U.P.B. Sci. Bull., Series D, Vol. 69, No. 4, 2007. ISSN 1454-2358

RESEARCHES REGARDING THE USE OF CONE PENETRATION FOR RHEOLOGICAL BEHAVIOUR CHARACTERIZATION OF SOME WHEAT FLOUR DOUGHS

Tudor CĂSĂNDROIU[1], Gheorghe VOICU[2], Li-Hua Ioana CHIH[3]

În această lucrare prezentăm rezultatele cercetărilor privind posibilitatea caracterizării consistenței aluatului din făină de grâu (o proprietate a comportării reologice pentru materialele cu caracteristici vâsco-elastice) prin variația adâncimii de penetrare în funcție de timp a unui con acționat de greutatea proprie.

În cadrul experimentărilor s-a utilizat un con plin din Plexiglas cu unghiul la vârf de 90^o și având masa de14.1 g. S-au utilizat probe din aluaturi preparate prin hidratarea (cu și fără sare din comerț, 1.5 g) a 100 g din diverse tipuri de făină de grâu autohton cu 55 ml apă distilată. A fost testată valabilitatea legii lui Velon de tipul $h = a \cdot \ln t + b$, *(h – adâncimea de penetrare, t – timpul, a, b – coeficienți), pentru care s-a găsit un coeficient de corelație* $R^2>0,97$ *și posibilitatea de a caracteriza consistența aluatului (direct legată de calitatea glutenului obținut prin componenta sa glutenina, care conferă preponderent proprietatea de elasticitate a aluatului vâsco-elastic) prin adâncimea maximă de pătrundere a conului,* h_{max}.

Informațiile obținute sunt utile atât la elaborarea unei proceduri de testare a calității de panificație a unei făini, cât și a selecției și dozării materiei prime.

In this paper is presented the researches results regarding the possibility to characterize the wheat flour dough consistence (an important property of its rheological behaviour as a material with viscoelastic properties), by variation of depth penetration vs. time, of a cone drived by his gravitationally weight.

During experimentations it was used a standard solid plexiglas cone with a 90^o apical angle, drived by his gravitationally weight corresponding to mass of 14.1 g. It is used dough samples prepared by hydration (with and without salt, 1.5 g) different wheat flours from Romania zone, with 55 ml distilled water for flour amount 100 g. It was tested the Velon law currency type $h = a \cdot \ln t + b$, *(h – penetration depth, t – time, a, b – coefficients), for which was found a correlation coefficient* $R^2>0,97$ *and the possibility to appreciate the dough consistency (in direct relation with the gluten quality, by his component glutenine, which preponderant confer the elasticity property of viscoelastic dough) through the maxim depth of penetration,* h_{max}.

The obtained data are used both to elaborate a testing procedure for flour bread making quality and for selection and dosing the raw materials.

Key words: wheat flour dough, bread, quality, consistence, rheological properties, cone penetration

[1] Prof., Dept. Of Biotechnical Systems, University "Politehnica" of Bucharest, ROMANIA
[2] Prof., Dept. Of Biotechnical Systems, University "Politehnica" of Bucharest, ROMANIA
[3] Eng., Drd, Dept. Of Biotechnical Systems, University "Politehnica" of Bucharest, ROMANIA

1. Introduction

The quality of a flour from the point of view of the characteristics suited for bakery, the production of sweets, or for the production of pasta, it is also evaluated through the physical and chemical properties (humidity, the ash, protein, acidity, finesse, colour, etc.), but it is taken into consideration also the mechanical and rheological properties of the prepared dough, in a couple of standard conditions, from the specific flour, [6,8,11,13,15,16,21,23,24,25].

The characteristics regarding the resistance of the dough made from wheat flour are important statements in regard with the qualitative evaluation of different types of wheat flour, and also in the selection of the raw material, either for the production of pasta or for the production of baking or sweet goods. The fundamental rheology is offering the parameters for the correct evaluation of the resistance of the dough in specific conditions in the presence of great tensions or deformations, and also of the data regarding the linear viscoelastic properties of the material. The different rheological methods (the creep test – constant tensions and/or the relaxation test – constant deformation), and also the dynamic rheoviscometric tests are being employed for the clarification of certain contributions of different components of the wheat flour regarding the viscoelastic properties of the dough, [6,8,9,11,13,20,21,23,24,25].

The wheat flours (dry substance) used, usually in the baking system, are being composed from proteins (10.1–12.94%), starch (62.73%–69.35%), sugars, cellulose and penthosans (4.57%–8.06%), lipids (1.57%–2.11%), mineral slats (ash) (0.48%–1.26%), vitamins, pigments, [1,12]. The humidity content of the wheat flour, for maintaining the quality for storage, is of 12%–14.5%. The main component of the proteins who are forming the glutenic proteins (≈85%) – glutein and gliadin – have the capacity, in the presence of water, to absorb it, and to inflate and to form a viscoelastic mass, called wet gluten (in a ratio of 22%–30% from flour), [1,12]. The wheat dough can be considered a compound material in which the gluten is forming a continuous matrix, and the starch particles are considered to be cast particles inside of this matrix.

The baking properties are also being influenced by the biochemical composition of the wheat flour, which is referring to the enzyme content – amilazyn and proteazyn – and which is exerts an action of disruption of the rheological properties of the dough, [1].

Also, from the physical characteristics of the flour, the granular structure is occupying an important place, and is influencing the rheological properties of the dough and the quality of the bakery products, [1,5]. Regarding the granular structure, our wheat flours, have the dimension of the particles until 160 μm, [12].

In [22], it was highlighted that the storage duration of the flour over 46 weeks, has a very important significance upon the consistency of the dough by consistency increasing, because of the gluten modifications with negative consequences over the quality of baking.

The proteic component through the wet gluten is a major factor in the evaluation of the dough's resistance to mixing, of the processing properties and of their rheological characteristics, [1,6,7,10,15,16,20,23,24].

