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FINAL BREAD DOUGH FERMENTATION – REQUIREMENTS, CONDITIONS, EQUIPMENT – A SHORT REVIEW

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Abstract: Bread is a food consumed daily and bread making industry occupies an important place in the consumption department. This industry is in a full process of expansion and automation; solutions for control and optimization of technological processes are continuously searched for obtaining good quality and cost-efficient products. Dough fermentation represents the largest stage of the technological process starting from kneading and continuing during all the other operations and the first part of baking. Intrinsically knowledge of the elements of influence over the fermentation process represents key points in obtaining superior quality products.
Keywords: bread, wheat dough, proofing, parameters control, proofing equipment

1. INTRODUCTION

Bread making can be viewed as a series of aeration stages in which bubbles are incorporated during mixing, inflated with carbon dioxide gas during proofing and the aerated structure modified and set by baking. (Campbell. G. M.. 1991).

Wheat flour is the most commonly used in bread making because it is the only cereal capable of delivering a highly aerated structure in the baked loaf. This is due to the unique properties of its protein content, which has the ability to form a continuous macromolecular viscoelastic network called gluten, when mixed with enough water and subjected to sufficient mechanical work. (Cuq et al 2003).

The yeast used for bread manufacturing is Saccharomyces cerevisiae, which can convert the fermentable sugars present in the dough into carbon dioxide and ethanol as the main products. The fermentation intensity depends on the form of the yeast and the availability of fermentable sugars in the flour, including maltose produced by starch hydrolysis (Hutkins. 2006). The increase in volume is the most apparent physical change related to the development of fermentation in the dough.

This review aims to highlight the importance of final bread dough fermentation and some necessary aspects that need to be considered regarding this stage of the bread making process.

2. MATERIAL & METHOD: Mandatory requirements for obtaining high performance during proofing

The basic ingredients used to create a dough mix are flour, water, leavening agent (yeast or chemicals) and sodium chloride (Voicu Gh. 1999).

The typical white flour is comprised of approximately 71% (of flour weight) carbohydrates (of which the vast majority is starch), 13% protein. 1% lipids and 14% water with a number of components making up the remainder (Blanchard et. al.. 2012). Each component participates in overall's flour quality and has a greater or smaller influence on dough behavior during processing.

The proteins, glutenin and gliadin occupy a leading role in flour quality evaluation. Glutenin is responsible for dough extensibility and gliadin for dough elasticity. (Burluc R.M. 2007). Because the structure and bread quality is much based on gluten matrix, the quantity of gluten and ratio of glutenin to gliadin will affect the breadmaking quality of wheat flour. (Xu et al.. 2007. Bordei D.. 2007). Another important parameter is the hydration capacity of flour, which represents the quantity of water absorbed by the flour components and can be determined using the Brabender farinograph (SR ISO 5530-1/1990); according to the standard procedure, the quantity of added water is determined for an optimal dough consistency of 500 B.U. Because of different technologies applied in industrial bread making, in many cases, the hydration capacity of flour requires some adjustments. (Burluc R.M.. 2007).

Studies performed by Chin and co-workers (2005) show that using 2% less water than optimum negatively affected the production of carbon dioxide in dough during proofing, producing loaves of lower volume. Due to inadequate gluten hydration, the retention of carbon dioxide is affected also. (Peighambardoust et al.. 2010).

Dough development during kneading is a key step in obtaining a good quality loaf of bread and is decisively influenced by type of kneader, speed rotation of the kneading arm, time of kneading, added water and specific energy input. (Hwang C. H. and Gunasekaran S.. 2000). It is believed that 90% of the final bread quality depends upon mixing. (Cauvain. 2000).

During kneading, air bubbles are incorporated in the dough (Cauvain et. al.. 1999) and are considered to be the nuclei of the gas bubble which will build during fermentation stages. Doughs from strong flours incorporate less air during mixing than doughs from weak flours and give larger loaf volumes, finer crumb structures, or both. The leavening agent generates gas (CO2) within the liquid phase, which diffuses in solution to the nuclei due to a concentration gradient (Shah et. al.. 1998). As a result, the nuclei expand into gas cells and the density of the dough is reduced. The next processing stages like punching, sheeting and molding will be carried out to redistribute gas cells so as to improve crumb appearance.

