

Effect of Gliadin Addition on Dough Mixing Properties of Wheat Varieties

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ABSTRACT: The effect of addition of 5% gliadin level to the flour of four selected wheat varieties differing in their baking performances was investigated. The study was performed using an advanced 4 g bowl of MicrodoughLab (MDL). All the four varieties differed widely in their physicochemical characteristics and HMW-GS composition. Various MDL parameters such as arrival time (AT), departure time (DT), dough development time (DDT), and dough stability observed a downturn by addition of 5% gliadin in all the varieties. Peak resistance (PR) showed a drastic increase in case of strong varieties DBW16 and HI977 and a downturn in weaker varieties such as C306 and HW2004.

I. INTRODUCTION

Wheat is the prime cereal crop of the world due to its extensive use in baked products. The unique viscoelastic characteristics of wheat are attributed to the gluten proteins; the type and quantity of which is important for determining the bread-making potential of a wheat variety (N Chaudhary, P Dangi, & B. S. Khatkar, 2016). The viscoelastic property of dough is result of not only the interaction of glutenin polymers but by the interaction of glutenins with the monomeric gliadin proteins.

Gliadins are a heterogeneous mixture of single-chain polypeptides that shares about 40% of the total endosperm protein. From years, HMW-GS are considered to be the major element in governing the bread quality of a wheat variety. However, numerous studies have focused on studying the effect of gliadin and its sub-groups on techno-functional quality of wheat (N. Chaudhary, P. Dangi, & B. S. Khatkar, 2016; N. Chaudhary, P. Dangi, & B. S. Khatkar, 2016). Wrigley, Lawrence, and Shepherd (1982) and Branlard and Dardevet (1985) explained 37-54% of the variation among the cultivars by correlating individual gliadin bands as obtained from electrophoretic analysis with functional dough parameters. Purified gliadin sub-groups (α -, β -, γ - and ω -) when added to the dough resulted in a decrease in dough strength with the relative weakening effects as observed ω -1 > ω -2 \approx α \approx β > γ - in the Mixograph. It is difficult to establish correlations between gliadin bands and technological properties as unlike HMW-GS, gliadins are encoded by large multigene families, thus effects ascribed to one gliadin can possibly be due to other associated gliadin groups or LMW-GS (Fido, Bekes, Gras, & Tatham, 1997). Weegels, Marseille, Bosveld, and Hamer (1994) observed a marked increase in bread loaf volume on addition of individual gliadin sub-groups to base flour. However, MacRitchie (1987) in reconstitution experiments concluded that addition of gliadins to base flour decreased the mixing time and loaf volume. Uthayakumaran, Tömösközi, Tatham, Savage, Gianibelli, Stoddard, and Bekes (2001) studied the effects of α -, β -, γ - and ω - gliadins on technological and functional aspects of dough and found that amongst all, γ -gliadin reduced the mixing time and R/E ratio to the greatest extent. However, α -type was least detrimental to loaf height and vice versa was in the case of ω -gliadins. The addition of increased levels of total gliadin and gliadin subgroups to cv. Hereward base flour lowered the overall dough strength, as manifested by downturn in the values for mixing time, mixing stability and work input. The declining order of these parameters for different gliadins was: ω 1 > γ > β > α - gliadins (Khatkar, Fido, Tatham, & Schofield, 2002a). Furthermore, as the concentration of gliadins in the flour increased, there was a cutback in dough strength and dough stability owing to the alteration in the gliadin-glutenin balance in dough (Khatkar, Barak, & Mudgil, 2013).

The importance of gliadins and its subgroups in deciding the functionality of wheat flour is a matter of concern over the years. Thus there is a need to perform experimentation with gliadins and to understand their role in dough

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 6, June 2016

rheology. This study investigated the effects of addition of gliadin to base flour of different varieties varying in protein content, gluten properties and HMW-GS composition in a 4 g MDL. Various MDL parameters were studied and the effects of gliadin addition on various parameters were demonstrated.

