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Instrumente Structurale
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Project co-financed from the European Social Fund through the Sectorial Operational Programme 'Human Resources Development 2007-2013'
Project title: Integration of Romanian Research in the Context of European Research - doctoral fellowships.
Contract Code: POSDRU/88/1.5/S/60370
Beneficiary: Lucian Blaga University of Sibiu

RESEARCH ON OPTIMAL FLOURS QUALITY INDICES FOR A NUMBER OF BAKERY AND PASTRY PRODUCTS, GIVEN THE QUALITATIVE VARIATION OF WHEAT BATCHES PROCESSED PER MILLING UNIT

~ ABSTRACT ~

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~ 2012 ~

DISSERTATION STRUCTURE

The present dissertation is based on research conducted in the laboratory of Boromir Group, part of Cibin Mill Group, Sibiu, and in the laboratory of "Technology, Equipment, and Quality Control in the Milling Industry", part of the Faculty of Agricultural and Food Sciences, and Environmental Protection with "Lucian Blaga" University of Sibiu.

The dissertation is divided into four chapters spanning over 219 pages, of which 45 are devoted to literature research, 16 to work methods and materials, and 149 to experiments. The thesis includes 95 figures and 65 charts, as well as nine pages of appendices. The works cited list includes 237 titles. Dissemination of results is reflected in the list of published articles related to the dissertation topic.

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Before proceeding to the presentation of the paper, I would like to extend my appreciation and gratitude to those who helped me prepare and complete this dissertation. I would like to take this opportunity to express my gratitude to prof. John Danciu PhD, scientific advisor of this dissertation, for his guidance and competence in coordinating all the work carried out during the preparation of this thesis. I would also like to thank engineer Mihai Ognean, PhD for his support in helping clarify various points.

I also wish to thank my colleagues in Cibin Mill Group and especially production manager Sorin Petcu for his understanding and material and logistic support provided to help carry out experimental work. I would also like to thank the committee members for their assessment of my doctoral dissertation.

Last but not least, I wish to thank my wife and children for their support and understanding during the preparation and completion of this dissertation.

Abstract

Raw material quality is extremely important in the milling industry due to its impact on finished product quality. Given the uneven character of wheat crops in recent years both qualitatively and quantitatively, an accurate analysis of raw material quality is essential in this food sector in order to allow it to be directed towards the appropriate bakery and pastry products. It also allows specialists to establish corrective techniques to improve the quality of flour resulted from wheat milling in order to obtain qualitatively consistent finished products. Seeing that over the years the milling industry has faced such problems as shortage of raw materials, quality issues, and especially variable quality within the same wheat batch, we have considered of prime importance to address two research directions in this paper, both meant to solve, or at least to provide solutions to the problems facing the food sector every year. It is common knowledge that wheat quality is not determined only by its gluten content and gluten deformation index, but a more detailed quality assessment is needed to provide information on the resulting flour quality. As we well know, dough rheology provides valuable information about the behavior of flour dough during different stages of the technological process of bakery and pastry production. Bakery and pastry products include a wide range of products both in terms of consumption and in terms of techniques and processes used to produce them. Therefore, these products want a type of raw material that would meet the manufacturing requirements in order to yield products that meet consumer demands. Directing wheat towards the categories of bakery and pastry products that can be produced from the flour obtained by grinding it requires thorough analysis of the wheat, which can only be done by laboratory grinding, followed by rheological analysis of the resulting flour dough. Laboratory grinding can be done by means of the laboratory mills available on the market. These laboratory mills vary greatly in terms of both their make-up and their grinding qualities. The positive effect of relating flour quality to industrial scale wheat quality is common knowledge, as is the fact that this relation is hardly ever used to assess wheat quality at laboratory scale. These are the reasons why the first research direction of the present dissertation has been addressed to analysing three of the most common laboratory mills, given their well known importance in accurately assessing wheat quality. To this purpose, 10 samples of different quality wheat have been ground on the three laboratory mills as well as on an industrial mill of 120t/24h. In order to assess laboratory mill output, the laboratory scale flour yield has been compared with the industrial scale flour yield, by means of a farinograph, alveograph, and mixolab, and by determining coefficients of correlation between flour quality parameters obtained at laboratory scale and those obtained industrially, with a view to creating laboratory mills that will provide the most accurate information on industrial flour quality. Given that correlation coefficients did not have the same value for parameters determined for an objective choice, the Multi-Attribute Decision Making – MADM was used, which is able to solve the Optimal Choice Problem - OCP.

Flour quality parameters are rarely optimal for bakery and pastry manufacturing, which leads to an increased tendency to improve flour quality, leading to the production of bakery and pastry products of consistent quality. The second research direction of the present dissertation, that is the idea of improving flour quality by means of additives, is the millers' ultimate opportunity to improve deficits in raw material quality. This was achieved by grinding 10 batches of various quality wheat harvested in 2010. White flour type 550 and brown flour type 1250 was obtained after grinding. Given that at certain times of the year or in years with serious quality problems, the milling industry has to produce consistent quality flour, with optimal quality parameters to obtain bakery and pastry products, regardless of raw material quality, the 10 samples of white flour were mixed with additives to improve their quality and the production of gluten biscuits, bread, and croissant-type pastry products. After grinding The brown flour obtained was also mixed with additives to improve bread quality. The effect of additives on flour quality was analysed by studying the rheological behaviour of dough by means of a farinograph, alveograph and mixolab. Studies and research on each rheological device have demonstrated that the laboratory mill provides the most accurate information on industrial flour quality. The mixing of additives, in its turn, has demonstrated that this is an efficient method to yield optimal quality flour properties for the production of bakery and pastry products regardless of quality indices variation of raw material.

Keywords: wheat, flour, additives, farinograph, alveograph, mixolab

Motivation and Objectives of the Dissertation

A percentage analysis of flour quality shows that approximately 75% depends on wheat grain quality parameters and 25% on the milling process. Even if only 25% of flour quality depends on the milling process, processors in the milling industry are required to improve flour quality so as to make it optimal for bakery and pastry product manufacturing.

Given the variety of wheat batches processed in the milling industry, the purpose of the present study has been, on the one hand, to provide a qualitative assessment of three of the most common laboratory mills, and, on the other hand, to improve flour quality parameters by mixing in additives, with a view to obtaining consistent quality flour needed for bakery and pastry product manufacturing enhancers. In order to achieve this purpose, devices such as the farinograph, alveograph, and mixolab have been used to analyse the rheological properties of dough. Moreover, three laboratory mills (Perten 120, Quadromat Jr. and Chopin CD1), as well as a 120t/24h industrial mill, have been used to provide the flour needed for analysis. The main purpose of this paper is to enhance knowledge on wheat qualitative analysis and on flour quality enhancement through the use of additives against the background of wheat quality parameters variation, which is in fact a common feature of Romanian crops.
The scientific objectives of this paper are:
- to identify the type of laboratory mill which provides the most conclusive information on industrial flour, in terms of parameters determined by means of a farinograph.
- to identify the type of laboratory mill which provides the most conclusive information on industrial flour, in terms of parameters determined by means of an alveograph.
- to identify the type of laboratory mill which provides the most conclusive information on industrial flour, in terms of parameters determined by means of a mixolab.
- to improve rheological parameters of dough made from white flour type 550, used to produce biscuits.
- to improve rheological parameters of dough made from white flour type 550, used to produce bread.
- to improve rheological parameters of dough made from brown flour type 1250, used to produce bread.

