EXPERIMENTAL RESEARCH ON ENERGY CONSUMPTION IN THE LAMINATION AND DRAWING OF DOUGH
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CERCETĂRI EXPERIMENTALE PRIVIND CONSUMURILE ENERGETICE LA LAMINAREA ȘI TREFILAREA ALUATURILOR

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ABSTRACT
This paper presents an analysis of the variation of energy consumption in the lamination and drawing process of bagel doughs. Also, the paper highlights the farinographic characteristics (water absorption, dough development time, and dough stability, degree of dough softening and farinographic index) of the flour used for the dough preparation for which the energy consumption during lamination and drawing was determined.

REZUMAT
Lucrarea dată prezintă o analiză a variației consumului de energie în procesul de laminare și trefilare a aluaturilor de covrigi. De asemenea, în lucrare se evidențiază caracteristicile farinografice (capacitatea de hidratare, timpul de dezvoltare a aluatului, stabilitatea aluatului, gradul de înmuiere a aluatului și indicele farinografic) ale făinurilor folosite pentru prepararea aluaturilor pentru care s-a determinat consumul de energie la laminare, respectiv trefilare.

INTRODUCTION
Shaping dough for bagels between counter-rotating profiled rollers of the lamination and drawing system, having the same or different diameters, is an operation often used in the bakery industry as a dough forming process. Repeated rolling of the dough is clearly an advantage to produce a structured system of it (*Bousquieres J. et al*., *2014*). This type of operation is performed for a wide range of bakery products, contributing to the development of the dough structure (*Haegens N., 2018; McCann Thu. H. et al., 2013*; *Munteanu et al, 2015; Steffe J.F., 1996; Yao N., 2004).* The deformation of the dough pieces by the mechanical action of rigid elements not only determines the improvement of the physical-mechanical properties of the previously divided dough, but also contributes to defining the aesthetic shape of the finished product (*Băisan I., 2023).*

The evaluation of the dough is made by its consistency, which represents a property of its rheological, complex nature, resulting from the combination of viscosity, plasticity, elasticity and which varies with humidity, temperature and time, with the proportion between the phases of the dough (solid-liquid-gas), with the biochemical composition of the flour, etc. The consistency of the dough is measured organoleptically, by feeling, or with the help of consistometers (with immersion penetrometers or by comparison with a standard kneading installation - farinograph). It influences the yield of the baking technological process. Dough consistency is measured in Brabender units (1 UB ≈ 10-3 daN·m). The dough is considered to have a normal consistency when it requires a maximum kneading time of 500 UB.

In the paper *(Munteanu et al, 2015)*, the lamination process is compared to the calendering process, which is often used in the paper, plastic, steel industry, etc. In this process, the piece of dough, properly dosed, is successively passed through one or more pairs of rollers, which by pressing is compacted and adjusted from greater to lesser thickness, forming a thin dough sheet, (*Yao N., 2004)*. Repeated lamination of the dough results in dough strips of uniform thickness and homogeneous structure, making the dough more plastic and easier to shape (*Băisan I., 2023).*

The mechanical stress behaviour of wheat flour dough is similar to viscoelastic bodies and can be described rheological by various constitutive mechanical models, which estimate the dough more or less accurately, (Burgers body, Bergstrom-Boyce) (*Mohsenin N.N., 2020; Patel M.J. et al., 2013; Chakrabarti Bell S. et al., 2010).*

Drawing process differs from lamination process in that the resulting dough is drawn between two profiled rollers and shaped into wicks/noodles of a certain thickness/width and length. This is due to the drawing rollers which are provided with grooves (circular for breadsticks, rectangular for hooks, etc). The drawing machines are equipped with devices for cutting the dough strands to different length and also have conveyor belts for transporting the strands to the next processing machine in the technological flow (*Băisan I., 2023).*

In specialized literature, the effects of sheeting is intensively researched in bakery, because the operation influences the quality of the finished product. In one of the most recent papers, *(Albasir M.O.S. et al., 2022)*, investigated, using the dynamic dough density technique, the effects of this operation on the development of the doughs used in the bakery, as well as on the baking process. In terms of volume and structure (for bread), the effects of the sheeting regime were examined on various bread doughs and pretzels made with different percentages of bran, having as a control sample a sample of dough without bran, these being laminated to a thickness of 6 , 9 and 12 mm. The results showed that the dough laminated to a thickness of 6 mm had a better gluten development, although the voids of gas development were less and with a larger average diameter.

