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RELATIONSHIP OF DAMAGED STARCH WITH SOME PHYSICOCHEMICAL PARAMETERS IN ASSESSMENT OF WHEAT FLOUR QUALITY.

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Abstract

The samples of 18 different semi hard flour from four different mills were analyzed for damaged starch (DS) and for various other physicochemical properties through Kernalyzer, solvent retention capacity (SRC) profile, Farinograph, Micro Visco-Amylo-Graph and Glutomatic to establish the correlations that may exist among them. It was found that water absorption and dough development time from Farinograph, beginning of gelatinization, peak, trough and final viscosities from Micro Visco-Amylo-Graph, sodium carbonate and lactic acid values from SRC tests, retained and passed gluten from Glutomatic while the protein from Kernalyzer were closely related to damaged starch as determined by enzymatic analysis using Megazyme kit. The particle size analysis showed that amount of large particle i.e. >160 micron is inversely proportional to percentage of damaged starch. Alkaline water retention capacity (AWRC) and sodium carbonate SRC values are directly related as the increase in damaged starch will also increase the water absorption/ holding capacity of flour. The overall exercise has revealed that lengthy enzymatic damaged starch analysis which requires skilled manpower as well, may be replaced by certain instrumental and simple SRC analysis especially for commercial purposes where rapid tests are so much desired. An interesting correlation was found between the DS and the difference in water absorption measured from Farinograph and Glutomatic. It is clearly demonstrated that starch intact to gluten proteins is invisibly damaged during milling.

Key words: Damaged starch, Particle size, Solvent retention capacity, Mixing time, High molecular weight proteins.

Introduction

Damaged starch (DS) is a man made component of wheat flour of significant importance as it alters rheological properties of dough and predicts end quality of baked products especially bread, pasta and biscuits. It is produced during milling when starch granules are mechanically ground to fine powder. However, quality and quantity of DS produced depends upon the type of kernel, its hardness, protein content, severity of milling and nature of tempering process involved. The DS which absorbs as much water as it own weight as compared to undamaged native starch that retains only 30% water, become more susceptible to amylolytic hydrolysis and produces more gas bubbles in dough, finally affecting the end quality during baking. Keskin and coworkers (2012) recently have reported that pentosans, ash, protein and falling number increase on tempering and differences are more prominent in hard wheat than their soft counter part. Tempering has great impact on milling and may reduce the amount of damaged starch reasonably (Rehman *et al.,* 2006 & Kweon *et al.*, 2009). The DS varies with respect to environmental conditions, genotype, season to season changes and has been reported from 2.76 to 4.77% in soft white winter wheat flour in the Pacific Northwest (Lin & Czuchajowska, 1996), gene type changes in wheat quality are reported earlier also (Kinaci & Gulcan, 2007). The common methods used for estimation of DS are Megazyme, Chopin rapid flour tester, Iodometric titration, Ultracentrifugation and AACC Refractometer method etc (Boyaci *et al.*, 2004; Tester *et al.,* 2006) that may also have significant influence on the quantitative values reported.

The functionality of DS has mostly been studied in bread and biscuits making, where it signifies the quality of flour and of the end products. DS, being responsible for greater water absorption (WA) facilitate the bread making process through enhanced fermentation of the sugar into CO_2 and water (Ahmedani *et al*., 2011 & Tabasum *et al.,* 2011). Strong gluten network is also responsible to hold gas during baking that increases the loaf volume of bread and reduces the diameter of biscuits (Stasio *et al.,* 2007; Colombo *et al.,* 2008; Dendy *et al.*, 1992). The influence of DS, although has been used long ago to evaluate the machining or handling properties of cookies dough such as consistency, stiffness, flow, adhesion and cohesion etc, however; it has not been widely studied as an effective parameter to control dough behavior and the end quality (Gaines *et al.,* 1988; 2006; Gutkoski *et al.,* 2007). The above mentioned dough handling properties are related to variation in energy input (rerolling 1-5 times), dough age or resting period (1-3 hr), dough temperature, flour chlorination, particle size, moisture and DS. The last parameter, for biscuit dough varied from 1.9-8.8%.

The objective of the present research was to study the influence of DS on cookies dough prepared from semi hard flours and to establish its relationship to other determinantal parameters measured with sophisticated instruments so that instead of performing extra test for DS, it may approximately be estimated by routine analysis, secondly, because industry desires quick and simple tests, the DS may be approximately evaluated by AWRC and sodium carbonate SRC instead of under taking the lengthy and sensitive enzyme based method.

Materials and Methods

Flour samples: Eighteen semi hard wheat flour samples were received from four different milling units in Karachi i.e. Masoom Flour Mills Private Ltd. (Masoom-X), Qandhari Roller Flour Mills Private Ltd. (Qandhari-X), Ghouri Roller Flour Mills Private Ltd. (Ghouri-X), and Madina Flour Mills Private Ltd. (Madina-X) for commercial processing of cookies (X represents the number of the samples).

Reagents: All the chemicals and reagents used were of analytical grades and mostly obtained from MERCK (Merck KGaA 64271 Darmstadt, Germany).

