IOSUD „Dunarea De Jos" University of Galati
Doctoral School of Fundamental and Engineering Sciences

DOCTORAL THESIS

ABSTRACT

The influence of rosehip powder addition on dough rheology and bread quality

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Seria I7: FOOD ENGINEERING Nr. 11
GALATI 2020

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The public defense of the doctoral thesis will take place online on **04.12.2020**, at 11:00 at the public address: https://teams.microsoft.com/l/team/19%3a1a86e71b0e5d47b08b6079122dbaf804%40thread.tacv2/conversations?groupId=6bc88f24-4976-48d6-99ce-26c43fcb3fd5&tenantId=445e5699-60fa-4f59-8e7f-778197a4d740

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Seria I 7: Food Engineering No. 11
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Content

Introduction

Motivation and scientific objectives of doctoral thesis

From the nutritional point of view, bread largely reflects the nutritional value of flour, the main ingredient from which it is obtained. To supplement some deficiencies or to improve its bioactive properties, bread is often fortified by the addition of various ingredients. Many of the additions, depending on the proportion in which they are used, change the proportion of the components in the flour, in particular influencing the formation of a strong gluten network able to retain the gases produced during fermentation, by reducing the proportion of gluten-forming proteins in the resulted mixture. To improve and to positively influence the quality and freshness of the bread, improvers are used.

Ascorbic acid (AA) or vitamin C is used both to accelerate the maturation of flour and to process weak flours, as well as for intensive and rapid kneading due to the important role of mediating oxidation reactions that stabilize the dough to maintain elastic and viscous properties, so that the dough retains as much fermentation gas as possible. AA also contributes to faster fermentation, to obtain a bread with a larger volume, finer crumb, smaller and more pores, evenly distributed, but also to reduce the thickness of the crust. These changes also result in a softer crumb, which makes the bread fresh longer.

AA used in bakery is obtained by chemical synthesis (E300). Current trends toward bioactive compounds from natural sources have identified the possibility of replacing synthetic AA with natural materials. There are many plant products that naturally contain high levels of AA, for example rosehips, cranberries, acerola and kakadu plums. Of these, acerola (was used in bread as an AA substitute with good results.

Rosehips have been used in research in the form of powder or extract, in various mixtures of ingredients, but no study aimed to replace synthetic AA with rosehips. The idea of using rosehips as a possible substitute for synthetic AA generated the objectives of this work.

General objective of the doctoral thesis is to determine the influence of the rosehip powder addition, as a natural substitute for ascorbic acid, on the dough rheology and bread quality.

Specific objectives resulting from the general objective are:

- The study of the role of ascorbic acid in flour and dough, in breadmaking and the possibility of replacing the synthetic compound with natural materials with a high content of vitamin C;
- To obtain and characterize of rosehip powder (Pm);
- The study of Pm influence on the physico-chemical properties of flour;

- The selection of the Pm addition range and the right flour for the study;
- The study of the Pm influence on the dough rheological characteristics;
- The study of the Pm influence on the physico-chemical and bread sensory properties;
- Submission of a patent application *Bread with rosehip powder addition and process for obtaining the same.*

Description of chapters of doctoral thesis

The first chapter presents information on the history of the appearance of bread and the importance of bakery products in human nutrition.

The second chapter contains an extesive review on bread additions, the use and role of ascorbic acid in bread making and the possibilities of replacing synthetic ascorbic acid with natural products high in vitamin C.

The third chapter presents the rheological properties of dough, the factors that influence them and trends in current research on dough rheology.

Aspects regarding the bread quality, the influence of some vegetal additions on bread properties and the evaluation of the bread quality characteristics are presented in the fourth chapter.

Materials and methods used in the research are briefly described in the fifth chapter.

The sixth chapter contains the characterization and selection of flour, the influence of rosehip powder on the flour and the selection of the rosehip powder addition range for the study.

The seventh chapter presents the results and discussion regarding the influence of rosehip powder addition on dough rheology resulted from the analysis of specific rheological parameters achieved through farinographic, extensographic, amylographic and reofermentographic tests.

The eighth chapter presents the results and discussion regarding the influence of rosehip powder addition on the physico-chemical and sensory characteristics of bread, highlighting the improvements due to rosehip powder addition and the bread acceptability by consumers.

The ninth chapter presents the results obtained and centralized following the color analysis of the images by color scanning of the bread crumb with added rosehip powder and processing using a software for conversion from RGB to CIE L*a*b*.

The last chapter contains the final conclusions of the study, the original contributions of the author of the doctoral thesis and the future research directions proposed.

1. The importance of bread in the diet

1.1. Brief history of the bread appearance

Bread, in the various forms in which it is produced, is one of the most important staple foods consumed by humanity over time (Cauvain, 2015, p. 1).

Many people consider bread as one of the oldest foods. Although the time when bread was discovered is unlikely to be identified, its production is estimated to be about 8,000 years BC (Zohari, 1986). The region in which it was first obtained is considered to be the Middle East, more precisely the region called the *Fertile Crescent* which includes current Iraq, Syria, Lebanon, Israel, Palestine, Jordan, Egypt, the south-eastern region of Turkey, the western edges of Iran and Cyprus (Havilland *et al*., 2013, p. 104).

Bread has evolved, over time, into various forms, with distinctive and different characteristics, bakers making traditional varieties based on the accumulated knowledge which aimed to make the best possible use of available raw materials to obtain bread with the desired quality by adapting existing methods and, often, the development of new ones (Cauvain, 2015, p. 2).

1.2. The importance of bakery products in human nutrition

Over the years, nutritionists' recommendations for dietary products that contribute to improving and maintaining the people's health have led to an increased consumption of cereal-based products, especially those with high fiber content and low energy products. These recommendations were the basis for the creation of the Nutritional Pyramid, at the base of which cereal-based products such as bread, pasta, and breakfast cereals are located, being considered the basis of a rational diet (USDA, 2011).

2. Additions to bread

2.1. Introduction: benefits of bread additions

Because bread is one of the most sold and consumed foods, for many peoples and categories of the population representing a staple food, bread is often fortified for the improvement of its bioactive properties (Boukid *et al*., 2019). The fortification of bread is achieved by enrichment with various ingredients, the most common being the flours of other cereals (rye, rice, barley, oats, corn), pseudocereals (buckwheat, millet), potatoes or seeds, but also fruits, fruit powders, mushrooms, spent grains from malt production, etc. (Martins *et al*., 2017).

The development of the food premixes industry allowed to obtain a large assortment of bread and bakery products for special purpose – functional bread, enriched with bioactive compounds: bread enriched in dietary fiber, hypoglycaemic products, vitaminized bread, etc. (Bijlwan *et al*., 2019; Gioia *et al*., 2017). At the same time, the protein fortification of the bread can be achieved by adding soy flour (Shao *et al*., 2009), soy milk flour (Nilufer-Erdil *et al*.., 2012), lupine protein isolate (Paraskevopoulou *et al*., 2012), sunflower defatted seeds flour (Grasso *et al*., 2020), legumes (Angioloni & Collar, 2012; Mohammed *et al*., 2012), protein derivatives from dairy industry (Kenny et al., 2000), etc.

2.2. The vegetable origin ingredients addition

2.2.1. Addition of flour or groats of other cereals. Bread and bakery products are also obtained from other cereals, other than wheat. Multigrain bread is rich in seeds and grains (Moraru & Georgescu, 1999, p. 350), having in its composition variable amounts of flour or cereal groats, for example: rice flour (Torbica *et al*., 2010; Wu *et al*., 2019), oat flour (Hager *et al*., 2011; Fraś *et al*., 2018), corn flour (Aprodu & Banu, 2015), barley flour (Al-Attabi *et al*., 2017), rye flour (Döring *et al*., 2015; Cardoso *et al*., 2019), flour of alac, spelt wheat or einkorn wheat (Geisslitz *et al*., 2017).

2.2.2. Addition of pseudo-cereal flour or seeds. There are numerous studies in the literature regarding the addition of pseudocereal flour in bread, for example: buckwheat flour (Nikolić *et al*., 2011; Liu *et al*., 2017), sorghum flour (Sibanda *et al*., 2015), millet flour (Singh *et al*., 2012; Wang *et al*., 2019), tef flour (Ronda *et al*., 2015; Shumoy *et al*., 2018), amaranth flour (Heredia-Sandoval *et al*., 2016; Miranda-Ramos *et al*., 2019).

2.2.3. Addition of tubers. Tubers were added in bread in the form of flour, e.g., flour obtained from potato tubers (Ezekiel & Singh, 2011; Cao *et al*., 2019, 2020), cassava (Rodriguez-Sandoval *et al*., 2016), yam (Amandikwa *et al*., 2016; Liu *et al*., 2019), sweet potatoes (Azeem *et al*., 2020; Mau *et al*., 2020; Monthe *et al*., 2019; Zhu & Sun, 2019), and artichoke (Barktiene *et al*., 2013).

2.2.4. Addition of legume flour. Legumes (beans, peas, lentils, chickpea, cassava, chia, peanuts, lupins, etc.) are rich sources of carbohydrates, vitamins and minerals (Wang *et al*., 2010). Peas, lentils, chickpea and beans are among the most important sources of protein, starch and dietary fibre (Perez-Hidalgo *et al*., 1997) whereas they contain 18.5-30% protein, 35.51% starch and 14.6-23.3% dietary fiber related to the dry matter (Dalgetty & Baik, 2003; de

Almeida Costa *et al.*, 2006; Wang *et al.*, 2009). Therefore, due to their rich amino acid composition and fiber content, legume flours are ideal ingredients for improving the nutritional value of bread and bakery products. (Mohammed *et al.*, 2012).

