Macrothink Institute™

Journal of Food Studies
ISSN 2166-1073
2014, Vol. 3, No. 1

Optimization of A Strong Wheat Flour Quality With A Low Alpha-Amylase Content by Using Response Surface Methodology

Silvia Mironeasa

Faculty of Food Engineering, Stefan cel Mare University of Suceava, Romania

Georgiana Gabriela Codină (Corresponding author)

Faculty of Food Engineering, Stefan cel Mare University of Suceava

Str. Universităţii nr.13, 720229 Suceava, Romania

E-mail: codina@fia.usv.ro / codinageorgiana@yahoo.com

Received: Dec. 7, 2013 Accepted: January 24, 2014 Published: December 1, 2014

doi:10.5296/jfs.v3i1.4694 URL: http://dx.doi.org/10.5296/jfs.v3i1.4694

Abstract

The aim of this study was to determine the effect of three commercial additives (Belpan AS, Belpan MOPA and Belpan Malt) on two parameters very used to characterize the quality of wheat flour namely gluten deformation index and falling number by using response surface methodology. The flour used like row material was a strong one with a low α amylase content. Each independent variable was tested at five levels: 0.00%, 0.50%, 1.00%, 1.50% and 2.00% (w/w, on weight of flour basis). The results showed that the Belpan Malt was the most effective additive on falling number and gluten deformation index values. The best results were obtained among the combinations between Belpan AS and Belpan Malt on the falling number. The optimum level of the formulation was found to be a mix containing 0.80% from each additive used in this study when desirability function method was applied.

Keywords: Wheat flour, Additives, Falling number, Gluten deformation index, Optimization

1. Introduction

In the last few decades different additives are used to improve the wheat flour quality. When we choose one type of additive we must take into account what wheat flour parameters we want to improve. For this we must know some wheat flour characteristics because depending on these values we can decide what additives we should use. The principal wheat flour quality indexes of which depends the technological wheat flour characteristics, it tenacity and gas formation capacity are protein and wet gluten content and quality, maltose index and α-amylase content (Bordei, 2005).

The quality of the wheat flour proteins can be established in an industrial scale by using some descriptive empirical methods like Extensograph, Alveograph (Campos *et al.*, 1997; Mirsaeedghazi *et al.*, 2008), Farinograph (Zounis and Quail, 1997; Connelly and McIntier, 2008), Mixograph (Zounis and Quail, 1997; Ren *et al.*, 2008), Mixolab (Codină *et al.*, 2010; Codină *et al.*, 2012) e.g. Also its quality may be established through gluten deformation index, glutenic index and Zeleny sedimentation index values.

Regarding the wheat flour α-amylase activity, the most common methods used to measure it are Falling Number method (Finney, 2001; Mares and Mrva, 2008), Rapid Visco Analyser method, the Brabender amylograph–viscograph method (Donelson *et al.*, 2001) and the Mixolab method (Collar *et al*., 2007; Codină *et al*., 2012).

Today, in a lot of bread making laboratory factories we can not find modern equipments like for example Alveograph, Rapid Visco Analyser, Mixolab in order to establish wheat flour quality parameters due to economical reasons. Therefore, to obtain information's about wheat flour quality these factories are using techniques classical but very useful to define it quality. For example, in Romania, almost all the bread making laboratory factories determine the wheat flour quality through the value of wet gluten content, gluten deformation index and falling number. Very few bread making factories has the possibility to characterize the wheat flour quality through it rheological behaviour with empirical methods like Extensograph, Alveograph, Farinograph, Mixolab, e.g.

Therefore we consider that it would be useful to evaluate the effect of some additives on the flour protein quality and α-amylase activity determined through the gluten deformation index and falling number values. Like additives used to improve wheat flour quality we choused different mixtures very used in Romania to improve strong wheat flours flour that can be a result of a dry season harvest year.

For this purpose we used response surface methodology method to find the best combinations between these additives in order to obtain an optimum of wheat flour quality defined through the gluten deformation index and falling number value.