Physicochemical analysis: Flour moisture contents were determined according to AACC approved method no. 44-19 using Brabender moisture analyzer (Duisburg, Germany) by drying 9 - 11 gm of flour at 155 °C for 20 minutes. Flour protein, ash contents and Zeleny values were estimated with Brabender Kernalyzer (Omeg Analyzer, Bruins Instruments, Germany). Flour particle sizes were measured through Fritsch vibratory sieve shaker (Oberstein, Germany) set at 2 mm amplitude for 10 minutes and the percentage of sizes >160, 160 to 100 and <100 was determined. The content of damaged starch was determined in duplicate according to the AACC 76-31 method using Megazyme kit (Megazyme International Ireland Ltd.). All the above mentioned physicochemical parameters are given in Table 1.

Solvent retention capacity & AWRC profiles of flours: Solvent retention capacity (SRC) tests were performed according to the approved method 56 - 11 (AACC 2000) and AWRC values were determined according to the AACC 56-10 method. Briefly describing, flour samples (1g) were suspended in 5 ml of water, 50% sucrose, 5% sodium carbonate, 5% lactic acid and $NaHCO_3$ solution (8.4g in 1 liter) separately. The samples were hydrated for 20 min (vortex for 5 second each at 5, 10, 15, and 20 minutes) and centrifuged at 1,000 × g for 15 minutes (not including time to achieve the speed), the supernatant in each case was decanted and the tube was drained at a 90° angle for 10 min on a paper towel. Each sample consisting the precipitates was weighed and the SRC / AWRC value for each sample was calculated according to Haynes and coworkers (2009). All SRC / AWRC analyses were performed in duplicate at least. The results are reported in Table 2.

Farinograph parameters: The rheological properties of dough were determined using Brabender Farinograph-E (Duisburg, Germany) according to AACC method no 54-21. A flour sample of 300 grams (14% moisture basis) was weighed and placed into Farinograph mixing bowl. Water from a burette is added to the flour and the curve is centered on the 500-Brabender unit (BU) line ±20 BU by adding the appropriate amount of water and was run until the curve leaves the 500-BU line. As the dough was mixed, the Farinograph records a curve on graph paper. The parameters included for study are water absorption (WA), dough development time (DDT), degree of softening (DoS) (ICC-12 min after peak time & 10 min after beginning), dough stability time (DST) and Farinograph quality number (FQN). The results are reported in Table 3.

Table 1. Physicochemical properties of wheat flour samples.

Flour	Damaged starch (%)	Moisture (%)	Kernalyzer analysis			Particle size (micron)		
			Protein (%)	Ash (%)	Zeleny	Above 160	160-125	Below 125
Madina-1	5.27	14.9	10.4	0.527	32	5.1	16.6	78.3
Madina-2	5.86	15.0	9.7	0.462	30	6.8	18.2	75.0
Qandhari-2	6.11	13.1	10.8	0.526	31	0.7	10.3	89.2
Qandhari-5	6.18	12.8	10.5	0.433	36	1.1	9.2	89.7
Ghouri-2	6.31	13.7	10.8	0.466	35	2.3	18.7	78.0
Qandhari-1	6.35	13.1	11.3	0.508	33	1.3	10.2	88.5
Ghouri-1	6.41	13.3	10.6	0.526	35	2.8	19.1	78.1
Masoom-2	6.50	14.1	11.8	0.568	34	0.5	11.0	88.5
Qandhari-4	6.64	13.1	11.1	0.527	33	1.8	12.0	86.2
Masoom-4	6.76	13.8	11.8	0.539	35	0.7	12.7	86.6
Ghouri-4	6.86	13.3	10.4	0.472	32	4.5	20.5	75.0
Ghouri-3	6.90	13.6	11.1	0.45	34	5.1	20.4	74.5
Masoom-3	6.96	14.2	11.5	0.526	36	0.9	13.2	85.9
Qandhari-3	7.03	12.6	11.2	0.503	33	2.1	9.7	88.2
Masoom-1	7.06	13.6	11.9	0.573	34	0.9	10.2	88.9
Masoom-6	7.84	13.5	11.6	0.677	32	0.8	11.5	87.7
Masoom-5	8.12	13.8	11.5	0.651	32	0.5	10.0	89.5
Ghouri-5	8.58	13.0	11.9	0.444	33	1.5	17.0	81.5

Table 2. Solvent retention capacities (SRC) and alkaline water retention capacities (AWRC) of wheat flour samples.

