amylose to amylopectin, the characteristics of each fraction in terms of molecular weight and its distribution, degree of branching, conformation, and the length of outer branches of the amylopectin (Whistler, Paschall, Bemiller, & Roberts, 1965). During germination α-amylase gets activated and catalyses the hydrolysis of α-1,4 glucosidic linkages in starch and gives rise to oligosaccharides of lower molecular weights such as dextrin, maltose and glucose which do not have any swelling power (Whistler et al., 1965). In maize starch the granular swelling during gelatinization is mainly a function of amylopectin content (Daniel, Whistler, & Roper, 1997). During germination the amylose content (%) increases and the starch granules with higher amylose content, are better reinforced and thus are more rigid causing swelling less freely when heated. This is also confirmed by the results obtained for determination of amylose by iodine. Hence, the swelling power of germinated starch is lower than that of non germinated starch.

The transmittance (%) of non-germinated starch was higher than that of germinated starch (Table 1). The paste clarity is directly related to the state of dispersion and retrogradation tendency of the starch. The factors which increase granule swelling and solubilisation, or those factors that inhibit retrogradation increase in the paste clarity (Whistler et al., 1965). Since the swelling power of non-germinated starch was higher, its paste clarity was also higher than that of the germinated starch.

The iodine binding capacity of germinated starch was found to be 1.352 times that of non germinated starch (Table 1). Helical amylose entraps iodine as an inclusion compounds and the amount of iodine binding is a property of amylose giving a deep blue complex (Daniel et al., 1997). The absorption of germinated starch at 620 nm in the presence of iodine solution is about 1.352 times than that of non germinated starch, which implies that the amylose content of the starch increased after germination. This is also supported in the literature that states that during germination the proportion of amylose in the starch increases and the composition of the amylopectin fractions alter and the average length of the polymer is reduced (Hough, Briggs, & Stevens, 1971).

3.2. Rheology study of starch paste

The effect of solid contents of thickener and the shearing time on the viscosity of paste over a wide range of shear rates was studied. The shear thinning index (STI) and the values of viscosity at 1 rpm shear rate (i.e. *K*-value) were used to compare the behaviour of thickeners. With an increase in concentration of thickener, the viscosity of the thickener paste increased. This is because of higher resistance being offered to the spindle movement at higher solid content (Table 2). The data also indicates that with increase in the shear rate the viscosity of the paste of germinated and non-germinated starches and their blends was found to be decreasing. Such substances are called as non-Newtonian, pseudoplastic, or shear thinning. When automatic flat-bed screen printing or rotary screen printing machine is used in textile printing, the thickener paste thins down due to the shearing action of the squeegee with thickener paste facilitating the transfer of printing paste through the screens to the fabric. However, during the stoppage of the machine, when the shear rate is reduced the viscosity of the paste is momentarily regained making the paste difficult to penetrate through the screen on to the fabric and thus protecting the fabric from under staining. This is how the pseudoplastic behaviour of the thickener is best used in the printing operation.

The germinated starch paste showed lower viscosity values at all the concentrations when compared with those of non-germinated starch pastes of the same solid content. This is because, during the process of germination the hydrolyzing enzymes get activated causing a rapid fragmentation of the whole starch molecule by cleaving the α-D-(1 → 4) linkages more or less at random places and bring about a slow, though extensive, conversion of starch to reducing sugars. The beta-amylases promote a rapid hydrolysis of the outer chains of starch molecules to maltose, but since

Table 2
Effect of solid content on viscosity of non-germinated maize starch at different shear rates.