Other details regarding the influences of the components of the flour over the rheological behaviour of the dough, and the evaluation of its specifically baking properties are being presented in [4].

The influences of different factors over the quality of the wheat flour, regarding the baking properties, are in a major way expressed trough the rheological properties, determined with the help of the specialized apparatus, which are utilizing, either the dough prepared from it, or are reproducing the process of obtaining the dough, [1,2,6,8,11,13,15,16].

Methods were developed and perfected and also adequate apparatus, which are used also in industrial labs and in scientific research labs. Those methods are being described in national, regional or international standards/protocols and in scientific literature, [1,2,6,8,11,13,15,16].

For determining the rheological properties of the dough, there can be used a suite of apparatus like the following: the pharinograph, the alveograph, the mixograph, and the extensograph. The behaviour of the dough is being presented in the curves drawn by these apparatus for the entire duration of the tests, using dough samples, in which the accuracy and precision of the reading is depending, in a major way, by the skill of the reader, [2,15,16]. Trough the values of this properties (the capacity of water absorption of the flour, the formation length-development of the dough, the stability, the moistness, the power of the flour, the elasticity, the extensibility, the resistance to deformation, etc.) the quality of the flour is being evaluated, from the perspective of the baking properties. To this we add the falling index (the index Hagberg – falling number, [15]), which is containing information regarding the content of the amilaza enzyme (especially α-amilaza) which has an activity to hydrolyze of the starch, influencing the gelatinization capacity of the starch, with direct implications over the quality of bread, [1,15]. Also, the rheological behaviour of the wheat flour doughs was researched, considering the humidity content, using the capillar plastometer, [18,19].

The permanent concerns of the researchers are being directed to the development of the simplest, quickest, and easiest but sure testing methods of the dough, for the evaluation of the baking properties of the dough, made from wheat flour, [4].

Our researches are being oriented in regard with the usage of the cone penetrometer method, during the testing of the dough consistency, in correlation with the firmness of the structure – texture of it, after the methodology described in [7]. This method is largely employed in the pharmaceutical industry, [14], and for the petroleum products, asphalt, beauty products and other semi-solid materials, [7].

At the testing of the wheat flour dough, the cone penetrometer method was being used at the testing of the consistency of the dough, [17], and at evaluating the influence of the sugar – salt solution, over the dough, [10]. This method was used by the authors at the study of the firmness of the texture of the pulp of the fresh apples after storage, in regard with the degree of ripe, [3]. Also, the results of our research with the same method, using samples of the wheat flour, presented in [4], it encouraged us to develop new researches in this regard.

The research is being a part of the same trend, and it has the following objectives: a) the testing of the dough consistency prepared from different wheat flours after the storage, using the cone penetrometer; b) the testing of the validity of the Velon's law, of the variation of the penetration depth in the dough of the cone, having time as an background parameter; c)the comparative evaluation of the differences in consistency of the dough, because of the length of the storage time; d) the evaluation of the influence of preparing conditions of the dough, over its consistency; e)the evaluation of the rheological characterisation of the dough behaviour, using the method of the cone penetrometer, towards the identification of new procedures, in the evaluation of the baking qualities of the wheat flours.

2. Theoretical Considerations

The consistency (firmness) of the wheat flour dough is one of the most important rheological properties of the materials belonging to the semi-solid category, in which the dough can also be included, [6,7].

For the measurement of the consistency the cone penetrometer method is used most frequently, by measuring the penetration depth of the cone under the pressure of its own weight.

Many international standards are describing procedures for the employment of the tests on different semi-solid materials, like, for instance: petroleum products, beauty products, pharmaceutical products, foods industry, construction industry, and other semi-solid materials, [7].

The penetration depth of the cone can be correlated with the structure-texture firmness of the dough, and also its consistency, [16].

In regard with the [4,10] considerations, at the equilibrium state of the cone, which is corresponding to the maximum penetration depth, we meet the relation:

$$P = K_{\alpha}^{*} \cdot h_{\max}^{2} \cdot \tau_c \tag{1}$$

where: P is the pressure force (own weight), in (N); h_{max} – the maximum penetration depth of the cone, in m; τ_c – the shearing yield limit of the dough, in

(Pa); K_α^* – the constant of the cone which is depending solely of the angle from the top of the cone.

From the 1 equation, it can be written:

$$h_{\max} = \left(\frac{P}{K_\alpha^* \tau_c} \right)^{1/2} \tag{2}$$

From the 2 equation, it can be stipulated that from a given cone, trough the α angle, and its own weight P, the maximum depth h_{max}, is depending only from the shearing yield limit τ_c, of the dough (the parameter which is describing the consistency of the dough), i.e. h_{max} is a measure of the consistency of the dough.

In regard with the variation of the penetration depth h, versus time t, in paper [14] it is being highlighted the validity of an equation empirical semi-logarithmical, in the situation of the pharmaceutical products, due to Velon, this being:

$$h = a \ln t + b \tag{3}$$

where: a and b are constant coefficients, risen from the experimental data.

The "b" coefficient is mainly dependent on the consistency of the product, so it can be sued as a value of this particular characteristic, [14].

The penetration speed of the cone v_c, vs. time t, it's being obtained from the (3) equation, and is being derived in accordance with the time.

$$v_c = \frac{dh}{dt} = \frac{a}{t} \tag{4}$$

Relation (4) is a hyperbolic type and from the beginning indicates a significant speed variation and insignificant at the end of the penetration.

We will analyze equation validity (3) related to wheat flour doughs and if there are possibilities to identify differences between flour types, related to cone's penetration speed in dough.

The relation validity (3) was tested by authors, with good results, in case of fresh apples pulp, resulting a correlation between the value of coefficient "b" and the ripe degree of texture apples (i.e. changing of consistence), [3].