Many scholars claim that dough lamination is more efficient from an energetic point of view, although from a mechanical point of view it is a complex process *(Kilborn R.H. et al. 1974; Levine L., 1996; Qi F. et al., 2008; Patel M. et al. 2013)*.

As a result of compacting the dough, a number of effects occur during the lamination/drawing process, such as: the evacuation of air from the dough mass, thus avoiding the worsening of its characteristics, an effect which could be produced by enzymatic oxidative processes; the transformation of the dough into a homogeneous and uniform mass with viscoelastic characteristics, characteristics produced as a result of the flour particles sticking together *(Dogan H. et al., 2006).*

In their paper, *Naik H.R. et al., (2007)*, compared bagels made from normal (control) flour dough with bagels made from different levels of added defatted soy flour. So, the second type of bagels had a decrease in moisture, fat, non-reducing sugars and starch. In the same time increased ash, protein, reducing and total sugars. On the other hand, the organoleptic evaluation of the bagels showed that a 5% level of defatted soy flour resulted in bagels with a texture, colour and flavour above the average level of acceptability. At the same time, bagels with added deffated soy flour had a longer shelf life (about 90 days in laminated bags) regardless of the amount of added defatted soy flour.

Response surface methodology (RSM) was used by *Paykary M. et al., (2015),* to study the optimization of leavening agents in extruded gluten-free brewer's rice hard pretzel. Through RSM was optimized the effects of yeast and bicarbonate of soda on several physical and mechanical properties (fracturability, porosity, hardness, expansion ratio, specific length, density, surface colour, water absorption index, water activity, and others). In conclusion, for the gluten-free pretzel is necessary 2.59 g bicarbonate soda and 8.05 g yeast at every 500 g of brewer’s rice flour.

Pretzels are a focused area for the researchers in bakery. In paper *(Schoenauer S. et al, 2019)*, the authors have applied some aroma extract dilution on pretzels to increase the flavour and aroma. The extract was obtained from the crust of freshly baked soft pretzels. *Dhaygude et al.* in their supplemented pretzel dough with barley flour and used as a natural sweetener honey paper *(Dhaygude V. et al., 2017)*. They varied honey between 20 - 40%, wheat flour between 50 and 80 g and barley flour between 20 and 40g. The results were analysed by the same RSM.

Physico-chemical properties, dough manoeuvrability and pretzel properties (as a final product) were investigated in paper written by *Naik H.R. et al., (2014).* The authors added soy flour in wheat dough in percentage of 0, 5, 10, 20 and 30%. The results showed that some properties (as development time for dough, dough stability, water absorption and dough consistency) increased their value, and some properties decreased their value (softening degree, mixing tolerance index, peak viscosity, gelatinization temperature) with addition of soy flour. The authors made also an organoleptic evaluation and found that at 5% soy flour pretzels have the best flavour, colour and texture and recorded an shelf life of 90 days.

The objective of this paper is to present the flour curves for three samples of wheat flour used in the preparation of bagels doughs, which were the samples for which the variation in energy consumption during lamination and drawing was determined. In order to show the variation of energy consumption in lamination and drawing, the experimental data obtained were processed in MS Office Excel.

