BREAD DOUGH RHEOLOGY STUDY BY MONITORING ENERGY PARAMETERS

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Abstract

The operation of kneading dough for bakery is complex, being influenced by many factors, among which we mention the type of flour used, the amount of water added, the kneading temperature, the speed of the mixer's active organs, the duration of kneading, etc. In the kneading process to obtain the dough, a series of physical changes occur in the structure of the protein networks. Through kneading, the rheological properties of the dough change due to the movement of the protein groups, and the amount of gluten that can be washed decreases. In this study we compared the standard method of determining the rheological properties with the farinograph and the direct method using a mixer common in the bakery industry where we monitored the energy parameters to finally determine the farinographic curve. The results obtained on the farinographic curves show that the direct method with the mixer is identical to that obtained by the standard farinographic method, with the mention that the latter must be used initially to calibrate the direct method.

Key words: dough, rheology, mixer, energy parameter

The most important baking properties of flours for obtaining bakery doughs are related to: the quantity and quality of wet gluten, the hydration capacity (to absorb water) of the flour, the capacity of the dough to form and retain gases and the gelatinization of the starch (Bourne M.C., 2002; McKenna B.M., 2003). During the kneading process to obtain the dough, a series of physical changes occur in the structure of the protein networks (Gousott P., 2005). The gluten that results from dough kneading has a different structure and physical properties than the native protein from which it originates (Gallagher E., 2009). Research has shown that after the operation of kneading the dough, the pores show differences, by increasing the distances of the crystalline reticular surfaces after swelling, the volume of the protein gel, as well as the amount of soluble protein, due to the mechanical actions of kneading (Singh R.P., Heldman D.R., 2009). In addition to a uniform distribution of dough components, kneading produces the formation of a characteristic protein structure (Guttierez A.R. *et.al*, 2003). Through the action of kneading, the rheological properties of the dough change due to the movement of the protein groups, and the amount of gluten that can be washed decreases (Gousott P., 2005). An important role in dough rheology is played by the duration and method of kneading, due to excessive and long-term kneading, the destruction of the protein structure occurs, respectively the slow secondary formation of a new structure with stable bonds (Bourne M.C., 2002; Roos T.H., 1995). The paper aims to study the rheology of the dough using two distinct methods, namely the farinograph method and the direct method with the mixer by monitoring the energy parameters.

MATERIAL AND METHOD

Type 650 flour with an average moisture content of 12.9% was used for the tests, and the dough obtained from this type of flour had an average moisture content of 45.3%. The rheological properties of the dough were determined using the Brabender farinograph (*figure 1*) and the Plutone 10 mixer (*figure 2*).

In the rheological determinations of the dough with the help of the farinograph, a balance with a resolution of 0.01 g was also used. The farinograph has a small vessel with a cooling jacket, in which a maximum of 300 g of flour and a quantity of determined by water depending on the type of flour. The amount of water is measured with the help of a burette positioned above the farinograph vat and is expressed in ml/100g of flour. This reflects the actual absorption of water in the flour. By kneading the flour with the farinograph, a diagram is obtained, and the

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obtained curve represents the average of the viscosity values represented in farinographic units (U.F.) with values between 480 U.F. and a maximum of 520 U.F., a record that indirectly represents the resistant torque obtained at the mixing arms. If the viscosity of the dough does not fall within the limit of 500 U.F., or if the values are outside the range of 480 ~ 520FU, then the amount of water added must be corrected.

The correction relation of the amount of water added:

$$V_c = V + 0.096 \cdot (C - 500) \qquad (1)$$

where: Vc (ml) the amount of corrected water; V (ml) current water quantity; C (U.F.) actual dough consistency.

Water absorption equation x (ml/100g):

$$x = (Vc + m - 300)/3 \qquad (2)$$

where: m (g) the amount of sample taken in the analysis. The error of the result must not exceed 1.0ml/100g, this being an average, and the final result is expressed with at least one decimal place.