Flour	Damaged starch (DS) (%)	Alkaline water retention capacity (AWRC)	Sodium carbonate SRC (SCSRC)	Water SRC (WSRC)	Lactic acid SRC (LASRC)	Sucrose SRC (SuSRC)
Madina-1	5.27	62.86%	77.51%	61.24%	74.98%	86.81%
Madina-2	5.86	65.56%	75.98%	63.44%	74.87%	85.29%
Qandhari-2	6.11	64.72%	74.82%	67.89%	73.83%	92.63%
Qandhari-5	6.18	69.92%	84.03%	68.35%	78.31%	98.13%
Ghouri-2	6.31	71.75%	88.49%	71.25%	81.52%	99.85%
Qandhari-1	6.35	70.66%	89.07%	71.85%	80.16%	105.00%
Ghouri-1	6.41	70.13%	85.31%	69.83%	81.83%	101.08%
Masoom-2	6.50	72.48%	89.80%	70.78%	81.29%	101.22%
Qandhari-4	6.64	71.55%	90.95%	67.00%	76.70%	96.19%
Masoom-4	6.76	72.23%	89.89%	72.13%	82.91%	102.36%
Ghouri-4	6.86	74.99%	87.29%	65.67%	78.16%	100.18%
Ghouri-3	6.90	72.56%	89.09%	80.03%	77.04%	93.66%
Masoom-3	6.96	72.37%	93.32%	74.97%	80.39%	100.33%
Qandhari-3	7.03	71.73%	90.43%	74.39%	79.31%	104.89%
Masoom-1	7.06	70.97%	90.98%	70.87%	82.12%	101.83%
Masoom-6	7.84	74.47%	91.27%	73.17%	91.17%	98.13%
Masoom-5	8.12	72.97%	91.49%	73.33%	80.81%	93.98%
Ghouri-5	8.58	77.99%	106.07%	72.56%	86.00%	97.96%

Table 3. Farinographic parameters of wheat flour samples.

Flour	Damaged starch (DS) (%)	Water absorption (WA) (%)	Dough development time (DDT) (min)	Dough stability time (DST) (min)	Degree of softening (DoS) (FU)*	Degree of softening ICC (DoS) (FU)	FQN
Madina-1	5.27	55.7	1.9	3.6	57	83	33
Madina-2	5.86	55.9	2.4	7.1	50	88	81
Qandhari-2	6.11	60.0	1.9	6.5	43	65	79
Qandhari-5	6.18	59.2	2.9	7.9	37	60	66
Ghouri-2	6.31	58.6	2.0	7.7	36	52	91
Qandhari-1	6.35	60.6	2.9	10.3	18	49	120
Ghouri-1	6.41	58.7	2.2	5.9	38	53	78
Masoom-2	6.50	61.1	4.7	5.7	51	86	75
Qandhari-4	6.64	59.1	2.3	9.9	32	51	42
Masoom-4	6.76	60.9	4.2	6.1	34	60	88
Ghouri-4	6.86	59.7	5.7	6.8	40	78	88
Ghouri-3	6.90	62.3	3.8	4.5	78	108	59
Masoom-3	6.96	61.0	3.3	4.5	48	61	75
Qandhari-3	7.03	61.4	2.0	9.1	26	55	106
Masoom-1	7.06	62.7	2.4	5.3	68	99	65
Masoom-6	7.84	62.5	5.2	7.3	41	78	87
Masoom-5	8.12	64.4	6.0	7.8	40	86	92
Ghouri-5	8.58	64.6	3.5	4.5	71	114	65

*FU = Farinograph unit

Micro visco-amylo-graph parameters: The effect of the DS on the pasting properties of wheat flour was measured using Micro Visco-Amylo-Graph (Brabender, Duisburg, Germany) according to AACC Method No 22-12. A sample of 15 g (14% moisture basis) was transferred to cup and 100 ml of distilled water (14% moisture basis) was added. The slurry was heated to 50 °C and stirred at 160 rpm for 10 s for thorough distribution of ingredients. The mixture was then held at 50°C for up to 1 min and then heated to 95°C over a period of 7.3 min. The slurry was held at that temperature for 5 min (holding time / pasting strength) and finally cooled to 50°C over a period of 7.7 min. The pasting temperature, peak time, peak viscosity (PV), trough viscosity (TV), final viscosity (FV), breakdown viscosity (BV) and setback viscosity (SV) were calculated from the pasting curve. The results are reported in Table 4.

Table 4. Micro Visco-Amylo-Graph parameters of wheat flour samples as compared to damaged starch.

Flour	Damaged starch (%)	Beginning of gelatinization		Peak viscosity (PV)	Trough viscosity (TV)	Breakdown viscosity (BV)	Final viscosity (FV)	Setback viscosity (SV)
		Torque	Temp. (°C)					
Madina-1	5.27	20	61.7	952	592	360	1200	608
Madina-2	5.86	21	61.3	1004	625	379	1219	594
Qandhari-2	6.11	15	61.6	993	696	297	1126	430
Qandhari-5	6.18	19	61.4	1017	669	348	1275	606
Ghouri-2	6.31	11	60.3	1019	661	358	1115	454
Qandhari-1	6.35	20	61.8	946	637	309	968	331
Ghouri-1	6.41	22	61.1	999	636	363	1170	534
Masoom-2	6.50	20	60.1	1041	669	372	1130	461
Qandhari-4	6.64	16	60.6	985	635	350	1240	605
Masoom-4	6.76	17	60.4	957	618	339	1118	500
Ghouri-4	6.86	20	61.1	993	633	360	1214	581
Ghouri-3	6.90	18	60.8	975	591	384	1145	554
Masoom-3	6.96	16	59.9	988	656	332	1010	354
Qandhari-3	7.03	16	60.9	1006	668	338	1037	369
Masoom-1	7.06	17	60.3	984	661	323	962	301
Masoom-6	7.84	18	60.3	938	544	394	1072	528
Masoom-5	8.12	18	60.5	907	557	350	1096	539
Ghouri-5	8.58	15	59.9	603	339	264	747	408

All values are given in Brabender unit (BU) except the temperature

Table 5. Percentage of various proteins of wheat flour samples as compared to damaged starch.

