Scientific Bulletin. Series F. Biotechnologies, Vol. XXI, 2017
ISSN 2285-1364, CD-ROM ISSN 2285-5521, ISSN Online 2285-1372, ISSN-L 2285-1364

STATISTICAL MODEL FOR INDUSTRIAL IMPROVING OF WHEAT FLOURS WITH CALCIUM LACTATE

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Abstract

*The aim of this research was to identify the main changes that the addition of calcium lactate induces to rheological properties of dough, in industrial environment. In this regard, a number of 62 wheat flours, coming from Romanian wheat, were additivated with variable amounts of calcium lactate, ranging from 10 to 300 g/100 kg. Both the control flours and the additivated flours with calcium lactate have been evaluated in terms of rheology, using the alveographic method. The results showed that treatment with calcium lactate caused a very significant increase of following parameters: Resistance (P, mm; t= 4.864***), dough capacity to absorb Mechanical work (W, 10^{-4} J/gram; t = 6.990***) and the ratio between Resistance and Extensibility (P/L; t=7.174***). Elasticity parameter increased significantly in dough treated with calcium lactate, compared to control flours. Also, treatments with calcium lactate caused a very significant decrease of some parameters, such as: Extensibility (L, mm; t=-2.751**, and gluten extensibility index (G). There were significant correlations between the amounts of added calcium lactate and the modification of Resistance (r=0.66***), Extensibility (r=-0.56***) and the P/L ratio (r = 0.85***).*

Key words: *alveogram, bread dough, calcium lactate, wheat flours.*

INTRODUCTION

Calcium lactate (calcium 2-hydroxypropanoate, E 327) is used in bakery products, either as a source of calcium for flour fortification, or to compensate the anti-nutritive effect of phytic acid. In all cases, calcium lactate has a technological effect of acidity reviser, due to its property to operate as a buffer system (Krupa-Kozak, 2015; Tamba Berehoiu, 2015).

By modifying the ionic strength of the dough, calcium lactate also exerts a significant effect on the conformation of gluten proteins (Basset et. al., 2014). Changing the gluten proteins conformation involves the proteic globules unfolding, so a large number of chemical groups become available to interact with other active groups of proteins or with water (Anderssen, 2007). In this way, spaces are created where water molecules penetrate, causing the swelling of the proteins.

Also, as the number of positive charges decrease (acidic pH), the electrostatic repulsions intra- and inter-molecular decrease too, it is therefore favored the emergence of new bonds, whose effects are the aggregation of molecules and finally, precipitation of the proteins (Maher et al., 1978).

This may explain why at the isoelectric pH, swelling, solubility, viscosity and osmotic pressure of the gluten proteins are minimal (Mathason, 1983; MacRitchie, 1992). Rheological effect is to increase the resistence and stability of dough. Therefore, increases the dough tolerance in kneading, fermentation and improves bread volume (Popa, 2007; Sudha et. al., 2008; Salinas et al., 2014).

This technology could be used to improve defective flours, such as those derived from wheat attacked by wheat bedbugs (Eurygaster sp.), which is a relatively common problem in the case of Romanian crops (Popa et. al., 2008).

The aim of this study was not to detect a dose-effect relationship, concerning the calcium lactat treatments for a standardized flour, because the effect of calcium lactat on the rheological properties of such flours is relatively well known. What we were interested in was the effect of variable treatments on some flours with variable alveographical parameters.

This variability is important to research in industry, where the flours of the same type never have similar values of quality parameters. We aimed to find out what is the predictable variability part of treatments with calcium lactate, in industrial variability conditions, on the rheological properties of dough, as described in alveographic method.

As known, alveographic parameters of dough are strongly correlated with the technological behavior. Therefore, the results will provide an important tool, in order to dose the amounts of calcium lactate, in correspondence with the technological needs of flours used in production flows.

MATERIALS AND METHODS

The tests were performed on 62 type 650 wheat flours (according to Romanian Indutrial classification, with an ash content expressed on dry matter of max 0.65%), coming from Romanian wheat harvests in the years 2014 and 2015. Flours were obtained from Farinsan SA., a manufacturer of milling industry. For each 62 flour samples were carried out alveographic analyzes, using a Chopin alveograph, according to the method described by SR ISO 27971: 2008.