Shear rate (rpm)	Viscosity at different solid contents of thickener (P)					
	7%	8%	9%	10%	11%	12%
0.5	920([a]520)	2100([a]1540)	3500([a]2700)	5120([a]3600)	7000([a]5200)	9300([a]7700)
1.0	590([a]370)	1280([a]1040)	2100([a]1850)	3250([a]2150)	3950([a]3250)	5450([a]4650)
2.5	320([a]244)	712.0([a]640)	1080([a]1020)	1640([a]1200)	2100([a]1700)	2820([a]2340)
5.0	210([a]180)	440.0([a]400)	660.0([a]630)	920([a]760)	1210([a]1100)	1720([a]1500)
10.0	130([a]120)	268.0([a]248)	405.0([a]395)	525.0([a]510)	760([a]720)	1100([a]890)
20.0	80.5([a]78)	165([a]155)	250.0([a]240)	302.5([a]292.5)	460([a]420)	700.0([a]520)
50.0	44.0([a]40)	90.0([a]84)	130.0([a]124)	154.0([a]148)	224([a]208)	344.0([a]290)
100.0	28.4([a]24)	56.0([a]48)	72.0([a]70)	94.0([a]88)	132([a]122)	220.0([a]172)

[a] Represent corresponding value for germinated starch paste.

Table 3
Effect of blend composition of germinated (G) (11%) and non-germinated (NG) (10%) maize starch on viscosity of stock paste.

Shear rate (rpm)	Viscosity of blends at various blend ratios of paste (NG:G) (P)				
	NG	70:30	50:50	30:70	G
0.5	5120	5120	5160	5160	5200
1.0	3250	3250	3250	3250	3250
2.5	1640	1660	1660	1700	1700
5.0	920	940	1020	1080	1100
10.0	525	540	600	690	720
20.0	302.5	310	330	392.5	420
50.0	154.0	168	176	200	208
100.0	94.0	96	100	116	122

these enzymes cannot hydrolyse or bypass a α-D-(1 → 6) linkage, a high-molecular-weight dextrin and maltose remains. These lower molecular weight compounds do not contribute to the viscosity and hence have lower viscosity. This drop in viscosity was recovered by increasing the solid content of germinated starch. By measuring the viscosity of germinated and non-germinated starches, it was found that 11% of germinated starch gave viscosity equivalent to 10% of non-germinated starch.

The effect of blend ratio of 10% non-germinated and 11% germinated starch pastes is also studied to find out probability of partial substitution of non-germinated starch by germinated starch. It is found that the viscosity of the blend increased with the increasing proportion of germinated starch paste (11%) in the blend (Table 3). We have already seen, that germinated starch shows lower viscosity as compared to the non-germinated starch when their solid content taken in for making the paste are identical. In other words, if the two pastes were mixed at the identical solid content level, obviously substitution of non-germinated starch paste by the germinated starch paste would give decrease in viscosity. However in an effort to match the viscosities of the two pastes initially before blending, the germinated starch paste was made using 11% solid content and non-germinated starch paste used at 10% solid content of maize starch. In such a situation, the germinated starch paste gave higher viscosity than that of the non-germinated starch paste, mainly because of higher solid content used.

In order to study the effect of shear-rate on lowering of viscosity in more detail, log-viscosity was plotted versus log shear rate. The shear thinning index (STI) values calculated from graph and

Table 5
Shear-thinning index (STI) and *K* values for blends of germinated (11%) and non-germinated (10%) maize starch thickener pastes.

	Blend compositions (NG:G)				
	NG	70:30	50:50	30:70	G
STI	0.7720	0.7522	0.7307	0.7107	0.7035
K	3090.29	3162.277	3235.936	3311.311	3311.311