Also the authors had indicated the validity of Velon's law in case of dough made from different types of wheat flour, [4].

In concordance with the suggestions from [10,14] we will evaluate the possibility either cone's depth penetration for a certain period of time or the duration to reach certain depth penetration so it can be taken as dough's consistence measure. Other information's related to these theoretical considerations are present in our paper work [4].

Within the framework of our experiments have been searched as well as in the working [4], validity of relations (3) and (4) and getting of the most plausible answer to the questions: 1) What is the most significant parameters (h, v_c) to define the dough's consistency (a rheological complex feature of the dough)? 2) Which of the two following parameters is more suitable to define the dough's consistency: the penetration depth h appropriate to a certain imposed duration t, or the duration t necessary to penetrate into an imposed depth of the cone? 3) To what extent and what time the penetration speed of the cone v_c is relevant to define the dough's consistency?

3. Materials and methods

In experiments have been used the same three wheat flour types, that is FA-480a, FA-650 and FN-1250, like the ones used in previous experiments from 2006, [4], after 12 months of conservation on laboratory environments terms.

These flours proceed from the production of year 2005, the southern zone of Romania, manufactured by SC. Spicul SA-Bucharest. The contents of humidity have been respectively of 11.5, 11.4 and 12.29%, and afferent ashes of 0.40-0.44%, 0.65-0.70% and 1.23-1.30%. The experimental doughs have been made in two variants: (175 g flour and 96.25 g distilled water) and (175 g flour and 96.25 g distilled water and 2.7 g salt), so it is 55 ml water to 100 g flour and 1.5 g salt to 100 g flour.

The mixture of ingredients and kneading has been made for 15 min, by using a dough-kneading machine, model Millers Choice, equipped with a single paddle shaft, at 150-160 revolutions/min, on a chamber temperature of 21-22^{0}C.

Before making the measurements after kneading, the dough was kept under rest, in a water bath on a temperature of 21-22^{o}C for 15 minutes. It has been used the working mode as described in [4].

In measurements the same cone has been used as well as in experiments made in 2006, [4], with a proper mass pressing action of 14.1 g, the established mass as optimum in measurements for wheat flours doughs, [4].

Measurements have been made on each 4-6 samples, lasting 20-30 min, when dough's consistency was considered stable enough on intervals of 20-40 min, [8]. To interpret results, they adopted medium values coming from measurements on 3-4 samples, whose values have been better grouped and could be considered, precisely enough, as reproducible.

Each sample used in measurements has been made of the corresponding quantity of dough and put into a cylindrical glass, whose dimensions kept recommendation of [14], that the measurements may not be affected owing to the outline effect, and consequently these may not be erroneous, (other informations in [4]). The penetration depth has been measured in penetrometric units (up), (1 up = 0,1 mm).

For each sample has been made 12 readings on intervals of 5 s, because within 60 s it may reach the maximum depth, h_{max}.

4. Results and discussions

The data of measurements (medium values) concerning the penetration depth of the cone h (in up), vs. time t (s) and for doughs made of three wheat flour types (FA-480a, FA-650 and FN-1250) and the two variants (with salt and without salt) are shown in table 1. With the data of this table, it has been tested the validity of Velon's law tested by equation (2), for all types of flours, after 12 months conservation and the two variants of making doughs. The coefficient's values a and b have been established through nonlinear regression, by using the model MicroCal Origin 6.0 and together with the correlation coefficient values R^2, as well as the appropriate coefficient values χ^2 appear in table 2.

Table 1

The cone penetration depths mean values h(up) vs. time t(s) for the three wheat flour after 12 months conservation and two different variants of prepared doughs

No.	Time t(s)	Wheat flour FA 480a		Wheat flour FA-650		Wheat flour FN 1250	
		Without salt	With salt	Without salt	With salt	Without salt	With salt
1	5	59.5	64.6	55.5	56.8	50.3	45.7
2	10	66.0	70.4	60.2	62.8	53.0	49.7
3	15	68.5	73.5	60.7	65.2	55.3	52.0
4	20	70.5	75.5	63.8	67.0	56.5	53.2
5	25	72.0	76.9	65.2	68.5	57.3	54.0
6	30	72.8	78.1	66.2	69.7	58.0	54.5
7	35	73.7	79.3	66.8	70.3	59.0	55.0
8	40	75.2	79.9	67.5	71.0	59.2	55.3
9	45	75.7	80.5	68.2	71.5	59.7	55.7
10	50	76.3	81.5	68.5	72.3	60.2	56.2
11	55	76.8	82.1	69.0	72.8	60.7	56.5
12	60	77.3	82.6	69.3	73.3	61.2	57.2

Table 2

The coefficient a and b values by Velon law (eq.2) for the three ahead flour types after 12 months conservation and two different variants of prepared doughs, and correlation coefficient R^2 and fitting coefficient χ^2, respectively

	FA-480 A		FA-650		FN-1250	
	Without salt	With salt	Without salt	With salt	Without salt	With salt
a	6.374	6.706	5.503	5.823	4.363	3.799
b	51.3	55.2	47.1	49.5	43.2	41.5
R^2	0.998	0.998	0.976	0.998	0.995	0.984
χ^2	0.036	0.029	0.269	0.030	0.034	0.081

The curves described by Velon's equations (2) for the coefficient's values a and b given in table 2 in relation to experimental points from table 1, for all situations are shown in fig.1(a,b,c).

By examining data in tab.2 and the curves in fig.1(a,b,c) in relation to experimental points, result that for the three follows wheat flours types researched (after 12 months conservation) and the two variants of making dough, experimental data are well described by Velon's law, because $R^2 \geq 0.976$ and $\chi^2 \leq 0.269$ (as a rule $\chi^2 \leq 0.081$).