There were determined the average values of the following parameters: the dough **resistance** to extension (P, mm); dough **extensibility** (L, mm), **extensibility index** (G) whose value is calculated based on the length of the curve (L), using formula $G=2.226\sqrt{L}$; the dough **absorbed energy** by stretching (W, 10^{-4} /Joules/gram dough); the dough **index of elasticity** (ie %), calculated as a ratio between resistance of dough at 40 mm at the beginning of the alveographic curve (P_{200}) and the maximum resistence (P); and finally **P/L ratio**, calculated as the ratio of the two parameters P and L, showing the extent to which the dough is more extensible, or more resistant.

Flours which were alveographic analyzed have been treated with variable amounts of calcium lactate, ranging from 10 to 300 g/100 kg of flour (100 - 3000 ppm).

The calcium lactate amounts applied for treatments were chosen according to the needs to improve mechanical work and P/L ratio parameters for each flour separately, taking into account the technical specifications of the respective flour.

The trade name of used **Calcium lactate** was Puracal PP/FCC, a fermentation product, dedicated to food industry, delivered by the French company Corbion. The product is characterized by a calcium content between 13.4 and 14.5% and has a minimum. of 96% stereochemical purity (L isomer). The dosage of calcium lactate was made after weighing with analytical balance, directly in the mixing bowl of alveograph. Before the proper analysis, flour and calcium lactate were homogenized in the mixing bowl of alveograph for 2 minutes.

The results were statistically interpreted using the professional software “Statistica”. Statistical analysis highlighted the average effect of the calcium lactate treatments on the alveographic parameters of flours in industrial environment.

RESULTS AND DISCUSSIONS

In industrial environment, due to large daily quantities of flours with different technical specifications, is suitable an average approach of quality parameters and of improving treatments.

The results of alveographic analyzes performed for control flours are shown in Table 1. (statistical variability estimates).

Table 1. Variability parameters for alveographic quality indices of the flours (n = 62)

Parameter	**$X \pm s_x$**	**Range of variation (min. – max.)**	**Coefficient of variation (%)**
Resistance (P, mm)	76.758 ± 8.028	62 - 99	10.459
Extensibility (L, mm)	70.758 ± 12.023	42 - 82	16.992
Gluten extensibility index (G)	18.647 ± 1.687	14.4 – 20.2	9.047
Mechanical work (W, 10^{-4}/Jouli/g)	175.548 ± 47.010	78 - 240	26.779
P/L	1.080 ± 0.223	0.82 – 1.71	20.648
Dough elasticity index (Ie, %)	46.714 ± 7.841	29.6 – 56.8	16.785

We observed in Table 1. that the studied flours were characterized by a higher variability of some alveographic parameters, namely: the mechanical work (W) and the resistance/ extensibility ratio (P/L). The other quality parameters are relatively homogeneous. In terms of average values of the analyzed parameters, it can be considered that the flours properties were characterized by modest bakery properties (alveographic mechanical work - below 200 W, P/L ratio greater than 0.65).

It can be noticed, from the variation ranges analysis of alveographic parameters, that in the test samples were included flours with very low bakery potential (with mechanical work W=78, or extensibility, L=42). The average effects of the addition of calcium lactate to the flours are shown in Table 2.

Table 2. Variability parameters for alveographic quality indices of flours treated with calcium lactate

Parameter	$X \pm s_x$	Range of variation (min. –max.)	Coefficient of variation (%)
Resistance (P,mm)	87.145 ± 14.545	52 - 123	16.690
Extensibility (L, mm)	64.790 ± 12.137	35 - 85	18.733
Gluten extenibility index (G)	17.831 ± 1.732	13,2 – 20,5	9.713
Mechanical work (W, 10^{-4} Joules/g)	200.081 ± 43.930	80 - 278	2.876
P/L	1.408 ± 0,438	0.82 – 2.89	31.11
Dough elasticity index (Ie, %)	49,006 ± 11.248	0 – 62.7	22.952

In Table 2, we observed that resistance parameter (P, mm) of dough had averaged an increase of 10.4 mm in the samples treated with calcium lactate, compared to control. The increase is statistically very significant t=4.864, p=0.000001, (Figure 1).

