Studying of mixing speed and temperature impacts on rheological properties of wheat flour dough using Mixolab

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Abstract. Wheat flour dough is highly non-Newtonian, time-dependent, strain-dependent and viscoelastic. These rheological properties are very sensitive to temperature, water content and composition. Dough mixing is one of the most important ways to characterize the quality of wheat flours. Proper dough development is affected by mixing intensity (mixing speed) and work imparted to the dough. The objective of this research was to study impact of mixing speed and temperature on thermomechanical properties of breadmaking quality wheat flours using Mixolab. Analysis was carried out at the constant water absorption (98% db) using standard Chopin+ protocol, which consisted of a heating/cooling cycle after a certain mixing time at constant mixing speed (60–120 rpm). Effect of temperature at 80 rpm, 100 rpm, 120 rpm, and effect of mixing speed at 30°C, 40°C, 50°C were also studied. Strong relationships were observed between the mixing speed (rpm) and the Mixolab parameters (dough consistency during mixing (C1), mixing stability, protein weakening (C2), starch gelatinization (C3), amylase activity (C4) and starch gelling (C5).
Mixing temperature was observed to have higher impact on dough consistency and stability than mixing speed. Softening effect of temperature was more significant at low mixing speeds.

Key words: mixing behavior, pasting, torque, dough consistency.

INTRODUCTION

The bread-making process consists of the three main steps. Those are mixing, fermentation and baking. The mixing process is the crucial operation in bakery product production by which the wheat flour, water, and additional ingredients are changed through the mechanical energy flow to coherent dough. (Gras et al., 2000; Zheng et al., 2000; Wilson et al., 2001). Dough mixing is one of the most important ways to characterize the quality of wheat flour samples. The dough development is a dynamic process where the viscoelastic properties are continuously changing. Therefore, dough properties are strongly influenced by the way of their mixing. For achieving the proper dough development, two basic requirements must be satisfied. The imparted mixing energy or work input must be higher than the critical limit of energy needed for gluten formation, and the mixing intensity must be above the critical level for the dough development (Kilborne & Tipples, 1972). These requirements vary with the flour properties and the type of mixer used (Frazier et al., 1975; Oliver & Allen, 1992). For this reason, decisions with respect to adequacy of dough mixing are still partly based on operator experience. Recently, a number of analytical methods have been investigated to monitor dough development based on physical or chemical description of dough properties. The most popular in-line process measurements, based on changes in dough physical properties, are that of mixing torque or power consumption of the mixer.

At laboratory scale (using analytical methods after dough sampling), dough development has been largely investigated by microscopy and chemical analysis. In industry, a wide variety of mixing geometries and speeds are used for dough development. The way the dough is mixed has a major impact on the rheological properties due to the time- and strain-dependent nature of dough. The farinograph and mixograph are two common devices for assessing flour properties during mixing in lab scale. Both mixers provide empirical measurements related to the torque and work input required to produce optimally mixed dough, despite dissimilar geometries and mixing actions. A new generation of analytical equipment is represented by Chopin (Tripette et Renaud, Paris, France). This apparatus measures and plots in real time the torque (in N·m) produced by passage of the dough between the two mixing arms, thus allowing the study of mixing and pasting behavior of the wheat flour dough systems. Mixolab could play a key role in ensuring flour performance matches customers' expectation in finished product (Gedrovica & Karklina, 2011). The quality of wheat-hemp composites prepared with different amounts of hemp flour (5, 10, 15 and 20%) was characterised by the mixolab rheological test by Hruskova et al. The most precise distinguishing of samples was observed during the mixing and starch retrogradation phases of the test. Correlation analysis confirmed proper relationships between mixolab and rheological parameters related both to protein properties (C1, C2, C1–C2 vs. farinograph and extensigraph ones) and starch or starch gel properties (C3, C4, C5 vs. amylograph ones) (Hruskova et al., 2013). There were several research studies of thermomechanical properties of different types of wheat, such as Indian and Chines (Dhaka & Khatkar, 2013) and (Chen et al., 2013).The objective of this research was to study impact of mixing speed on thermomechanical properties of Hard Red Spring flours using Mixolab. Hard Red Spring wheat flour stands out as the aristocrat of wheat for baking bread, bagels and hard rolls. It has the highest protein content of all U.S. wheats (usually 13–16%) which, in turn, corresponds with greater gluten content in dough. Understanding the effects of mixing speed variation on gluten strength and also starch gelatinization, amylase activity and starch gelling of Hard Red Spring wheat flour is important when creating the distinct structural and textural characteristics that consumers desire in baked products.