Also it was been ascertained a significant enough difference among penetration depth values, to these three types of flours, among doughs made only with distilled water and the ones made with water and salt, for the first two flours (FA-480a and FA-650), their depths being deeper for salted doughs in comparison with flour FN-1250 where there is a reverse situation, probably because of a less content of gluten and content of ashes (mineral salts) higher for FN-1250.

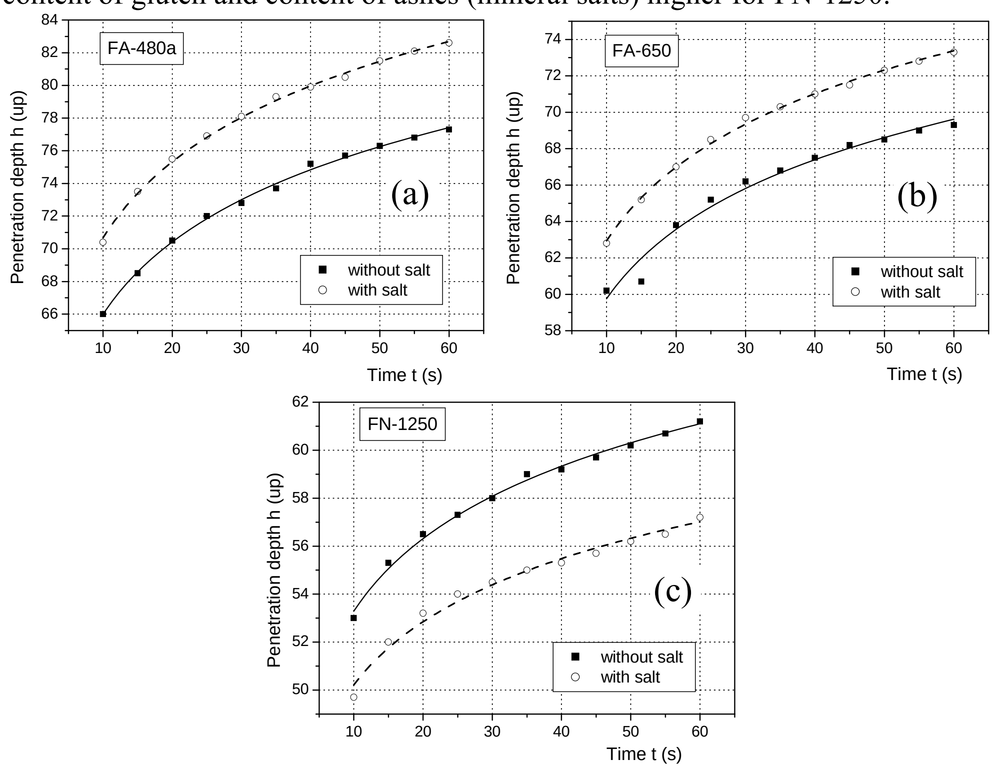

Fig.1. Comparison of cone penetration depth h(up) vs. time t(s) for the three different wheat flour types after 12 months conservation and two variants of prepared doughs
(■,○ – experimental data; -------, - - - - - Velon law curves)

In fig.2(a,b) is represented comparatively the penetration depth curves of the cone relying on time, for doughs made of three types of flour, only with distilled water in fig.2 (a), and with distilled water and salt in fig.2 (b).

It was been ascertained a significant emphasis of differences among consistency doughs of three flour types, both in making dough only with water- fig.2(a) and in making dough with water and salt fig.2(b), differences having the same sense in two ways of making doughs.

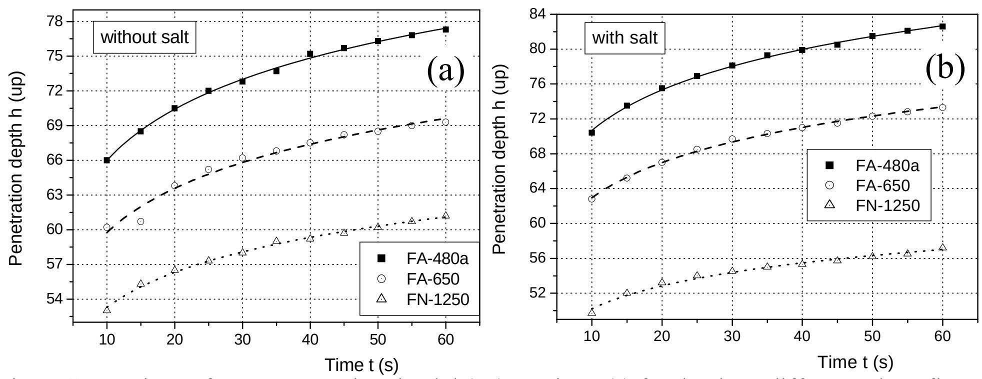

Fig.2. Comparison of cone penetration depth h(up) vs. time t(s) for the three different wheat flour types, after 12 months conservation and two variants of prepared doughs a)without salt; b)with salt
(■, ○, ∆ – experimental data; -------, - - - - - , · · · · · Velon law curves)

To emphasize influence of flour conservation time on dough consistency and by that on flour bakery features, in fig.3(a,b,c) was described the variation of penetration depth relying on time, for the three types of flour at two moments of experiment corresponding to 12 months of conservation.