- to improve rheological parameters of dough made from white flour type 550, used to produce croissant-type pastry products.

1. Documented Study

1.1. Wheat quality

1.1.1. Botanical description of wheat

1.1.2. Anatomical features of wheat

1.1.3. Wheat milling

1.1.4. Chemical composition of wheat

1.1.5. Quality assessment of wheat

1.1.6. Laboratory grinding

1.2. Flour quality

1.2.1. Chemical composition

1.2.2. Biochemical composition

1.2.3. Gluten content

1.2.4. Rheological properties

1.2.5. Bakery additives

1.3. Flour quality indices for several product groups

1.3.1. Flour quality indices for biscuits

1.3.2. Flour quality indices for bread

1.3.3. Flour quality indices for croissant-type pastry products

2. Methods, Devices, and Equipment

Wheat traders and millers are particularly interested in assessing the physicochemical and rheological quality of wheat before purchasing, and especially before grinding. For a conclusive assessment, wheat has to be ground in one of the types of laboratory mills on the market, in order to provide the necessary information related to forming batches for grinding, to the milling process, and to resulting flour quality. In order to imitate the actual milling process as efficiently as possible, the wheat samples must be conditioned before experimental milling. Laboratory milling meant to determine wheat quality is a very important stage in selecting appropriate wheat batches for grinding, depending on the final purpose of the resulting flour. Laboratory scale grinding equipment includes a wide variety of devices, among which hammer mills, semi automatic and automatic mills, and experimental mills. Wheat milling and conditioning was performed according to the milling methodology described in SR EN ISO 27971:2008 (ASRO, 2010). Hectoliter mass determination was performed according to SR EN ISO 7971-3:2010 (ASRO, 2010), wheat vitrescence was determined according to STAS 6283-2/1984, wheat moisture according to STAS SR ISO 712:2010 (ASRO, 2010), mineral content according to SR ISO 2171/2010 (ASRO, 2010), wet gluten content of whole groats according to SR EN ISO 21415-1:2007 (ASRO, 2008), gluten index according to SR EN ISO 21415-2:2007 (ASRO 2008), and α-amylase activity measured by the Hagberg-Perten Falling Number according to SR ISO 3093/2007. Rheological properties of dough were determined by means of a farinograph, according to SR ISO 5530-1/2007, using ICC evaluation, by means of an alveograph, according to SR EN ISO 27971/2009, and a mixolab, according the instructions manual and using the standard Chopin+ protocol (CHOPIN Applications Laboratory, 2009). The baking test was performed by means of the single-phase long fermentation method (AACC Method 10-09). Kneading was performed by means of a farinograph and the final fermentation and baking were done in a **Debag City Monsun** oven with inbuilt leavening chamber.

The wheat batches used were part of the 2010 harvest and were ground in a120t/24h industrial flour mill with a 79% extraction rate (0.55% flour and 1.25% flour ash), (Appendix 8). The following additives were used to improve flour quality:

• protease, Appendix 1
• hemicellulase, Appendix 2
• fungal α-amylase Appendix 3
• malt flour, Appendix 4
• cysteine, Appendix 5
• vital wheat gluten, Appendix 6
• ascorbic acid, Appendix 7

The enzymes (protease, hemicellulase, fungal α-amylase, malt flour), as well as the cysteine and ascorbic acid come from Mühlenchemie company, while the vital gluten from SYRAL Belgium.

To determine the relationship between quality parameters, as well as the relationship between additive dosage and flour quality parameters we used the coefficient of determination R2, which, expressed as a percentage, shows how much of the variation in the dependent variable is explained by the estimated equation. Given that correlation coefficients for flour quality parameters are different for each method used and parameter importance for the same device is also different, the choice of the most appropriate work method has been made by means of Multi-Attribute Decision Making – MADM, able to solve the Optimal Choice Problem - OCP.

3. Studies and Research on Quality Variation of Processed Wheat Batches and its Influence on Flour Quality Indices

The raw material in the milling industry is wheat, which is ground into flour, the raw material for the bakery industry. Wheat flour quality greatly affects the quality of bakery and pastry products, given that flour is the main ingredient used to produce them. Any variation in flour quality may lead to the manufacturing of products not complying with quality standards, and therefore to significant financial and economic loss. Because of the same economic reasons, processors in the milling industry are concerned with wheat quality and require a quality assessment before purchasing. Therefore, an accurate assessment of wheat quality parameters before purchasing and especially before grinding has become a requirement and an important step in achieving consistent flour quality for bakery and pastry products. Laboratory mills are employed to provide useful information about the quality and behavior of wheat at grinding stage and clues about quality parameters of the resulting flour. The present paper is not concerned so much with the ability of laboratory mills to produce large amounts of flour with low mineral content, but rather with flour quality and the relation between the physicochemical and rheological indices of flour obtained by industrial milling and those of flour obtained by laboratory milling in three of the most simple and common laboratory mills: Perten 120, Quadromat Jr. Brabender, CD1 Chopin test mill, with a view to identifying the technique and grinding device which provides the most conclusive information on wheat quality.

For this purpose, 10 wheat batches harvested in 2010 were selected, with the following quality parameters: hectoliter mass ranging from 77.7 kg/hl to 85.8 Kg/hl, mineral content ranging from 1.24% to 1.71%, vitrescence between 33% and 88%, wet gluten content between 18.9% and 28.4%, deformation index between 3 mm and 6.5 mm, falling number between 149 seconds and 476 seconds, and protein content between 11.4% and 14.8%. A first examination of the values of the 10 wheat samples selected for analysis shows a large variability of parameters for all quality indices analysed. In addition to physicochemical analyses, tests performed in order to determine the rheological properties of dough, namely the behaviour of flour dough, are extremely important from a technological point of view. By determining the rheological properties of dough, important information is obtained about the quality of gluten proteins, valuable information that helps specialists improve and direct flour, as raw material for bakery and pastry, towards specific products of the kind. In order to be able to determine the rheological properties of wheat flour dough, wheat has to be ground in such a way as to obtain grain size similar to that of flour obtained by industrial milling. This type of grinding can be performed in any laboratory mill, with or without conditioning, if the product obtained by grinding can produce rheologically analysable dough. It is important how rheological parameters of the product obtained by laboratory milling and rheological parameters of flour obtained by industrial milling can be correlated to provide accurate information on flour quality obtained by wheat grinding in an industrial mill.