Figure 1 **Farinograph Brabender**

The used Plutone 10 mixer has a vat with a capacity of 10 l and three speeds (I-108 rpm, II - 195 rpm, III - 355 rpm). The experiments were carried out in the second gear. To determine the energy parameters with the help of the mixer, a Voltcraft electronic voltmeter was used to determine the current voltage, a Voltcraft electronic cofismeter to determine the cosine function of the phase shift angle, as well as a PicoLog electronic oscilloscope to determine the variation in the intensity of the electric current. The rheological determinations with the help of the mixer using the energy parameters by which the torque resistant to the spiral axis of the mixer was determined. This resistant torque obtained on the spiral axis varies depending on the development stage of the dough. The equation of the resistant mechanical torque on the spiral axis of the mixer is:

$$M[N * m] = \frac{\mathrm{P}[W]}{\omega[rad/s]} = \frac{U * I * cos\varphi}{\frac{2\pi n}{60}[rpm]} \qquad (3)$$

where: M (Nm) the resistant mechanical torque; ω (rad./s) pulsation; n (rpm) spiral spindle speed.

Active power equation:

$$P[W] = U * I * cos\varphi \qquad (4)$$

where: U (V) the voltage, I (A) the intensity, cosφ the power factor (0, 1).

Figure 2 **Planetary mixer - Plutone 10**

The equation of specific energy consumption ε (Wh/kg):

$$\varepsilon = \frac{E}{m_d} \qquad (5)$$

where: md (kg) mass of dough.

RESULTS AND DISCUSSIONS

Following the rheological determinations of the dough by the two methods, with the Brabender farinograph and the Plutone 10 mixer, two diagrams were obtained according to *figure 3*.

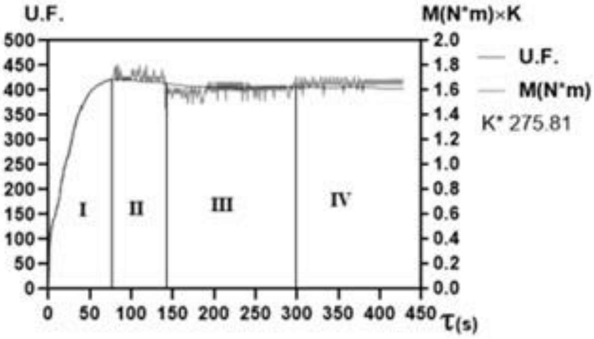

Figure 3 **The rheological diagrams obtained with the farinograph (U.F.) and the mixer (M)**

In the diagrams obtained with the farinograph and the mixer, four stages of dough formation are distinguished that give information on water absorption, the time of formation and development of the dough, the stability of the dough, the degree of softening of the dough, the elasticity of the dough.

Stage I: The first phase of dough formation mainly involves the moistening of the flour particles. Water becomes dispersed between the flour particles by the movement of the mixing arm. The hydrophilic properties of the particles that adsorb the liquid on their surface, cause the predominant occurrence of shear forces in the product, developing a high resistive torque to counteract the adhesion forces. The variation of the resistant torque at the mixer spiral shaft reaches a maximum of 1.65 Nm, and at the farinograph arm it reaches a maximum of 420 U.F. In the first phase of dough formation, the most important material variables are the surface properties of the flour particles, their shape, size, degree of adsorbed water in the flour, as well as water temperature.

Stage II: In the second phase of dough formation, swelling and stabilization take place. When the maximum point is reached, the solubility and swelling reactions are complete. Solubility and swelling depend on both raw materials and mixing parameters. In the kneading process the starch, proteins and enzymes in the flour are important for the rheological characteristics of the dough. Higher water content requires more mixing to reach the optimum dough consistency.

Stage III: In the third phase of dough formation, a slight softening of the dough can be observed, which may be caused by non-compliance with the technological parameters. In the diagram obtained with the mixer, the dough has a lower stability period in relation to the diagram obtained with the farinograph.

Stage IV: During a longer kneading, a greater resistance of the dough is observed, because the type of flour is type 650, which has a higher content of bran, which opposes greater resistance to the kneading process, due to the gluten content that it makes the dough more viscous, harder to work with, and the mixer puts more effort into the mixing process.

Recording the results at the spiral axis of the mixer with the help of energy parameters.

Following three tests performed on the planetary mixer for semi-white flour type 650 where 56% water was added, the average resistance torque curve during mixing is presented according to *figure 4.*

Figure 4 distinguishes the stages of interest:

Stage I: In the first zone, the development time is represented, by adding water in sufficient time to reach maximum consistency. The resistant torque increases in the first seconds from the start of mixing up to 1.15 Nm, after which it remains at this average until the sticking phase begins when the water integrates into the flour and the resistant torque at the axis of the mixing arm increases to a value of 1.35 Nm.