MATERIALS AND METHODS

The experimental research was carried out at the Department of Biotechnical Systems, Politehnica University of Bucharest. To carry out the experiments, three commercial types of white flour type 650 were used: FA1 with a moisture content of 9.56%, FA2 with a moisture content of 10.45%, FA3 with a moisture content of 11.59%, and the quantities of ingredients used to prepare the doughs were: 1 kg flour, 45% water and 10% oil in relation to the quantity of flour, 12 g salt, 5 g yeast, 100 g sugar. A DitoSima BM20S spiral-arm planetary mixer was used both for mixing the pretzel recipe components and for kneading the dough. The mixing time of the recipe components was 2 minutes in the first gear of the kneading arm, and 10 minutes in the second gear to carry out the dough kneading process.

After preparing the doughs, they were taken out of the kneading trough, rolled out by hand with a wooden roller into a sheet about 13 cm wide, 89 cm long and about 1 cm thick, to ensure an initial thickness of the dough before lamination. The dough sheets obtained were inserted between the lamination and drawing rolls of the dough strand machine. The rolls speed was 40 rpm, the distance between the lamination rolls was set in the 6th step, i.e. 2.7 mm, and the working space for drawing was a rectangle with length L = 6.1 mm and width l = 2.3 mm.

For the flours used in the experiments, farinographic determinations were made using the Brabender Farinograph-E, an electronic apparatus consisting of a special biuret used to measure the amount of water and a mixer with two "∑" shaped kneading arms that rotate in opposite directions. The mixer tank has a capacity of 300 g and is fitted with a double jacket through which distilled water is recirculated at a temperature of 30 ± 1°C. The farinograph software plots, in real time, the farinographic curve. This curve is indicating the rheological characteristics of the dough, which is the basis for assessing flour quality. The flour curve is drawn as a result of the resistance of the dough to the kneader shaft.

Flour farinographic characteristics indicates usually the quality of flours. These characteristics are of particular importance in the technological process of obtaining both bakery and pastry products *(Păucean A. et al., 2015; Qi F. et al., 2008).*

During the kneading operation, flour and water are gradually transformed into a homogeneous viscoelastic dough, the moistened flour particles bind to each other forming, at first, small agglomerations that grow slowly, eventually binding together to form the dough with elasto-visco-plastic properties from which the air has been removed. The mixing process promotes several physical, chemical and physico-chemical changes that lead to the development and formation of dough. Of course, the kneading process is one way to characterize the quality of flour samples.

Not all types of flour are equally suitable for a specific end product. Determining the quality of flour is therefore of particular importance as it relates to the desired end product and its manufacturing process (*Ștefan E.M. et al., 2013).*

The following test steps were carried out with the Brabender electronic farinograph according to the following methods AACC 54-21, ICC 115/1, ISO 5530-1 *(Păucean A. et al., 2015; http://www.maxmixers.com/sigma-mixer/sigma-blade-mixer/hydraulic-tilt-soap-and-dough-sigma-blade.html):*

- 300 g of flour were weighed with a Kern precision 0.1 g balance;
- the flour has been placed in the mixer bowl;
- covered the blender with the transparent plastic protective cover;
- the device was started, and after the flour had been mixed for 60 seconds, water was added from the dough mixer; the volume of water added to form the dough is close to the volume needed to obtain a dough with a consistency of 500 BU;
- during the mixing of the ingredients inside the mixer bowl, the computer screen of the Brabender farinograph software program records and plays back the farinographic curve;
- the plotting of the farinographic curve continues for at least 10 minutes after the close of development time;
- when the "end of test" message appears, switch off the machine and clean the mixer;

An example of a farinographic curve is shown below in Figure 1.

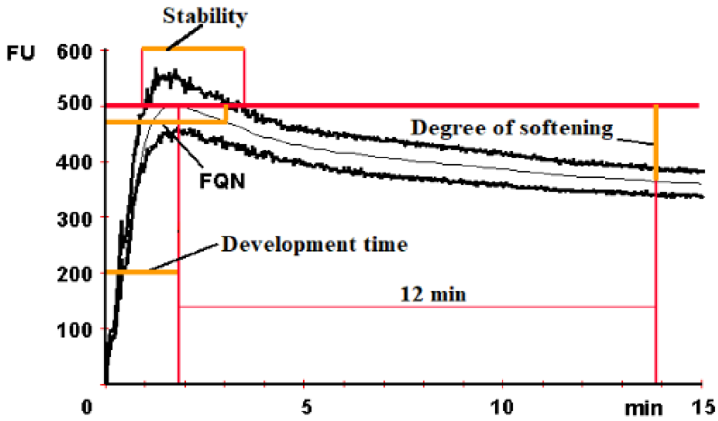

Fig. 1 - Example of farinographic curve and how to interpret it (*Voicu Gh., 1999)*