Wheat grinding in a Perten 120 laboratory mill was performed without wetting for all wheat samples analysed. The milling industry in our country is faced with special circumstances compared to other countries with more consistent raw material quality (Germany, Austria, France, Hungary), and compared to countries that import a high amount of raw materials (Italy, Greece). These countries are not faced with such great variation of wheat quality and such low quantity of wheat batches per milling unit. Therefore, these countries manage to obtain complete analyses of a wet grain batch in about 26-28h. The technique of grain sample wetting is not used in our country at industrial level, mainly because of the time needed for wheat sample conditioning before milling (24h). Grain wetting has not been performed in this type of laboratory mill because of the high probability that the 500μm mesh sieve of the laboratory mill may become plugged. After sifting the product obtained by grinding in the Perten 120 laboratory mill, through a 140μm mesh sieve, a 38% to 42% product percentage was obtained, which was analysed by means of a farinograph, alveograph, and mixolab. In order to compare flour quality obtained in laboratory mills and its parameter correlations to quality indices of industrial flour obtained in the other laboratory mills, grain samples were ground according to SR ISO 27971:2009, with and without wetting.

The 10 grain samples were ground in a 120t/24h industrial mill (Appendix 8), and the moisture content of the resulting groats was found to be 16.5%. From the point of view of the composition of the two flours, the purpose of the study was to use all parts of the flour in order to obtain similar wet gluten content for the two types of flour. It was also tried to obtain white flour whose ash content would not exceed 0.55%, to enable it to be used as raw material in pastry manufacturing. In order to form appropriate grain batches for grinding, to perform the milling process in the best conditions and with the best results, and to achieve a balanced flour quality, it is important for processors in the milling industry to know the correspondence between tests performed on wheat and tests performed on the flour obtained by grinding the same wheat.

3.1. Variation of Physicochemical Quality Indices

After charting the dependence of the ash content of industrial flour for the 10 samples and the ash content of flour obtained in the three laboratory mills, it was found that the coefficient of determination was low for all samples, except that of the flour obtained in the laboratory mill Perten 120. The value of the linear correlation coefficient R^2- 0.4761 indicated an medium correlation with the industrially obtained flour from the point of view of mineral content.

Wet gluten content is one of the most important indices from an economic point of view when it comes to purchasing wheat for the milling industry, and just as important for the bakery and pastry industry. Gluten proteins are the most important proteins in the composition of dough. Gliadins contribute to dough viscosity and glutelins to dough elasticity (Khatkar, 1995). A graphical representation of the interdependence between the samples' ash content, shows a very high coefficient of determination $d = R^2$. The wet gluten content of the resulting flour correlates very well with the wet gluten content of the original wheat. The highest value of the coefficient is recorded for the wet gluten content of the whole wheat groats.

The falling number is an indicator of α-amylase activity in wheat and, if the values are lower than 160 s, the wheat batch is unusable in bakery.

A graphical representation of the relation between the falling number of industrially milled white flour and the falling number of laboratory milled flour indicates a very high coefficient of determination $d = R^2$. The falling number of the flour obtained by grinding correlates well with the falling number of the whole groats and that of the flour milled in the laboratory mills analysed. The best correlation coefficient (R^2-0.934) was recorded for the flour obtained by milling wetted grain in the CD 1 Chopin laboratory mill.

3.2. Variation of Rheological Quality Indices Determined by Alveograph

The alveograph provides information on dough rheological properties of biaxial extension under constant hydration. The method is based on the tensile strength of a sheet of dough let to rest for 20 minutes and then subjected to a stream of air at constant pressure by inflating a bubble in the sheet of dough until it bursts. The values of the air pressure inside the bubble are recorded up to the bursting point and extrapolated graphically as a curve indicating dough resistance to deformation. (Dubois et al., 2008).

Analyses indicated higher values of P index for Quadromat Jr. Mill, because of the higher degree of starch damage and higher values for wet grinding compared to dry grinding. Higher dough tenacity means higher hydration capacity for these samples. Dough produced at constant hydration is stiffer, more resistant to deformation when subjected to air pressure; hence the definition according to which P is a measure of dough resistance to deformation. For dry wheat grinding in the 3 laboratory mills, the best correlation is obtained for Perten 120, where the coefficient of determination R^2 is 0.7177. This correlation coefficient is higher than the one for the other two laboratory mills, but lower when compared to wet grinding, in the case of which the highest coefficient of determination is recorded for Quadromat Jr. Laboratory mill, i.e. R^2-0.7897.

The L value indicates the length of the curve and is used as a measure of dough extensibility estimating its handling properties. A graphical representation of the relationship between variables indicates a better correlation for Quadromat Jr. laboratory mill, and higher values for dry grinding compared to wet grinding. A good R^2 -0.5673 correlation was recorded for dry grinding in the Quadromat Jr. laboratory mill.

Analysis indicates substantial differences between grinding with and without preliminary conditioning, which suggests increased strength of flour obtained by grinding with preliminary conditioning. Kweon et al. (2009) have also noticed an increase in flour quality and a decrease in mineral content of flour obtained by wet grinding.

R^2 coefficients of determination for the three laboratory mills are high and very close in value for flours obtained by wheat grinding in the Quadromat Jr. şi CD1 test mills, and slightly higher for wheat grinding after conditioning compared to dry grinding, which strengthens the idea that wheat conditioning produces higher quality flours. The highest coefficient of determination (R^2-0.8631) was recorded for flour ground in Perten 120 laboratory mill.

P/L ratio is the balance between dough strength and extensibility, which, along with W value is an important indicator of flour characteristics for various bakery and pastry products. Analysis indicates higher values for grinding after conditioning compared to grinding without preliminary conditioning, due to the influence of P value. Slightly higher values were recorded for flour ground with Perten 120 laboratory mill compared to industrially milled white flour, due to higher pentosan content, which contribute to a slight increase in hydration capacity and hence in P/L ratio. The big discrepancy in P/L ratio for the 3 laboratory mills points to the importance of the type of grinding mill employed.

Analysis indicated low I_e values for flour obtained by Perten 120 grinding because of the higher bran content compared with white flour, which negatively influences dough elasticity and extensibility. Lower values were also recorded for dry grinding as compared to wet grinding, which is easily explainable given the higher flour quality resulted from milling after wheat conditioning.

A graphical representation of parameter variation has shown that quality indices have different coefficients of determination. The technological value of quality indices does not bear the same weight for all parameters, therefore the Multi-Attribute Decision Making - MADM method has been used for an objective choice. After applying this method, it was seen that the laboratory mill that provides the most accurate information on industrial flour quality determined by alveograph is the Perten 120 mill, followed by Chopin CD1 and Quadromat Jr., for wet grinding.

3.3. Variation of Rheological Quality Indices Determined by Farinograph

Changes in the rheological properties of gluten occurring during mixing largely determine the quality of the finished product (Dobraszczyk and Morgenstern, 2003). During this stage, gluten proteins are hydrated, they swell and, under the influence of mechanical action, they come together and form a three-dimensional viscoelastic gluten network. The farinograph provides information on changes in the rheological properties of dough of stable consistency during kneading. This information is connected to the hydration capacity of flour, dough development time, stability, and degree of softening.