Flour	Damaged starch (DS)	Passed gluten (PG)	Retained gluten (RG)	Wet gluten (WG)	Dry gluten (DG)	Water binding capacity (WBC)	Gluten index (GI)
Madina-1	5.27	2.8	22.1	24.9	8.2	16.7	89
Madina-2	5.86	2.3	19.8	22.1	7.0	15.1	90
Qandhari-2	6.11	11.0	19.3	30.3	9.2	21.1	64
Qandhari-5	6.18	2.3	26.8	29.1	9.6	19.5	92
Ghouri-2	6.31	12.0	16.2	28.2	9.9	18.3	57
Qandhari-1	6.35	3.3	23.2	26.5	8.8	17.7	88
Ghouri-1	6.41	6.8	20.6	27.4	8.7	18.7	75
Masoom-2	6.50	14.8	16.2	31.0	9.3	21.7	52
Qandhari-4	6.64	2.0	23.8	25.8	8.4	17.4	92
Masoom-4	6.76	11.9	17.1	29.0	9.3	19.7	59
Ghouri-4	6.86	8.1	19.9	28.0	8.9	19.1	71
Ghouri-3	6.90	10.9	19.0	29.9	9.5	20.4	64
Masoom-3	6.96	16.4	14.3	30.7	10.0	20.7	47
Qandhari-3	7.03	6.8	20.2	27.0	8.7	18.3	75
Masoom-1	7.06	15.5	15.7	31.2	9.9	21.3	50
Masoom-6	7.84	11.5	17.0	28.5	10.0	18.5	60
Masoom-5	8.12	13.7	15.0	28.7	9.4	19.3	52
Ghouri-5	8.58	14.6	13.3	27.9	8.8	19.1	48

Glutomatic parameters: The Perten Glutomatic - 2001 (Huddinge, Sweden) was used to determine the wet gluten (WG), retained gluten (RG), passed gluten (PG), dry gluten (DG), water binding capacity (WBC) and gluten index (GI) of flour samples according to the approved Method 38-12 (AACC, 2000). Briefly describing, a 10-gram sample of each flour is weighed and placed into the Glutomatic washing chamber on top of the polyester screen. The sample is mixed and washed with a 2 percent salt solution for 5 minutes. The wet gluten is removed from the washing chamber, placed in the centrifuge holder, and centrifuged. The residue retained on top of the screen and passed through the screen is weighed. The results are reported in Table 5.

Statistical analysis: All the data collected were analyzed according to standard statistical procedures using Microsoft Excel (2007). Linear correlation coefficients among different quality parameters were determined by making scattered graph between data of two different parameters and finding their R square value (R^2) through trend line.

Results and Discussions

Relationship of damaged starch and physicochemical properties of the flour: Numerous studies have proved that DS increases water absorption to the extent of 100% and it should be expected that flour having high DS will have higher moisture level than the flour with lower percentage of DS. It is reported earlier that water affects physiochemical properties of wheat (Noorka *et al*., 2009). However, in the present study, unexpectedly the moisture content of the flours are haphazardly related to DS (Table 1). One explanation may be given that samples represented here were freshly milled and the damaged starches present in the flour did not get enough time to absorb moisture from the atmosphere or the dry environment in Sindh may be responsible. Secondly, the wheat kernels already had increased or decreased levels of moisture which effected DS as it largely depends on the milling conditions, ash and protein contents. A direct positive correlation is found in protein and ash content with the DS which has been reported earlier as well (Barrera *at al*., 2007; Keskin *et al.*, 2012; Colombo *et al.*, 2008). The grain hardness strongly depends upon protein and ash contents and produces comparatively more DS from hard kernel than from the soft varieties. Zeleny values varied slightly between 30-36 and are lower as compared to values earlier reported (Fargested *et al.*, 1999). Zeleny values actually show sedimentation capacities of high molecular weight proteins and usually coincide with the lactic acid SRC as is the case here. The firmness or the particle size of the flour is also directly related to the level of DS produced. Fine particle size require more severe milling conditions and longer time that results in increased production of DS. It is illustrated in Table 1 that flour Madina-1 & Madina-2 having 5.1 and 6.8% of particle size above >160 micron produce less of DS (5.27 and 5.86%) than flours from Masoom mill and Ghouri mill with 0.5 and 1.5% of particle above >160 micron producing 8.12 and 8.58% DS respectively. Recently, Barak and coworkers (2012) have shown that particle size of the flour is related to variety of chemical properties such as falling number, SRC, AWRC, wet/dry gluten and DS. The statistical analysis in figure 1 shows R^2 as 0.451 for protein and DS contents in flour indicating mild correlation between the two parameters. It indicates that approximate value of DS may be estimated by considering other parameters and specific DS analysis may not be so essential for routine commercial purpose.