The final proof stage is responsible for determining the structure of the bread crumb (Shah et al.. 1998), but all previous stages in the bread making process are equally significant.

Gas retention is of considerable interest due to its repercussion on the crumb structure and volume of bread (Giannou et al 2003) and depends on the rheological properties of the gluten matrix and its capability of expanding under carbon dioxide production and the growth of the internal surface of dough, which takes place up to a critical point.

The desirable loaf volume of yeast-fermented products is achieved only if the dough provides a favorable environment for yeast growth and gas generation and, at the same time, possesses a gluten matrix capable of maximum gas retention. (Sahlstrom, Park and Shelton, 2004). The fermenting power is characterized by the quantity of gas produced in a dough prepared from flour, water and yeast, fermented in certain conditions of temperature and humidity. The fermenting power depends on enzymes α and β – amylase, which transform a part of starch into maltose, as well as the quality of the yeast. (Voicu Gh.. 1999).

During fermentation, the metabolism of yeasts chemically transforms assimilable carbohydrates into carbon dioxide and ethyl alcohol as the principal finished products. As a related amount of alcohol forms, which is water-miscible, it influences the colloidal nature of the wheat proteins and changes the interfacial tension within the dough. In addition, carbon dioxide, which partly dissolves in the aqueous phase of the dough, migrates toward the initial nuclei of the air bubbles formed during kneading causing their growth. (Akbar A. et. al.. 2012). Approximately 95 % of fermented sugars are transformed in ethylic alcohol and carbon dioxide and the rest of 5 % in superior alcohols, organic acids and volatile compounds. (Voica D.. 2010).

3. RESULTS

— Conditions necessary for an optimal final fermentation

The dynamics and intensity of carbon dioxide formation are influenced by the flour properties, dough composition and technological process and proofing parameters; these factors are interdependent. The fermentation process takes place only if there are optimal conditions regarding the nutrition environment and the microclimate parameters. Under favorable conditions, the proving time should allow for the action of the yeasts and enzymes in the dough. (Sluimer 2005).

Proofing of the dough should be optimized for the production of good quality baked products. An insufficient proofing time results in products with a reduced volume and poor crumb structure, whereas excessive proofing can produce sticky doughs with low viscosity, which are difficult to handle. Excessive proofing times also represent unnecessary cost to the bakeries (Sinelli et al. 2008). The parameters necessary for a good control of the proofing process are the proofing time, temperature and relative humidity.

The usual final proofing time can vary between 15 min and 60 min, depending on the weight of dough loaf, dough consistency and quantity of yeast, the bulk fermentation degree, temperature and relative humidity.

If the bread making process implies a multi-phase technological process (with bulk fermentation time), the proofing time is greater than in the case of direct technological process (which uses intensive kneading, no intermediate fermentation and greater quantities of yeast).

The normal proofing temperatures are 30–35 °C and a relative humidity of 70 – 85 %. (Burluc R.M. 2007). The relative humidity varies directly with temperature and air distribution speed inside the proofing chamber. The values must be chosen so as to avoid or limit humidity losses from the loaves to the environment, which results in crust formation on the surface of the loaf and affects the product quality. Also a higher humidity level (e.g. 90%) will wet the surface of the loaf, resulting in higher degrees of stickiness and irregular baking. For example, if the proofing temperature is 35 °C and the air distribution speed is 1.5 m/s, the optimal value for relative humidity should be between 73 % and 75%.

— Equipment used for final fermentation of dough

Final fermentation (final proofing) takes place in enclosed spaces called provers. A general classification is presented in figure 1.

The discontinuous provers (figure 2) uses tray carriages (figure 3) on which the dough loaves are placed. This type of prover is mainly used for small production units.

The air conditioning systems are of small capacity but the control panel allows for temperature and humidity control. An improved air circuit inside the proofing chamber is shown in figure 4.