MATERIALS AND METHODS

This study was done in the laboratory of Department of grain Science and Industry at Kansas State University.

One batch of Hard Red Spring wheat (1.4% ash, 13.2% protein, 16% moisture, 98% water absorbtion) was used for the experiments in this study during 5 consecutive days.

A standard Mixolab curves (Fig. 1) were used to determine a set of parameters listed in Table 1. C1 and C2 are related to protein quality, whereas C3, C4 and C5 are related to the starch characteristics. Fig.1 shows the results of experiment No 3 (Table 2). Correlations between mixing speed and the mixolab parameters and also the correlations between initial bowl temperature and mixolab parameters were investigated.

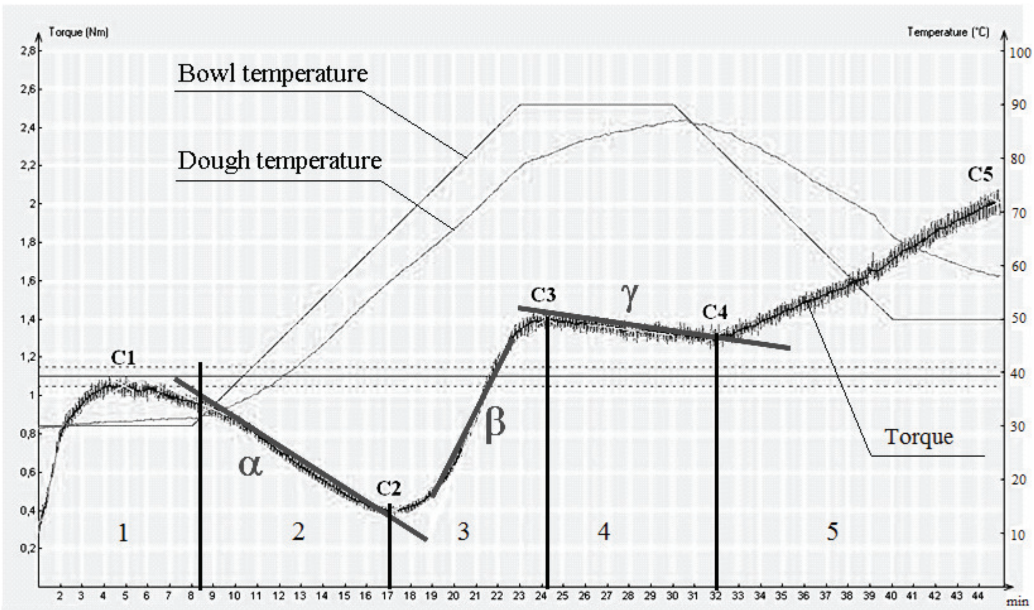

Figure 1. Mixolab Chopin+ protocol curve. Experiment No 3 (80 rpm and 30°C); where: α, β, and γ are the indicators of protein weakening, starching speed and enzymatic degradation.

Zone 1: Dough Development – at constant temperature, the start of the test determines the water absorption capacity of the flours and measures the characteristics of dough during mixing (stability, elasticity, absorbed power); Zone 2: Protein reduction (α) – when dough temperature increases, consistency decreases. The intensity of this decrease depends on protein quality; Zone 3: Starch gelatinisation (β) – as from a certain temperature, the phenomena linked to starch gelatinisation become dominant and an increase in consistency is then observed. The intensity of this increase depends on the quality of the starch and, in some cases, on the additives; Zone 4: Amylase activity (γ) – The value of consistency at the end of the plateau depends considerably on the endogenous or added amylasic activity. The greater the decrease in consistency, the greater the amylasic activity.