Relationship of damaged starch with solvent retention capacity and alkaline water retention capacity profile: The solvent retention capacity (SRC) parameters establish a close association with flour quality, quantity and functionality profiles useful for predicting baking performance of the flour and are compared with DS values (Table 2) where each value represents a particular component of flour. AWRC values have strong positive correlation as they increase from 62.86 to 77.99 with the constant increase in DS from 5.27 to 8.53 (Fig. 2A). AWRC are based on the solubility of at least three components of the flour as proteins, water insoluble pentosans and DS. AWRC, sodium carbonate SRC (SCSRC) and water SRC (WSRC) are also closely positively associated and are inversely roportioned to cookies diameter (Guttieri *et al.,* 2006). This indicates that DS percentage may be used to identify the nature of hard and soft flours and will predict the variation in size of the biscuits.

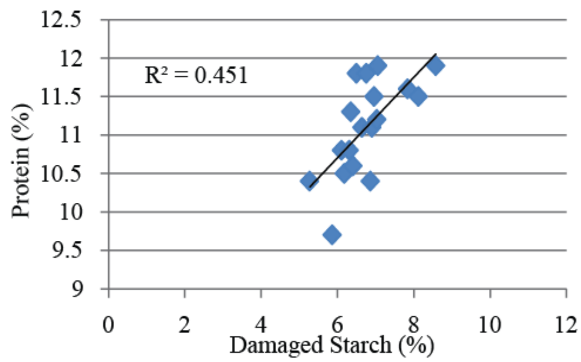

Fig. 1. Damaged starch relation to protein contents of wheat flour samples.

A number of methods are available for measuring gluten proteins that indicate gluten strength. Lactic acid SRC (LASRC) values shows positive correlation with DS as both the values increase in coordination (Fig. 2D). LASRC is more closely related to the concentration of high molecular weight glutinins that are positively related to bread loaf volume (LV). However, they are inversely related to biscuit dimensional properties. It has been observed earlier that higher values of glutinins produce biscuit of reduced diameter in view of the high elasticity of dough (Wieser & Kieffer, 2001; Wieser *et al.*, 2003). The pentosans and gliadin contents of flour are extracted in sucrose solution and the SuSRC values are positively related with DS. Gliadin proteins are single chain, low molecular weight proteins which either has single or no intra disulphide bridge as compared to glutinins having multiple disulphide bridges making them polymeric. Gliadin control viscosity of the dough and viscoelastic properties are due to both types of the gluten. All the values as AWRC, SCSRC, WSRC, LASRC and Sucrose SRC (SuSRC) are positively related to DS (Fig. 2, A-E), showing that SRC analysis may predict the amount of DS in flour approximately.

Relationship of farinographic properties of flour with damaged starch: The water absorption (WA), dough development time (DDT), dough stability time (DST), degree of softening (DOS) (ICC-12 min after peak time & 10 min after beginning) and Farinograph quality number (FQN) were measured by Farinograph (Table 3). The values elaborate compositional characteristics of the flour and are closely related to dough behavior. Some of these values show association with DS values and predicts end quality of baked products. It is now well documented that damaged starch granules absorbs more water than the intact starch granules. The WA from Farinograph constantly increased with increase in DS (Fig. 3A), that also elevated the DDT from 1.9 to 3.5 min (Fig. 3B). It further facilitated the conversion of starch to dextrin and glucose by amylase. Increase in mixing also increase dough stiffness and decrease diameter of the biscuits (Barak *et al*., 2012; Haynes *et al.,* 2009; Singh & Khatkar, 2005). Top grain (multiple surface crack) is another end quality parameter of biscuit which depends on water absorption of sugar during mixing and recrystallization of sucrose during heat up take and water evaporation in the baking process (Barrera *et al*., 2007). DST although increased (Table 3) however, not rhythmically. Both DoS values also increased inconsistently. FQN which represent all parameters of Farinograph and is more related to gluten network or the dough strength increased but not with a constant rate. It may be attributed to the fact that DS of various flour samples given in table 3 is also increasing inconsistency although constantly. The WA and DDT may be used to relate the presence of DS in flour.

Relationship of damaged starch with micro visco-amylo-graph pasting curve: The presence of DS in flour significantly changed the pasting behavior of the dough as indicated by various viscosities measuring the thermal damage during phases of heating & cooling (Table 4). The pasting temperature (PT) which shows the first increase in viscosity by at least 25 cp over a periods of 20 s was slightly decreased with increase in DS. PT shows the initial stage of the process of gelatinization which is enhanced by increase in DS. In fact, PT predicts the textural characteristics of baked products which are associated with starch gelatinization (Ragaee *et al.*, 2001). The maximum or the peak viscosity (PV) was significantly decreased during an increase in DS (Fig. 4D), although the temperature required for reaching at the maximum viscosity remains almost the same. This decrease might be attributed to two different parameters, firstly, the higher absorption of water by the damaged starch making the solution less viscous and secondly the surface of starch granules is exposing more hydrophobic groups after molecular degradation. Trough viscosity (TV) (Fig. 4B) which shows the minimum hot paste value and is a measure of holding strength of the dough at that temperature is strongly related to the end quality (Ragaee & Abdel-Aal, 2006). Breakdown (BV) and setback (SV) viscosities also decrease from 360 to 264 and 608 to 408 respectively with increase in DS. The BV shows the holding strength of starch that will hold more water and will require longer baking time making the texture harder and color darker. The decrease in FV (Fig. 4C) shows slow reassociation of starch molecules after cooling at 50°C and is responsible for increase in the viscosity again, however, that increase in viscosity decreases with the increase in DS as shown in Table 4. The temperature required to start Beginning of gelatinization and FV is also related to retrogradation of starch which decreases as the starch gets damage more (Fig. 4, A&C).