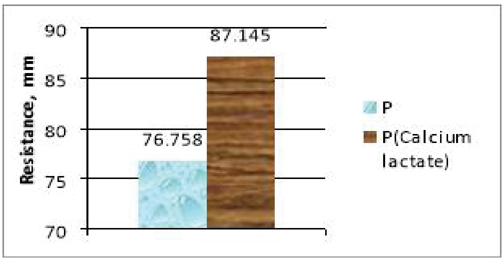

Figure 1. The effect of calcium lactate treatment on dough resistance (P) parameter

Figure 2, shows the regression equation between the amount of lactate used for the flours treatment and the values of resistance parameter. We noticed that the addition of calcium lactate contributed very significantly to increase of dough resistance (r=0.66***). In fact, 43% of the variation in resistance alveographic parameter (P, mm) is due to the addition of calcium lactate (r^2 = 0.43).

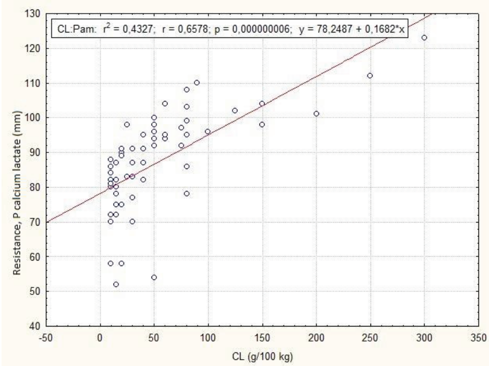

Figure 2. Regression between alveographic resistance (EMP) and the amount of added calcium lactate (CL, g/100 kg)

The addition of calcium lactate caused a significant decrease of Extensibility (L, mm) parameter value (t=-2.751**). The decrease was on average, of 5.97 mm (Figure 3).

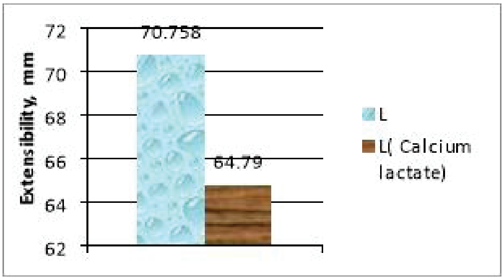

Figure 3. The effect of calcium lactate treatment on dough extensibility (L) parameter

Almost 31% of extensibility parameter variation can be explained on account of calcium lactate dose variation (r^2=-0.31).

The regression equation that describes the decrease of dough extensibility parameter, due to the increase of calcium lactate amount, is shown in Figure 4.

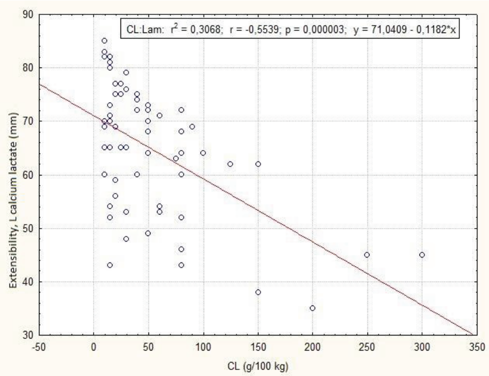

Figure 4. Regression between alveographic extensibility (L, mm) and the amount of added calcium lactate (CL, g / 100 kg)

As it was natural, given that it is a quality indicator derived from extensibility values, the extensibility index of gluten (G) registered a significant decrease in the flours treated with calcium lactate, compared to flours untreated (t =- 5.751, p=0.000001). This reduction was of 0.816 points.

The ability of dough to absorb mechanical work (W), namely the alveographic parameter that correlates most strongly with bread volume, as supports data in the literature, recorded a very significant increase in the flours treated with calcium lactate, from 175.5 10^{-4}/Joules/ gram dough, to 200.1 10^{-4}/Joules/ gram dough (t = 6.990 ***, p = 0.0000001, (Figure 5).