The Mixolab is a recording dough mixer used to measure the rheological properties of doughs subject to the dual stress of mixing and temperature changes. It measures the torque (in N·m) produced by the dough between two mixing blades. The test is based on the preparation of a constant dough sample weight hydrated to obtain a target consistency during the first test phase. In the ‘Chopin+’ protocol, the dough weight is 75 grams and the target consistency is 1.1 N·m (± 0.05 Nm).

Mixolab analysis were carried out at the constant water absorption (98% db) using standard ‘Chopin+’ protocol, which consisted of a heating/cooling cycle after a certain mixing time at constant mixing speed (60–120 rpm). Required amount of flour for analysis was calculated by Mixolab software according to input values of flour mixtures moisture as well as water absorption. The total mass of flour and distilled water placed into bowl was 75 g. Initial bowl temperature for each experiment is shown in Table 2.

Table 1. Mixolab parameters

Point	Description
C1	Maximum consistancy obtained in the first 8 min (water absorbtion)
C2	Protein weakening as a function of mechanical work and temperature
C3	Starch gelatinisation
C4	Hot gel stability
C5	Starch retrogradation in the cooling phase
Slope α – slope of curve between end of period at 30°C and C2	Protein weakning speed under the effect of heat
Slope β – Slope of curve between C2 and C3	Starch gelatinisation speed
Slope γ – Slope of curve between C3 and C4	Enzyme degradation speed

Table 2. Experiment composition (target torque for C1 – 1.1 N·m)

Experiment	Number of experiment	Mixing speed, rpm	Initial bowl and 1-st step temperature, °C
Speed effect study	1	60	30
	2	70	30
	3	80	30
	4	90	30
	5	100	30
	6	110	30
	7	120	30
Temperature and speed effects study	8	80	40
	9	80	50
	10	100	40
	11	100	50
	12	120	40
	13	120	50

After dough mixing stage (8 minutes) samples temperature increase with the speed 4°C min^{-1} during 15 minutes; at this point, there was a holding period for 7 minutes at 90°C, followed by a temperature decrease with the speed 4°C per min during 10 minutes; then the mixture reached 50°C and hold at this temperature for 5 minutes. Total analysis time was 45 min. The mixing speed during the entire assay from very beginning until the end was 60, 70, 80, 90, 100, 110 and 120 rpm, respectively to the experiment. 5 replicates were carried out for each type of experiments.

RESULTS AND DISCUSSION

Initial testing has focused on mixing flour-water dough to peak development at varying speeds (Fig. 2). Work input to reach peak torque was determined and compared (Pastukhov & Dogan, 2010).

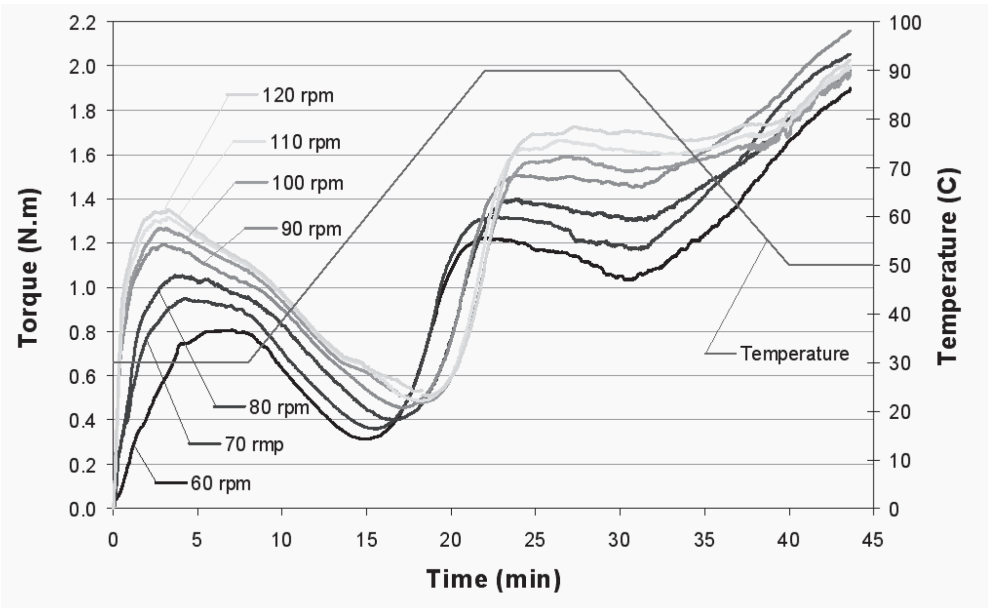

Figure 2. Mixolab curves obtained at varying mixing speeds (60−120 rpm) using 'Chopin+' protocol (Speed effect study).