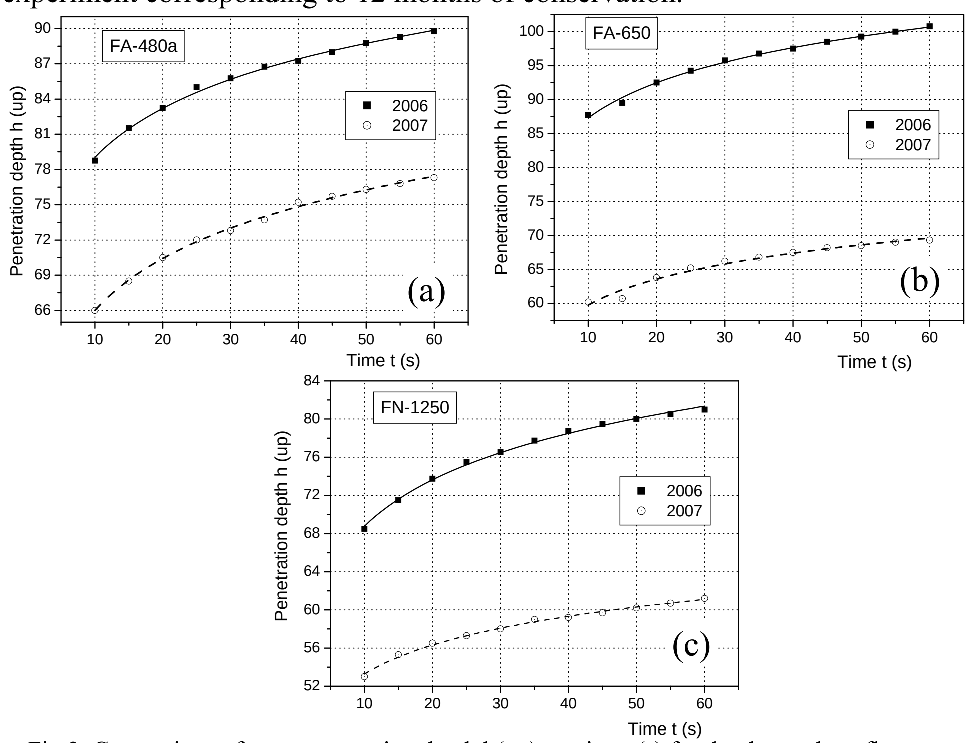

Fig.3. Comparison of cone penetration depth h(up) vs. time t(s) for the three wheat flour types (dough without salt)
(■, ○ – experimental data; -------, - - - - - – Velon law curves)

It was been ascertained for all three types of flour, rendered by diminishing of penetration depth to conservation time. This emphasize existence of some alterations in the dough structural resistance, probably induced by some alteration taking place in the gluten content by diminishing it for a conservation period longer than 6-8 weeks, [22], which worsen the bakery features.

Out of data given in tab.3 concerning the coefficient values a and b by Velon's law for three wheat flour doughs types and for experiments made in 2006-2007, it is noticed significant differences and the same sense of coefficient values "b", which can be taken as a measure of dough consistency directly related to its structure, considered as a semi-solid material, [3,4,10,14].

Also values almost to unit of correlation coefficient R^2, ($R^2 \geq 0.966$) show that experimental data referring to penetration depth can be well anticipated by Velon's law (eq.3), when knowing the coefficient values "a" and "b" (established values from experimental data).

Table 3

The coefficient values a and b by Velon law (eq.3) for the three wheat flour types and only water dough prepared, for two experimental time, and correlation coefficient R^2 and fitting coefficient χ^2, respectively

Flour types	Experiment year	a	b	R^2	χ^2
FA 480 A	2006	6.045	65.106	0.997	0.039
	2007	6.374	51.323	0.998	0.036
FA 650	2006	7.469	70.088	0.995	0.111
	2007	5.503	47.089	0.976	0.269
FN 1250	2006	7.028	52.578	0.997	0.055
	2007	4.363	43.270	0.995	0.034

It has been searched if penetration speed variation of the cone vs. time is hyperbolical type (eq.3).

Because the data referring to penetration depth have been registered at intervals of $\Delta t = 5s$, it was possible to calculate medium speed values v_{mi} on each interval:

$$v_{mi} = \frac{h_{i+1} - h_i}{\Delta t} \quad (5)$$

values assigned to moments t_{mi} corresponding to half of each interval, that is:

$$t_{mi} = \frac{t_i + t_{i+1}}{2} = t_i + \frac{\Delta t}{2} \quad (6)$$

where: h_i, h_{i+1} are the depths of penetration which are the equivalent of the particular time frames t_i, and respectively t_{i+1}.

During of the measurements for every particular sample the following pairs of experimental values were obtained (t_{mi}, v_{mi}), and was researched the viability of their description trough the hyperbolic type function:

$$v_c = \frac{\alpha}{t} + \beta \tag{7}$$

The values of the coefficients α and β (eq.7) were found by the means of the non-linear regression, being obtained from the data of the measurements performed in the year 2006, [4] and the year 2007 (look tab.1) for the three types of flour, using the computing software MicroCal Origin 6.0 and together with the values of the coefficients in the R^2 correlation, and also the corresponding values of the analogical coefficient χ^2, are presented in the tab.4.

Table 4

The coefficient value α and β (eq. 7) for the three wheat flour types doughs ant two different variant of prepared doughs and makes experiment in 2006 and 2007 year, and correlation coefficient R^2 and fitting coefficient χ^2, repetitively

Experiments effectuated in 2007					
Flour type	Dough type *)	Coefficients values			
		α	β	R^2	χ^2
FA-480A	FS	9.701	-0.108	0.938	0.009
	CS	8.947	-0.071	0.983	0.002
FA-650	FS	7.949	-0.060	0.916	0.008
	CS	9.048	-0.103	0.958	0.005
FN-1250	FS	4.323	0.006	0.896	0.003
	CS	6.345	-0.073	0.954	0.003
Experiments effectuated in 2006					
FA-480A	Without salt	8.115	-0.066	0.976	0.002
FA- 650		9.006	-0.026	0.979	0.002
FN-1250		16.557	-0.310	0.905	0.039

*) FS – dough without salt; CS – dough with salt

In the fig.4(a,b,c) are presented the curves described by the eq.7 for the values of the coefficients α and β given in the tab.4, linked with the experimental points which are in accordance with the variation of speed of penetration if the cone in the dough according to time.