Hydration capacity is the amount of water absorbed by dough to achieve standard consistency of 500 BU. This parameter is particularly important for measuring bakery products yield, which directly influences their production cost. Hydration capacity is influenced by the main flour components, namely protein, starch, and pentosan content. A graphical representation of data indicates higher coefficients of determination for flour obtained by wheat grinding after conditioning.

The value of Pearson's correlation coefficient R-0.8985 is high and indicates a very high correlation between hydration capacity of flour obtained by industrial grinding and by laboratory grinding using a Perten 120 mill.

The value of the coefficient of determination R^2-0.8073 measures the strength of the relationship, which is 80.73% due to the linear relationship between the two variables. Dough development time refers to the time needed for the dough to reach maximum consistency and it depends on protein quality. The dough development time increases with proteolytic degradation of proteins, starch grain size, and starch degradation due to increased surface area for water absorption. Analysis has shown significantly higher values of development time for the product obtained from laboratory grinding on Perten 120, given that water-soluble pentosans increase dough development time and consistency because of their delayed hydration capacity (Bordei 2004).

For dough development time, a medium correlation index has been obtained for flour resulted from grinding on Perten 120 laboratory mill, as well as for grinding after wheat conditioning in other 2 laboratory mills. Unlike the other determinations, the linear correlation index R^2 was higher for the product obtained by grinding without preliminary conditioning. The best linear correlation factor was obtained for flour resulted from grinding without preliminary conditioning on Quadromat Jr. laboratory mill. The linear correlation factor $R^2 = 0.8098$ measures the strength of the relationship, which is 80.98% due to the linear relationship between the two variables.

Dough stability is the time interval, expressed in minutes, between the moment where the upper edge of the farinograph curve intersects the line corresponding to maximum dough consistency and the moment where it exceeds it. Stability is an important indicator of mixing tolerance; strong flours exhibit higher stability. Stability is an important indicator of dough quality and is strongly influenced by protein quality; therefore it is only natural that products obtained by grinding after wheat conditioning should exhibit higher values, given that flour quality is positively influenced by wheat conditioning (Kweon et al., 2009). A graphical representation of the values of this parameter indicated a low correlation for the product obtained by grinding in the Perten 120 laboratory mill, given that, even though this product exhibits high gluten content, it is poor quality gluten from the peripheral area of the grain. The highest linear correlation factor (R^2-0.6897) was recorded for the product obtained by grinding wheat after conditioning on the Quadromat Jr. laboratory mill. The degree of softening (UF) is the difference in consistency measured between the center of the curve at the end of dough development and the center of the curve 12 minutes after this point. In practice, a high degree of softening is associated with poor quality flour even if the flour exhibits high hydration capacity. An increase in the degree of softening is an important indicator of proteolytic degradation of wheat (Tamara Dapčević Hadnađev). Analysis has indicated a rather significant variation of this parameter, which is perfectly explainable given that the degree of softening is strongly influenced by the type of grinding and the physicochemical properties of wheat. However the product obtained by grinding without conditioning on the Perten 120 laboratory mill exhibited a medium to high linear correlation factor R^2- 0.65, which indicates a high linear correlation with the degree of softening of white flour type 550 obtained by industrial grinding, 65% due to the linear relationship between the two variables.

A graphical representation of parameter variation has indicated different values of the coefficients of determination for quality indices. The technological value of quality indices does not have the same significance for all parameters; therefore the Multi-Attribute Decision Making – MADM method has been employed for an objective choice of laboratory mill. By applying this method, it has been found that the laboratory mill which provides the most accurate information on industrial flour quality determined by farinograph analysis is Brabender Quadromat Jr., followed by Chopin CD1, and Perten 120.

3.4. Variation of Rheological Quality Parameters Determined by Mixolab

Mixolab is a complex device that measures the rheological properties of dough and combines the results of farinograph and amylograph analyses. Mixolab analyses protein quality during dough kneading (dough forming time, hydration capacity, stability, elasticity, softening), dough behavior when heated to the point where coagulation of proteins occurs, starch gelatinization (gelatinization and gelatinization temperature), analysis of enzyme activity (proteolytic and amylolytic), starch behavior on cooling (gelatinization and retrogradation). The first stage of the analysis was conducted at a temperature of 30 ° C for 8 min, during which flour hydration occurs and forms a three-dimensional viscoelastic structure. The parameters recorded at this stage are similar to those obtained by using a farinograph and provide information on dough behavior during mixing.

The second stage begins with a temperature increase in the mixing chamber, which leads to a gradual heating of the dough. The heating, as well as the mechanical action of the kneading arms leads to protein softening, which releases water. As a result, the free water content increases and dough consistency decreases. Minimum consistency of the dough is achieved at the end of this stage. Analysis shows the influence of wheat grain hydration before milling on the quality of the product obtained after milling, including on protein quality. Very low values have been recorded for products obtained by grinding on Perten 120 laboratory mill because of the poor quality of proteins, although the wet gluten content is highest in these products. As for the other two laboratory mills, a significant increase in C_2 parameter has been recorded for products obtained by milling after wheat conditioning, as a result of protein quality improvement. A high linear correlation coefficient R^2- 0.6591 was recorded at this stage for flour obtained from wheat after conditioning on Quadromat Jr. laboratory mill.

During this stage, the increase in temperature leads to protein denaturation and releases water, which becomes available for starch. Starch granules absorb water and therefore increase the consistency of dough. The starch granules swell until they reach the maximum of gelatinization point C_3. This process ends when, under the mechanical action of the kneading arms and the influence of temperature, a physical splitting of starch granules occurs, followed by a decrease in dough consistency (Rosell, 2007). Analysis has shown an increase in the value of C_3 parameter and of the linear correlation factor for wheat ground after conditioning, due to improved gelatinization properties of starch. The highest linear correlation coefficient was recorded for flour obtained by grinding on Quadromat Jr. laboratory mill. This coefficient, R^2-0,5225, indicates a medium to high correlation with white flour type 550 obtained by industrial grinding.

During the fourth stage of analysis (enzyme hydrolysis), dough temperature rises because the temperature in the mixing chamber is maintained at 90 ° C. The gelatinization process ends when a physical splitting of starch granules occurs under the mechanical action of the kneading arms and the influence of temperature (Rosell, 2007). Following starch granule splitting and the increase in dough temperature, dough consistency decreases until room temperature begins to drop. This point of minimum consistency represents the starch gel stability. The highest linear correlation factor R^2- 0.8086 was recorded for the product obtained by grinding on Perten 120 laboratory mill. The value of the correlation factor is high and shows a good correlation with white flour obtained by industrial milling.