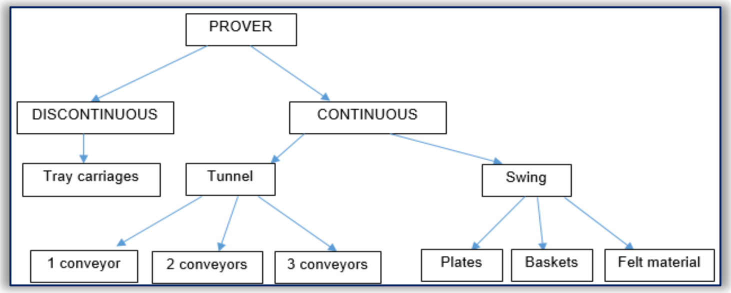
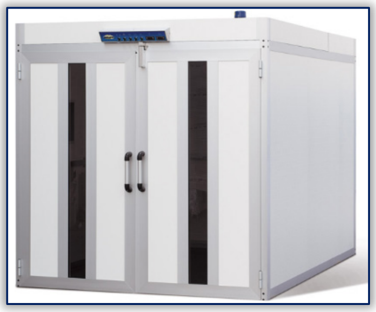


Figure 1 - Prover classification



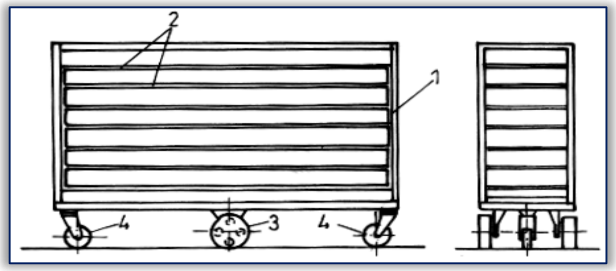


Figure 3 - Mobile carriages for discontinuous prover: 1 – metallic frame, 2 – plates, 3 – movement wheels, 4 – guidance wheels (Voicu Gh.. 1999)

Figure 2 - Discontinuous prover with two doors (source: internavytec.ro, castgrup.ro)

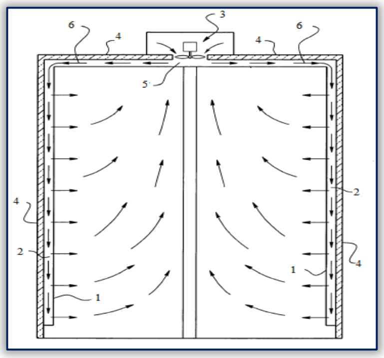


Figure 4 - Improved air circulation inside discontinuous prover / Dospitor discontinuu cu sistem îmbunătățit de ventilație în incintă: 1 – ventilation grids; 2 – air distribution pipes; 3 – fan; 4 – isolation panels; 5 – aspiration grid; 6 – air distribution. (Thompson Hine Llp. 2004)

Continuous provers are used in high capacity production units where usually, the processing stages are chained.

Tunnel provers are composed of an isolated tunnel through which travels one or more overlaid conveyors. The conveyor is charged at one end with dough loaves which are discharged at the opposite end. The proofing time is represented by the time it takes to cross the tunnel length. In order to facilitate the dough loaves transfer into the oven, the conveyor's width and speed must be the same with the ovens. In the case of tunnel provers, the leading element is represented by the oven. For example, if the oven's length is the same as the prover's, the proofing time will be determined as the baking time multiplied with the conveyor number.

The air conditioning unit has an automated control panel with integrated PLC (Programmable Logic Controller) which controls the input of temperature and humidity in the proofing chamber. The air is distributed in the prover using distribution pipes in arrangements that facilitate the uniformity of temperature and humidity values inside the proofing chamber.

A classic air conditioning unit is comprised of: gas-air heat exchanger (charged with steam at 105°C), gas-air heat exchanger (charged with chilled water at 5-7°C), a water cooling system, air filters, steam spray system (which charges the air with humidity up to 90%), flow fan, safety sensors and temperature and humidity sensors, electrical valves for heating, cooling and steam charge control.

Figure 5 - Tunnel prover with three conveyors (source: Pani Enterprise Arges)

A classic air conditioning system scheme is shown in figure 6. The newest tunnel provers have automated systems for conveyor length adjustment and dough infeed and outfeed which are synchronized with the automated scoring system and the oven infeed conveyor.