2. Materials and methods

2.1. Basic ingredients

Commercial wheat flour (harvest 2013) obtained from S.C. Dizing S.R.L. Brusturi, Neamt County, Romania Company presents the follow characteristics: moisture content 14.2 %, wet gluten content 28.2%, gluten deformation index 2 mm, ash content 0.64 and falling number 429 s. For the wheat flour sample, the following specific qualities were determined: moisture content (ICC Standard Method No. 110/1), wet gluten content (ICC Standard Method No. 106/1), gluten deformation index (SR No. 90), ash content (ICC Standard Method No. 104/1), and the falling number (ICC Standard No. 107/1).

Additives (commercial names Belpan AS, Belpan Mopa and Belpan Malt) commercialized by S.C. Enzymes & Derivates Romania was used as the additives agents. The effect of additive dose was evaluated at five levels: 0.00%, 0.50%, 1.00%, 1.50% and 2.00% (w/w, on weight of flour basis).

Belpan AS contains diastatic malt flour, stearoyl 2 lactilat, ascorbic acid, cystein, fungal alpha-amylase, fungal hemicellulase and xylanase.

Belpan Mopa contains diastatic malt flour, soybean flour with enzymatic activity, 2-steoryl lactylate, ascorbic acid, and cystein.

Belpan Malt contain only diastatic malt flour.

2.2. Statistical Analyses

To study the effects of the additives on the properties of wheat flour, the following three types of commercial additives were used as independent variables: Belpan AS (B_AS), Belpan MOPA (B_Mo) and Belpan Malt (B_Ma) at a level range from 0 to 2 g/100 wheat flour – additives blend basis. Levels of additives were selected on the basis of manufacturer-recommended levels.

A central composite design (CCD) response surface methodology (RSM) with three factors and five levels was generated by the Stat Ease Design Expert 7.0.0 software package (trial version). The complete experimental design required 18 experimental runs that consist of 8 factorial points, 4 centre points and 6 axial. The centre point in the design was repeated four times to allow the estimation the adequacy of the model. The experimental results were analyzed by multiple regression method. For each of the response variables, falling number value and gluten deformation index, a quadratic model was used to data fitting as follow equation

$$y = b_0 + \sum_{i=1}^{3} b_i \cdot X_i + \sum_{i=1}^{3} b_{ii} \cdot X_i^2 + \sum_{i=1}^{2}\sum_{j=i+1}^{3} b_{ij} \cdot X_i \cdot X_j \quad (3)$$

where y is the predicted response, b_0 a constant, b_i - coefficient of linear effects, b_{ii} - coefficient of quadratic effects, b_{ij} - coefficient of the interaction effects and X_i are the independent variables. The statistical significance of the coefficients in the regression equations and the quality of the models' fitness was evaluated by analysis of variance (ANOVA). The fit of each model to the experimental data was given by the lack-of-fit test, coefficient of determination, R^2 and adjusted coefficient of determination, adjusted-R2 and coefficient of variation, CV.

2.3. Optimization procedure

Calculation of the optimal mix of additives from the wheat flour was performed using a multiple response method called desirability (Myers and Montgomery, 1995). The desirability functions involve transformation of each predicted response into an individual desirability function, d_n, which includes the desires and researcher's priorities when building the optimization procedure for each of the independent variables. The value of individual desirability function, d_n ranges between 0, for a completely undesired response, and 1, for a fully desired response. For simultaneous optimization of the two responses, falling number value and gluten deformation index were used following modified desired function (Eq.1) developed by Derringer and Suich (Dereinger and Suich, 1980):

$d_n = 0$ if $y_n < A$

$$d_n = \left(\frac{y_n - A}{B - A}\right)^s \quad \text{if} \quad A \le y_n \le B \tag{1}$$

$d_n = 1$ if $y_n \le B$

where *A* and *B* are the constraints of the response, respectively the lowest and the highest values of y_n and *s* is a weighing factor.

The individual desirability functions are then combined into a single composite response, namely total desirability function, D ($0 \le D \le 1$) defined as the geometric mean of the individual desirability function d_n, which can be expressed as:

$$D = (d_1 \cdot d_2 \cdot \ldots \cdot d_k)^{(1/k)} \tag{2}$$

where d_n, n = 1, 2, … *k* is the individual desirability function for each response. A high value of D indicates the more desirable and best combination of additives doses, which is considered as the optimal solution of this formulation mix that generated the best results for falling number value and gluten deformation index.