During the fifth stage of analysis (starch gelatinization), the temperature in the mixing chamber drops to 50 ° C and it is maintained there for 5 min. This stage continues the bread manufacturing process simulation and corresponds to the cooling stage. Once the bread core is no longer exposed to heat, gelatinization occurs due to the process of restoring hydrogen bonds in the starch structure and consistency increases. Products obtained by grinding wheat subjected to preliminary conditioning on Quadromat Jr. laboratory mill and CD1 test mill exhibit an increase in C_5 values and linear correlation coefficient. A high correlation for this parameter was recorded for Perten 120 laboratory mill. The linear correlation index R^2- 0.7646 indicates a linear relationship between the two variables in a percentage of 76.46%.

The same as in the case of alveograph and farinograph analysis, a graphical representation of parameter variation has shown different values of the coefficients of determination for quality indices. The technological value of quality indices for mixolab was considered the same for all parameters, therefore the Multi-Attribute Decision Making - MADM method has been used for an objective choice of laboratory mill. It has been found that the laboratory mill which provides the most accurate information about the quality of industrially milled flour for mixolab analysis is Chopin CD1, followed by Brabender Quadromat Jr. and Perten 120.

4. Research Results on Use of Additives to Improve Flour Quality Indices

Bakery product manufacturing is one of the oldest branches of the food industry and, along with flour milling; it is one of the main branches of the food industry.Following the development of bakery industry characterized by increasing mechanization and automation technology, product diversification, implementation of new manufacturing processes and technologies, and last but not least increasing consumer requirements, the milling industry has had to adapt in order to meet the bakery industry requirements for raw material quality. The raw material used to obtain the flour needed to manufacture bakery and pastry products is wheat, which does not exhibit the same quality characteristics over time in terms of baking parameters for the following reasons:

- use of unsuitable wheat varieties;
- use of unsuitable agricultural technologies and equipment;
- lack or misuse of specific fertilizers;
- climate conditions.

Depending on the quality characteristics of bakery and pastry products and the manufacturing methods employed, flour, as the main raw material to these products, must meet certain quality requirements for each product. Meeting these quality requirements is essential for achieving the optimal rheological and enzyme parameters required in order to obtain high quality bakery and pastry products.

In some cases, these parameters of technological quality are hard to meet, mainly because of problems related to quality variation of bakery parameters. Consequently, the milling industry has to use additives in order to improve flour quality parameters in order to manufacture bakery and pastry products that will meet consumer requirements.

Given the variability of wheat batches processed in the milling industry, the present study discusses the use of additives to improve quality parameters of flour resulted from wheat milling, with a view to producing consistent quality flours needed for manufacturing bakery and pastry products. Typically, the same type of flour and different amounts of additives are used in order to determine the effect of the additive, the optimal amount, and tendencies in the variation of the flour quality parameters analysed. The purpose of the present paper is to improve the rheological quality parameters of flours resulted from the milling of 10 samples of wheat grain of different quality levels. Ten samples of white flour of different quality levels for bakery products, as well as ten samples of brown flour, were obtained after grinding.

Given the variation of quality parameters of the 10 samples compared with the parameters needed for the production of bakery products, biscuits, and croissants-type pastry products, the use of additives proved necessary in order to achieve the flour quality parameters needed to manufacture these products. Given that flour quality parameters were different for the 10 flour samples, parameter improvement in order to achieve constancy of these parameters was performed by using different amounts of additives.

The objectives aimed at this stage of the paper were:

- to improve rheological parameters of white flour type 550, used in biscuit manufacturing.
- to improve rheological parameters of white flour type 550, used in bread manufacturing.
- to improve rheological parameters of brown flour type 1250, used in bread manufacturing.
- to improve rheological parameters of white flour type 550, used in croissant-type product manufacturing.

4.1. Improving Flour Quality for Biscuit Manufacturing

Biscuit dough should be modeled with little effort and without ulterior deformation of the pieces of dough. To that end, the flour meant for biscuit manufacturing should have a sufficiently low protein content of medium quality and high extensibility. Flour quality indices can greatly influence the quality of biscuits, especially if flour quality is superior in terms of the quantity and quality of gluten, which may lead to the manufacturing of misshaped finished products or products exhibiting uneven porosity. It often happens that the raw material (wheat) does not possess optimal qualities for biscuit manufacturing. In order to obtain high quality products, dough plasticity must be kept under control by modifying gluten quality. This can be achieved by means of exogenous protease enzymes.

Exogenous protease enzymes contribute to reducing dough kneading time and dough consistency (Barrett, 1975).

The technological effect of enzyme additives depends not only on the source of enzymes, but also on flour quality. Therefore, gluten softening has different values for equal amounts of bacterial protease enzymes, which demonstrates the importance of gluten proteins in proteolysis

(Hanford, J. 1967). The use of protease enzyme additives makes dough more moldable and improves volume and texture for gluten biscuits and cracker biscuits. The most appropriate enzyme for biscuit dough is the bacterial protease enzyme obtained from *Bacillus subtilis*, which has an optimal pH between 7 and 8.5. (Iorga and Câmpeanu).

Combinations of protease enzymes, amylases and cysteine can be used to improve biscuit flour quality, depending on the quality parameters of the control flour sample. For the purpose of the present study we have chosen a bacterial protease enzyme (Alphamalt BK 5020) marketed by Mühlenchemie and used with the purpose of increasing gluten extensibility, preventing deformation during cooling, improving color quality, and preventing cracking of the finished product.

In order to determine the optimal amount of protease enzyme additive required, a set of tests was performed by mixing protease enzyme additive with consistent quality flour with wet gluten content of 28.4% and W -259 determined by alveograph. Since flour quality is the main drawback of these flours, it was associated with W parameter determined by alveograph. A relationship was established between this parameter and the amount of protease additive required.

$$y = 241{,}0e^{-0{,}09x}$$

A coefficient of determination R^2- 0.978 was recorded for this relationship This value indicates a very high correlation between the protease additive and the value of W parameter, which is 97.8% due to the linear variation between the two variables. Given that the amount of additive required for protease varies according to the quality of flour, the amount of additive required for each type of flour was slightly modified. Therefore, the amount of BK 5020 bacterial protease additive for flours of variable quality can be determined by using the relation obtained by graphical representation between the value of control W and that of W obtained after the use of protease additive on the x axis and protease amount on the y axis.

$$y = 0.033\,x + 2.076$$

where y is the amount of protease additive required.

The relation obtained has a residual value of only 5%, and is 95% due to the linear variation of the variables.

P/L ratio is the balance between elasticity and extensibility. It is an important index, which can affect the quality of biscuits. During the baking and cooling stages, biscuits are prone to shrinking or deformation. Bacterial protease additives influence dough tenacity (P) but not extensibility (L) so that the relation between protease additives and P/L ratio modification does not exhibit a value as high as for W parameter.