2.2.5. Addition of fruits. Although fruits have been added to bread for a long time, many studies have recently been reported that have investigated the influence of the addition of fresh cut fruits and dried fruits in pieces or in the form of flour/powder on the physico-chemical, sensory and functional properties of bread: fresh and dry pomelo (Reshmi *et al.*, 2017), fiber of pears, apples and dates (Bchir *et al.*, 2014), apple powder (Lauková *et al.*, 2016), chestnut flour (Dall'Asta *et al.*, 2013; Moreira *et al.*, 2014), banana flour (Ho *et al.*, 2013), powder of green coffee beans (Jakubczyk *et al.*, 2018), dried pumpkin flour (Rakcejeva *et al.*, 2011), carob seed flour (Papakonstantinou *et al.*, 2018), etc.

2.2.6. Other additions. In wheat flour and in bread, many other additions are used, either for consumption or for study, such as: seeds or flour from defatted seeds (sesame, buckwheat, flaxseeds, millet, poppy), oilseeds (sunflower, pumpkin), dietary fibre from wheat, barley and oats (Sabanis *et al.*, 2009) or from potatoes, flour of germinated cereals (wheat, barley, maize) (Özlem *et al.*, 2011), flour of wheat germs (Sun *et al.*, 2015), flour of defatted corn germs (Siddiq *et al.*, 2009), flour of apricot kernels (Dhen *et al.*, 2018), wastes from processing of hot peppers (Sowbhagya *et al.*, 2015), flour of dry onion skin (Gawlik-Dziki *et al.*, 2013), husk flour (Karnopp *et al.*, 2015), flour of tomato seeds (Mironeasa *et al.*, 2016), flour of grapeseeds (Meral & Dogan, 2012; Peng *et al.*, 2010), flour of grapeskin (Mironeasa *et al.*, 2018), mushrooms (Ulziijargal *et al.*, 2013), spices: moringa leaves, sesame seeds, cumin and millet (Agrahar-Murugkar, 2020), algae (*Chlorella vulgaris*) (Graça *et al.*, 2018).

2.3. Improvers used in the bakery

Improvers are ingredients used in baking, in very small quantities, to positively influence the quality and freshness of the bread and bakery products. The selection of the improver is made according to what needs or is wished to be improved and knowing the main technological properties of the flour, especially the power of the flour and its ability to form gases so as to obtain the best possible result (Bordei, 2004, p. 383).

The most used improvers in bakery are:

- Amylolytic enzymes: α-amylase from cereal malt, fungal α-amylase (*Bacillus subtilis*), β-amylase, fungal amylo glucosidase (*Aspergillus niger*);

- Proteolytic enzymes: malt proteases, *A. oryzae* or vegetable proteases (papain, bromelain);
- Pentosanase: exogenous or fungal xilanases;
- Fungal lipases;
- Lipoxygenases from wheat or soy flour;
- Transglutaminase produced by the bacterium *Streptoverticillium*;
- Cellulases;
- Natural emulsifiers: lecithin from oil demucilagination;
- Synthetic emulsifiers: polyalcohol esterified with paraffin chains;
- Oxidizing agents: L-ascorbyl acid (E300), KBr (E924), KI (E917);
- Reducing agents: L-cysteine.

2.4. The use and role of ascorbic acid in bakery

Ascorbic acid (AA) is used as an improver in bread making since 1935 (Wieser, 2012, p. 461). AA is added either in flour or directly in dough. The role of AA in baking is to mediate oxidation reactions that stabilize the dough for preserving its elastic and viscous properties so that the dough can retain gases and go through the stages of the bread making process (stretching, shaping, etc.) (Wieser, 2012, p. 459). In the presence of oxygen and ascorbate-oxidase, an enzyme naturally present in flour, AA is converted to dehydroascorbic acid (DHA) – the active form in the dough. The improvement effect produced in the dough by the DHA is based on the rapid removal of endogenous glutathione which would otherwise cause the dough to weaken by the reciprocal exchange of SH / SS groups with gluten proteins (Grosch & Wieser, 1999). Glutathione (GSH) is a tripeptide, γ-glutamyl-cysteinyl-glycine, naturally present in flour, both free and protein bound. GSH can form disulfide bonds (SS) with low molecular weight gluten proteins (LMW-GS), thus preventing them from participating in cross-links that lead to the formation of the gluten network and thus weakening the gluten network (Li *et al*., 2004b; Joye *et al*., 2009a).

First, AA is oxidised to DHA by oxygen present in the dough. The reaction depends on the amount of oxygen mixed into the dough. Thus, the rate of AA oxidation in dough is correlated with the speed of the mixer; it is significantly increased when the speed of the mixer is increased (Wieser, 2012, p. 462).

In the subsequent reaction, endogenous GSH is converted to GSSG by DHA which is reduced to AA (Wieser, 2012, p. 462), such as the cycle resumes. Ascorbic acid is reformed which explains that relatively small amounts of AA are sufficient for flour and dough improvement, respectively (Belitz *et al*., 2009, p. 718). The ascorbate – glutathione cycle, also called Halliwell – Asada, is presented in fig. 2.3 (Szőllősi, 2014, p. 92).

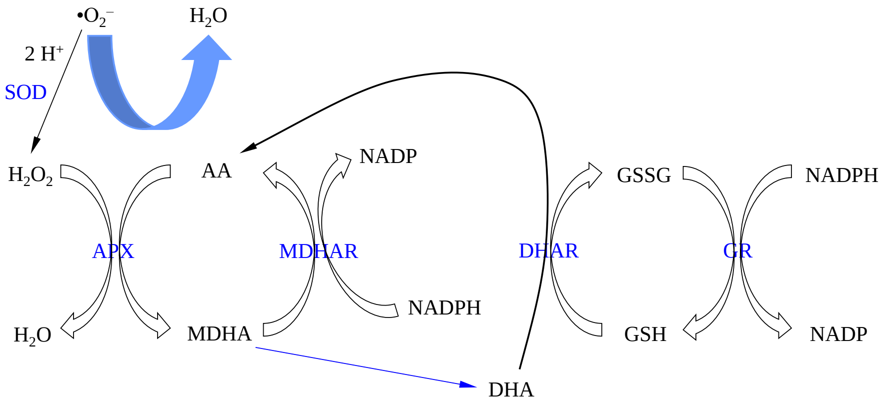

Fig. 2.3. Ascorbate–glutathione cycle/ Halliwell–Asada (after Szőllősi, 2014, p. 92)
Blue arrows represent non-enzymatic reactionse.
AA –ascorbic acid; MDHA – monodehydro-ascorbate; DHA – dehydro-ascorbate; GSH –reduced glutathione; GSSG – oxidized glutathione; APX – ascorbate peroxidase; MDHAR – monodehydro-ascorbate reductase; DHAR – dehydro-ascorbate reductase; GR – glutathione reductase; SOD – superoxide dismutase; NADPH – nicotinamide-adenine-reduced phosphate dinucleotide; NADP – nicotinamide – adenine – dinucleotide phosphate.

AA is used as a bread improver as its addition to dough causes an increase in loaf volume and an improvement in crumb structure. It belongs to the slow-acting oxidising improvers: the reaction rate is described as being quick during the initial reaction and then longer lasting because of its cyclical nature (Wieser, 2012, p. 462). Indeed, the process takes place at high speed at the beginning, respectively in the first 10 minutes of kneading, after which it decreases due to the depletion of the reactive –SH groups (Berlitz *et al*., 2009, p. 717).

These processes require a rapid development of the dough which, once obtained, must be stabilized so as to have good mechanical strength and good gas retention properties. Because of that, the duration of dough obtaining when adding antioxidants must be short, the method of bread making being the direct one. Therefore, AA is an oxidizing agent used to make bread through processes with little or no dough development time (*no-time dough*). In addition to improving the ability of gluten to retain gases, ascorbic acid also contributes to a faster proofing, to obtain a bread with a larger volume, a finer crumb, smaller and more pores, evenly distributed, and to reduce the thickness of the bread crust. These changes also result in a softer crumb, which makes the bread looks fresh longer (Campbel & Martin, 2012).

2.5. Possibilities of synthetic ascorbic acid replacement

Although vitamin C is naturally present in many fruits and vegetables, most of the AA that supplies the bakery industry is obtained through chemical reactions that use glucose as a raw material. Therefore, ascorbic acid is classified as a chemical compound and has the number E300.

Sahi (2012) presents some of the results of a research realized at Campden BRI, UK, which aimed to replace synthetic AA with AA-rich plant materials. Acerola cherry extract was used in the research. Disclosed experimental data shows that the addition of acerola cherry extract leads to a dough with good farinographic and extensographic properties. Thus, the development time of the dough was equal to that obtained for the control sample with the addition of synthetic AA, and the degree of softening in the kneading tests in farinograph was reduced to 65 UB, but close to that of the dough with synthetic AA (70 UB), both much lower than the degree of softening of the control (120 UB). The resistance to deformation was similar to that produced by chemically synthesized ascorbic acid, although the extensibility of the dough was lower. The bread volume, crumb structure and texture were similar to those of bread obtained with chemical ascorbic acid.