3. Results and discussion

3.1. Effect of process variables on the falling number and gluten deformation index

The range and the levels of both coded and actual values for independent variables Belpan AS, Belpan MOPA and Belpan Malt used in this study are shown in Table 1. The amounts of this additives used were in the range commonly used in wheat flour for bakery product.

The experimental design consisted of five levels for each of the three variables and three replications for each experimental condition (Table 2). A rotatable Central Composite Design (CCD) was employed in this study to perform the experiments by varying simultaneously all the variables. The axial point (star point) α has been determined from the condition for a CCD to be a rotatable design and may be written as follows (Myers and Montgomery, 1995):

$$\alpha = (2^k)^{1/4} \quad (3)$$

where 2^k is the number of points in the factorial part of the central composite design. In this study, $k = 3$ factors and the value of α is 1.682.

Table 1. Experimental range and levels values of the independent variables

Independent variable	**Variable symbol**	**Range studied (%)**	**Levels**				
			- α	-1	0	+ 1	+ α
Belpan AS	B_AS	0.00 – 2.00	0.00	0.50	1.00	1.50	2.00
Belpan MOPA	B_Mo	0.00 – 2.00	0.00	0.50	1.00	1.50	2.00
Belpan Malt	B_Ma	0.00 – 2.00	0.00	0.50	1.00	1.50	2.00

Table 2. Central Composite Design showing independent variable level combinations

Experimental design point	**Process variables**		
	B_AS	**B_Mo**	**B_Ma**
1*	0	0	0
2	0	0	α
3	-1	-1	1
4*	0	0	0
5	0	0	- α
6	-1	1	-1
7*	0	0	0
8*	0	0	0
9	α	0	0
10	-1	1	1
11	1	1	-1
12	0	α	0
13	1	1	1
14	1	-1	1
15	-1	-1	-1
16	- α	0	0
17	1	-1	-1
18	0	- α	0

* = centre points; B_AS = Belpan AS; B_Mo = Belpan MOPA; B_Ma = Belpan Malt

The estimated regression coefficients of the quadratic polynomial models for de response variables, falling number (FN) and gluten deformation index (GDI), are shown in Table 3.

Table 3. Significant coefficients (95% confidence interval) of the design factors of the regression fitting model for wheat flour quality parameters

Factor	FN (s)	GDI (mm)
Constant	185.50	12.4
B_AS	-13.15	0.81
B_Mo	- 4.78	0.31
B_Ma	- 15.15	1.00
B_AS * B_AS	1.65	- 0.19
B_AS * B_Mo	ns	ns
B_AS * B_Ma	3.28	ns
B_Mo * B_Mo	ns	- 0.16
B_Mo * B_Ma	ns	ns
B_Ma * B_Ma	1.75	- 0.13
R^2	0.96	0.96
Adjusted-R^2	0.92	0.92
Lack of fit	ns	ns
CV	5.98	7.49

ns = no significant effect ($P > 0.05$); FN = falling number value; GDI = gluten deformation index, B_AS = Belpan AS; B_Mo = Belpan MOPA; B_Ma = Belpan Malt; R^2 = coefficient of determination; CV = coefficient of variation

Analysis of variance (ANOVA) shows that the quadratic models adequately represented the data obtained for wheat flour quality. The regression models were highly significant for FN and GDI with coefficients of determination (R^2) exceeding 90%, which indicates that a high proportion of variability is well explained by the each model. The lack-of-fit tests did not result in a significant F-value, indicating that the models obtained for FN and GDI are sufficiently accurate for predicting the quality of wheat flour blended with these additives. The coefficients of variation (CV) for each quality parameter of wheat flour show a small value, giving a better reproducibility.

As can be seen in Table 3, the effect of quadratic term of additive Belpan MOPA value on FN is insignificant. This effect is probably due to its components which not act on wheat flour starch or of it α amylase content like 2-steoryl lactylate, ascorbic acid and cystein.

Figure 1a–c shows the response surfaces of the falling number as functions of the doses of B_AS, M_Mo and B_Ma. As it can be seen in Figure 1a and Table 3, the response surfaces showed that the B_AS and B_Ma had a negative effect on FN value, while the interaction between this had a positive effect on the FN value. Major positive effect on FN was provided by quadratic effect of B_AS and B_Ma. It is clear from Figure 1b that the FN value decreased with the increased of the dose of B_Mo and B_AS, but increased by quadratic effect of B_AS. According to Figure 1c, increasing the doses of B_Ma and B_Mo resulted in decreases in the FN value.