On the farinographic curve (figure 1), given by the resistance of the dough to kneading, one can read:

- water absorption – the amount of water absorbed by the flour to form the dough with a standard consistency of 500 FU (1 FU = 1 BU - Brabender Units, 1 BU ≈ 10^{-3} daN·m);
- dough development time - indicates the time from when water is added until the dough reaches the maximum consistency of 500 FU;
- dough stability – indicates the length of time the dough retains its normal consistency of 500 FU; stability time is correlated to flour strength;
- degree of softening – indicating when the dough has broken down *(Qi F. et al., 2008)*.

RESULTS

After recording the farinographic curves using the Brabender E-Farinograph (Figure 2), the characteristics of the farinograms obtained were read and noted in Table 1. The data obtained must fall within the ranges of the values of the assessment indicators in Table 2.

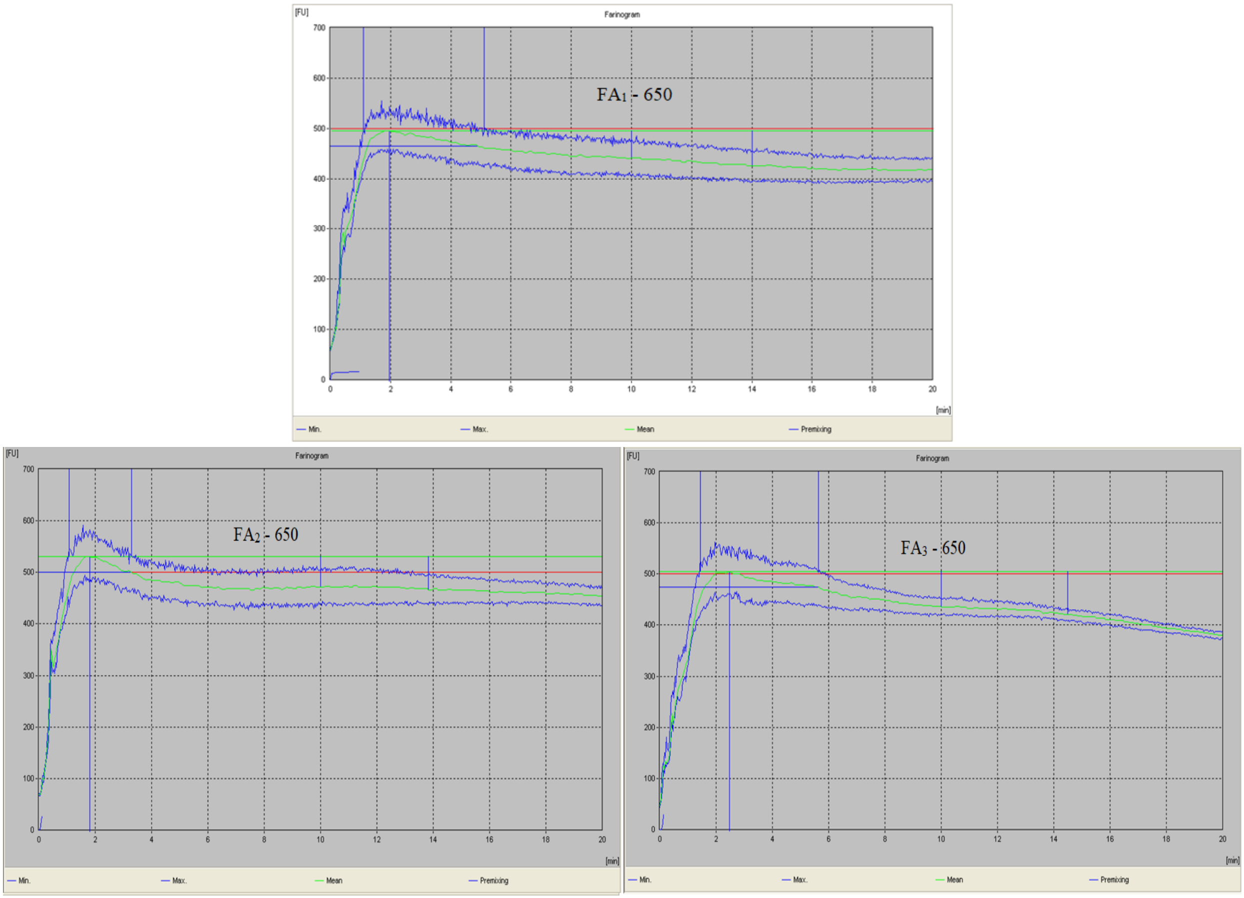

Fig. 2 - Farinograph curves experimentally obtained with the Brabender farinograph for dough made from the three types of FA 650 type of wheat flour (FA_1, FA_2, FA_3)

Table 1

Farinograph characteristics for the three commercial types of wheat flour FA_1 650, FA_2 650, FA_3 650

Farinograph characteristics	Wheat flour FA 650		
	FA_1	FA_2	FA_3
Water absorption [%]	65.7	62.1	60.1
Corrected for 500 [FU]	65.6	62.2	60.2
Dough development time [min]	2	1.8	2.5
Dough stability [min]	4	2.2	4.2
Degree of softening [FU]	70	59	69
Farinograph index	49	33	56

Table 2

Criteria for assessing flour quality, *(David A.P. et al., 2009)*

Flour	Farinograph characteristics				
	Water absorption [%]	Dough development time [min]	Dough stability [min]	Degree of softening [U.F.]	Farinograph index
Very good	more than 65	more than 3	more than 8	under 60	more than 65
Good	60 - 65	2 - 3	5 - 8	60 - 80	50 - 65
Satisfactory	55 - 60	1.5 - 2	3 - 5	80 - 100	40 - 50
Unsatisfactory	less than 55	less than 1.5	less than 3	more than 100	Sub 40