The research conducted at Campden BRI shows that the performance of chemical additives, such as ascorbic acid, can be achieved with natural plant materials with high concentrations of ascorbic acid so that these plant materials can be used to replace the chemical ascorbic acid and pave the way for larger possibilities of additives selection, especially when clean labeling is desired (Sahi, 2012).

Rosehip fruits *(Rosa canina L.)* are used in food due to their rich content of bioactive compounds such as polyphenols, essential fatty acids, galactolipids, folates, antioxidants, vitamins and minerals, especially for vitamin C (ascorbic acid), rosehips being recognized as a vegetal source that is rich in vitamin C. The vitamin C content in fresh rosehips of the variety R. canina L. usually varies between 100 and 1400 mg / 100 g (0.03–1.3%), with average values in the range of 400–800 mg / 100 g (Ziegler *et al*., 1986; Czyzowska *et al*., 2014).

Rosehips in powder or extract form have been used in baking in various formulas. However, no research or trial has been conducted to study the replacement of synthetic AA with rosehip. Therefore, the research presented in this doctoral thesis is original and aims for the first time to replace chemically synthesized AA with rosehip powder.

5. Materials și methods

5.1. Materials

5.1.1. Wheat flour. Wheat flour used in research (white flour 550 type, intermediate wheat flour 900 type, whole wheat flour 1250 type and wheat flour with bran 1350 type), came from the processing of wheat for bakery (common wheat *Triticum aestivum* L.) from the harvests of the years 2013–2017 cultivated in the N-E Development Region of Romania, in Botosani, Neamt, Suceava and Bacau counties.

5.1.2. Rosehip powder was obtained from rosehips harvested by hand from Dofteana area, Bacau County, at the end of August, in the years 2013-2017. The rosehips were sorted, washed and wilted, then the pulp was separated from the seeds. The rosehip pulp was dried in atmospheric conditions (t = 20°C, φ = 60%). After grinding the dried pulp, the powder obtained was sifted to separate the particles with the size of 180 µm, similar to the granulometry of wheat flour. The composition of rosehip powder was: moisture 13.40 ± 0.15 %, ash 6,50 ± 0.07 %, proteins 4.89 ± 0.11 %, lipids 0.76 ± 0.01 %, carbohydrayes 73.66 ± 0.19 % from which reducing sugars 65.03 ± 0.21 %, fibers 8.63 ± 0.03 %, and vitamin C 820 ± 37.75 – 200 ± 24 mg/100 g.

5.1.3. Reagents and laboratory utensils specific to the methods for determining the physico-chemical composition of flour and rosehip powder.

5.1.4. Laboratory equipment used: INFRATEC 1241 Grain Analyzer apparatus, mechanical sieve, Sartorius thermobalance, calcination furnace, Kjeldahl installation, Glutomatic apparatus, centrifuge with special sieve, thermostat, Brabender E farinograph, Brabender E amylograph, Brabender E extensograph, Chopin reofermentometer, ultracentrifugal laboratory mill, oven, analytical balance with an accuracy of 0.0001 g.

5.2. Methods

The methods for determining the quality indicators of wheat flour and rosehip powder are summarized in the following table:

Quality indicators	UM	Method
Granulosity	µm	SR 90:2007
Moisture	%	SR 90:2007
Ash	%	SR EN ISO 2171:2010
Acidity	degrees	SR 90:2007
Total protein	%	SR EN ISO 20483:2014

Wet gluten	%	SR EN ISO 21415-1:2007
		SR EN ISO 21415-2:2016
Dry gluten	%	SR EN ISO 21415-3:2007
Gluten deformation	mm	SR 90:2007
Gluten index	%	SR EN ISO 21415-2:2016
Carbohydrates	%	Iodometric method - Luff-Schoorl
Lipids	%	Extraction with organic solvents
Fibres	%	SR ISO 6541:1993
Vitamin C	mg/100 g	Iodine titration
Heavy metals	mg/kg su	Atomic absorption spectrometry
Microorganisms	CFU/g	Cultivation on a nutritious medium

5.2.3. Methods for the dough rheological properties determination

The following methods were used to determine the dough rheological properties: Farinographic method (5.2.3.1.)
Extensographic method (5.2.3.2.)
Amylographic method (5.2.3.3.)
Fermentographic method (5.2.3.4.)

5.2.4. Baking test

The white flour bread with rosehip powder addition was obtained by using the direct method of dough preparation, in accordance with the standard SR 90:2007 requirements. The leavened dough was placed in an oven belonging to the technological flow of S.C. Dizing S.R.L. Brusturi, Neamt County.

5.2.5. Methods for bread characteristics determination

The physico-chemical analysis of bread included:
- determination of moisture, porosity, elasticity and acidity of the crumb (SR 90:2007);
- determination of bread volume (SR 90:2007);

5.2.6. Sensory analysis methods

The sensory analysis of the bread complied with the requirements of the standard SR 90:2007. Sensory evaluation was performed by 21 panelists (7 men and 14 women) previously trained and coached.

The external appearance of the bread, the shape symmetry, the volume, the color and the crust structure, the elasticity and porosity of the crumb, the taste, the smell, the aroma, the signs of microbial alteration and the presence of foreign bodies were evaluated. Two specific tests were applied: the 20-point test and the hedonic test.

5.2.7. Analysis of colour and image of bread

The analysis was performed on six bread samples made with wheat flour without Rp (control) and with Rp addition of 0.5, 1.0, 1.5, 2.0, and 2.5 %.

The procedure for digitizing the image of the bread slices was carried out with a scanner CanoScan 9000F at an optical resolution of 300 dpi generating a linear physical resolution of 0.0846 mm / pixel and area 0.0071 mm^2/pixel and the background was black. The samples were scanned on both sides on the first, second, and third days, resulting in 36 scanned images.

Univariate statistical analysis was used to determine statistical differences between samples for factors rosehip powder concentration and storage time (days). Multivariate sequences were used for principal component analysis (PCA), multivariate analysis of variance (MANOVA) and hierarchical cluster analysis (HCA) to determine the grouping of samples, using chromatic parameters and bread porosity.

5.2.8. Calculation methods and statistical data analysis

Each experiment was performed in duplicate and the results were used as mean ± standard deviation. Processing of experimental data – calculations, graphs, etc. – was carried out in the Excel program of Microsoft Office 2010 package.

Statistical analysis of experimental data was also performed in Excel and consisted of one-way dispersion analysis (One-way ANOVA, ANOVA = Analysis of variance) to determine whether the differences between the values of parameters are significant or not, depending on the significance level (p-value) that was compared with a standard significance level, usually $\alpha = 0.05$ (Hubbard, 2003, p. 105; Judd *et al*., 2017, p. 168).

6. Determining the flour assortment and the additions of Rp

6.1. The selection of flours

6.1.1. Assorted flour analysed

In order to establish the type of flour with which the experimental work will be realized, several flours produced by SC Dizing Brusturi - Neamţ, SC Pambac SA Bacau or other mills were analyzed: white flour 550 type (five assortments) intermediate flour 900 type (four assortments), wholemeal flour 1250 type (four assortments), black flour 1350 type (three assortments).

The quality indicators of the flours were determined: moisture, ash content, protein content, wet gluten content, and sedimentation index, dry gluten content, gluten deformation index, acidity, hydration capacity, maltose index, drop rate and granularity.

The analysis of the value of these indicators allowed the selection of an assortment from each type of flour for future experiments.

6.2. The analysis of flour mixtures with rosehip powder

Mixtures of each selected flour variety and Rp addition of 3, 6, 9, 12, 15, 18 and 21 % were obtained. A number of 28 mixtures of wheat flour with Rp resulted. All the mixtures were chemically analysed to determine the moisture, ash content, protein content and wet gluten content.

6.3. The selection of rosehip powder additions

The analysis of the results leads to the idea to use a Rp addition under 6 %. Thus, 1.0 %, 2.5 %, and 5.0 % additions were chosen.

6.3.1. Physico-chemical composition of FA mixtures with 1, 2.5 and 5.0 % Pm

FA-PM mixtures were analyzed (Table 6.11).

Table 6.11. Physical-chemical properties of flour mixtures

Sample	Moisture, %	Ash, %	Protein, %	Wet gluten, %
Control (WF)	14.15 ± 0.02 a	0.550±0.002 a	14.75±0.01 a	34.10±0.07 a
WF-Rp 1.0 %	14.14 ± 0.01 a	0.610±0.002 b	14.65±0.00 b	33.76±0.09 b
WF-Rp 2.5 %	14.13 ± 0.01 a	0.699±0.004 c	14.50±0.01 c	33.29±0.07 c
WF-Rp 5.0 %	14.11 ± 0.01 a	0.848±0.002 d	14.26±0.02 d	32.39±0.08 d

WF – white flour, Rp – rosehip powder, WF-Rp – mixtures of wheat flour with rosehip powder;

a, b, c, d – Letters different in the the same column indicate significant differences between average values ($p < 0,05$)

6.3.2. The farinographic test

WF type 550 (control) and WF-Rp mixtures with predetermined Rp additions (1.0; 2.5 and 5.0 %) were tested with the farinograph obtaining independent farinograms, in duplicate, for each flour. The farinograph software calculates and provides the values of the farinographic parameters: water absorption (WA), dough development time, dough stability, softening degree at 10 minutes from the beginning of mixing / kneading and 12 minutes after the maximum farinographic curve is reached, and farinographic quality number (farinographic note).