For all situations, the experimental data are well described by the hyperbolic type function (eq.7) because $R^2 \geq 0.9$ and $\chi^2 \leq 0.009$. Because the values of the β coefficient are very close to the value of zero (0) then this values could be neglected for the specific experimental domain, so that the penetration speed correlated with time can be described, in a reasonable manner, by the means of eq. (4), obtained through theoretical analysis.

Also, from the fig.4(a,b,c) it can be observed that any particular lack of resemblance among the variation curves of the penetration speed vs. time, could not be highlighted, if we compare it with the preparing mode of the dough (with or without salt), for neither of the researched flour types.

In the fig.5(a,b) were represented the variation curves of the penetration speed from the three types of flour (after 12 months of preservation) and the two types of preparation of the dough (without salt – fig.5(a) and with salt – fig.5(b)).

It is perceived that it is impossible to highlight the major differences using the curves of the speeds, among the consistency of the doughs of the three flour types, no matter the preparation employed in the making of the dough. In conclusion the penetration speed can't be used for the description of the structure of the dough for the different flour types, and, also, for their specific baking properties.

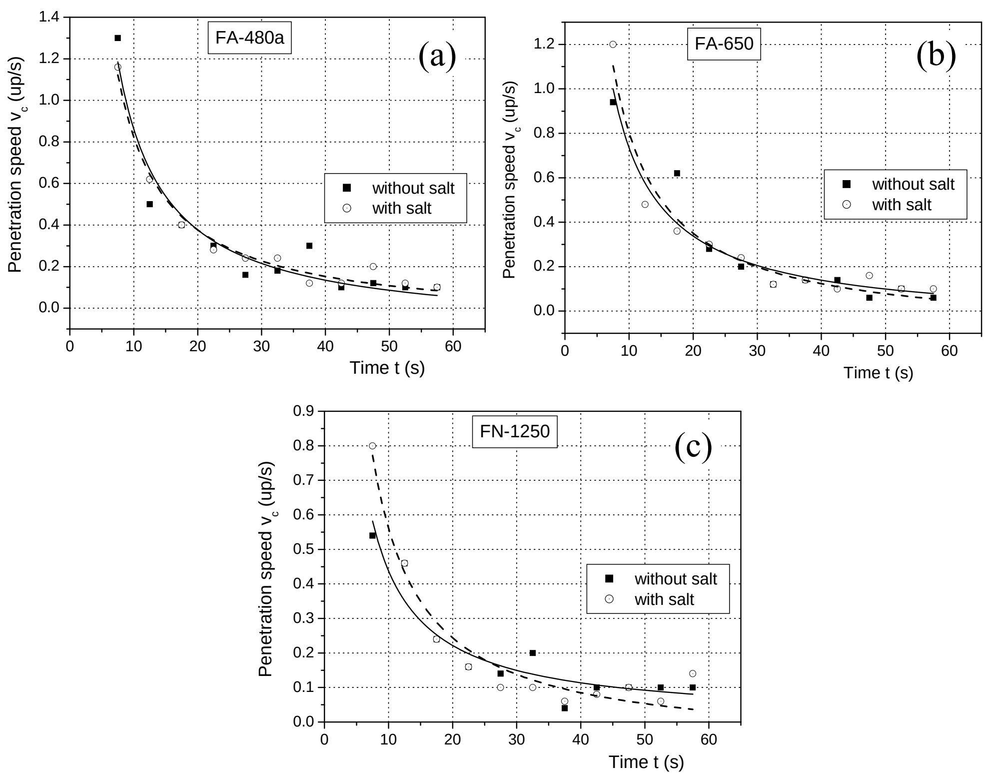

Fig.4. Comparison of cone penetration speed v_c(up/s) vs. time t(s) for the three wheat flour types after 12 months conservation and the two variants of prepared doughs (without salt; with salt) (■, ○ – experimental data; -------, - - - - - – eq. 7 curves)

The same conclusion can be drawn from the analysis of the fig.6, in which the penetration speed in accordance with time was represented, for the three types of flour and the dough prepared without salt, and the experiments performed in 2006.

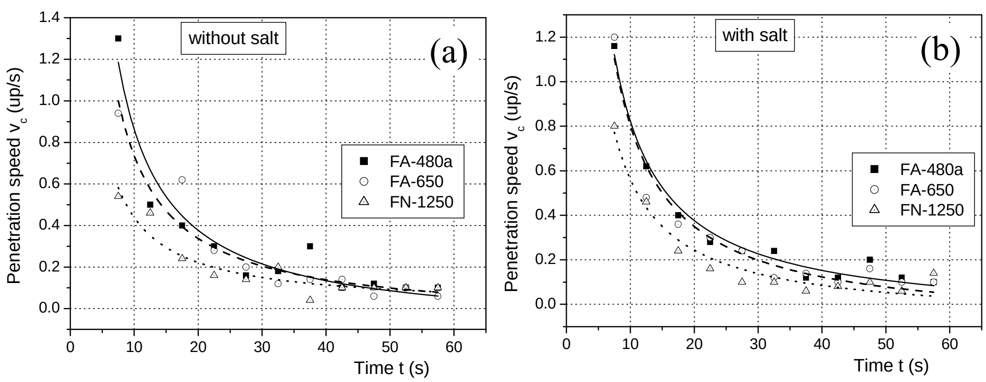

Fig.5. Comparison of cone penetration speed v_c(up/s) vs. time t(s) for the three wheat flour types after 12 months conservation and the two variants of prepared doughs (without salt; with salt)
(■, ○, ∆ – experimental data; -------, - - - - - , · · · · · – eq. 7 curves)