II. MATERIALS AND METHODS

A. Materials

Four wheat varieties commonly cultivated in India viz. C306, DBW16, HI977 and HW2004 were selected and procured from different research institutes and stations. The grains were tempered at 15.5 g/100 g moisture content for 24 h. Milling was carried out using Chopin laboratory mill (Model CD1, Villeneuve la Garenne, France). The flour of each variety was packed in an air-tight container and stored at -18 °C for further analysis.

B. Chemical analyses

Crude protein content was determined by following standard AACC (2000) method. SDS sedimentation value of flours was estimated (Axford, McDermott, & Redman, 1979).

C. Gluten extensibility test

Measurements were performed with a TA-XT 2i Texture analyzer (Stable Micro System) using Kieffer dough/gluten extensibility rig with the test speed of 3.3 mm/s and data acquisition rate of 200 pps. The test mode of the instrument used was force in tension.

D. Isolation of wheat gluten

Wheat flours were defatted by successive extraction with chloroform according to MacRitchie (1987). Flour (100 g) was defatted using 200 ml of chloroform, the solution was allowed to filter through filter paper at room temperature and the whole process was repeated thrice. The defatted flour was dried at room temperature. Gluten was isolated from defatted flour using glutomatic instrument as per standard ICC method followed by freeze drying. Dry gluten, wet gluten and gluten index were determined. Freeze-dried gluten samples were finely ground in a pestle mortar and stored in air-tight pouches at -18 °C.

E. Fractionation of wheat gluten into gliadin and glutenin

Gluten powder (50 g) was dissolved in 200 ml of 70 % ethanol; the mixture was kept for stirring on a magnetic stirrer for 3 h at 25° C followed by centrifugation for 30 min at 1000 g at 4° C and the process was repeated thrice. The supernatants were pooled and ethanol was removed from the gliadin extracts using rotary evaporator at 30° C. The gliadin and glutenin fractions, thus, obtained were freeze dried and powdered in pestle and mortar (N. Chaudhary, P. Dangi, & B. S. Khatkar, 2016).

F. MicrodoughLab analysis

Total gliadin (5% w/w) was added to flour of each variety to demonstrate its effect on dough rheological properties. A 4 g MDL (Perten Instruments, Huddinge, Sweden) was used to observe the dough rheological properties. The dough was mixed for 10 minutes at 63 rpm of mixing blades at 30° C for all the varieties. Various mixing parameters viz. peak (FU), arrival time (min), dough development time (min), dough stability (min), departure time (min), dough softening (FU) and peak energy (Wh/K) were determined by MDL.

G. Data Analysis

Data was analyzed using SPSS software version 16.0 (SPSS Inc.). The mean comparison was carried out using one way ANOVA with Duncan's multiple range test and the statistical significance was observed at $p < 0.05$.

III. RESULTS & DISCUSSION

H. Physicochemical properties and HMW-GS composition

Table 1 represents the analytical and compositional properties of wheat varieties. The protein content has been the primary factor for determining the end-use quality of a wheat variety as it tends to form a strong or weak gluten network depending on their quantity and quality (Khatkar, Bell, & Schofield, 1996). All the varieties differed significantly in protein content (PC), SDS sedimentation volume (SDSV), dry gluten (DG), resistance to extension and to extensibility (R/E) ratio, gluten index (GI) and gliadin/glutenin ratio (Glia/Glu). C306 had highest protein content but lower SDSV (45ml) while HI977 had highest SDSV (62ml) with slightly lesser PC (12.43). On the contrary, HW 2004 had minimum PC (8.68%) and least SDSV (35ml). SDS sedimentation volume shows the variation in gluten protein