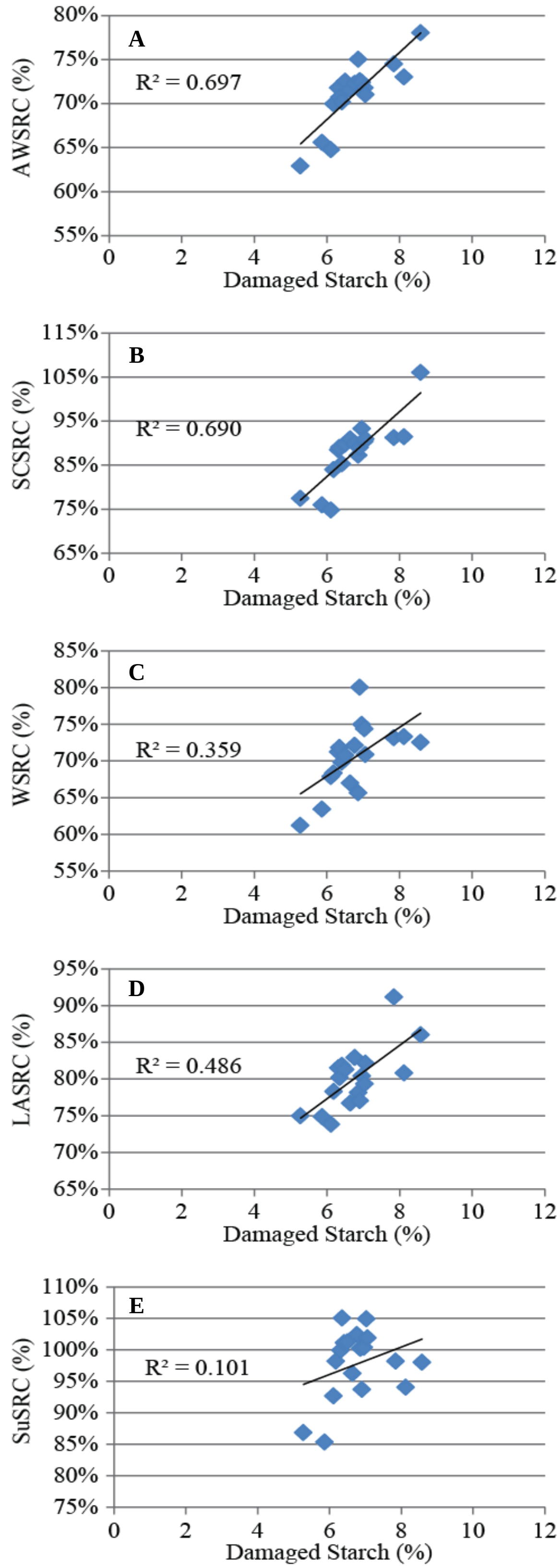

Fig. 2. The graphs show damaged starch relationship to alkaline water retention capacity (A), sodium carbonate SRC (B), water SRC (C), lactic acid SRC (D) and sucrose SRC (E) of wheat flour samples.

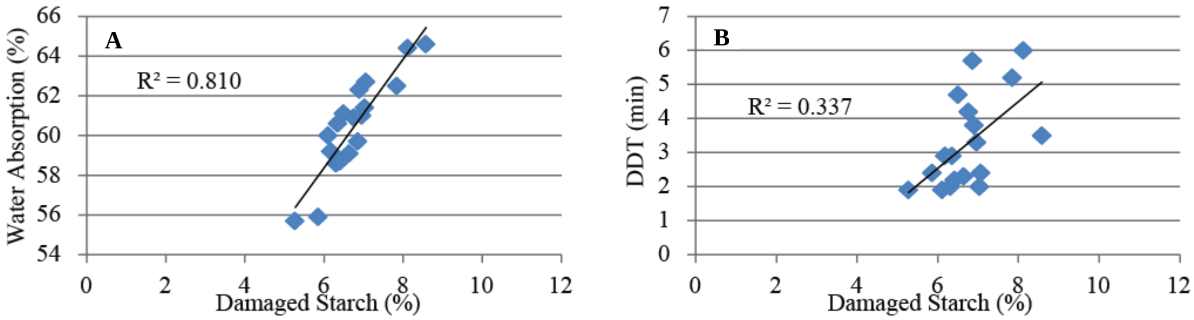

Fig. 3. Damaged starch relation to Farinograph water absorption (A) and dough development time (B).