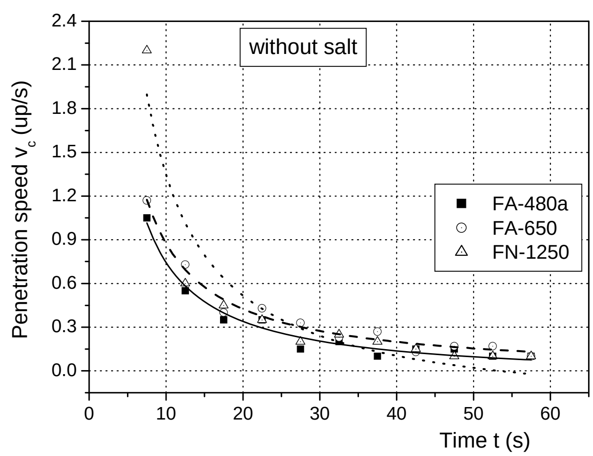

Fig.6. Comparison of cone penetration speed v_c(up/s) vs. time t(s) for the three wheat flour types and experimental tests effectuated en 2006 year
(■, ○, ∆ – experimental data; -------, - - - - - , · · · · · – eq. 7 curves)

To underline the fact if the penetration speed could be adopted as a value proper for the description of the changes in structure and components of the different types of flour, and after different periods of time of storage, translated in the changes brought to the structure, in the fig.7(a,b,c) were represented in a comparative manner, the different penetration speeds in accordance to time, for the three types for flour and the experiments performed at a 12th month interval.

It can be observed that no particular differences had risen for the speeds taken from the same flour and after a storage period of 12 months, for every one of the three types of flour.

As a result it can be sad that the variation of the penetration sizes described above (minus the speed of penetration) for the doughs made from different types of wheat flour and from different storage periods, there can be correlated with the consistency (firmness) of the dough, which is, mainly, determined from the quality and composition of the proteins and the specific water absorption capacity of the particular type of flour, [5,6,8,13,21,22,24,25].

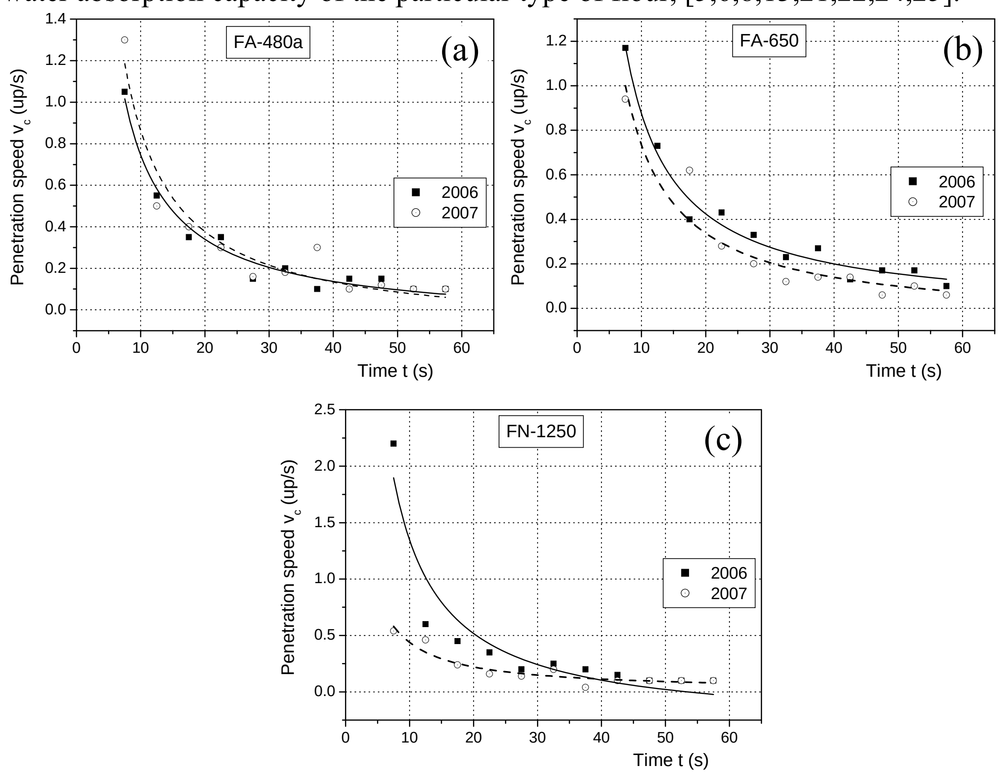

Fig.7. Comparison of cone penetration speed v_c(up/s) vs. time t(s) for the three wheat flour types (doughs without salt) and at two moments of experimental tests 2006 and 2007 years (■, ○ – experimental data; -------, - - - - - – eq. 7 curves)

5. Conclusions

Both the past researches [4], and the present ones regarding the structure of the consistency of the dough (prepared) from the different types of wheat flour, through penetration experiments with cone, are encouraging.

The most significant results regarding the characterisation of the consistency of a dough are obtained through the depth of penetration of a full standard cone, made from Plexiglas, with the top angle of 90^0 and with its own mass of pressure of the cone of 14.1g.

The viability of the Velon's law (eq.2) was tested for the wheat flours after a storage period of 12 months, and it was found out that it was being keep, the values of the a and b coefficients are being given in the tab.2, for the correlation coefficient $R^2 \geq 0.976$.

Also, just like in our past researches [4], it was highlighted the fact that the values of the "b" coefficient from the Velon's law varies along with the dough's consistency, being directly linked with its structure which is being determined by the gluten content, which is diminishing along with the increase of the storage time [22], (see tab.3), and so the values of the "b" coefficient can be used as a standard for the measurement of the change of the quality of the flour after the storage.

The durations of the cone penetration can be selected at 30–40 s from the value of the depth of penetration, important information regarding the consistency of the dough can be obtained, and also eventual differences having their origins in the initial storage conditions, and both of the data could be used to evaluate the baking quality of the specific wheat flour (see fig. 2 and fig. 3).

Regarding the penetration speed, for doughs prepared from different types of wheat flour and different storage periods of time, it is an irrelevant measure for the evaluation having the consistency of dough as a description.