The prover with swings is composed of two parallel chains which form a conveyor that circulate on a series of carriers. At certain distances, the swings for dough proofing are suspended on the conveyor chains and are driven with a step by step elevator system. (Voicu Gh. 1999). This type of prover can be adapted for different types of swings, as shown in figure 8.

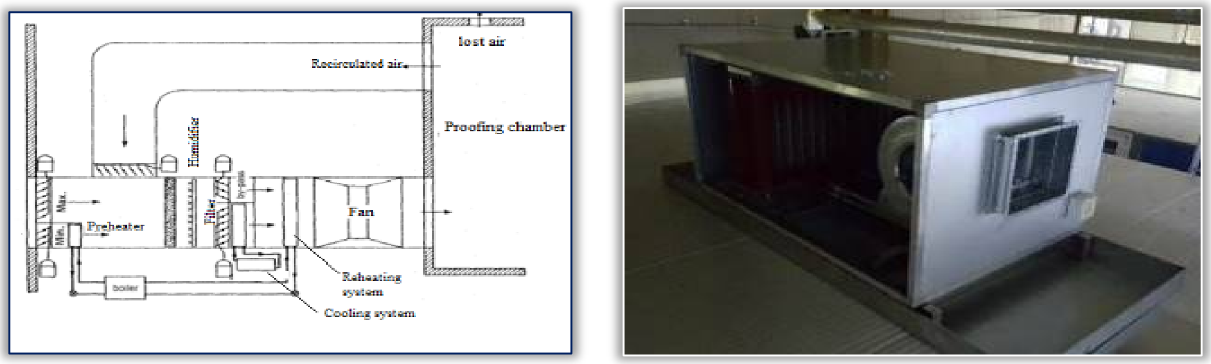


Figure 6 - Classical scheme for air conditioning unit - left. (Jennings. B.H..1978) and air conditioning unit for tunnel prover - right. (source: S.C Biotehnologicreativ SRL)

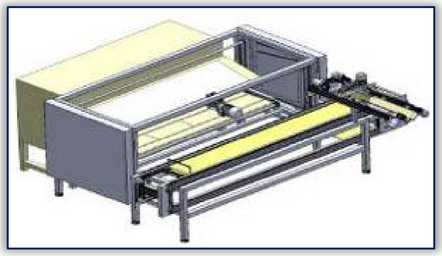


Figure 7 - System for automated infeed of tunnel prover (source: Technobit Automatizari SRL)

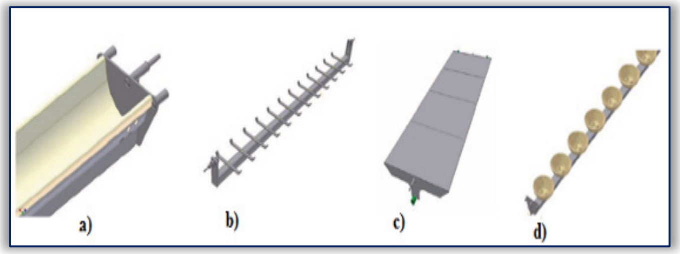


Figure 8 - Swing types: a) Metallic concave form with felt material support. b) swing for trays. c) straight plate. d) swing with baskets

A relevant example of prover designed for trays is shown in figure 8. Due to the complexity of the prover's functioning, all systems are automated and controlled with the help of an integrated control panel.