Strong relationships were observed between the mixing speed (rpm) and the following Mixolab parameters: (Fig. 3) a) time needed to reach point C1; b) torque in point C1; c) torque in point C2; d) C1–C2 difference indicating progressive protein weakening; e) torque in point C3; f) torque in point C4; g) C3–C4 difference indicating starch stabilization; h) α; i) total work done (sum of the torques during the experiment).

It is known from (Sabovics et al., 2011) that decrease of triticale flour proportion in blend during mixing with constant speed results to increasing of the dough stability and does not change dough properties substantially. Changing the mixing speed we discovered that dough consistency increased while the stability decreased with increasing mixing speed (Fig. 2, Fig. 3). The higher the mixing speed the faster the achievement of point C1 takes place and the higher the torque in this point (Fig. 3 a, b). The same situation with torque in points C2, C3, C4, but the time needed to reach these points are increasing with increasing of mixing speed. C2–C1 difference increased indicating progressive weakening in dough network at elevated mechanical energy input and temperature. Maximum viscosity (point C3) increased possibly due to quick rupture of starch granules leading to lower pasting temperatures and to higher paste consistency. C3–C4 difference – fall in viscosity (stability when hot) is decreasing when mixing speed is increased. Value of α slope increases monotonically with increasing of mixing speed, indicating the protein weakening (Fig. 3 h).

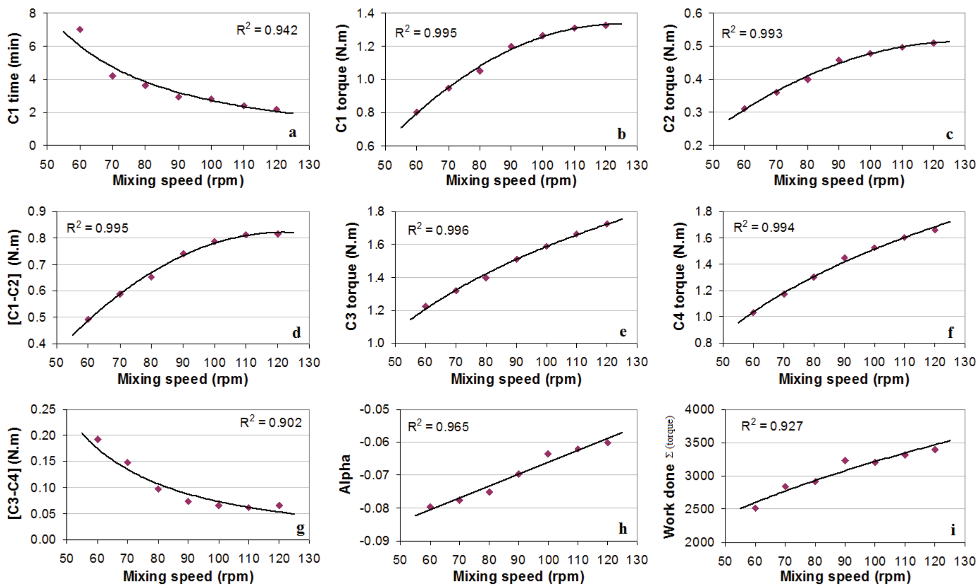

Figure 3. Correlations between mixing speed and Mixolab parameters.

