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STUDY ON RHEOLOGICAL BEHAVIOR OF BAKERY DOUGH

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Abstract: *Bread and bakery products represent basic food daily consumed of all the people. In this context, the quality characteristics of the bread have an important role regarding the consumer choice. So, in this study are specified the rheological properties of dough and its influence on bread.*
Keywords: *dough, rheological, bread, kneading*

1. INTRODUCTION

The dough is a complex colloidal medium that is formed during the mixing of the flour with the addition of water. The rheological characteristics of dough and the extensibility or elasticity are due to the most to the gluten, which is formed during the process of mixing from the protein of wheat flour gluten. The gliadins cause the extensibility of gluten and the bread volume, and the gliadins causes the extensibility of gluten and its tolerance to the mixing. By adding certain substances of oxidation to the dough, the protein network suffers some important changes, caused by the conversion of cysteine aminoacid in cystine, forming some disulfuric linear molecules in protein fiber [6].
The kneading is the technological operation after which is obtained a homogeneous mass of dough with a specific structure and rheological properties (strength, extensibility, viscosity, elasticity, plasticity), by mixing raw and auxiliary materials. The rheological characteristics of dough affect directly the quality of final product: the elasticity of the core and the peel, the volume and the form of the bread, as well as maintaining its freshness. When the dough has the elasticity and the extensibility sufficiently high, results loose bread, with developed volume and core which has pores with thin walls. If the dough is too tough, the bread is obtained undeveloped, with dense core and when the dough is too extensible, the bread is flatting and it has low volume and coarse porosity [6].

2. THE FORMATION OF THE DOUGH AND THE PROCESSES THAT OCCUR

During the kneading process there takes place a number of physical, chemical, biochemical, colloidal and microbiological processes that cause significant changes of the substances in the dough mass.
The physical processes depend on the way of mixing the flour with water. Depending on the manner of conducting the operation, the forming of the dough is divided into two stages: mixing the raw and the auxiliary materials and proper mixing of the mixture thus obtained.
In the first moments of the mixing, the flour water absorption leads to the formation of small wet clumps separately. Following the contact with water, is developing the hydration heat, around 27 cal/g of flour.
Continuing the mixing, it is reached the development stage of the dough , when little wet clumps merge into an uniform mass, and the water from its surface disappears, becoming smooth and shiny and begins to manifest the elastic properties. The time for the optimum development of the dough is 2…25 minutes, depending on the quality of the flour, the water added and the type of mixer.
The next phase is the stability of the dough when it is subject to the distortion due to the velocity of the gradients that arise.

The last phase of mixing, which should be avoided is the softening of the dough, and is characterized by changing the rheological characteristics. The dough becomes soft, slightly elastic and highly extensible and finally loses cohesion, becoming sticky and just like a viscous liquid.
The phases of dough forming can be observed by tracing the farinograph curve.
During the kneading, due to the heat of hydration and the transformation of part from mechanical energy into heat kneading, the dough temperature increases. The increase of dough temperature accelerates its formation. Exceeding the optimum temperature of dough formation, 28°C, leads to the increase of enzyme activity, the dough viscosity decreases, which has negative influence on the rheological properties of dough and can occur even distortion of proteins.
The colloidal processes are represented by the hydration and swelling processes of the dough components.
Hydration of the flour is a complex meal. Flour components bound water in various ways. Although the protein and the starch binds the largest amount of water in the dough, an important role also have the pentozans.
The proteins from flour bind the water both by absorption and by osmosis. The osmosis leads to the swelling of gliadin and glutenin resulting the gluten. The water related through absorption forms around the proteins the film hydration [4].
At the formation of the gluten an important role is played by the amount of water used. Not enough water will not satisfy the necessary required by the gluten, its structure is not formed completely, and its quality will be poor [4].
Biochemical processes occuring under the action of enzymes and they tend to the degradation of macromolecular constituents of flour to form simpler compounds which modifies the rheological characteristics of dough [4].
As a result of amilolyses process, during the kneading the dextrins and the maltose increase in the dough. They, in particular β – dextrins contribute to the increase of the dough viscosity. Also, the dough begins to activate the lipoxygenase, which in the presence of oxygen oxidizes the polyunsaturated free fatty acids and their monoglycerides [1].
The nature of chemical groups on the protein structure leads to the formation of covalent bonds as: disulfide, as well as non – covalent bonds: hydrogen bonds, hydrophobic bonds, ionic bonds. The gluten is formed so as a result of the interaction between gluten protein. The main role in the formation of gluten plays the glutenin, which favors the interactions and the associations with other proteins and other constituents of flour. Due to its large molecule, the hydrated proteins can form films, and at the kneading, its ability to interact increases.
During the kneading in the dough is included some air. A part is dissolved in the aqueous phase, and the remaining air forms microbubbles. These bubbles contribute to the pore formation in the dough at the kneading, and the oxygen from the air takes part in the oxidation processes from the dough.