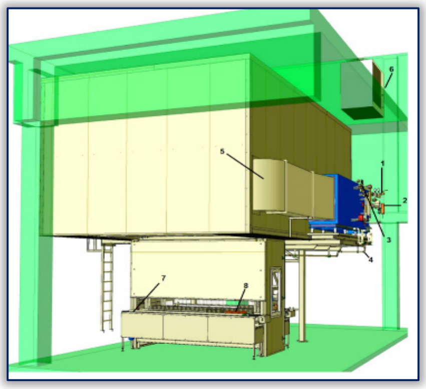


Figure 9 - Suspended tray prover-general view: 1. Steam spray unit. 2. Steam infeed unit for heat exchanger. 3. Chilled water infeed unit for heat exchanger. 4. Condensed steam collector. 5. Ventilation unit. 6. Water cooler. 7. Withdrawal conveyor. 8. Pushing tray device (Gostol Gopan. 2014)

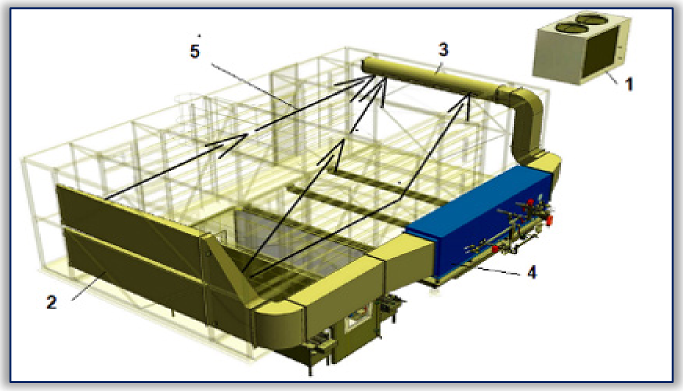


Figure 10 - Air circulation inside the prover: 1. Chiller. 2. Treated air charging. 3. Air aspiration from prover. 4. Air conditioning unit. 5 Air currents inside prover. (Gostol Gopan. 2014)

In the first phase, the air is charged with humidity thanks to the steam spray unit; in the next phase, the air passes through the steam based heat exchanger where is heated up to a set point level. The cooling system is automatically activated when the air temperature exceeds the set point value. The sensors for humidity and temperature permanently measure the values inside the prover, transmitting data to the PLC, which takes the appropriate decisions for keeping the temperature and humidity values within the set parameters. Figure 10 shows the air circulation inside the prover.

4. CONCLUSIONS

Although a variety of cereal grains can be used in baking, wheat flour is most commonly used due to the quality of its protein content to form a viscoelastic matrix, called gluten, which is largely responsible for dough's behavior during processing stages and gas retention during proofing.

Flour quality, recipe used (quantity of added water and yeast), the technological process, dough development, inclusion of air bubbles during kneading, gluten network capability to retain gas during proofing, environment parameters and equipment proficiency are some of the most important factors which must be taken into consideration in order to obtain bread of good quality.

During proofing the increase in volume is a result of yeast carbon dioxide production. The yeast used for bread manufacturing is Saccharomyces cerevisiae. Yeast metabolizes the sugar in the dough and produces carbon dioxide causing the gluten walls to expand. The conditions for growth are warmth, moisture and food.

The proofing stage takes place in closed spaces, called provers which by design, can be discontinuous or continuous, with different shapes and sizes, dependent on the specific technology applied. The most performant provers are completely automated. The proofing time is established according to the technological process and varies with dough mass, composition and consistency; in most cases, the proofing time is between 15 min and 60 min.

For optimal proofing results, the fermentation chamber must have a temperature value between 30 – 35 ℃ and a relative humidity of 70 – 85 %. A higher temperature requires a higher humidity level. The humidity level must not exceed 90%. These parameters are insured with automated air conditioning units which are designed to continuously deliver the set point values established to suit the technological process. Besides temperature and relative humidity, air circulation and the speed of air distribution inside the proofing chamber are of great importance because between these aspects there is an interdependence relation which influences the proofing process activity.

All stages in the bread making process are significant, but proofing is the defining operation that establishes crumb structure and overall appearance of the bread piece.