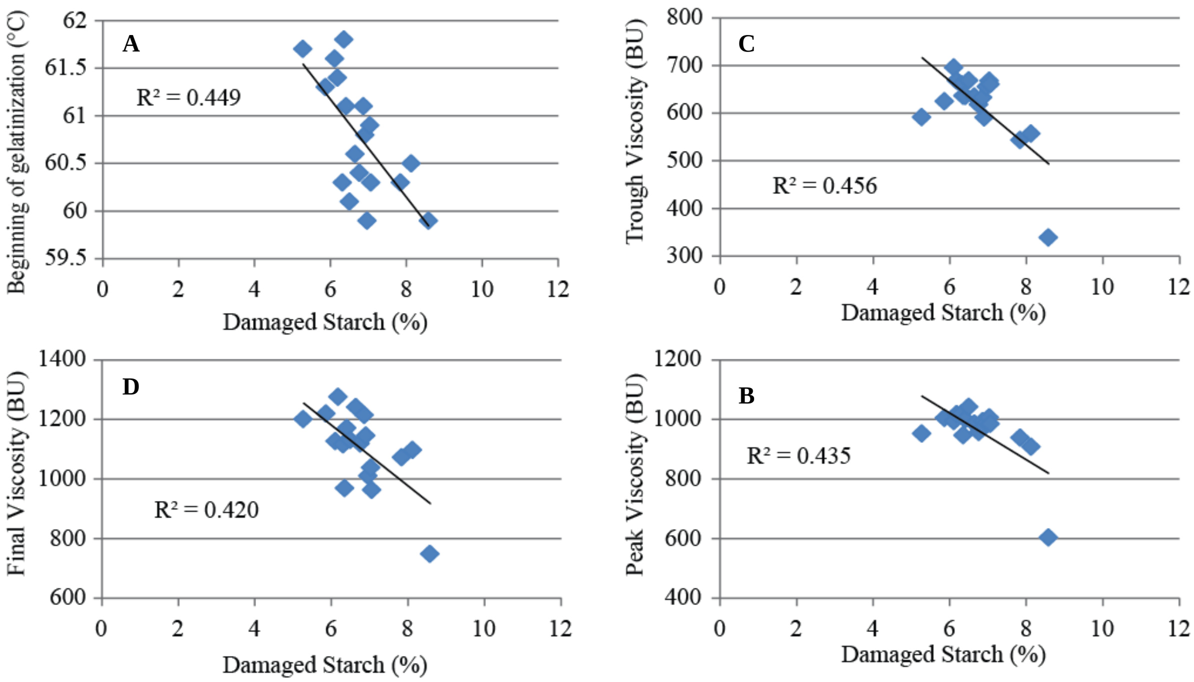

Fig. 4. Damaged starch relation to beginning of gelatinization (A), peak viscosity (B), trough viscosity (C) and final viscosity (D).

The PV, TV, BV and FV all decrease as DS increases and are associated with dimensional, textural and moisture contents of the biscuits. This may be explained keeping in mind that behavior of starch during heating and cooling. Starch molecules in general and amylose molecules in particular first get dissociated and absorb water in the inter and intra molecular spaces, that raise the viscosity, then generate gel structure during cooling which again raise the viscosity, that is why FV and SV values are always higher than BV but both of them decrease as the damaged starch increases. Moreover, starch retrogradation hich indicate reordering of starch molecules gets lower when DS raises, which also slow down syneresis. The paste stability is indicated by low setback values and decrease with increase in DS, highest paste stability show lowest breakdown and is shattered by the presence of DS. The influence of DS on the pasting curve is important in control of the texture of biscuits.

Relationship of glutomatic proteins with damaged starch: Glutomatic is commonly used in industry and research for evaluating flour quality with reference to gluten behavior. The values like wet gluten (WG), dry gluten (DG), retained gluten (RG) and passed gluten (PG) are estimated. The gluten index (GI) and water binding capacity (WBC) are calculated. GI indicates the gluten network developed or the gluten strength of the dough / wheat flour. Moreover, water binding capacity or water absorption of gluten proteins (WG - DG) may also be calculated that supports in achieving the desired gluten strength and indicates the amount of water approximately required for a particular flour, adjustment may be made in water addition for a specific recipe. All the gluten fractions separated i.e. WG, DG, RG and PG differ on molecular basis, therefore perform defined functions in mixing to produce a dough of specified nature. Starch and protein interactions in mixing are known, naturally, the damaged starch and proteins may form complexes as expected, however the nature and frequency will be different producing a different end product. We tried to evaluate the impact of DS on the various types of the Glutomatic proteins as shown in Table 5. Figure 5A indicates the positive direct association of DS and PG while figure 5B & 5C show inverse relation between DS & RG and DS & GI.