the *K*-values i.e. viscosity at 1 rpm, which gives an indication of flow property (since more is the *K*-value, less flowing will be the thickener paste) are given in Tables 4 and 5. The STI values of non-germinated starch paste increased as the solid content increased from 7% to 10% and subsequent increase in solid content brought about reversal in the trend. This initial progressive increase in rate of fall in viscosity with respect to increase in shear rate may be attributed to the larger extent of breakage in H-bonding and displacement of polymeric structure during the increase in shear rate. However, this process of thinning down seems to have been countered beyond the optimum level of solid content i.e. in the range of 11–12% in which case, the thinning process seems to have been slightly retarded due to the effect of increase in viscosity at higher levels of solid content. The STI values for germinated starch paste increased with increasing solid content from 7% to 12%. The STI values of non-germinated starch paste were higher than that of germinated starch paste, irrespective of the solid content. This indicates that the higher viscosity of the paste of non-germinated starch is responsible to show higher STI values. In case of blend, STI values of 0.7720 of non-germinated starch paste decreased progressively as it was increasingly substituted by germinated starch paste. The blends of the pastes showed overall decreasing trend due to the less swelling power of the germinated starch paste as compared to that of non-germinated one having higher swelling power. However the *K* values were found to be higher for germinated starch mainly because of higher solid content as discussed earlier.

It is also important to study the effect of time of shearing at a given shear rate on the viscosity of the paste. The results in Tables 6 and 7 indicate that from the start, there was a gradual decrease in viscosity, which then levelled off after lapse of certain time of shearing. When at a particular shearing rate, the paste is sheared, the polymer chain molecules are increasingly displaced from one plane to the other, breaking the intermolecular

Table 4
Shear-thinning index (STI) and *K* values for non-germinated (NG) and germinated (G) maize starch pastes.

		Solid content (%)					
		7	8	9	10	11	12
NG	STI	0.6586	0.68	0.7164	0.7720	0.7555	0.7175
	K	588.84	1256.92	2089.29	3090.29	4168.69	5623.41
G	STI	0.5291	0.6296	0.6712	0.7008	0.7035	0.7139
	K	371.53	1000.0	1819.70	2238.72	3311.311	4677.35

Table 6
Effect of shearing time on viscosity of non-germinated maize starch at different shear rates for 10% solid content.

Shear rate (rpm)	Viscosity at different shearing time (P)							
	1.0 min	2.0 min	3.0 min	4.0 min	5.0 min	8.0 min	10.0 min	15 min
1.0	3300	3250	3250	3250	3250	3250	3250	3250
2.5	1680	1640	1640	1620	1620	1600	1600	1640
5.0	920	920	920	920	920	920	920	920
10.0	525	525	525	525	520	520	520	520
20.0	302.5	302.5	302.5	302.5	302.5	300	300	300
50.0	152	152	152	150	150	150	150	150
100.0	92	92	90	90	90	88	88	88

Table 7
Effect of shearing time on viscosity of germinated maize starch at different shear rates for 11% solid content.

Shear rate (rpm)	Viscosity at different shearing time (P)							
	1.0 min	2.0 min	3.0 min	4.0 min	5.0 min	8.0 min	10.0 min	15 min
1.0	3300	3300	3300	3250	3250	3250	3250	3250
2.5	1720	1700	1700	1700	1680	1680	1680	1680
5.0	1100	1100	1090	1090	1090	1090	1090	1090
10.0	720	715	715	715	715	715	710	710
20.0	417.5	417.5	415	415	415	415	415	415
50.0	208	208	208	208	208	208	208	208
100.0	122	120	120	120	120	118	118	118

H-bondings which bring down the viscosity. Such an operation when continued, further effect of the time of shearing gets nullified and once the whole system gets properly stirred, the viscosity does not show any thixotropic influence of the thickener.

3.3. *Analysis of fabrics printed with vat dyes using these starches*

The printing of vat dyes on cotton was carried using germinated and non-germinated starch pastes and their blends. *K*/*S* and L^*, a^*, b^* values (refer Table 8) for vat dye printed samples indicate that colour depths (*K*/*S*) in case of germinated maize starch paste were lower than those for the non-germinated maize starch paste. Blends of these two thickener pastes gave *K*/*S* values, which increased with the increase in the proportion of starch from non-germinated or sound grains. The results show similar trend for both anthraquinone (Novatic Rubine 6BS) and indigoid (Novatic Navy Blue RA) vat dyes. This may be attributed to higher swelling power and more clarity of non-germinated maize starch than that of germinated starch. The shear thinning index (STI) of non-germinated starch paste is higher than germinated starch paste and in case of blends, it is found to be increasing with the proportion of non-germinated starch paste in the blend increased. The amount of colour transferred to the print would thus be higher for higher STI values, which in turn reflect in higher *K*/*S* values giving this trend. In case of 50:50 blend, the *K*/*S* decreased only by 3.55% in case of Novatic Navy Blue RA and 8.77% in case of Novatic Rubine 6BS indicating that there existed a good scope for partial substitution of non-germinated starch by germinated starch.