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 6, June 2016

potential to imbibe water and it largely depends on the quantity as well as the quality of gluten proteins in wheat flour. SDSV varied slightly among C306 and DBW16, although PC (11.59%) was somewhat lesser in DBW16. Previous studies had demonstrated that the dough strength properties of wheat varieties have been related to the quantity and type of HMW-GS present such as 2*, 7+8, 17+18 and 5+10 which are superior to the allelic null (i.e. silent), 20 and 2+12 (Hoseney, 1994; P.I. Payne, Holt, Jackson, Law, & Damania, 1984). It is visible from the results that C306 and HW2004 acquired huge difference in DG content, although, same HMW-GS composition and *Glu-I* score. This variation could be attributed to the proportional discrepancy of proteins. HI977 and DBW16 exhibited varied physicochemical properties, yet possessed same *Glu-1* score and HMW-GS differing at *Glu-B1* loci expressing subunit 17+18 and 7+8, respectively (Kasarda, 1999; P. I. Payne, Nightingale, Krattiger, & Holt, 1987). Huang and Khan (1997a) reported that subunit 5 and 2* being larger in molecular size, contribute greater to the dough mixing properties. The positive effect of the subunit 5+10 has been demonstrated largely due to the presence of an extra cysteine residue (Wieser, 2007).

Table 1. Physicochemical properties of wheat varieties

	C 306	DBW 16	HI 977	HW 2004
PC (%)	12.56c	11.59b	12.43c	8.68a
SDSV (ml)	45.0b	46.0c	62.0d	35.0a
DG (g/100g)	11.7d	9.6c	8.9b	7.8a
R/E	0.38a	0.58b	1.49d	0.78c
GI	62.9b	77.8c	98.7d	61.6a
Glia/ Glu	1.58c	1.14b	0.76a	1.83d
<i>Glu-A1</i>	Null	2*	2*	Null
<i>Glu-B1</i>	20	7+8	17+18	20
<i>Glu-D1</i>	2+12	5+10	5+10	2+12
<i>Glu-I</i>score	4	10	10	4

PC- Protein content; SDSV- Sedimentation volume; DG- Dry gluten; R/E- Resistance to extension/extensibility; GI- Gluten index; Glia/Glu- Gliadin/Glutenin ratio. Values followed by different letters are significantly different at p<0.05

I. Rheological properties

The rheological characteristics of various wheat varieties are illustrated in Table 2 and MDL graphs are shown in figure 1 and 2. Based on MDL parameters, HW2004 and DBW16 were found to be the weakest varieties with *Glu-I*score of 4 and 10, respectively. These two varieties took shortest period of time (1.4 min) to develop dough with parallel arrival time (0.8 min), yet differed in their departure times with DBW16 exhibiting comparatively longer time (2.8 min) and stability (2 min). On the other side, HW2004 dough was noticed to be most pliable (100 FU) among all. C306 took slightly longer DDT (1.8 min) and AT (0.9 min) in comparison to HW2004 and DBW16 but same DT (2.8 min) as DBW16. Moreover, C306 dough was noticeably softer (95 FU) than DBW16 (75 FU) and HI977 (30 FU). As postulated from MDL results, HI977 was depicted as the strongest variety by virtue of highest DDT (5.4 min), AT (2.1 min), DT (8 min), stability (5.9 min) and least softening of dough (30 FU).

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 6, June 2016

Table 2 Rheological properties of wheat varieties and effect of gliadin addition

MDL Parameters	Control				Added 5% gliadin			
	C306	DBW16	HI977	HW2004	C306	DBW16	HI977	HW2004
PR (FU)	500f	499e	496c	498d	480b	515g	520h	470a
DDT (min)	1.8a	1.4a	5.4c	1.4a	1.4a	1.2a	3.2b	1.2a
AT (min)	0.9a	0.8a	2.1b	0.8a	0.7a	0.8e	2.0b	0.7a
DT (min)	2.8ab	2.8ab	8.0d	2.2a	2.2a	2.2a	5.6c	1.8a
Stability (min)	1.9ab	2.0ab	5.9d	1.3a	1.4a	1.4a	3.6c	1.1a
Softening (FU)	95d	75c	30a	100d	120f	130g	60b	115e
EAP (Wh/kg)	2.6b	1.8a	8.3c	1.8a	1.8a	1.7a	4.9	1.5a

PR-Peak resistance, DDT- Dough development time, AT-Arrival time, DT-Departure time, EAP-Energy at peak. Values followed by different letters are significantly different at $p < 0.05$