Ie elasticity index is a dough elasticity indicator, therefore a very good relation was obtained for this parameter as well. A graphical representation of the difference between the Ie of the control flour sample, the Ie of the flour with additives, and the amount of protease enzyme added to improve the quality of the 10 samples has indicated a coefficient of determination R^2 of 0.945, which indicates a linear relationship of 94.5 % between the variables analysed for the relation:

$$Y = 0.345\,x + 0.969$$

where y is the amount of protease additive

Starting from this relation and knowing the value of the elasticity index that we want to obtain after the use of the additive, we can calculate the amount of protease enzyme required.

4.2. Improving White Flour Quality for Bread Manufacturing

Bread is a spongy bakery product characterized by large loaf volume, uniform porosity, elastic core, crispy crust, and dryness to the touch. Bread is consumed daily and comes in many types and forms according to manufacturing technique, equipment, manufacturing area, and last but not least the type of flour used. Regardless of all these factors that differentiate the various types of bread, raw material quality, and especially gluten quality, are critical for the manufacturing of a high quality product. Therefore, during mixing, bread flour must be able to form dough capable of retaining fermentation gases produced during fermentation and baking, in order to produce bread of appropriate loaf volume. At the same time, it must be able to form enough carbohydrates to feed the baking yeast, which, in turn, should be able to produce enough gas to get a high porosity core with on baking. During the final proofing stage, the dough should be elastic and extensible enough to be able to retain the gases released and form a product with high porosity and high volume.

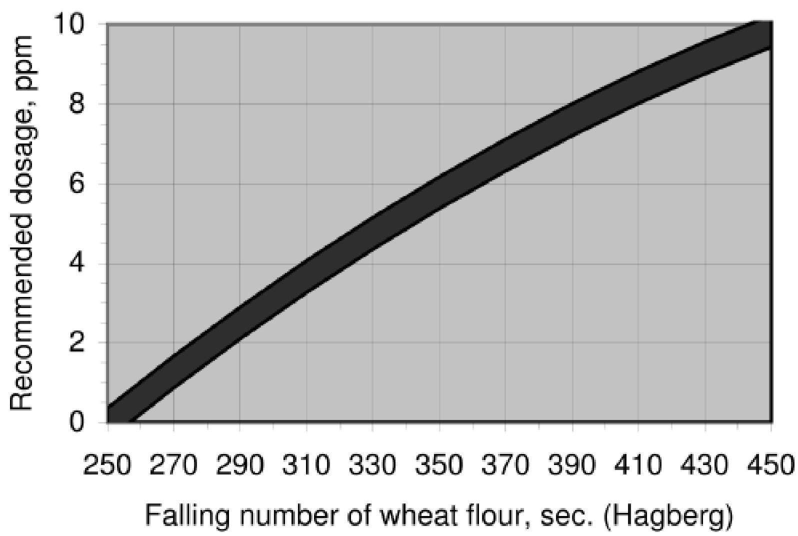
In practice, it rarely happens to obtain flour with constant physicochemical and rheological characteristics over time as long as the raw material exhibits variable quality indices, which are sometimes lower than the minimum required to manufacture certain products. In order to achieve optimal and constant quality indices for bakery product manufacturing, an efficient solution is to use additives in order to adjust certain quality indices so as to achieve consistent quality products.

In the present study we have chosen to use standard additives. Depending on the quality indices of the control flour sample, we have used different amounts of ascorbic acid, hemicellulase, α-amylase, malt flour, vital gluten, and cysteine. In most samples, enzyme active malt flour was used to adjust amylase activity, because the former does not soften the dough and does not decrease mixing stability as much as fungal α-amylase does. However, fungal α-amylase was used for flours whose stability allowed it. In most cases, flours used in bakery product manufacturing do not display sufficient amylase activity to yield appropriate products and the products obtained are undeveloped and exhibit low porosity, coarse crumb, and pale crust.

In order to provide the required amount of fermentable carbohydrates, the flours were combined with malt flour additives (Appendix 4) and, in some cases, with fungal amylase (Appendix 5).

A fungal hemicellulase produced by *Bacillus subtilis* was used in order to convert water-insoluble pentosan chains to water-soluble fractions, with a view to improving water absorption and mechanical properties of dough (Appendix 3). Enzyme additives increase gas production capacity and sometimes soften the dough, which must contain gases released during the stage of fermentation and the first baking stage. Ascorbic acid was used to strengthen the structure of gluten bread and increase retention of fermentation gases. Where it was found that wet gluten content was below the preset limit, vital gluten was used as flour additive (Appendix 7). After the baking test and result analysis based on bread appearance one or two types of additives were created for the 10 flour samples. Analysis of control samples indicated a high variability of baking indices. In order to obtain final products of consistent quality, that is appropriate loaf volume, elastic crumb, uniform porosity, and crispy crumb, flour quality parameters must be within the preset limits for all quality indices.

The first stage of the study aimed to improve enzyme activity (amylases and hemicellulases) and gas retention by using oxidants (ascorbic acid) and reducing substances (cysteine) for flours whose P/L ratio was higher than required. Thus, the first step in improving flour quality for bread is to optimize α-amylase content. This is achieved by means of fungal α-amylase additives, if the mixing stability of the flour allows it, or by malt flour additives. According to technical specifications, the amount of malt flour additives should be between 30-200 g / 100kg of flour depending on the falling number of the control flour sample. A 0.1% amount of additive causes the value of FN to decrease by 60-110 seconds, while a 0.2% amount decreases the value of FN by 100-150 seconds. Fungal α-amylase additives (140,000 SKB) were used according to the following chart:



Once the α-amylase content had been improved, ascorbic acid was added to strengthen the gluten network weakened after the addition of enzymes. In the case of flours whose P/L ratio was higher than required, cysteine was added to increase dough extensibility. Baking tests with hemicellulases indicated that the optimal amount for white flour was 2g/100kg of flour. The purpose of the second stage of the study was to optimize not only enzyme activity but also the gas-retention capacity, by adding vital gluten to samples that did not meet the minimum quality requirement for wet gluten content. In terms of the amount of wet gluten required in bakery product manufacturing, the control samples exhibited values ranging between 22 and 31% wet gluten. During the second stage of quality improvement, wet gluten content was optimized to obtain consistent quality products. Following the use of vital gluten additives in white flour used for bakery products and croissant-type pastry products, a graphical representation of the difference between the wet gluten content of the samples with additives and the control samples on the x axis and the amount of vital gluten additive on the y-axis, a linear relationship resulted, which was 98.7% due to the linear relationship between variables, with a 1.3% residual value.

$$y = 0.538\, x + 0.052$$

where y is the amount of vital gluten needed to increase wet gluten content.

After the first stage of quality improvement, the specific volume increased by 6% to 56% compared to the initial specific volume of the flour samples. After the second stage of improvement, the specific volume increased by 23% to 68% compared to the initial specific volume of the flour samples.