6.3.3. The extensographic test

The doughs from control flour and the WF-Rp mixtures with the 1.0% 2.5% and 5.0% Rp addition, water and salt were prepared in the farinograph for the extensographic test. Then the doughs were tested with the extensograph which draw extensograms for each dough sample. Extensographic curves are drawn in the extrensogram for each test at 30, 60 and 90 min.

Extensographic characteristics were determined from extensograms: resistence to extension (deformation), R_{50}, in EU, extensibility, E, in mm, maximum resistence to extension, R_{max}, in UE, extensographic quality index, $Ic = R_{50}/E$, in UE/min, maximum quality index, Icmax = Rmax / E, in UE / min and energy, in cm^2, measured below the extensographic curve.

6.3.4. The amilographic test

The amylographic test applied to the dough is useful to determine the rheological properties of the flour gel. Water and flour are mixed to obtain a suspension that is heated at a constant rate of 1.5°C/min. The amylograph draws the amylogram which represents the variation of gel viscosity as a function of time and temperature. The amylogram determines the time when gelatinization begins, gel temperature and viscosity at the beginning of gelatinization, and evolution of gelatinization over time, the curve recording a maximum corresponding to the maximum gelatinization for which the maximum temperature, in °C and maximum gelatinization viscosity in AU are achieved.

6.3.5. The fermentographic test

The fermentographic test performed with Chopin reofermentograph provides important information about the dough development and the production of gases during the dough fermentation at 30°C, for a determined duration of 3 hours (180 min). The maximum height of the dough, H_m in mm, the time in which the maximum height is obtained, T_1, in minutes, the height of the dough at the end, h, in mm and the stabilization time relative to the maximum point, at height of 12 % of H_m, but not less than 6 mm are determined from the dough deevelopment curve. The gaseous release graph provides the time T_x where the CO_2 loose from the dough begins, total gas production volume, lost CO_2 volume and retained CO_2 volume.

6.3.6. Partial conclusions – selection of rosehip powder addition level

The study of the influence of Rp addition on the rheological properties realized in the farinographic, extensographic, amylographic and fermentographic tests allows the following findings:

- The Rp addition ensures a fibre intake that significantly increases ($p < 0.05$) the flour WA;
- The Rp addition ensures the presence of AA in the dough; DDT significantly decreases ($p < 0.05$) and DS significantly increases ($p < 0.05$) for additions below 2.5 %;
- The dough has a very high resistence to extension and is less extensible for 2.5 and 5.0 % Rp additions;
- The effort required to stretch the piece of dough decreases significantly ($p < 0.05$) for additions greater than 2.5 % Rp;
- The temperature at the beginning of gelatinization, the maximum gelatinization temperature and the maximum viscosity increase with significant differences ($p < 0.05$) with the Rp addition;
- The maximum height and the final height of the dough increase significantly ($p < 0.05$) with the Rp addition up to 2.5 % Rp after which they decrease;
- The Rp addition stabilizes the dough (the relative stabilization time is zero);
- The volume of gases retained in the dough increases with the Rp addition.

The Rp addition has a positive influence on the rheological parameters, especially on WA, DDT, DS, dough energy, resistence to extension, maximum resistence to extension, gelatinization temperature, maximum and final dough height, falling percentage, volume gases lost during fermentation, and volume of gases retained in the dough.

Rheological tests presented for 1.0 %, 2.5 % and 5.0 % Rp addition compared to the control, especially extensographic and reofermentographic tests indicate that the Rp addition must be below 2.5 % to obtain a proper dough and a higher bread with good porosity and elasticity.

Rp additions of 0.5 %, 1.0 %, 1.5 %, 2.0 % and 2.5 % are proposed in the following studies for an efficient analysis and proper discussion.

7. The influence of rosehip powder addition on dough rheology

To study the influence of Rp addition on the dough rheology, WF 550 type, untreated with AA or other improvers, and additions of 0.5 %, 1.0 %, 1.5 %, 2.0 % and 2.5 % Rp were used.

7.1. The influence of rosehip powder on white wheat flour - rosehip powder mixture composition

The mixtures obtained were analyzed to determine the following physico-chemical parameters: moisture, ash, protein, lipid, carbohydrate, fibre and wet gluten content, and sedimentation index, respectively the energy value was calculated.

The Rp addition influences the mixtures composition as follows::

- moisture varies insignificantly ($p > 0,05$);
- ash content increases significantly ($p < 0.05$) with the Rp addition as Rp contains more ash than WF;
- protein content decreases significantly ($p < 0.05$);
- lipids content and carbohydrates varies insignificantly ($p > 0.05$);
- wet gluten content decreases significantly ($p < 0.05$) with the Rp addition which does not contain gluten-forming proteins;
- the index sedimentation varies significantly ($p < 0.05$) with the Rp addition, but it remains in the range 20–39 characteristic for a good quality flour;
- the energy value shows insignificant variations ($p > 0.05$) with the Rp addition because the two components have close energy value, and the Rp additions are small.

7.2. The influence of Rp on dough farinographic characteristics

Farinographs are commonly used to determine the WA in flour, especially industrial (Mondal & Datta, 2008; D'Apollonia, 2015).

The farinogram obtained with the Brabender E farinograph, for the control sample (WF) is presented in fig. 7.9 as an example.

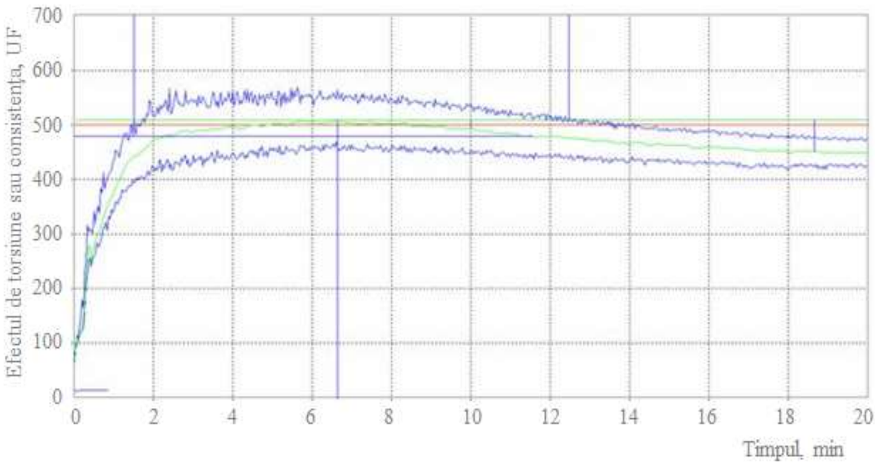

Fig. 7.9. The farinogram of control sample (WF)

The flour water absorption (WA), %, dough development time (DDT), min, dough stability (DS), min, degree of softening and farinographic quality number are determined from the farinograms.

7.2.1. Water absorption. WA of the two controls, WF și WF-AA, respectively of WF-Rp mixtures, obtained when applying the farinographic method, is represented in figures fig. 7.10 and 7 as a function of Rp addition.

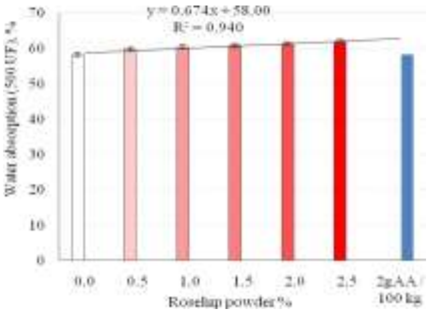

Fig. 7.10. The flour CH corrected for 500 UF as a function of Rp addition

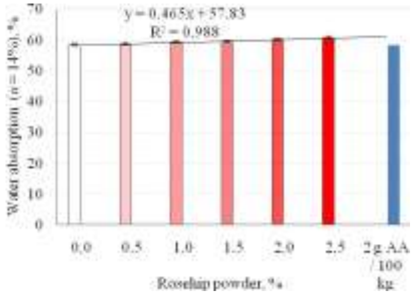

Fig. 7.11. The flour CH, corrected for *u* = 14 % as a function of Rp addition

WA increases linearly (R^2 = 0.95–0.98) with Rp addition from 58 % (control) to 60.8 % for the WF-$Rp_{2.5}$ sample. Variations are significant ($p < 0.05$). The two controls have the same WA as they differ only in AA addition.

Because the protein content of the mixtures decreases as a result of Rp addition in WF, the increase of WA is due to the intake of fibres by the Rp addition, a conclusion reached by many other researchers: addition of orange fiber (Gómez *et al*., 2003), wheat bran (Banu *et al*., 2012), hydrated apple powder (Lauková *et al*., 2016), carrot pomace powder (Kohajdová *et al*., 2012), mango peel powder (Ajila *et al*., 2008).

7.2.2. The dough development time. DDT is the time from water addition to the flour until the dough reaches the maximum consistency without breaking. During the mixing phase, water hydrates the flour components and the dough is developed (Lauková *et al*., 2016). DDT for the control sample was 6.7 min, and for WF-Rp mixtures varied between 6.6 min (1.0 % Rp) and 7.2 min (2.5 % Rp), an insignificant variation ($p > 0.05$), although at the limit ($p = 0.054$). Therefore, the Rp addition has a relatively small influence on DDT (fig. 7.12).

The WF-AA control has a DDT of 6.6 min, lower than the WF control, reflecting the fact that the addition of AA in the flour reduces the DDT. Similar data have been reported in several studies, e.g. increasing of DDT from 1.5 min (control) to 3.5 min (addition of 15 % apple pomace fibre from the manufacture of apple juice) (Sudha *et al*., 2007) increasing of DDT from 3.5 min (control) to 11 min for the addition of 15% hydrated apple powder to white wheat flour (Lauková *et al*., 2016), increasing of DDT from 3.43 min (control) to 5.53 min (15 % apple pomace powder) (Kohajdová *et al*., 2014).