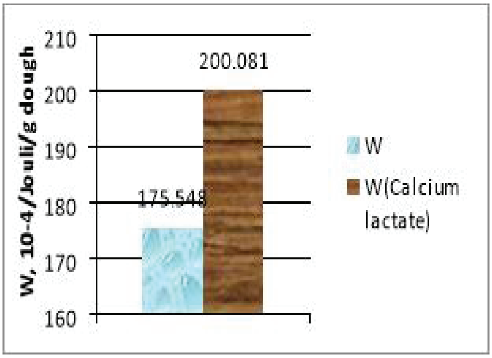

Figure 5. The effect of calcium lactate treatment on dough mechanical work (W, 10-4/Joules/gram dough)

An interesting aspect of our results is the lack of a linear correlation between the amounts of calcium lactate used for flour treatments and the values of alveographic mechanical work parameter (r=0.094ns).

Although the treatments with calcium lactate increase significantly the values of this parameter, as mentioned previously, the mechanism by which calcium lactate acts on the mecanical work, involves probably factors that have not been included in this analysis.

The most important of these appears to be the initial values of mechanical work in the treated flours, because if we introduce those values in a multiple regression model, then it can be explained 72% of the mechanical work variability. Multiple correlation coefficient of the regression equation was r=0.85 (Figure 6).

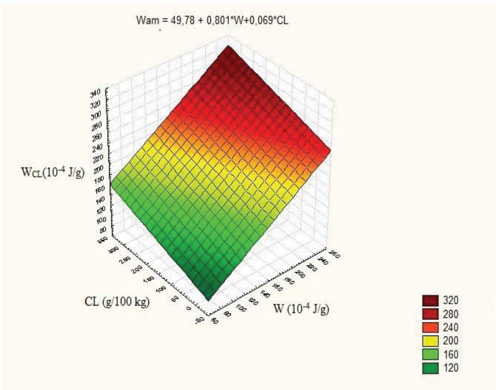

Figure 6. The relationship between the alveographic mechanical work (Wam) of treated flours, the amount of added calcium lactate (CL, g / 100 kg) and the initial alveografic mechanical work (W) of untreated flours

Relationship between dough resistance and extensibility (P/L ratio) was the alveographic parameter that registered the most spectacular growth, after treatments with calcium lactate, from an average value of 1,080 to an average value of 1.408 (t=7.174***; p=0.0000001) (Figure 7).

This is due to an increase of dough resistance and a concomitant decrease of dough extensibility.

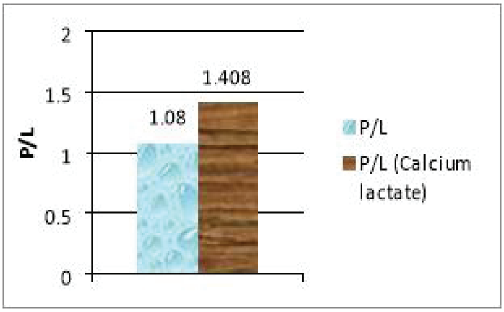

Figure 7. The effect of calcium lactate treatment on the dough P / L ratio

The P/L parameter showed the strongest correlation with the added amount of calcium lactate (r=0.85***). In fact, 73% of its variation may be explained by variation of the added amount of calcium lactate ($r^2 = 0.73$).
Figure 8 shows regression between P/L and the added amount of calcium lactate.

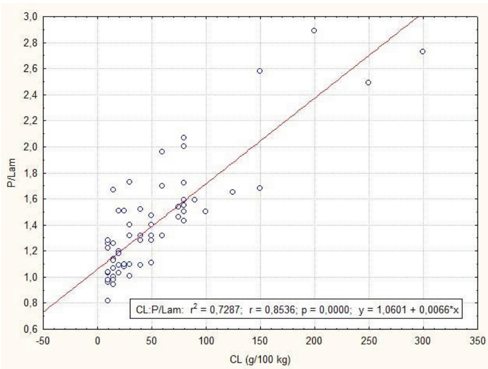

Figure 8. The regression between the resistence/ extensibility (P/L) ratio and the amount of added calcium lactate (CL, g / 100 kg)

The correlation between the amount of added lactate and the average of P/L ratio in the treated flours, was strong enough and allowed to obtain a descriptive model, faithful to the relationship between dose and response, on account of the initial value of the P/L ratio in the treated flours.
Thus, Figure 9 shows a graphical model that describes the relationship between the initial value of P/L ratio in untreated flours, the dose of added calcium lactate and the value of P/L ratio in treated flours.
Multiple correlation coefficient of the model was 0.98 and describes about 96% of the P/L ratio value in the treated flours, on account of calcium lactate amount variation and on the initial value of P/L ratio (Popa et. al., 2009).