4.3. Improving Brown Flour Quality for Bread Manufacturing

Brown flour is generally produced together with white flour as intermediate product and the quality and consistency of its quality parameters are often unsuitable for bakery product manufacturing. The most important indices are protein quantity and quality, which influence gas retention during fermentation and baking and hydration capacity, which influences finished product yield and freshness. Another important index, one which influences gas release, is falling number, which provides indirect information on the amylase activity of flour. In order to produce consistent quality bread, flour quality parameters must be optimized so as to achieve consistent quality products that meet processors' and consumers' demands. Due to variability of wheat quality indices, there is a fairly large variation of brown flour quality indices, including mineral content variation. This demonstrates the importance of quality consistency of raw materials, which is well reflected in the quality of finished products. Raw material quality is in fact the main cause of complaint and of poor quality bakery products. This high variability of bread indices cannot be corrected by using the same type of additive for all samples because the latter do not exhibit the same enzyme activity or the same gluten protein quantity and quality.

Therefore, in order to correct quality deficiencies and to optimize these parameters, flour quality must be individually improved according to the physicochemical and rheological parameters of control samples. Therefore, fungal α-amylase was used in order to control and increase gas release capacity and speed. A fungal hemicellulase produced by *Bacillus subtilis* was used in order to convert water-insoluble pentosan chains to water-soluble fractions, with a view to improving water absorption and mechanical properties of dough (Appendix 2). Ascorbic acid was used as an oxidant to optimize gas retention (Appendix 7), and, during the second stage of quality improvement, vital gluten was added to the ascorbic acid (Appendix 6) in order to improve the wet gluten content of the samples whose content was found to be below the preset limit. Vital gluten and fungal α-amylase were added in the same manner as in the white flour samples, except for sample 5, where 3% instead of 1.5% was needed due to poor quality of the control sample.

After the first stage of quality improvement, the specific volume increased by 18% to 82%, compared to the initial specific volume of the flour samples. After the second stage of quality improvement, the specific volume increased by 21% to 85%, compared to the initial specific volume of the flour samples.

4.4. Improving Flour Quality for Croissant-Type Product Manufacturing

Although there are views on the quality of flour used for croissant-type products which claim that there is no need to use high protein flour, industrial practice shows that all flour mills that produce flour for croissant-type products deem necessary the following quality indices for these products: high protein content 13.5% to 14%, 38%-42% wet gluten, W> 400, P/L-0.5-0.6, hydration capacity > 57%, stability > 15 minutes, falling number > 350 sec. Flour intended for croissant-type products should have good hydration capacity, therefore protein content must be high and starch degradation optimum during the grinding process. Wet gluten content must be high and of good quality so that the dough can incorporate the sugar and fat in the recipe and the resulting product can have a spongy texture and high volume. Gluten extensibility must be lower than in flour for bakery products in order for the dough to be easy to handle during rolling and not cause tears in the structure during rolling and folding. In order to obtain a spongy texture, gluten quality must be high so that the dough can withstand the pressure of fermentation gases released during fermentation and baking.

In order to improve flour quality for croissant-type product manufacturing, vital gluten can be used to increase wet gluten content needed to obtain high quality flour.

Gluten quality and extensibility is very important, given that gluten quality may determine the use of other additives for quality improvement that may alter gluten extensibility to the optimum level needed. The use of ascorbic acid is recommended if gluten exhibits too high extensibility; conversely, if it is too stiff, cysteine can be used to increase extensibility. The falling number of flours intended for croissant-type pastry products is not as important as in the case of flours intended for bakery products, because in the former case the manufacturing recipe contains enough sugar to feed the yeast during fermentation. However, malt flour, which also enhances flavor, as well as fungal amylase, can sometimes be used.

Given that vital gluten additives have a slightly different effect depending on the initial flour quality and quantity, a graphical representation of the increase in wet gluten content after the addition of vital gluten records a relation for vital gluten additives, based, in a proportion of 98.7%, on the linear relationship between the two variables.

$$Y = 0.538\,x + 0.052$$

where y is the amount of vital gluten, expressed in percentages, needed to increase wet gluten content.

Only vital gluten was used in the present study for the quantitative and qualitative improvement of rheological properties of flour intended for the manufacturing of croissant-type products, while ascorbic acid and cysteine were used to optimize gluten extensibility.

5. General Conclusions

5.1. Conclusions on Outcomes

Given that the milling industry must produce consistent quality raw material for the bakery industry, one of the factors influencing the achievement of this purpose is the method used for wheat quality assessment before milling.

Important correlations of physicochemical and rheological parameters were obtained from experimental tests, which can be summarized as follows:

1. Physicochemical tests performed on whole wheat groats correlate well and very well with 550 type white flour obtained through grinding, but, in some cases, the product obtained by laboratory mill grinding correlates better, as follows:

- In what concerns the analysis for mineral content performed on whole groats, it was found to correlate weakly (Pearson correlation coefficient r = 0.52), but the correlation was significant (Pearson correlation coefficient r= 0.69) for products resulted from grinding on Perten 120 laboratory mill.
- As far as the gluten index is concerned, analysis performed on the product resulted from grinding on Perten 120 laboratory mill and that on whole groats indicated a moderate correlation, r = 0.59 and r = 0.58 respectively; these correlations are better than those obtained from other analyses.
- In what concerns the falling number, the correlations were very good for products resulted after wheat milling after conditioning on CD1 test mill and on Quadromat Jr. and for whole groats (r = 0.97, r = 0.96 and r = 0.96).
- As far as gluten content is concerned, very good correlations were obtained for all products, and almost perfect correlations for whole groats analysis and for products resulted after wheat milling without wetting on CD1 test mill (r = 0.98 and r = 0.97, respectively).

Whole wheat groats analysis proved to be the best method of predicting physicochemical indices of white flour type 550 obtained through industrial grinding.

2. Since analyses for determining the rheological properties of industrially-processed dough are done by wheat grinding without wetting, we have confronted the values of rheological parameters of white flour type 550 obtained by industrial grinding and the values of flour obtained by grinding on the three laboratory mills: Perten 120, Quadromat Jr., and Chopin CD1 test mill.

For rheological analyses by means of alveograph:

- It resulted a high correlation factor r=0.84 for the P indicator and a very high one for the W parametre in what concerns Perten 120 laboratory mill.

- It resulted a high correlation factor r=0.75 for the L indicator and a medium one r=0.71 for P/L ratio in what concerns the Quadromat Jr. laboratory mill.
- In what concerns CD1 test mill, the I_e parametre was found to correlate well (r=0.74) with that of flour.

For rheological analyses by means of flourgraph:

- The Perten 120 laboratory mill had a good correlation value r=0.9 for hydration capacity and r=0.74 for softening; for FQN, correlation with industrially obtained flour was found to be medium (r=0.72).
- Quadromat Jr. laboratory mill exhibited a good correlation value, r=0.9, for dough development time.
- For CD1 test mill, the correlation factor was found to be high (r=0.75) for dough stability.

For rheological analyses by means of mixolab:

- Perten 120 laboratory mill best correlated for hydration capacity, as well as for C_2, C_4, and C_5 parameters.
- Quadromat Jr. laboratory mill best correlated for dough stability and for C_3 parametre.
- Laboratory CD1 test mill best correlated for dough development time.