On addition of 5% gliadin to the flour of different varieties of diverse baking quality, the mixing properties of the resulted dough got altered as gliadins decreased the strength of the dough by changing the Gli/Glu ratio (Khatkar, Bell, & Schofield, 1995). Surprisingly, peak resistance (PR) increased in case of DBW16 and HI977 and decreased in C306 and HW2004 when compared to the control, which is possibly related to the HMW-GS and gluten proteins composition of these varieties. DDT, AT, DT and stability in all the varieties were prominently affected by addition of gliadin and observed a declined trend. It has also been postulated by MacRitchie (1992) that addition of gliadin minimizes the dough mixing time and stability. An increased level of gliadin produces weaker dough which get developed early and loses its ultimate strength in the form of stability. Generally, the strong varieties possess higher dough stabilities and utilized for breadmaking, whereas weaker varieties with lower dough stability are considered good for cookie making suggesting that the dough stability have prime importance in deciding the technological quality of flours. Addition of gliadin obviously decreases the percentage of glutenin in a dough system and makes all kinds of dough remarkably softer by increasing its extensibility and viscosity. This transforms the equation of gliadin and glutenin balance in the dough (Khatkar, Barak, & Mudgil, 2013). It is also evident from the results that the strong varieties are greatly negatively influenced by the addition of gliadin, whilst weak varieties are influenced to a lesser extent. Uthayakumaran, Tömösközi, Tatham, Savage, Gianibelli, Stoddard, and Bekes (2001) has also depicted that peak dough resistance was increased by adding gliadin sub-groups to the base flour. HI977, the strongest variety is most affected by the gliadin addition as maximum PR was increased in it. DDT of HI977 was cut down by 2.2 min, while DT and stability were decreased to 5.6 min and 3.6 min from 8 min and 5.9 min, respectively. In addition, the softening was intensified double fold (60 FU). HW2004 was observed weakest on MDL parameters and least change in these parameters were observed after adding gliadin to this variety. Energy at peak (EAP) was observed maximum for HI977 in all varieties, being stronger variety evidently. EAP in a dough system is the energy required to touch the peak height. The requirement of this EAP was decreased when gliadin content was increased in the flour of all the varieties.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 6, June 2016