Stiffness of prints is determined by measuring the bending length of printed fabrics. It was observed that bending length of samples printed with starch from non-germinated maize was higher than that of germinated starch, which may be related to higher amount of starch left on the fabric contributing to the stiffness of the samples. This is mainly due to higher solubility of the germinated starch than that of the starch from sound grains.

In order to confirm the residual starch on the printed fabric, Tegewa test was carried out. In this case fabrics were printed using non-germinated and germinated starch pastes and all other ingredients except the colorant. Printed fabrics were steamed, subjected for oxidation and washing. The fabric samples were then kept in Tegewa solution for 1 min, rinsed with cold water, and dabbed with filter paper and these fabric samples were compared immediately with violet scale. The results showed presence of starch for both the printed samples and thus confirmed the contribution of residual starch in enhancing stiffness.

Vat dye printed fabrics showed similar washing fastness ratings (IS0-III) for both the germinated and non-germinated starch

Table 8
Analysis of samples printed with starch from non-germinated (NG) and germinated maize (G) and their blends.

Std./batch name	*K*/*S*[a]	% Decrease in *K*/*S*	Bending length[b] (cm)	Washing fastness		Crocking fastness	
				Change in shade	Staining	Dry	Wet
Dye: Novatic Navy Blue RA (λ_{max} = 550 nm)							
100% N.G	5.0764	0.00	1.516	4–5	5	5	4–5
30G:70N.G	4.9946	1.611	1.483	4–5	5	5	4–5
50G:50N.G	4.8961	3.551	1.416	4–5	4–5	5	4
70G:30N.G	4.8170	5.109	1.366	4–5	5	4–5	4–5
100% G	4.6500	8.399	1.300	4–5	4–5	5	4
Dye: Novatic Rubine 6BS (λ_{max} = 510 nm)							
100% N.G	1.6619	0.00	1.616	4–5	5	5	4–5
30G:70N.G	1.5718	5.421	1.60	4–5	5	5	4–5
50G:50N.G	1.5161	8.773	1.566	4–5	5	5	4–5
70G:30N.G	1.4913	10.265	1.55	4–5	5	5	4–5
100% G	1.4062	15.386	1.50	4–5	5	4–5	4

[a] Values are means of three determinations.
[b] Values are means of four determinations.

printed samples and even for their binary blends (refer Table 8). Vat dyes are known for having all-round fastness properties (Shenai, 1990). Analysis for dry and wet rubbing (crocking) fastness showed that although dry rubbing fastness ratings for germinated and non germinated starch printed samples were excellent and similar, in case of the wet rubbing fastness, the germinated starch printed samples showed slightly but distinctly lower (1/2 grade) rubbing fastness. This may be attributed to removal of the dye along with more soluble germinated starch during wet rubbing. However, rubbing fastness of 4 and 4–5 indicating “very good” to “excellent” grade, does not, anyway impairs the acceptability of the prints, as any material having performance grades 4 and above is considered as satisfactory.

In the present work, germination was imitated in the laboratory, to avoid variations which may cause due to varying conditions of poor storage of maize. We have carried out preliminary experiments on germinated rotten grains from one of the outlets and, the results are more or less similar to our findings presented in this paper. However, in further work, samples of industrial rotten grains from various outlets will be collected and studied independently so that the results obtained will be representative of actual rotten grains. The extent of variations in the performance of starches obtained from such grains can also be analysed.