From the analysis of the curves and farinographic parameters in Figure 2 and Table 1 for the three types of FA 650 wheat flours, it can be seen that the dough development time values vary within narrow limits, from 1.8 minutes to 2.5 minutes, and this observation leads to the fact that the three commercial types of flours fall in terms of development time within the standard values of a satisfactory to good flour.

The standard values of a good flour also include the water absorption values, which have been corrected by the farinograph so that the other farinographic parameters can be properly estimated and interpreted.

Regarding the data obtained for the stability time, it is observed that the lowest value, i.e. 2.2 minutes was recorded for white flour FA_2, while for white flour FA_3, an average stability time of 4.2 minute was recorded, followed by of a stability time of 4 minutes for FA_1 flour. Through this analysis, it can be concluded from the point of view of dough stability time, FA_2 flour falls within the standard values of an unsatisfactory flour, and the dough stability time of FA_3 and FA_1 flour falls within the standard values of some flours satisfying.

Also, in the farinographic curves in Figure 2 and Table 1, both the softening degree of the dough and the farinographic index, index by which the quality of the flour is assessed, are presented. It can be seen that the values of the degree of softening for FA_2 flour fall within the standard values of a very good flour, while the farinographic index ranks it as an unsatisfactory flour.

The values of the degree of softening and the farinographic index for the FA_3 flour place the flour in the standard values of a good flour, while the values of the degree of softening and the farinographic index for the flour FA_1 place it both in a satisfactory and good flour, respectively.

FA_3 flour shows the most parameters that correspond to flour from the category of good flours, and FA_1 and FA_2 flours show values that fall within several standard parameters for several flour categories

The results obtained for the energy consumption in lamination and drawing are presented in Table 3.