7.2.3. The dough stabily. DS represents the difference between the processing time and the hydration time and is measured in minutes (fig. 7.13). DS increases from 11 min (control) to 11.8 min (0.5 % Rp), then decreases below the value for the control, reaching 10.4 min (1.5 % Rp) and 9.6 min (2.5 % Rp); the differences are significant ($p < 0.05$).

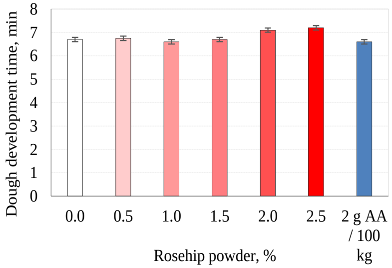

Fig. 7.12. DDT as a function of Rp addition

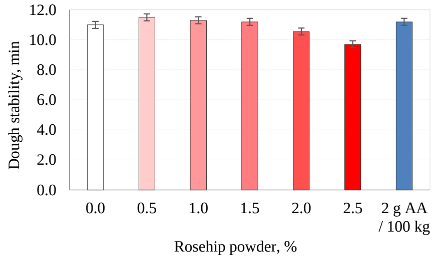

Fig. 7.13. DS as a function of Rp addition

DS gives some indication of the flour tolerance to mixing-kneading (Lei *et al*., 2008). Nassar *et al*.(2008) reported an increase in SA from 5.9 min (control) to 12.4 % and 11.5 min, respectively, for the addition of 25 % peel or pulp orange flour. DS was considerably higher than the values obtained by adding buckwheat flour, in which case the DS increased from 0.3 ± 0.1 min (control) to 4.6 ± 0.3 min for an addition of 30 g buckwheat flour / 100 g wheat flour (Nikolić *et al*., 2011). The opposite effect has been reported by Sudha *et al*. (2007) after adding apple pomace powder in different proportions. Thus, DS decreased from 4.2 min to 2.1 min for an addition of 15% apple pomace content. These results are supported by Rosell *et al*. (2010) who observed a decrease in DS to increased additions (12.5–25 %) of quinoa flour to wheat flour and by Liu *et al*. (2016) who reported a decrease in DS to potato flour additions of up to 30% in wheat flour.

7.2.4. The degree of softening. *Softening degree of the dough after 10 minutes* from the beginning of the test for samples with Rp addition has values that do not fall in a tendency to increase or decrease compared to the value obtained for the control sample. The softening degree of the dough after 10 minutes for FA-AA is 18 FU, equal to that of the sample with 1.0 % Rp. Instead, the *softening degree of the dough after 12 min* has an ascending variation with the increase of the addition of Rp; the differences are significant ($p < 0.05$).

7.2.5. The farinographic quality number of the samples with Rp addition is usually higher than that of WF control, except for the sample with 2.0 % Rp. The variation is insignificant ($p > 0,05$). Farinographic note of the dough for the WF-AA sample is between the values for 1.0 and 1.5 % Rp addition. The farinographic note higher than that of the control shows that Rp addition has a positive influence on it, a fact also observed by Nikolić *et al*. (2011).

7.3. The influence of Rp on dough extensographic characteristics

The extensograph measurements provide useful information about the visco-elastic behavior of the dough. The extensograms generated at testing flours after 30, 60 and 90 min are analyzed to obtain quantitative information about *resistance to extension* (R_{50}), BU, *maximum resistance* (R_{max}), BU, *extensibility*, *E*, mm, *energy* (the area under the extensographic curve), cm^2 and R/E ratio.

The resistance to extension (R_{50}, BU) as a function of Rp addition is presented in fig. 7.18.

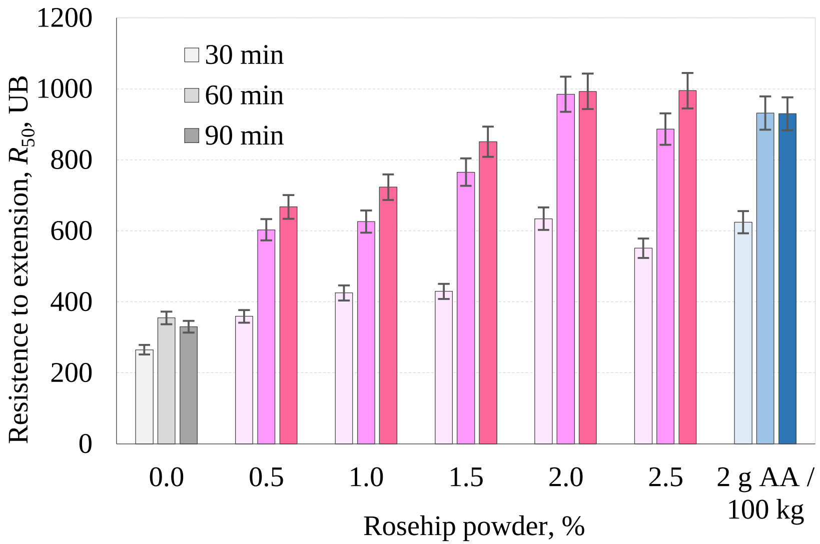

Fig. 7.18. Resistence to extension of dough as a function of Rp addition

Because of the content of vitamin C, the addition of Rp determined the increase of R_{50} for all samples, at all durations (30, 60 and 90 min) except R_{50} of the control sample at 90 min which is less than at 60 min and R_{50} of of the WF-$Rp_{2,5}$ mixture which has lower values than for the WF-$Rp_{2.0}$ mixture for all durations. The differences are significant (p <0.05). R_{50} for the WF-$Rp_{2.0}$ mixture at 60 (985 BU) and 90 min (993 BU) and for the WF-$Rp_{2.5}$ mixture at 90 min (995 BU) almost reach the maximum possible to be recorded with the Brabender E extensograph (1000 EU).

The extensibility of the dough as a function of Rp addition is presented in fig. 7.19.

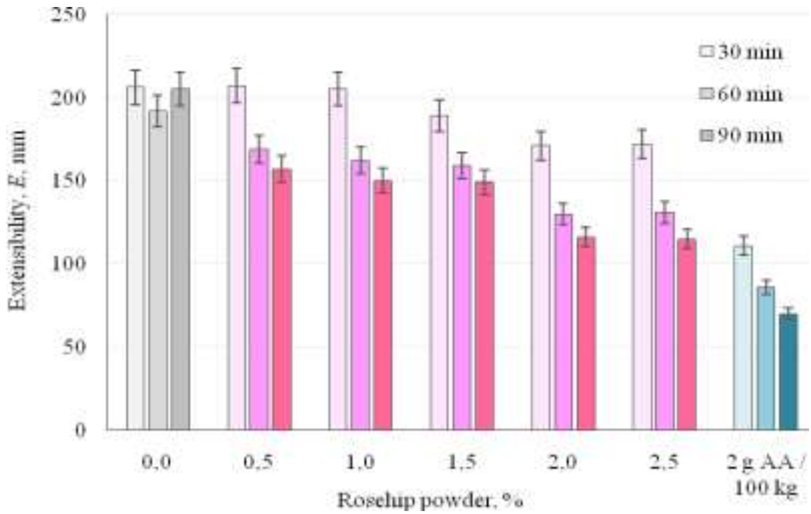

Fig. 7.19. Extensibility of the dough as a function of Rp addition

E decreases insignificantly ($p > 0.05$) for 0.5 and 1.0 % Rp after 30 min. A significant decrease ($p < 0.05$) of *E* is observed for the other additions and durations. Also, *E* shows very close values for 2.0 and 2.5 % Rp additions (171 ± 0,71 mm and 172 ± 1,41 mm for the 30 min test, 130 ± 0,71 mm and 131 ± 1.41 mm for the 60 min test, 116 ± 1.41 mm and 115 ± 1.41 mm for the 90 min test). The dough with the addition of ascorbic acid has the highest decrease in *E*, between 46.1 and 65.8 % compared to the control. Koletta *et al.* (2014) replaced 60% refined wheat flour with wholemeal rye, barley and oatmeal flour and obtained a decrease of *E* compared to the control which led to an increase in the R_{50}/E ratio. Similar results were obtained with the addition of fibres obtained from peas, cocoa, coffee, oranges and wheat and the addition of microcrystalline cellulose in proportions of 2 and 5 % (Gómez *et al.*, 2003). However, other studies presented different results: Mohammed *et al.* (2012) reported a decrease in both R_{50} and *E* with the addition of 10, 20 and 30 % chickpea flour in wheat flour, and an increase depending on the resting time periods of 45, 90 and 135 min.

The authors have claimed that additions of chickpea flour greater than 20 % reduced the gluten content of the mixture, resulting in a weaker gluten network, which explains the decrease of R_{50} and *E* and worsening of the rheological dough properties and the bread characteristics.

R_{max} has a similar evolution R_{50}, but with higher values, determined when the extensographic curves reach their maximum value.

The extensographic quality index values, R_{50}/E and R_{max}/E increase proportional with the Rp addition and resting time between extensographic tests. Smaller increases are observed for resting times of 90 min versus 60 min. The highest values of extensographic quality index were obtained for the sample with the AA addition. All differences are significant ($p < 0.05$).