4. Conclusion

Starch extracted from germinated maize grains after 24 h of germination was found to be slightly degraded compared to non-germinated maize starch. The viscosity of the paste in both the cases increased with increase in solid content. The viscosity of 10% non-germinated starch paste was similar to that of 11% germinated starch. The shear thinning index of germinated maize starch paste was found to be lower than that of non-germinated starch. Hence vat dye prints obtained using germinated starch were slightly lighter than that obtained using the non-germinated starch. The binary blends however could be used with minimum loss in colour values of the prints. The viscosity of the paste attained constant value after certain shearing time. Lower stiffness of the prints with germinated starch was an added advantage in printing. Thus germinated maize starch can replace non-germinated maize starch partially if not fully. The so called germinated maize starch which is otherwise treated as waste can thus be put to use in textile applications.

References

Bandyopadhyay, B. N., & Bhattacharya, N. (1998). Carboxymethyl starch as an alternative to alginate for reactive printing. *Colourage*, *45*(annual), 141–151.

Booth, J. E. (1983). *Principles of textile testing*. London: Butterworths.

Craig, S. A., Maningat, C. C., Seib, P. A., & Hoseney, R. C. (1989). Starch paste clarity. *Cereal Chemistry*, *66*, 173–182.

Dang, T. L., & Prasil, M. (2001). Rheological behaviour of reactive printing pastes and its effects on print parameters. In *Texsc' 98, Vol. 3* (pp. 508–511), vide WTA (2001) 3660.

Daniel, J., Whistler, R., & Roper, H. (1997). Starch. *Ullmann's encyclopedia of industrial chemistry* (pp. 721–726). Weinheim: Wiley-VCH Verlag GmbH and Co.

Hough, J. S., Briggs, D. E., & Stevens, R. (1971). *Malting and brewing science* London: Chapman & Hall., p. 65.

Juliano, B. O. (1971). A simplified assay for milled-rice amylase. *Cereal Science Today*, *16*, 334–340.

Pandey, A., & Raja, K. C. M. (1992). Recent trends in carbohydrate research. In *Proceedings of 8th Conference* Trivandrum, India, (p. 248).

Prasil, M., & Dang, T. L. (1996). Rheological behaviour of disperse dye printing pastes. *Vladkha a Textl*, *3*(3), 89–91.

Shenai, V. A. (1990). *Technology of dyeing*. Mumbai: Sevak Publications.

Sostar, S. (1997). Rheological properties of printing pastes-bases of rheology-I. *Texstilec*, *40*(3–4), 59–65.

Subramanian, V., Hoseney, R. C., & Bramel-Cox, P. (1994). Shear thinning properties of sorghum and corn starches. *Cereal Chemistry*, *71*, 272–275.

Teli, M. D., Shanbag, V., Dhande, S. S., & Singhal, R. S. (2007). Rheological properties of *Amaranthus paniculates* (Rajgeera) starch vis-à-vis maize starch. *Carbohydrate Polymers*, *69*(1), 116–122.

Teli, M. D., Shanbag, V., Rohera, P., Sheikh, J., & Singhal, R. S. (2009). Application of germinated maize starch in textile printing. *Carbohydrate Polymers*, *75*(4), 599–603.

Teli, M. D., & Vyas, U. V. (1990). Rheological behaviour of textile thickeners. *American Dyestuff Reporter*, *79*(2), 15–18.

Trotmann, E. R. (1984). *Dyeing and chemical technology of textile fibres*. England: Charles Griffin and Company Ltd.

Whistler, R. L., Paschall, E. F., Bemiller, J. N., & Roberts, H. J. (1965). *Starch: chemistry and technology*. London: Academic Press Inc. Ltd.

Yanez, G. A., & Walker, C. E. (1986). Effect of tempering parameters on extraction and ash of prosomillet flours and partial characterization of proso starch. *Cereal Chemistry*, *63*, 164–167.