Fig. 4 shows the effect of temperature at 80 rpm (a), 100 rpm (b), 120 rpm (c), and effect of mixing speed at 30°C (d), 40°C (e), 50°C (f) observed in the second set of experiments

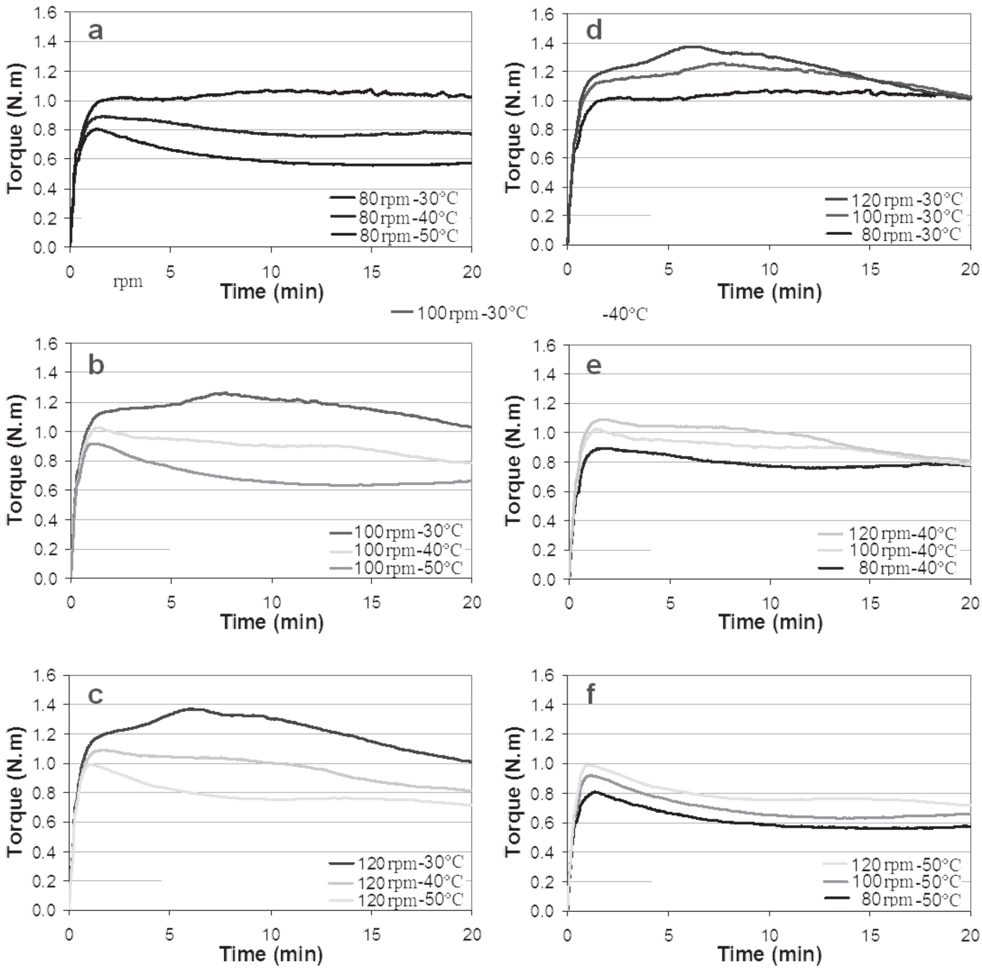

Figure 4. Effect of temperature at a – 80 rpm, b – 100 rpm, c – 120 rpm, and effect of mixing speed at d – 30°C, e – 40°C, f – 50°C.

CONCLUSIONS

Results indicated that the speed at which dough is deformed during mixing can cause it to develop differently.

Dough development time decreased significantly with gradual increase in mixing speed.

Stability of gluten network dropped sharply as mixing speed increased as indicated by C1–C2 and α (slope of the descending curve) values.

Increase in mixing speed resulted in increased higher dough consistency independent from the mixing temperature. Mixing temperature was observed to have higher impact on dough consistency and stability than mixing speed. Softening effect of temperature was more significant at low mixing speeds. The present study showed that Mixolab has ability to easily model different speed variations and results of these experiments indicate that the speed at which dough is deformed during mixing can cause it to develop differently. However, further work is required for modeling more complicated mechanical motion of mixing arms as we can meet in real mixers. It can be concluded that Mixolab is a suitable instrument for progressive work in scientific laboratories and industrial bakeries.

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