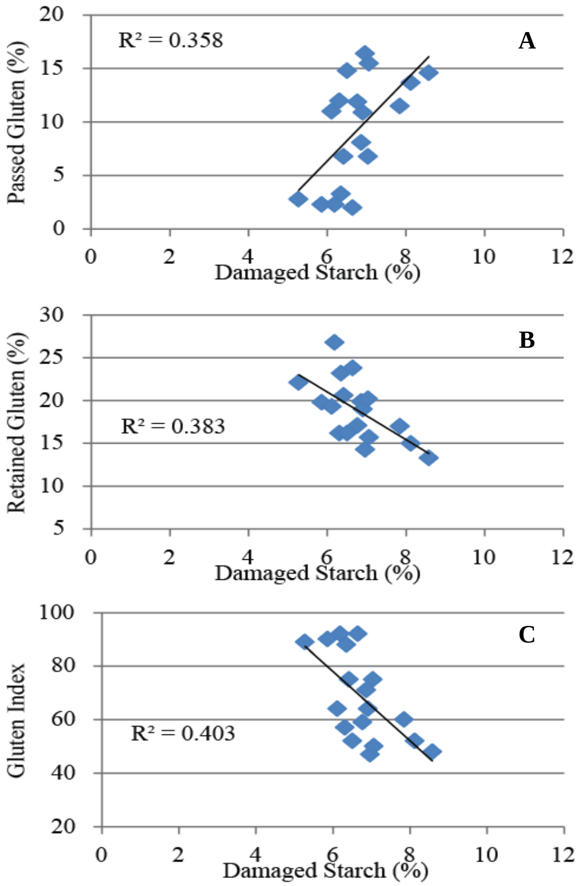

Fig. 5. Damaged starch relations to passed gluten (A) retained gluten (B) and Gluten Index (C) of wheat flour samples.

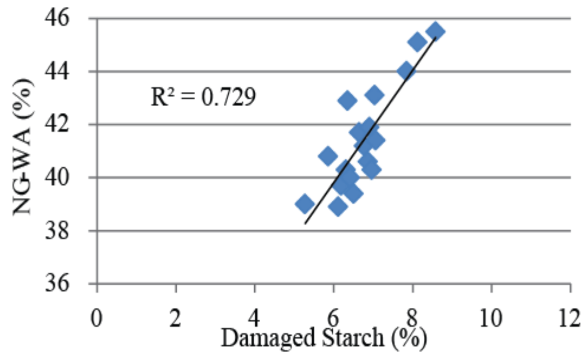

Fig. 6. Relationship between DS and the difference between F-WA & G-WA (NG-WA).

Water absorption capacity (WAC) of various components of flour is an extremely important property of dough that governs the dimensional and textural characteristics of biscuits. It has been found that water absorption obtained by Farinograph is higher and more closely related to DS (Fig. 3A) having R^2 as 0.810 and WAC of gluten proteins is comparatively low (Table 6). The data in table 6 have illustrated that difference in Farinograph water absorption (F-WA) and Glutomatic water absorption (G-WA) is strongly related with DS content (Fig. 6 presenting R2 value as 0.729, which is also associated to particle size Stasio *et al.*, 2007). The findings suggest that to evaluate the amount of water required for developing appropriate network of gluten, the non-gluten water absorption (NG-WA) including water absorption from other hydrophilic component will be predictive and helpful.

Table 6. Quantitative comparison between DS and the NG-WA (difference in F-WA and G-WA).

Flour	DS (%)	F-WA (%)	G-WA (%)	NG-WA (%)
Madina-1	5.27	55.7	16.7	39
Madina-2	5.86	55.9	15.1	40.8
Qandhari-2	6.11	60	21.1	38.9
Qandhari-5	6.18	59.2	19.5	39.7
Ghouri-2	6.31	58.6	18.3	40.3
Qandhari-1	6.35	60.6	17.7	42.9
Ghouri-1	6.41	58.7	18.7	40
Masoom-2	6.5	61.1	21.7	39.4
Qandhari-4	6.64	59.1	17.4	41.7
Masoom-4	6.76	60.9	19.7	41.2
Ghouri-4	6.86	59.7	19.1	40.6
Ghouri-3	6.9	62.3	20.4	41.9
Masoom-3	6.96	61	20.7	40.3
Qandhari-3	7.03	61.4	18.3	43.1
Masoom-1	7.06	62.7	21.3	41.4
Masoom-6	7.84	62.5	18.5	44
Masoom-5	8.12	64.4	19.3	45.1
Ghouri-5	8.58	64.6	19.1	45.5

Conclusions

The present study has elaborated the relationship between the intrinsic composition of some local flours, and the sophisticated equipment indices that have revealed that the physicochemical analysis may indicate the wheat flour behavior in processing of various bakery products particularly cookies. The instrumental analytical values have also shown strong links and DDT, beginning of gelatinization and RG / PG were predictive for DS concentration in flour. It is also summarized that some of the values or their combination may predict the approximate concentration of DS in flour which will be useful for taking measures during processing.

It is the first time that relationship of damaged starch with Glutomatic proteins (i.e. passed and retained gluten) is shown that retained gluten decreases with increase of DS while passed gluten increases. We are also reporting for the first time that a strong relationship exists shown between the difference of F-WA and G-WA i.e. the water absorption among the hydrophilic flour components as gluten proteins are water insoluble. The further studies on glutomatic proteins will be helpful in estimating the damage starch in wheat products.

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