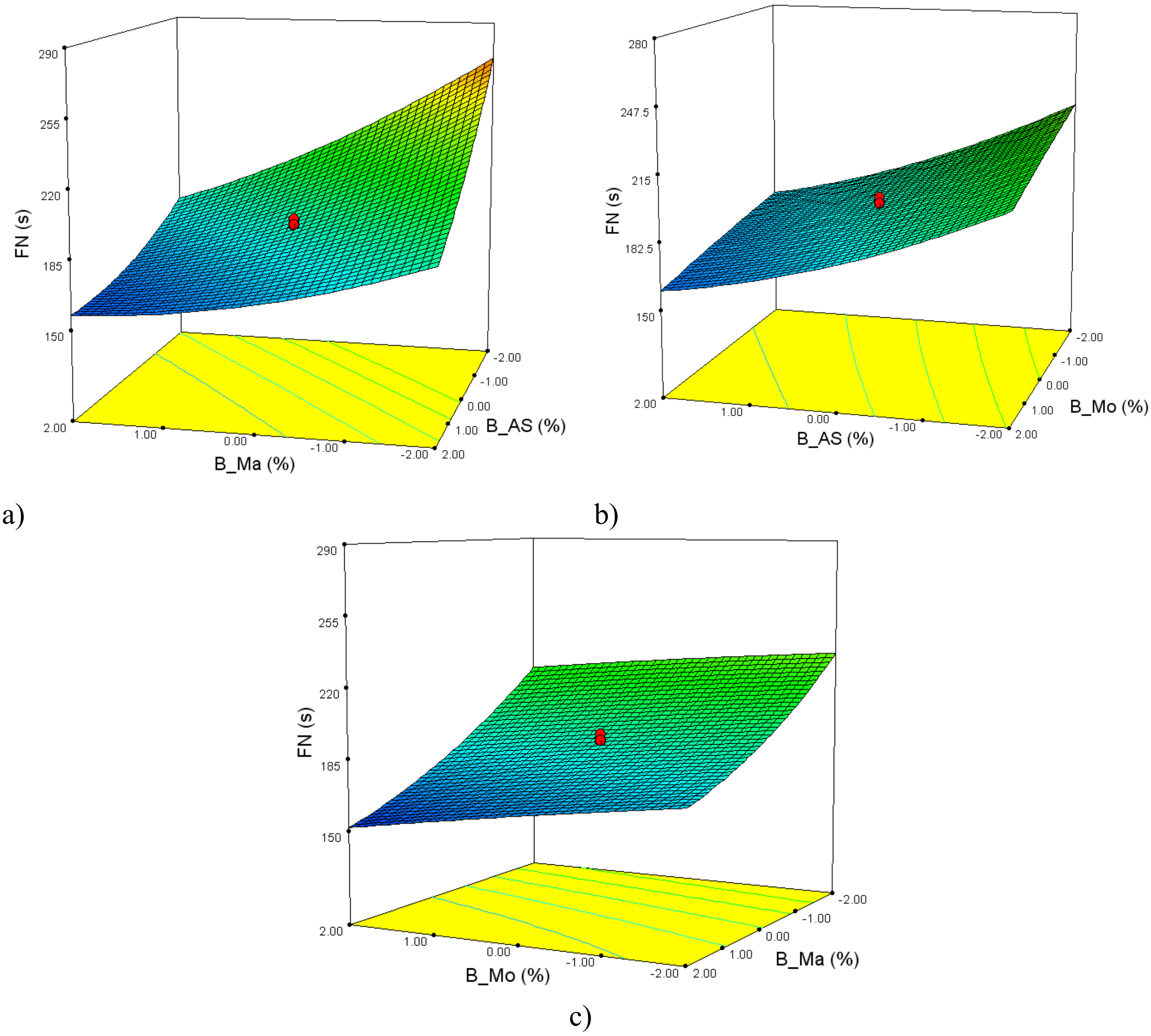
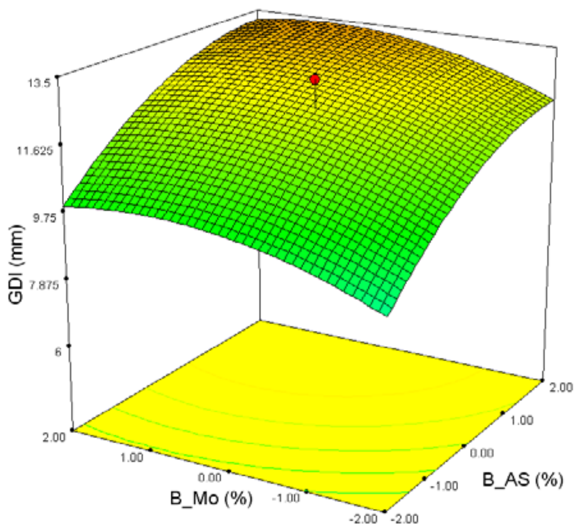
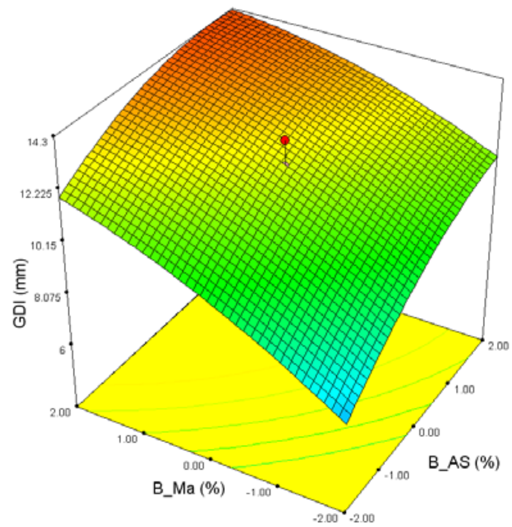