From the fig.1(a,b,c) it can be perceived, that through the variation of the penetration depth, the mode used for the preparing of the dough (with or without salt) is influencing, in an specific manner, the consistency of the dough, and this is why it is necessary to adopt the same mode of preparing the dough, for establishing a comparison between the consistencies of different doughs.

This particular data is very useful in the development of future researches in this field, researches relevant for the building of adequate protocols for testing the flours, from the perspective of the baking quality, and also from the perspective of the selection and the necessary dosage of the primary goods.

The results presented above are enriching the data bases regarding the testing of the consistency of the wheat flour dough, for usage in the evaluation of the baking quality with the help of the penetration cone [4,7,10,16].

B I B L I O G R A P H Y

[1]. *C. Banu*, Manualul Inginerului din industria Alimentară, **vol.II**, Editura Tehnica, Bucureşti, 1999

[2]. *M.I.Bason, Mc Dang, R.I.Booth*, Dough mixing on the Newport Scientific doughLAB compared to the standard Brabender farinograph (summary of the paper), The Technical Journal of Newport Scientific World, 1, april 2004.

[3]. *T.Casandroiu, N. Oprita,* Cercetări experimentale privind evaluarea comportării la compresiune şi la penetrare a unor soiuri de mere, Raport ştiinţific de cercetare la contractul UPB – ICDVPH, UPB, 1994.

[4]. *T.Casandroiu, Gh.Voicu, Cr.Mieila*, Experimentally researches concerning rheological behavior of the wheat flour dough under the dead load of a cone penetrator, Bul. Institut. Politehnic Iaşi, Tomul LII (LVI), Fasc. 6C, 2006, Secţia, Construcţii de maşini (prezentată la Conferinţa internaţională ACME-2006, Universitatea Tehnică „Gh.Asachi" Iaşi), pag.257-267
[5]. *N.M.Edwards, J.E.Dexter, M.G.Scanlon,* Starch participation in durum dough linear viscoelastic properties, Cereal Chemistry, 79(6), 2002
[6]. *N.M.Edwards, J.E.Dexter, M.G.Scanlon,* The use of rheological techniques to elucidate, durum wheat dough strength properties, The 5th Italian Conference on Chemical and Process Engineering (ICHEAP-5), Florence, Italy, vol.2, 2001, www.grainscanada.gc.ca.
[7]. *W.S.Goldenberg, R.Shah*, A useful tool the determination of consistency in semi-solid substance, www.koehlerinstrument.com
[8]. *B.Launay*, A simplified nonlinear model for describing the viscoelastic properties of wheat flour doughs at high shear strain, Cereal Chemistry, 67(1), pp.25-31, 1990
[9]. *A.L.Leonard, F.Cisneros, J.L.Kokini*, Use of the rubber elasticity theory characterize the viscoelastic properties of wheat flour doughs, Cereal Chemistry, 76(2), pp.243-248, 1999
[10]. *Iu.A.Macihin, S.A.Macihin*, Inginernaia reologhia piscevâh materialov, Legcaia i piscevaia prom-sti, Moskva, 1981
[11]. *S.A.Mohsen, N.Phan-Thien,* Stress relaxation and oscillatory tests the distinguish between doughs prepared from wheat flours of different varietal origin, Cereal Chemistry, 75(1), pp.80-84, 1998
[12]. *C.Moraru, et al.*, Tehnologia şi utilajul industriei morăritului şi crupelor, Fasc.2, Univ. "Dunărea de Jos" Galaţi, 1988
[13]. *M.P.Morgenstern, M.P.Newberry, S.E.Holst*, Extensional properties of dough sheets, Cereal Chemistry, 73(4), pp.478-482, 1996
[14]. *A.Popovici, T.Bela, P.Iosif, G.Suciu*, Reologia formelor farmaceutice, Ed. Medicală, Bucureşti, 1985
[15]. * * * - Criteria for judging quality, www.theartisan.net/flour_criteria _judging.htm
[16]. * * * - Caracteristicile reologice ale aluatului, www.anamob.ro
[17]. *J.F.Steffe*, Rheological methods in food process engineering (second edition), Freeman Press, East Lansing MI 48823, USA, 1996.
[18]. *Gh.Pasat, Gh.Iordache*, Determinarea constantelor reologice pentru unele aluaturi alimentare, Food Sciences and Technologies, vol.III, nr.5, 1995
[19]. *Gh. Iordache, Gh. Pasat,* Studiul reologic al unor aluaturi alimentare, Food science and Technologies vol III, nr. 5, pp.7-10, ICA-Bucureşti, 1995
[20]. *S.Uthayakumaran, M.Newberry, N.Phan-Thien, R.Tanner,* Small and large strain rheology of wheat gluten, Rheologica Acta, 41, pp.162-172, Springer-Verlag, 2002
[21]. *M. Keentok, M. Newberry, P. Grass, F. Bekes, R. Tanner,* The rheology of bread dough made from four commercial flours, Rheologica Acta, 41, pp.173-179, Springer-Verlag, 2002
[22]. *A. Mis,* Influence of the storage of wheat flour on the physical proprieties of gluten, Int. Agrophysics, 17, pp.71-75, 2003
[23]. *J.T.Schober, I.Ch.Clarke, M. Kuhn,* Characterization of functional properties of gluten proteins in spelt cultivars using rheological and quality factor measurements, Cereal Chem. 79(3), pp.408-417, 2002
[24]. *W. Li, J.B.Dobraszczyk, D.J.Schofiend,* Stress relaxation behavior of wheat dough, gluten and gluten protein fractions, Cereal Chem. 80(3), pp.333-338, 2003
[25]. *C.F.Wang, S.X.Sun,* Creep-recovery of wheat flour doughs and relationship to other physical doughs tests and breadmaking performance, Cereal Chan. 79(4), pp.567-571, 2002