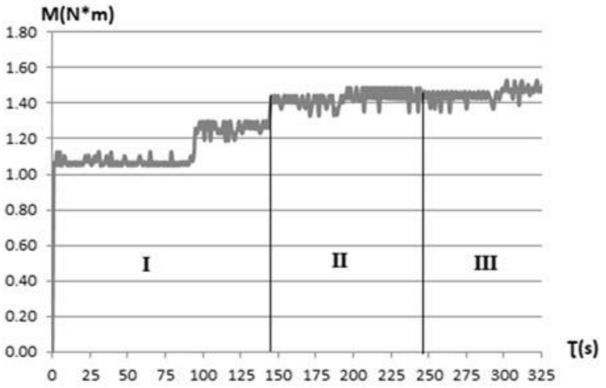

Figure 4 **The resistant torque curve obtained at the mixer shaft during mixing**

Stage II: The stability of the dough is represented in the second stage, which represents the time interval in which the maximum consistency is recorded when the dough is formed and the water is fully integrated into the product mass and the resistant torque increases to a maximum of 1.42 Nm.

Stage III: In the third zone, a slight softening of the dough can be observed and the resistant torque tends to decrease to the value of 1.41 Nm, after which there is an increase to a resistant torque of 1.5 Nm as a result of the increase in the viscosity of the dough characteristic of stage IV.

During the mixing operation with the planetary mixer, the speed of the mixing device was maintained in the second stage of operation at 195 rpm. To calculate the consumption of specific energy, relation (5) was used, and the area shown with a hatch in Figure 5 represents the mechanical energy introduced into the dough for its formation and finalization. For the accuracy of the calculations, the area was calculated using the Prism software.

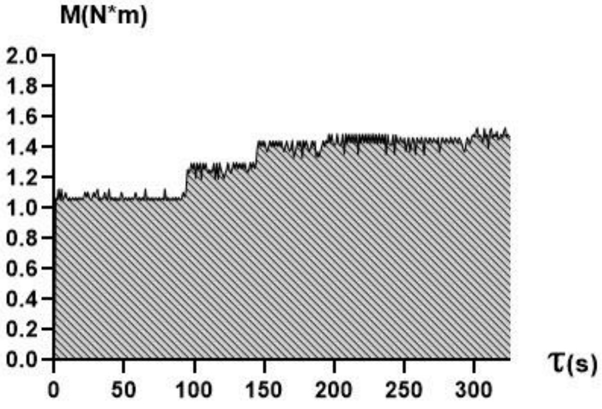

Figure 5 **Representation of the area for the calculation of the energy required to obtain the dough**

The specific energy consumption for obtaining the dough from semi-white flour type 650 has the value of 1.52 Wh/kg.

CONCLUSIONS

The aim of the paper was to study the rheology of the dough using the farinograph method and the mixer method through energy parameters. The study of dough rheology using type 650 flour is important in establishing the manufacturing technology of bakery products.

After performing the experimental determinations using the Brabender farinograph and a planetary mixer we can say that the two methods are close in terms of the values obtained. Through the farinographic method as a standardized method in baking, precise rheological characteristics are obtained as a result of the control of temperature parameters during kneading, but the method has the disadvantage of a high equipment cost and a long time for the preparation of each sample.

The method of determining the viscosity variation by monitoring the torque at the spiral shaft of the planetary mixer with the help of energy parameters presents a number of advantages, such as low cost of the devices (the planetary mixer is usually used in production and is not special for experiments), accuracy at data recording and ease of parameter determination. The disadvantage of the method is represented by the modification of the calibration when changing the type of mixer.

Using the method of determining the viscosity variation by monitoring the torque at the spiral axis of the mixer with the help of energy parameters, it is possible to obtain farinographic dough viscosity curves similar to those obtained in the farinograph with much lower costs. But the farinograph being the benchmark method for determining the viscosity of bakery doughs is necessary for calibrating the torque monitoring method at the spiral axis of the mixer and determining the value multiplication coefficient for a certain type of flour.

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