The energy of the dough E_a, cm^2, as a function of Rp addition is presented in fig. 7.23. This parameter quantifies the total force applied during the dough extension which results in dough deformation. The energy is calculated by the extensograph software as a product of the dough extension force (BU or EU) and the distance from the abscissa (cm). The higher the energy, the higher the tolerance of the dough.

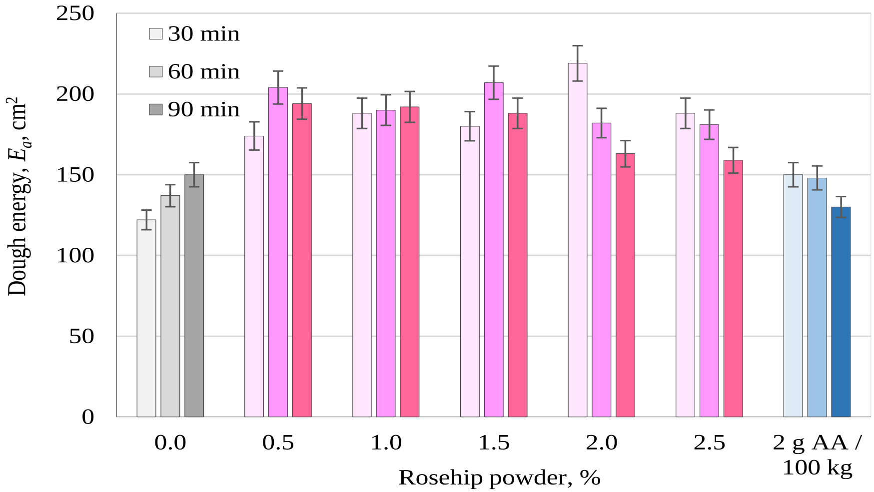

Fig. 7.23. Dough energy as a function of Rp addition

The energy required for the control dough extension until it breaks increases as a function of the resting time with significant differences ($p < 0.05$): 122 cm^2 at 30 min, 137 cm^2 at 60 min and 150 cm^2 at 90 min. E_a increases, also, to the control, for all Rp additions ($p < 0.05$). At 1,0 % Rp addition, E_a differs insignificantly ($p > 0.05$) according to the resting time (188 cm^2 at 30 min, 190 cm^2 at 60 min and 192 cm^2 at 90 min), and for larger additions, decreases with significant differences according to the resting time. The smallest increase of E_a, compared to the control is presented by the sample with the AA addition, with decreasing variation according to resting time: 150 cm^2 at 30 min, 148 cm^2 at 130 min ($p > 0.05$) and 80 cm^2 at 90 min ($p < 0.05$). These lower values of E_a at the AA addition compared to the Rp additions can be explained by the lower E of the dough obtained from WF-AA.

The results are different from those obtained in other studies due to the specificity of the additions and the dose used. Thus, Koletta *et al*. (2014) found that E_a was lower with the addition of 60 % wholemeal rye, barley and oatmeal flour in wheat flour than for the control due to the lower content of gluten forming proteins in flour mixtures. Also, E_a decreases with the addition of 10, 20 and 30% chickpea flour in wheat flour for all resting times 45, 90 and 135 min. This effect can be pronounced by the presence in chickpea flour of unwanted enzymes that strongly interact with gluten proteins and thus inhibit the development of the desired rheological properties (Mohammed *et al*., 2012).

7.4. The influence of Rp on dough amylographic characteristics

The amylographic test applied to the dough serves to determine the rheological properties of the flour gel. The amylogram is a curve that represents the variation of the gel viscosity formed as a function of time and temperature. The time when gelatinization begins, the temperature and the gel viscosity at the beginning of gelatinization and the evolution of gelatinization over time are established from the amylogranm. The maximum gelatinization temperature is presented in fig. 7.25, and the maximum viscosity in fig. 7.26.

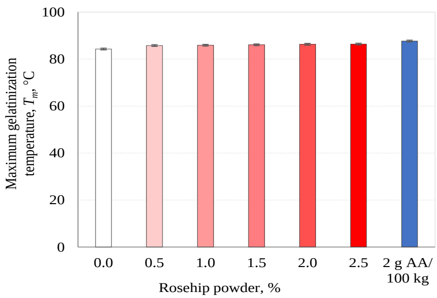

Fig. 7.25. The maximum gelatinization temperature as a function of Rp addition

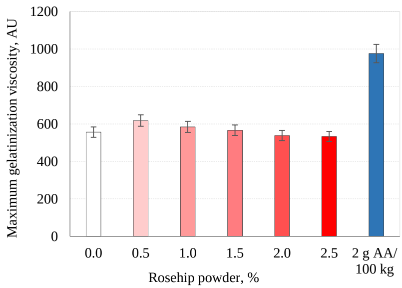

Fig. 7.26. The maximum gelatinization viscosity as a function of Rp addition

The gelatinization temperature increases significantly ($p < 0.05$) from 61.0°C for the control, at 62.9°C for the 2.5 % Rp addition, and for the WF-AA sample it has the value 61.6°C. The maximum gelatinization temperature has a similar evolution, an increase with significant differences ($p < 0.05$) from 84.3°C for the control, at 86.4°C for the 2.5 % Rp addition. In contrast, for the WF-AA sample it has a higher value, 87.7°C. The maximum gelatinization viscosity increases from 556 AU for the control, to 618 AU for 0.5 % Rp then gradually decreases to 533 AU for 2.5 % Rp. For the AA addition in the flour, the maximum gelatinization viscosity is 976 AU.

7.5. The influence of Rp on dough reofermentographic characteristics

Dough development and its ability to form and retain gases during fermentation were studied by the fermentographic test realized with the Chopin F reofermentometer for a determined duration of 3 hours (180 min).

The graph provided by the reofermentometer for dough development allows the determination of the maximum height of the dough, *Hm*, in mm (fig. 7.27), the time when the dough reaches its maximum height, T_1, in min (fig. 7.28), the height of the dough after the 3 hours of fermentation, *h*,, în mm(fig. 7.27), and the stabilization time relative to the maximum point, at a height of 12% of Hm, not less than 6 mm, T_2 and T_2', in minutes, values used for the calculation of the dough tolerance. The reofermentogram also indicates the percentage of dough falling after 3 hours compared to the time T_1 when the maximum height is recorded, *(Hm - h) / Hm.*

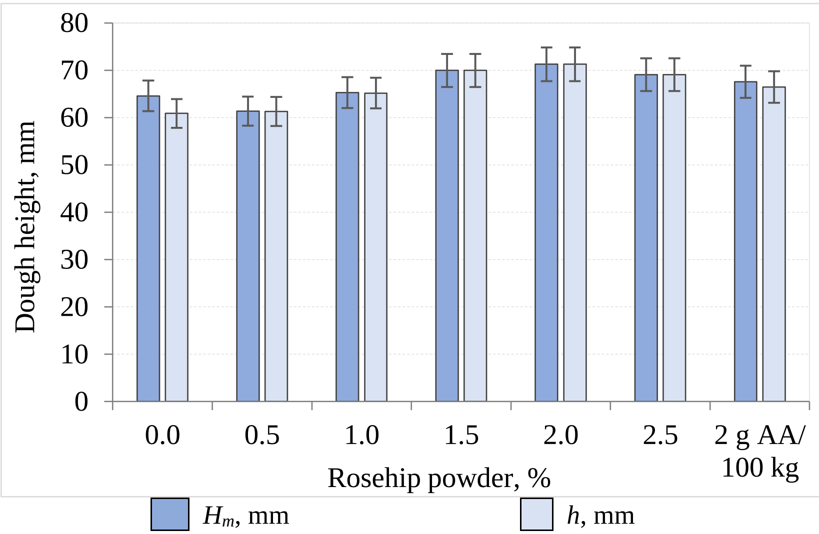

Fig. 7.27. Dough height as a function of Rp addition

From the point of view of dough height and the percentage of fall, all the Rp additions contribute to the formation of a stable dough.

The results in the literature are different as the purpose of the additions was another. Thus, Cao *et al.* (2020) showed that the dough height decreases significantly with the addition of potato pulp greater than 30 %, a dough height lower than 58 % being obtained with an addition of 50% of potato pulp.

The time until the maximum height is obtained (fig. 7.28) is almost double for all Rp additions and for the AA sample compared to the control (96 min). Thus, the maximum height is obtained at the end of the fermentation time (180 min) for samples with 1.5 %, 2.0 %, and 2.5 % Rp and only two minutes earlier (178 min) for the additions of 0.5 % and 1.0 % Rp, respectively for the AA addition.

The T_x time at which the loss of CO_2 from the dough begins has higher values than the control (69 min) for the additions of 0.5 % Rp (91 min), 1.0 % Rp (84 min) and 1.5 % (83 min), respectively AA (80 min) and lower for the rest of the samples: 68 min for 2.0 % Rp and 67 min for 2.5 % Rp.