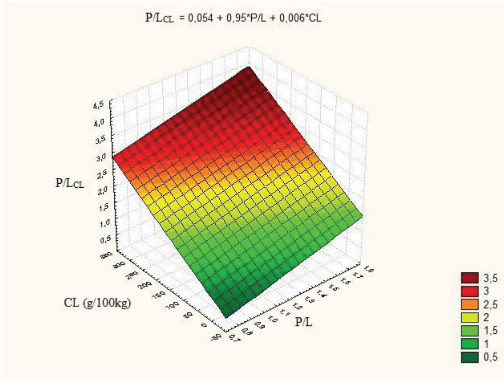

Figure 9. The relationship between the resistance/ extensibility (P/L_{CL}) ratio in the treated flours, the amount of added calcium lactate (CL, g / 100 kg) and the initial value of P/L ratio in untreated flours

Dough elasticity index (Ie, %) increased significantly in the flours treated with calcium lactate, compared to control flours (from 46.7% to 49.0%, t=2.121*, p=0.038) (Figure 10).
The Ie parameter value of analyzed flours increased significantly with increase of added calcium lactate amounts (r=0.35*, p=0.05).
However, only about 12% of the Ie parameter variation may be associated with the variation of added calcium lactate amount. By introducing in the model the initial value of elasticity index in untreated flours (as we did for the alveographic mechanical work and the P/L ratio), the explained variation increase to 43%.

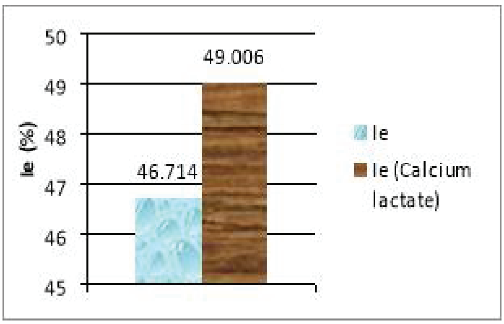

Figure 10. The effect of calcium lactate treatment on the dough Elasticity index (Ie, %)

Most changes in the elasticity index of flours treated with calcium lactate, as we can see, are due to some factors that have not been included in this analysis.
As our analyzes have shown, the effects of calcium lactate addition on the alveographic parameters, generally refers to increase of resistance and mechanical work.

CONCLUSIONS

In terms of average values of the analyzed parameters, it may be considered that control flours were characterized by modest bakery properties (alveographic mechanical work W, below 180, P/L ratio greater than 1.0).
Calcium lactate treatments led to a very significant increase of resistance parameter (P, mm), of dough capacity to absorb mechanical work (W, 10^{-4} J/gram) and of the resistance/ extensibility ratio (P/L).
Elasticity index increased significantly in dough treated with calcium lactate, compared to control flours.
Calcium Lactate treatments led to a very significant decrease of some parameters, namely: extensibility (L, mm), and index of gluten extensibility (G).
Highly significant correlations were established between the amount of calcium lactate-dough resistance (positive correlation, r=0.66***), and the amount of calcium lactate-extensibility (negative correlation, r=-0.55***).
Multiple regression between the initial value of the dough mechanical work (W), the added amount of calcium lactate and the final amount of mechanical work, describes 72% of the mechanical work variability in the flours treated with calcium lactate (r=0.85), in industrial practice.
Multiple regression between the initial value of the flours P/L ratio, the added amount of calcium lactate and the final value of P/L ratio, describes 96% of the the P/L ratio variation, in the flours treated with calcium lactate (r=0.98).
Our results authorize the effects anticipation of calcium lactate dosage on dough rheology in industry, where the flours technical specification are very different.
These results can be used for the defects correction of the flours alveographic parameters, and for maximizing the dough potential in the case of normal or fortified flours.

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