2.1. The factors which influence the dough formation

The formation of the dough and its rheological properties are affected by a number of factors, as they are represented in the following figure 1.
The kneading conditions are represented by the intensity of kneading, the amount of energy transmitted to the dough, the kneading duration. It decreases with the increase of the speed of the kneading arm. The kneading duration influence a lot the kneading properties, thus lead to an optimal development, or an incomplete development or to an development too high [1].
The flour quality. The dough obtained from flour of poor quality is different from the dough obtained from flour of good quality. The dough made from low flour the protein' films break easily, even before their uniform distribution in the dough. In the dough obtained from flour of high quality the hydrated proteins are elastic, and to a kneading too high, the protein films present just a few breaks. This stability to this kneading is one of the most important characteristics of flour required.
The amount of water. A higher or a smaller quantity of water different than is required to achieve the normal consistency extends the kneading duration. Dough is very sensitive to a kneading too high, contrary to the dough that has a sufficient tolerance.
The electrolytes, particulary the salt (NaCl). The addition of neutral salts modifies the nature and the intensity of the hydrophobic interactions between the gluten proteins. Increasing of the ionic strength in the dough following the introduction of salt reduces the water capacity of retention by proteins [1].

2.2. The constituent phases of dough

From the physical point of view, the dough is composed of three phases: solid, liquid and gas.
The solid phase is composed of insoluble constituents and bound water: gluten proteins limited swollen, starch granules, bran particles and other solid ingredients.