Figure 1. Response surface plots of falling number index. B_AS = Belpan AS; B_Mo = Belpan MOPA; B_Ma = Belpan Malt

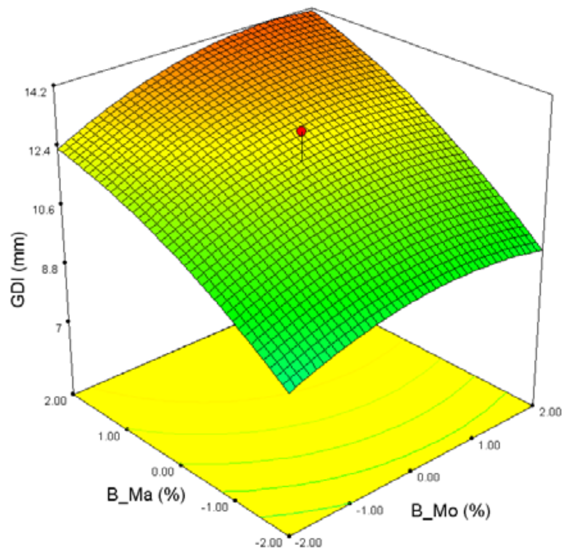
Positive linear effects of all used additives were observed on GDI (Table 3). These effects might be attributed to its components like diastatic malt flour and cystein. It is clear from Table 3 that GDI was increased by addition of each additive in wheat flour, but decreased by quadratic effect of it. The statistical analysis of the coefficients of the model for GDI revealed that the interaction coefficients were non-significant. It indicated that independent variables individually affected the response variable, GDI. It is clear from Figure 2a-c that the GDI was increased with the increased of level addition of B_AS, B_Mo and B_Ma, but decreased by quadratic effect of this. On the other hand, interaction effect between this additives on the GDI was insignificant ($P > 0.05$).



a)



b)



c)

Figure 2. Response surface plots of gluten deformation index. B_AS = Belpan AS; B_Mo = Belpan MOPA; B_Ma = Belpan Malt

3.2. Optimized solution for the formulation

Multiple response optimizations were performed to determine the optimum levels of commercial additives Belpan AS, Belpan MOPA and Belpan Malt to achieve the desired response goals. Falling number value were desired in range from 240 s to 260 s and gluten deformation index were specified in range from 6 mm to 8 mm. The best combinations between these additives in order to obtain an optimum of wheat flour quality were extracted by Design Expert software. The optimum level at 0.80% of each commercial additive used in this study was found, which should lead to 257.09 s for falling number value and 7.59 mm for gluten deformation index in order to improve the wheat flour quality.