Given the bakery industry needs in the context of increasing automation, diversification of product range, and so on, we can say that improvement of flour quality parameters specific for various bakery products has become an economical need for both supplier and purchaser.

If flour quality intended for biscuit manufacturing is not satisfactory, its parameters may be improved by protease enzymes or, in some cases, by protease, amylase, and cysteine combinations.

As one might learn from this research paper, different quantities of protease are necessary for each type of flour and its quality, depending on their rheological parameters so that the variation of quality parameters is minimal after quality improvement.

Baking flour quality of is the most difficult to obtain because it implies optimizing all parameters, and, as we well know, the same additive may positively influence some parameters and negatively others, and other additives need to be used in order to counteract this effect.

Baking flour quality improvement involves optimization of quality parameters of the main flour components (starch, gluten, pentosans, lipids, and enzymes). Thus, flour quality improvement involves modification of all flour components in order to obtain the best results in what concerns the quality of the product for which the flour was intended.

It may be said that flour quality improvement for croissant-type products is the easiest to achieve, given that gluten quantity and quality is essential for such products, and quality improvement is easily achieved by vital gluten additives. The quality of flour for croissant-type products is easier to obtain because the main issue which appears during the process of ameliorating baking flour, namely an increase in gas production, does not apply to this process since there is enough sugar in the croissant recipe to saturate yeast.

5.2. Contributions to the Industry

In what concerns the rheological analysis performed on products obtained through wheat grinding with or without wetting, the best correlations with industrial flour resulted for the product obtained through wheat grinding without wetting on Perten 120 laboratory mill, and for the product obtained through grinding after conditioning on Quadromat Jr. laboratory mill.

Since correlation coefficients for flour quality parameters are different for each method applied, and parameter relevance for the same machine is not the same, and moreover due to insufficient laboratory equipment in the milling industry, which does not benefit from all the machines presented in this research paper, the laboratory mill which offers the most conclusive information was established for each machine analyzing dough rheological properties. Because of this situation, in order to choose the best working method, the Multi-Attribute Decision Making (MADM) method was applied because of its efficiency in solving the Optimal Choice Problem (OCP).

- In what concerns the analyses performed with the **alveograph**, Perten 120 laboratory mill proved to be the best choice with the highest anticipated value, followed by Chopin CD1 mill for wheat grinding after conditioning and by Quadromat Jr. mill for wheat grinding after being conditioned.

- In what concerns the analyses performed with the help of a **farinograph**, the best choice is Brabender Quadromat Jr. laboratory mill for wheat grinding after conditioning, followed by the Chopin CD1 mill for wheat grinding after conditioning, and by Perten 120 mill for wheat grinding without conditioning.
- In what concerns the analyses performed with the help of **mixolab**, the best choice is Chopin CD1 laboratory mill for wheat grinding after conditioning, followed by Brabender Quadromat Jr., for wheat grinding after conditioning, followed in turn by Perten 120, for wheat grinding without conditioning;

In order to improve biscuit flour quality, some diagrams for the Alphamalt BK 5020 protease additive have been established for different quality flours.

In order to improve both white and dark flour quality, suggestions have been made for quality improvement in the context of flour quality-index variability.

In order to improve the quality of flour for croissant-type products, diagrams have been established to calculate the vital gluten additive content for different quality flours.

5.3. Recommendations

As a consequence of the results obtained, we can state that a very important aspect is wheat wetting before grinding, which is valid for industrial grinding as well; the types of flour resulted after conditioning the wheat before grinding with laboratory mills offer more conclusive pieces of information than the ones offered by the types of flours resulted after grinding dry wheat. Due to these results we emphasize the importance of wheat rheological analyses before grinding, practice which became a necessity in order to optimise the process in the milling industry, in order to predict/estimate the quality of industrial flour but also with the purpose of obtaining products of a constant quality in the long run.

As a result of the fact that it is highly possible for quality indices to vary at least as much as those presented in this research paper, it is recommendable to avoid using complex additives to improve different quality flours. These additives are recommended only if the quality of improved flour exhibits consistent quality parameters in time. Taking this into consideration, it is not recommended to use the same amount of additives on types of flour of different qualities, and moreover without having made the rheological analyses necessary to identify the direction where the additives are needed.

The process of improving flour quality must take place only after an analysis of flour quality parameters, using the appropriate additives in the appropriate amounts; otherwise an overdose may lead to products far inferior to the ones we have begun with.

All these additives must be mixed in relation with production factories, because the quality indicators necessary for this type of product may be different from those described in this research paper, and the requirements of production lines may also differ from case to case.

5.4. Future research topics

In this research paper there was an emphasis on the importance of wheat evaluation at laboratory level before industrial grinding, and on the importance of a laboratory mill which yields the amount of flour needed for laboratory mill tests, so that one might achieve a possible change of laboratory mills so as to improve flour quality, as well as accuracy of information on flour obtained through industrial grinding.

Furthermore, more emphasis was placed on improving relations of additive use and on creating flour quality improvement techniques according to the particularities of the technological manufacturing process.

Scientific dissemination

List of papers published in the thesis

1. Daniel Vizitiu, Ioan Danciu, (2011). Evaluation of Farinograph and Mixolab for prediction of mixing properties of industrial wheat flour. In Acta Universitatis Cibiniensis Series E: FOOD TECHNOLOGY Vol. 15(2), indexat Chemmical Abstracts, Food Science Central, CABI www.cabi.org/AbstractDatabases.asp?SubjectArea=&Subject=&Section=sc&letter=A&PID=125
   http://saiapm.ulbsibiu.ro/rom/cercetare/ACTA_E/AUCFT_2011.html
2. Daniel Vizitiu, Mihai Ognean, Ioan Danciu, (2012). Rheological Evaluation of Some Laboraory Mills. In Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj Napoca, Food Science and Technology, volume 69(2), AcademicPres (EAP), Cluj Napoca, pag. 440-446. Print ISSN 1843-5246. Electronic ISSN 1843-5386 –B^+, ISI Thomson Index
   http://test.usamvcluj.ro/ojs/index.php/agriculture/issue/view/3
3. Daniel Vizitiu, Mihai Ognean, Ioan Danciu, (2012). Laboratory Milling: Rheological Evaluation of Dry and Tempered Wheat. In Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj Napoca, Food Science and Technology, volume 69(2), AcademicPres (EAP), Cluj Napoca, pag. 530-531. Print ISSN 1843-5246. Electronic ISSN 1843-5386 –B^+, ISI Thomson Index
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4. Daniel Vizitiu, Ioan Danciu, (2012). Rheological evaluation of dry and tempered wheat on laboratory scale using Mixolab device. Analele Universității din Craiova Biology, Horticulture, Food Produce Processing Technology, Environmental Engineering, volume XVIII (LIII), pag. 455-460. Print ISSN 1453-1275, B^+ (CNCSIS).
   http://www.anucraiova.3x.ro/cont.html
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