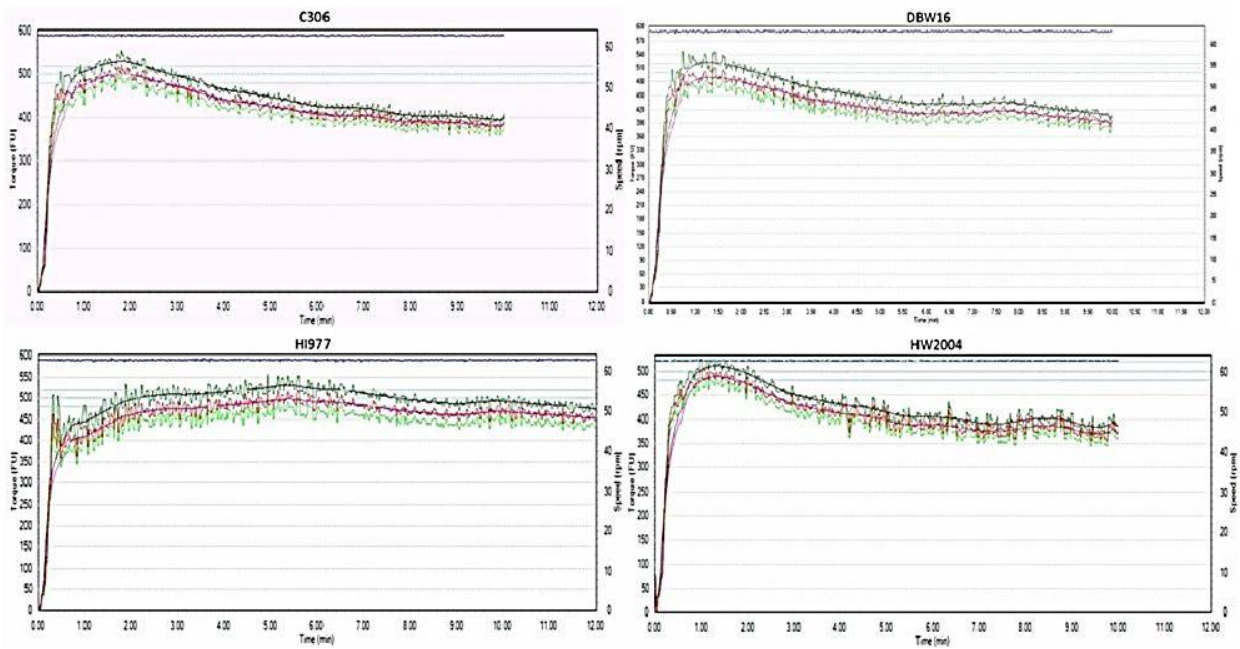


Figure 1. MDL profile of wheat varieties

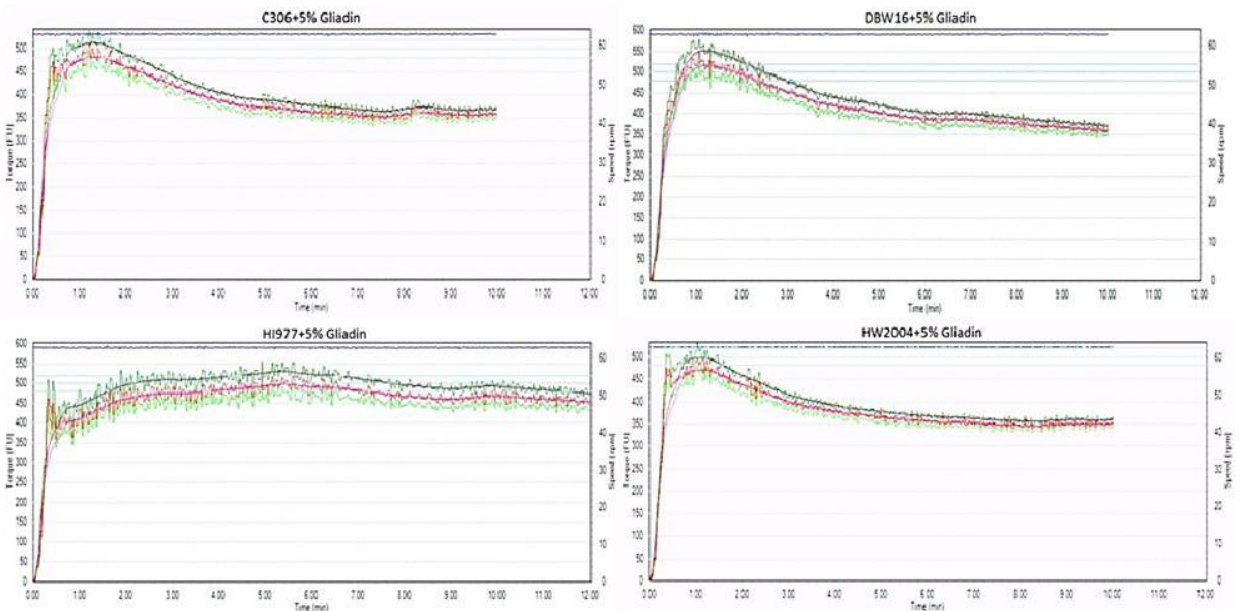


Figure 2. MDL profile of wheat varieties with 5% added gliadin

IV. CONCLUSION

Considerable efforts were carried out by addition of gliadin in different wheat varieties. DDT, AT, DT, stability, softening and EAP of all the varieties were prominently affected by addition of gliadin. Increased content of gliadin produced weaker dough which got developed early and dough lost its ultimate strength in the form of stability. It is also

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 6, June 2016

evident from the results that the strongest varieties are most affected by the addition of gliadin inversely, whereas weak varieties are influenced lesser, comparatively.

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