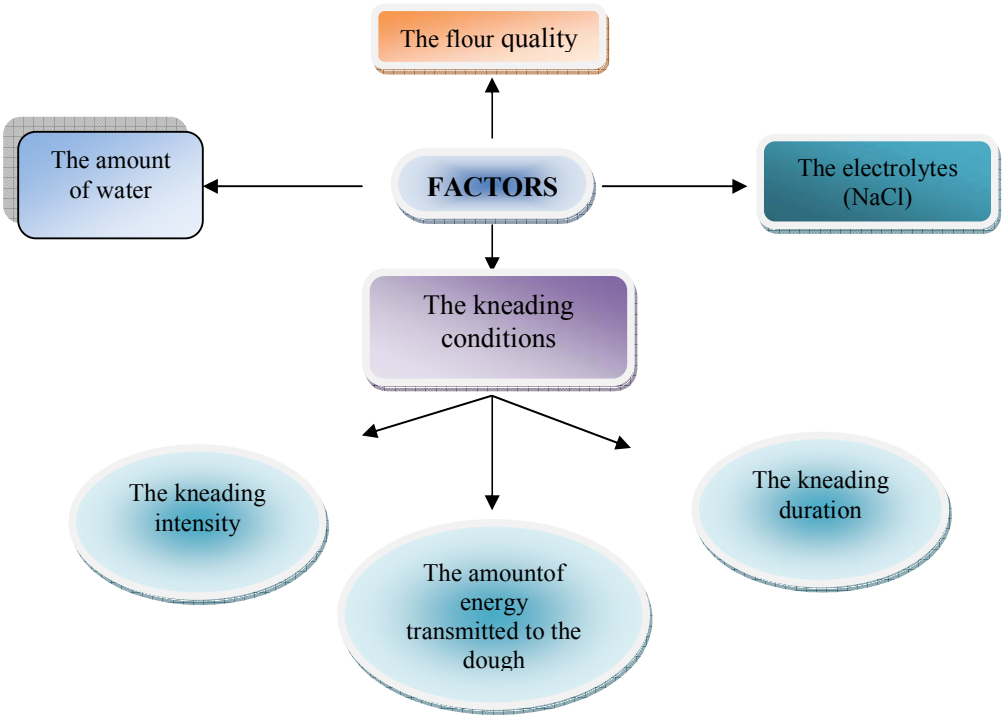

Figure 1: The factors which influence the dough formation

The liquid phase is formed in that part of water which is not bound by adsorption and there the soluble constituents of the dough which are dissolved: minerals, simple sugars, dextrins, water soluble proteins, polypeptides, amino acids. It is found partly in the form of thin films surroundings the elements of the solid phase and most of it is in the dispersed state, osmotic input by the gluten proteins in the swelling process. The liquid phase represents 8-37% by the weight of the dough. A big influence on the liquid phase has the flour quality and the kneading time. To a normal kneading it represents approx. 20%, and to a short kneading about 11% by the dough weight.
The gas phase is formed of air bubbles included in the dough while kneading. It is presented as an emulsion of gas in the liquid phase of the dough, and mostly in form of air bubbles included in the gluten protein which are swelling. To a normal kneading, the gas phase reaches 10% of the dough volume. To the kneading extension it can reach 20% [1].

3. THE DOUGH AND ITS RHEOLOGICAL PROPERTIES

As defined by The International Organization of Standardization (ISO Standard 5492.1.1977), the food rheology is the science that deals with the study of the deformation and the flow of raw materials, the intermediates and the finished products in the food industry.
The rheology accepts as old models the bodies with uniform properties, those whose behavior is described by linear law. The perfectly elastic solid (Hooke), perfectly plastic solid (St. Venant) and purely viscous fluid (Newton) are particular rheological bodies.
The rheological properties express the deformation of dough in time under the action of external forces exercised on it.
The dough prepared from wheat flour is a non-liner visco-elastic body. It has properties which are characteristic to both solids and liquids, and therefore has an ideal behaviour intermediate between solids and the liquids: when it is stress, some of the energy is dissipated and the other part is stored [2].

3.1. The rheological properties of bread dough

The rheological properties of dough are: elasticity, viscosity, relaxation, creep. All these properties are largely due to the gluten which is formed at the mixing, but also how it interacts with the other components of the flour and the dough ingredients [3].

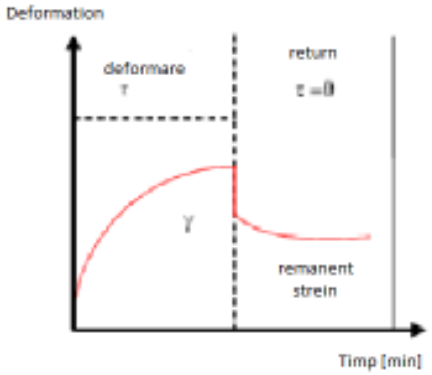

Figure 2: The deformation and its returning for a visco-elastic body
T- the applied voltage, γ-deformation

The elasticity is a property of a solid, deformable to reversibly store strain energy [5].

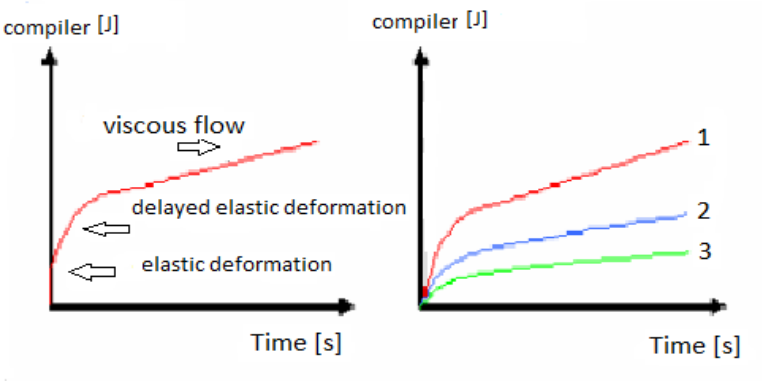

Figure 3: The typical curve of a viscoelastic material/ Deformation curves of dough from what flour (1-strong flour, 2-good flour, 3-weak flour)