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References

[1] Akbar A.. Aamir S.. Moazzam R.K.. Muhammad A.S.. Muhammad R.A.. (2012). Yeast, its types and role in fermentation during bread making process-A Review. Pakistan Journal Food Science, 22(3) pp. 171-179;
[2] Blanchard C.. Laboure H.. Verel A.. Champion D.. (2012). Study of the impact of wheat flour type, flour particle size and protein content in a cake – like dough: Proton mobility and rheological properties assessment. Journal of Cereal Science. Vol. 56. pp. 691 – 698;
[3] Bordei D.. (2007). Quality control in bread making industry – Analysis methods. (Controlul calitatii în industria panificatiei – Metode de analiza). Ed. Academica. Galati;
[4] Burluc R. M.. (2007). Technology and quality control in bread making industry.(Tehnologia şi controlul calităţii în industria panificaţiei). Galati. http://www.scribd.com;
[5] Campbell. G. M.. (1991). The aeration of bread dough during mixing. PhD Thesis. (University of Cambridge);
[6] Cauvain. S. P.. Whitworth. M. B.. & Alava. J. M. (1999). The evolution of bubble structure in bread doughs and its effect on bread structure. In G. M. Campbell. C. Webb. S. S. Pandiella. & K. Niranjan (Eds.). Bubbles in food (pp. 85–88). St. Paul. MN: Eagan Press;
[7] Cauvain S.P.. 2000. It's got form. European Baker. Vol. 38. pp. 24-28;
[8] Chin N.L.. Campbell G.M.. Thompson F.. (2005). Characterisation of bread doughs with different densities, salt contents and water levels using microwave power transmission measurements. Journal of Food Engineering. Vol. 70. pp. 211-217;
[9] Cuq. B.. Abecassis. J. & Guilbert. S. (2003). State diagrams to help describe wheat bread processing. International Journal of Food Science and Technology. 38. 759-766;
[10] Giannou. V.. Kessoglou. V. & Tzia. C. (2003). Quality and safety characteristics of bread made from frozen dough. Trends in Food Science and Technology. Vol. 14. pp. 99-108;
[11] Gostol Gopan. (2014). Fermentation chamber FKP K140. Technical brochure. (Camera de fermentare FKP K140. Broşura instalaţiei);
[12] Hwang C. H. and Gunasekaran S.. (2000). Determining Wheat Dough Mixing Characteristics from Power Consumption Profile of a Conventional Mixer. Cereal Chem. Vol. 78. pp. 88-92;
[13] Hutkins. R.W. (2006). Bread fermentation. in Microbiology and Technology of Fermented Foods. ed. By Blackwell Publishing. pp. 261-299;
[14] Jennings. B.H.. (1978). The Thermal Environment: Conditioning and Control. Harper & Row. New York;
[15] Peighambardoust S.H.. Fallah E.. Hamer R.J.. van der Goot A.J.. (2010). Aeration of bread dough influenced by different way of processing. Journal of Cereal Science. Vol. 51 Issue 1. pp. 89-95;

[16] Sahlstro¨m. S.. Park W.. and Shelton D. R.. (2004). Factors influencing yeast fermentation and the effect of LMW sugars and yeast fermentation on hearth bread quality. Cereal Chemistry. Vol. 81. Issue 3. pp. 328–335;
[17] Shah. P.. Campbell. G. M.. McKee. S. L.. & Rielly. C. D. (1998). Proving of bread dough: modelling the growth of individual bubbles. Transactions of the Institution of Chemica lEngineers. Part C. Vol 76. pp. 73–79;
[18] Sinelli N. Casiraghi E. Downey G.. (2008). Studies on proofing of yeasted bread dough using near- and mid-infrared spectroscopy. J Agric Food Chem. Vol 56. pp. 922–931;
[19] Sluimer P. (2005). Principles of breadmaking: functionality of raw materials and process steps. St. Paul: The American Association of Cereal Chemists Inc.;
[20] Thompson Hine Llp. (2004). Dough proofing apparatus and related methods. US Patent Application Publication. US 2004/0226457. NOV. 18;
[21] Voica D.. (2010) Reaserches regarding yeast activity in dough. Technological aspects. (Cercetări privind activitatea drojdiei în aluat. Aspecte tehnologice). PhD Thesis;
[22] Voicu Gh.. (1999) Processes and equipments for bread making industry. (Procese si utilaje pentru panificatie). Bren Publishing House;
[23] Xu J.. Bietz J. A.. Carriere C. J.. (2007). Viscoelastic properties of wheat gliadin and glutenin suspensions. Food Chemistry. Vol. 101. pp. 1025-1030.

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