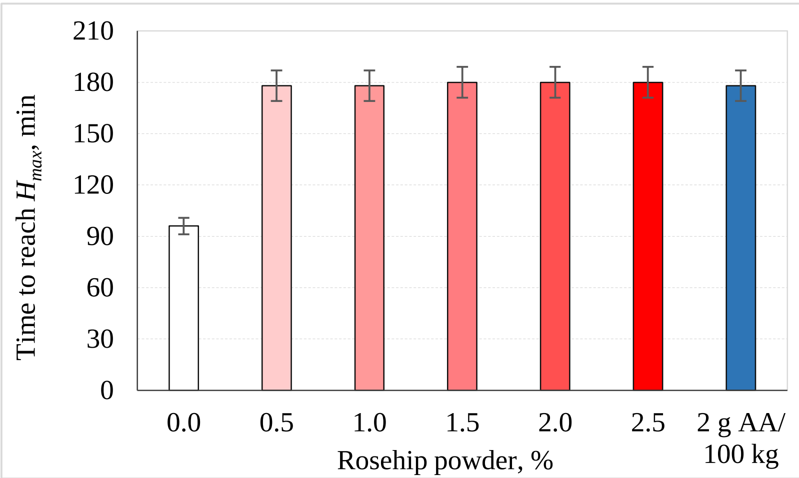

Fig. 7.28. The time to reach the maximum height as a function of Rp addition

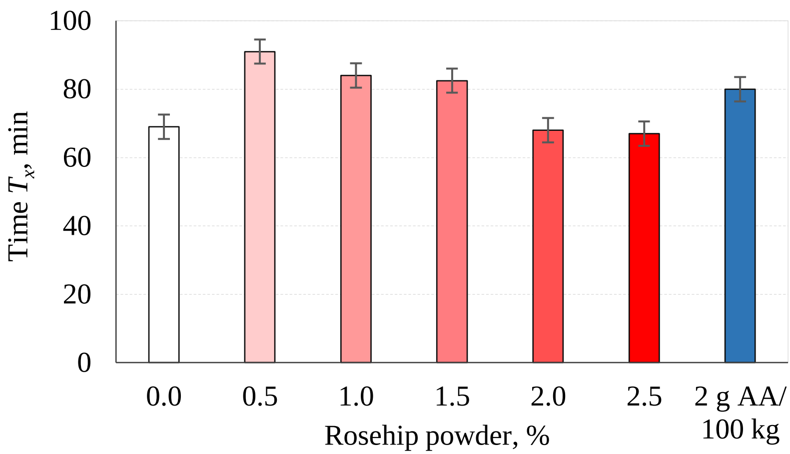

Fig. 7.30. The time T_x at which the gas loss begins as a function of Rp addition

In the present study, the rosehip powder addition has the role of supplementing the ascorbic acid needed to stabilize the gluten network so that it would be able to retain as many fermentation gases in the dough as to obtain a bread with increased porosity. To determine how this was done, the total volume of gas, lost and retained volumes (fig. 7.31) were determined from the reofermentogram. Thus, the total volume of gas has relatively close values for all samples, as follows: 1,344 ± 2.83 mL for control, 1,212 ± 2.83 mL for 0.5 % Rp, 1,285 ± 1.42 mL for 1.0 % Rp, 1,286 ± 1.42 mL for 1.5 % Rp, 1,342 ± 2.83 mL for 2.0 % Rp, 1,310 ± 2.83 mL for 2.5 % Rp and 1,302 ± 4.25 mL for the addition of AA. The differences are significant ($p < 0,05$).

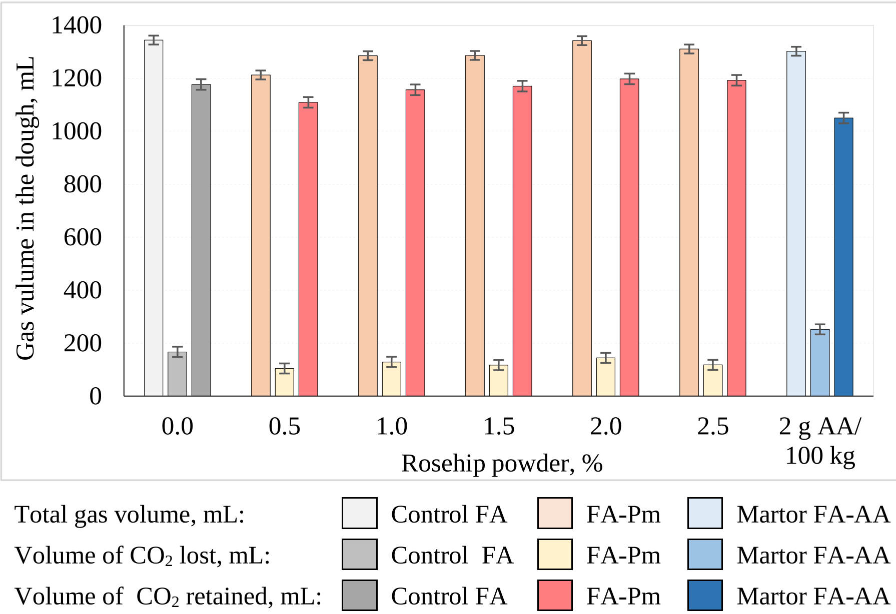

Fig. 7.31. The volume of gases at fermentation as a function of Rp addition

The volume of gas lost from the dough during fermentation has values between 104 and 144 mL for the samples with Rp addition, lower than for the control (167 mL). The highest value was obtained for the sample with the AA addition. Therefore, the volume of gas retained in the dough, calculated as the difference between the total volume and the volume of gas lost in the dough has the values: 1,177 mL for control, 1,109 mL for 0,5 % Rp, 1,157 mL for 1,0 % Rp, 1,170 mL for 1.5 % Rp, 1,198 mL for 2.0 % Rp, 1,192 mL for 2.5 % Rp and 1,050 mL for 2 g AA / 100 kg flour. Compared to the control, the volume of gas retained in the dough for Rp additives increases until 2.0 % Rp, then decreases. The differences are significant ($p < 0.05$).

The coefficient of gas retention in the dough has values between 89.3 % and 91.5 % for 0.5–2.0 % Rp and 88.45 % for 2.5 % Rp all being higher than the 87.6 % of the control.

The gas retention coefficient in the dough is closely related to gluten quality. The stronger the structure of the gluten network, the more it is able to retain the gas produced by fermentation (Pasqualone *et al.*, 2019). Therefore, the gas retention coefficient in the dough is important as it affects the volume of gas retained in the dough and determines the quality of the product. (Xu *et al.*, 2018). Huang *et al.* (2008) observed that increased values of the gas retention coefficient in the dough will allow to obtain a bread with high volume and well developed porosity.

Cao *et al.* (2020) affirmed that the potato pulp addition contributed to a significant increase in the total volume of CO_2 from 1,506.7 ± 25.4 mL for the control to 1,697.3 ± 7.6 mL for the sample with the 30 % potato pulp addition. In contrast, the gas retention coefficient in the dough decreased from 73.8 % for the control to 69.8 % for 30 % potato pulp addition. The potato pulp addition can weaken the gluten network and has negative effects on gas retention capacity (Cao *et al.*, 2020).

7.6. Partial conclusions - the influence of Rp on dough rheology

The study of the influence of Rp addition on dough rheology allows the following findings:

- The Rp addition in wheat flour influences the composition of mixtures by insignificant decrease ($p > 0.05$) of moisture, significant increase ($p < 0.05$) of ash, significant decrease ($p < 0.05$) of protein and wet gluten content and insignificant variation ($p > 0.05$) of lipid and carbohydrate content.
- The farinographic parameters are influenced by the Rp addition as follows:
  - WA increases significantly ($p < 0.05$) with the Rp addition likely due to the contribution of the fibre intake of WF-Rp mixtures;
  - DDT varies insignificantly ($p > 0.05$) with the Rp addition;
  - DS varies significantly ($p < 0.05$) with the Rp addition, lower values than the control obtained for Rp additions greater than 1.5 %;
  - Relevant degree of softening obtained at 12 min after reaching the maximum increases significantly ($p < 0.05$) with the Rp addition;

  Although significant influences of the addition of Rp on the processing properties of the dough are found, it is not possible to establish, from the farinographic analysis, if there is an optimal Rp addition, respectively what Rp additions can be recommended for use as a substitute for ascorbic acid in bread making.

- The addition of 0.5–2.5 % Rp in wheat flour influences the extensographic parameters as follows:
  - R_{50} increases with significant differences ($p < 0.05$) with the Rp addition and resting time, at 2.0 % Rp reaching the maximum values the apparatus can record;
  - The extensibility of the dough decreases with the addition of Rp, at the beginning insignificant ($p > 0.05$), then significant ($p < 0.05$);
  - R_{max} increases significantly ($p < 0.05$) than control, similar R_{50}, but at additions greater than 1.5 % the maximum values the apparatus can record is reached;
  - Extensographic quality indices increase indicating a good dough;
  - The energy required to dough extension until break increases compared to the control but does not show significant differences ($p > 0.05$).

  From the extensographic analysis it results that the Rp addition must be made so that the resistance to extension increases very much; under the experimental conditions of the study, the optimal values of the Rp addition are up to 2.0 %.
- The addition of 0.5–2.5 % Rp in wheat flour influences the amylographic parameters:
  - Temperature at the beginning of gelatinization and the maximum gelatinization temperature increase with significant differences ($p < 0.05$) with the Rp addition;
  - Maximum gelatinization viscosity shows significant differences ($p < 0.05$) with the Rp addition and indicates the obtaining of a more viscous flour gel at high Rp additions.
- The addition of 0.5–2.5 % Rp in wheat flour influences the reofermentographic parameters:
  - The maximum height of the dough varies significantly with the control;
  - The doughs are stable because the height of the dough at the end of fermentation has values almost identical to H_m, except for the control;
  - The T_x time at which the loss of CO_2 from the dough begins has higher values than the control for the additions of 0.5–1.5 % and AA, respectively lower for the rest of the samples;
  - The total gas volume has relatively close values for all samples;
  - The volume of gas lost from the dough during fermentation has lower values for samples with the Rp addition compared to the control;
  - The gas volume retained in the dough increases to the Rp addition 2.0 %, then decreases.