The dough elasticity is provided by gluten, and particularly by glutenin, and that consists in that the dough deforms reversibly to a given applied force, then is it irreversibly deformed. The dough has an instantaneous elasticity that occurs upon the force application, and an elastic delay which occurs after the removal of the force.
The viscosity is the property of the bodies to resist to the deformation. The viscosity of the dough is an apparent viscosity, which, unlike the viscosity of the liquid, depends not only on the temperature and pressure, but also of a number of other factors such as the rate of shear that the dough has previously submissively.
The relaxation is the process of bone resorption, by decrease of the internal pressures of the dough, while maintaining the shape. The reabsorb of the pressures is made through the gradual elastic deformation in plastic deformation. The relaxation does not occur until the cancellation of internal tensions, but up to a limit determined, that is the limit of the elasticity, under the relaxation does not develop.
The relaxation time is the time when the tension from dough decreases of 2.7183 times, respectively with the base of natural logarithms e = 2.7183.
The creep is the property of a solid to flow slow and continuous under the action of a constant load [5].
The factors which influence the rheological properties of the dough
The rheological properties of dough play an important role in the production process, where the dough is subjected to the action of forces that realize the appearance of tensions and causes its deformation [3].
The quality of the flour, respective the protein content and the glutenin/gliadin report, has a great influence on the properties of dough. Thus, responsible of the dough viscosity are the gliadins which contribute to the dough extensibility, while the glutenins gives elasticity and resistance, increasing the resistance to breaking [2].
During the technological process, the dough is subjected to tensile and shear tensions.
The viscosity at the breaking by stretching and the breaking tension increases with the protein content of the flour, which explains the good performance of baking of the flour with high protein content [3].

The study of the dough behavior at shear with rotary viscometer showed that, at the request through shear, it increases its viscosity, proving its growth resistance. Increasing the viscosity of the dough to the severance occurs when it drops. The maximum viscosity to the shear decreases with the incresing of the protein content, but increases with the glutenin/gliadin ratio [1].
The amount of water. Increasing the water content is accompanied by a reduction of the elastic properties of the dough and its viscosity.
The rheological properties of the dough, the elasticity and the viscosity, increase until certain values of water content, corresponding to the maximum swelling of the protein, after which the value decreases. The optimum consistency is achieved when the dough contains enough water for the flour swelling components. An optimal swell of the components influence favorably the shape stability of the dough and the bread quality [1].
The optimum temperature for dough is 28…32°C. During the mixing process, the dough temperature increases due to the heat released during the hydration of flour particles and to the pass of an energy quantity into thermal energy. Increasing the temperature above the optimum temperature leads to the elasticity worsening and consistency of the dough, due to the increase of the fermentative activity. Lowering the temperature under its optimal value shrinks the dough plasticity with negative consequences on products quality [1].
Due to the temperature influence on enzyme activity, on the microbiota activity and on the rheological properties of the dough, it is best to use a lower temperature to the process of the weak flours and to the strong flours a higher temperature.
The kneading time is influenced by: the quality of the flour, the water quantity and the speed of the kneading arm.
Depending on the flour quality used, the dough can be formed slower or faster. The dough prepared from flours with high extraction and big extraction is more sensitive to the kneading than those obtained from low extractions flours and high extraction.
The dough of low consistency is very sensitive to a high kneading, contrary to the consistent dough which has a big tolerance. The kneading time decreases with the kneading arm speed [2].
For the traditional kneading, the kneading duration is between 6 and 12 minutes, while in case of the indirect method, the yeast is kneading 6…10 minutes, and the dough 8…12 minutes [2].
The end of kneading. It is appreciated through sensory analysis. The dough well kneading should be smooth, tight, consistent, flexible and easy to detach by the arm mixer and by the box wall where has been kneaded. At the manually sample, stretched between thumb and forefinger, the dough should stretch into a thin strip, transparent and flexible without breaking. The dough insufficiently kneaded is homogeneous, but is sticky and viscous. The dough excessive kneaded is highly extensible, without tenacity and to the manual sample it breaks.

4. CONCLUSION

- The dough is a complex colloidal medium that is formed during the mixing of the flour with the addition of water.
- The rheological characteristics of dough and the extensibility or elasticity are due to the most to the gluten, which is formed during the process of mixing from the protein of wheat flour gluten.
- From the physical point of view, the dough is composed of three phases: solid, liquid and gas.
- Depending on the flour quality used, the dough can be formed slower or faster. The dough prepared from flours with high extraction and big extraction is more sensitive to the kneading than those obtained from low extractions flours and high extraction.

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