Table 3

Dough parameters and energy consumption during lamination and sheeting

Flour	Moisture content (%)	Water absorption, (ch %)	Energy consumption in drawing ($x10^3$ J)	Specific energy consumption in drawing ($x10^3$ J/kg)	Energy consumption in lamination ($x10^3$ J)	Specific energy consumption in lamination ($x10^3$ J/kg)
FA_1	9.56	65.6	9.00	5.39	11.52	6.91
FA_2	10.45	62.2	6.84	4.10	10.80	6.47
FA_3	11.59	60.2	6.48	3.88	9.72	5.83

From Table 3 and Figure 3, it can be seen that the energy consumed for sheeting and lamination of dough pieces prepared with the three types of flour is different and show that they increase with decreasing moisture content and increasing hydration capacity of the flour.

Considering that the quantities of water in the recipe were respected, 45% water and 10% oil in relation to the quantity of flour, and that the hydrating capacity of the flour and the moisture content were not taken into account, it can be said that the difference in the energy consumption values is due to the small quantities of water and oil used to prepare the dough.

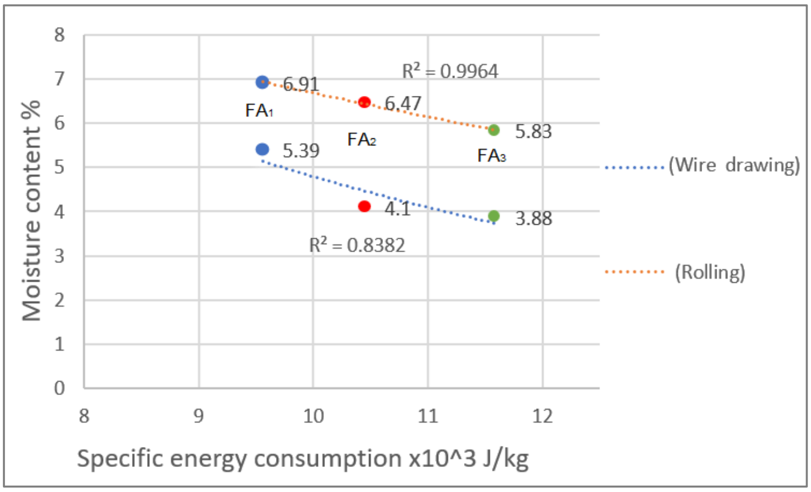

Fig. 3 - Variation of energy consumption in the lamination and drawing of bagel dough

Considering the 11.59% moisture content of FA_3 flour and the water absorption of 60.2%, the quantities of water and oil in 55% of the flour quantity were sufficient to produce a dough that resulted in a consumption of $6.48x10^3$ J in lamination and $9.72x10^3$ J at drawing, compared to the energy consumption recorded for the dough made from FA_2 flour with moisture content of 10.45% and 62.2 % water absorption, respectively for the dough made from FA_1 flour which had a moisture content of 9.56% and 65.6 % water absorption.

For the dough prepared with FA_1 650 flour, the quantities of water and oil were not sufficient to cover the required flour water absobtion of 65.6%, and this led to an increase in energy consumption to 9.00x103 J for lamination and 11.52x103 J for drawing.

CONCLUSIONS

Analysing the data presented, it can be seen that the values of the flour parameters for the three types of flour analysed varied within wide limits, so that the flours fell into several standard parameters of several flour categories (they cannot be placed in a single category/class). The flour that showed the most parameters that met the criteria for a good flour is FA_3 flour (water absorption of 60.1%, dough development time 2.5 minutes, degree softening of 69 FU).

An increase in the moisture content and a lower value of the water absorption of the flour led to a decrease in the energy consumption during drawing from 11.52x103 J to 9.72x103 J, but also to a decrease in the energy consumption during lamination from 9.00x103 J to 6.48x103 J. It should be noted that these values, which were also the lowest, are recorded for FA_3 flour which also showed the best farinographic characteristics.

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