Conclusions

Response surface methodology was an efficient statistical tool able to model the influence of Belpan AS, Belpan MOPA, and Belpan Malt on gluten deformation index and falling number value. These results suggested that by modifying the proportion of these additives, we can obtain an optimum of wheat flour quality analyzed by these parameters values.

The final result for optimization suggested that best formulation containing 0.80% Belpan AS, 0.80% Belpan MOPA and Belpan 0.80% Malt could be a good mixture of these three commercial additives in order to achieve the wheat flour quality.

Statistical optimization method predicted the best formulation, under which both falling number value and gluten deformation index were simultaneously optimized, to improve the wheat flour quality.

References

Bordei, D. (2005). *The modern technology of bread making* (2nd ed.), AGIR Publish. House, Bucharest, pp. 79.

Campos, D.T., Steffe, J.F., & Perry, K.W.N.G. (1997). Rheological behaviour of undeveloped and developed wheat dough. *Cereal Chemistry, 74*, 489-494. http,//dx.doi.org/10.1094/CCHEM.1997.74.4.489

Codină, G.G., Mironeasa, S., Bordei, D., & Leahu, A. (2010). Mixolab versus Alveograph and Falling Number. *Czech Journal of Food Sciences, 28*, 185-191.

Codină G.G., Mironeasa S., & Mironeasa C. (2012). Variability and relationship among Mixolab and Falling Number evaluation based on influence of fungal α-amylase addition. *Journal of the Science of Food and Agriculture, 92*, 2162-2170. http,//dx.doi.org/10.1002/jsfa.5603

Collar, C., Bollaín, C., & Rosell, C.M. (2007). Rheological behaviour of formulated bread doughs during mixing and heating. *Food Science Technology International, 13*, 99-107. http,//dx.doi.org/10.1177/1082013207078341

Connelly, R.K., & McIntier, R.L. (2008). Rheological properties of yeasted and nonyeasted wheat doughs developed under different mixing condition, *Journal of the Science of Food and Agriculture, 88*(13), 2309-2323. http,//dx.doi.org/10.1002/jsfa.3352

Derringer, G., Suich, R. (1980). Simultaneous optimization of several response variables. *J. Qual. Technol. 12*(4), 214–219.

Donelson, J.R., Gaines, C.S., Donelson, T.S., & Finney, P.L. (2001). Detection of wheat preharvest sprouting using a pregelatinized starch substrate and centrifugation. *Cereal Chemistry, 78, 282-285.* http,//dx.doi.org/10.1094/CCHEM.2001.78.3.282

Finney, P.L. (2001). Effects of falling number sample weight on prediction of α-amylase activity. *Cereal Chemistry, 78*, 485-487. http,//dx.doi.org/10.1094/CCHEM.2001.78.4.485

ICC (2010). Standard Methods of the International Association for Cereal Chemistry, 110/1, 106/1, 104/1, 107/1, 173. International Association for Cereal Science and Technology, Vienna.

Mares, D., & Mrva, K. (2008). Late-maturity α-amylase: low falling number in wheat in the absence of preharvest sprouting. *Journal of Cereal Science, 47*, 6-17. http,//dx.doi.org 10.1016/j.jcs.2007.01.005

Mirsaeedghazi, H., Emam-Djomeh, Z. & Mousavi, S., M., A. (2008). Rheometric measurement of dough rheological characteristics and factors affecting. *International Journal of Agriculture & Biology, 10*, 112–119.

Myers, R. H., & Montgomery, D. C. (1995). Response surface methodology: Process and product optimization using designed experiments. John Wiley & Sons, New York, NY.

Ren, D., Walker, C., & Faubion, J.M. (2008). Correlating dough elastic recovery during sheeting with flour analyses and rheological properties. *Journal of the Science of Food and Agriculture, 88*, 2581-2588. http,//dx.doi.org 10.1002/jsfa.3378

SR 90:2007. Wheat flour. Analysis method. Romanian Standards Association (ASRO), Bucharest, Romania.

Zounis, S. & Quail, K.,J. (1997). Predicting test bakery requirements from laboratory mixing tests. *Journal of Cereal Science, 25*, 185-196. http,//dx.doi.org 10.1006/jcrs.1996.0075