In conclusion, the Rp addition in wheat flour improves the rheological properties of the dough in a similar way to synthetic AA, even if there are some differences that are caused by other components of Rp. These differences are relatively small as the addition does not have to be done in large quantities. In addition, some differences are beneficial, for example increasing the water absorption of the dough most likely due to the intake of fibre by the Rp addition.

According to the experimental results, flour parameters and vitamin C content of Rp, additions up to 2.0 % Rp could be recommended, mentioning that there is necessary to know the vitamin C content of Rp at use.

8. The influence of rosehip powder addition on the physico-chemical and sensory properties of the bread

8.1. Introduction. Determination of bread quality

To determine the physico-chemical and sensory of bread properties, from the flours used to study the influence of rosehip powder on dough rheology, bread was obtained according to the manufacturing recipe and technological parameters presented in the thesis. The dough was prepared by the direct method, and after fermentation it was divided into pieces of 380 g, placed in baking trays, then baked in the oven at Dizing Ltd. From each flour: WF (control 1), WF-$Rp_{0.5}$, WF-$Rp_{1.0}$, FA-$Pm_{1.5}$, WF-$Rp_{2.0}$, WF-$Rp_{2.5}$ and WF-AA (control 2) dough was prepared in sufficient quantity to obtain five loaves each. After baking, the bread was labeled and left for two hours at ambient temperature for cooling, then it was prepared for physico-chemical and sensory analysis.

For the bread obtained, moisture (%), acidity (degrees of acidity), dimensions (length, width and height, mm), volume (cm^3/100 g bread), specific volume (cm^3/g bread), porosity (%), and crumb elasticity (%) were determined. Sensory analysis was also performed by the 20-point test and the hedonic test.

8.2. The influence of Rp addition on physico-chemical characteristics of bread

8.2.1. The influence of rosehip powder on bread dimensions

Images in section of bread obtained are presented in fig. 8.1.

a)

b)

c)

d)

e)

f)

g)

Fig. 8.1. Section photos of the breads obtained:
a) White flour control bread (WF)
b) Bread with 0,5 % Rp (WF-$Rp_{0,5}$),
c) Bread with 1,0 % Rp (WF-$Rp_{1,0}$)
d) Bread with 1,5 % Rp (WF-$Rp_{1,5}$)
e) Bread with 2,0 % Rp (WF-$Rp_{2,0}$),
f) Bread with 2,5 % Rp (WF-$Rp_{2,5}$),
g) White flour control bread
with 2 g AA/ 100 kg flour (WF-AA)

The height of the bread is higher than control sample for all samples with the Rp addition, less for 0.5 % Rp which is 97.15 ± 0.07 mm compared to the control (100.10 ± 0.14 mm). The height increases by 1.0% Rp (113.05 ± 0.07 mm) and 1.5 % (115.50 ± 0.14 mm) then decreases slightly to 2.0 % Rp (111.15 ± 0.21). mm) and 2.5 % Rp (108.25 ± 0.07 mm). Bread obtained from flour with the AA addition has a height of 113.90 ± 0.28 mm, close to and located between the height values for the addition of 1.0 % and 1.5 % Rp.

8.2.2. The influence of rosehip powder on bread volume

The ***bread volume*** is, for most domestic consumers, one of the main criteria for evaluating the quality of bread and also one of the main decision-making elements of purchase. The bread volume was determined according to STAS 91: 2007, gravimetric method, by displacing a volume of rapeseed. The results obtained for duplicate determinations are presented in fig. 8.3.

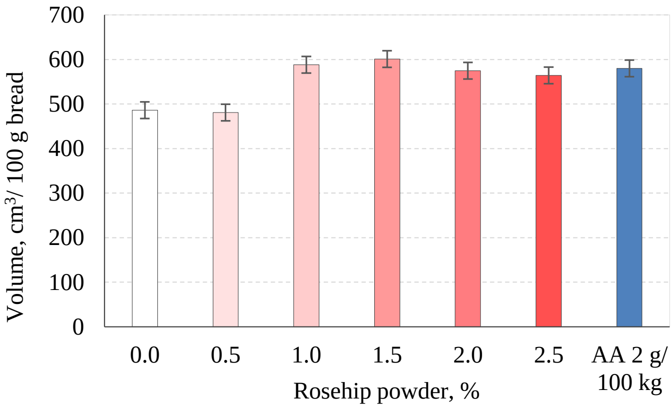

Fig. 8.3. The bread volume as a function of Rp addition

8.2.3. The influence of rosehip powder on bread moisture

The bread moisture increases compared to the control (u_0 = 41.81 ± 0.40 %) for all samples with Rp addition, being between 42.64 ± 0.33 % (1.5 % Rp) and 43.92 ± 0.15 % (2.0 % Rp). The differences are significant ($p < 0.05$). The moisture of the sample with 2.5 % Rp is 42.51 ± 0.34 %, located between the moisture of the control and the sample with 0.5 % Rp, so lower than in the case of the other additions. The control sample with the AA addition has a moisture of 42.06 ± 0.16 % close to that of the control WF (without Rp addition). The increase in bread moisture is due to the increase in the water absorption of WF-Rp mixtures due to the added fiber content of Rp.

Similar results are reported in the literature. Thus, toasted bread with high fiber content obtained by adding 10, 20 and 30 % fine or coarse bran, dark or light in color and wheat germ has a higher moisture content than the bread obtained from unbleached wheat flour (u = 39.29 ± 0.34 %) for all types of bran. The increase of moisture is due to the higher amounts of water used to prepare the dough as a result of bran addition that contributes to fiber content. Also, the moisture increases slightly with the percentage of bran used (Sidhu *et al.*, 1999).

8.2.4. The influence of rosehip powder on bread acidity

The acidity of bread obtained only from white wheat flour (control) is the lowest (2 degrees of acidity), the bread obtained from flour with the addition of Pm or AA having higher values of acidity. The acidity values increase with the increase of the Rp addition, but with insignificant differences ($p > 0.05$), reaching 2.20 degrees of acidity for 2.5 % Rp. Bread with the AA addition has an acidity of 2.05 degrees acidity, very close to that of the control sample.

The acidity values of the bread with the Pm and AA addition are not due to ascorbic acid as it is consumed during kneading, and if it somehow remains in excess in the dough, it is distorted when baked. Other components of rosehip powder, for example organic acids present in the composition of rosehips, undetermined, may be responsible for the values obtained for acidity.

8.2.5. The influence of rosehip powder on crumb porosity

The breads obtained are characterized by high porosity values (fig. 8.6). Thus, the control bread had a porosity of 87.75 ± 1.06 %, and for breads with the Rp addition higher values were obtained, except for the sample with 0.5 % Rp for its care is lower, 87.50 ± 0.71 %.

Values increase for 1.0 % Rp (90.00 ± 0.71 %) and 1.5 % Rp (90.70 ± 0.99 %) then decrease to 89.00 ± 0.71 % by 2.0 % Rp and 89.4 ± 0.57 % for 2.5 % Rp. The sample with the AA addition had a porosity of 88.6 ± 1.56%. The differences are significant ($p < 0.05$).

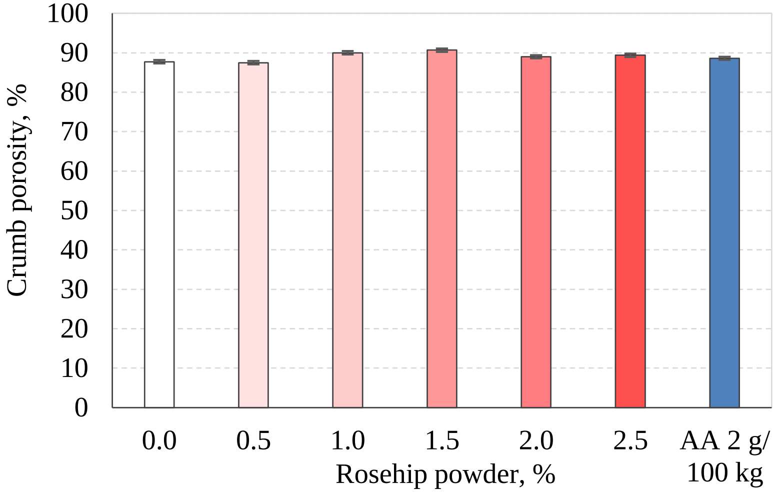

Fig. 8.6.Crumb porosity as a function of Rp addition

Correlating the data obtained for porosity with the images shown in fig. 8.1 for breads in section, it is observed that the pores are generally small and their distribution is uniform, with a few exceptions of larger pores, located near the bread crust. This means that the kneading was efficient and favoured the incorporation of sufficient air in the dough so that in it remains, after the consumption of oxygen in the oxidation reactions, small pores of nitrogen, as nuclei in which the carbon dioxide resulting from fermentation will accumulate (Cauvain, 2015, p. 28–29).

8.2.6. The influence of rosehip powder on crumb elasticity

The elasticity of the bread crumb is its property to return to its original shape after the action of the pressing force is turned off. It depends on the quality and quantity of gluten in the flour and the freshness of the product (Bordei, 2007, p. 517). The experimental data obtained are presented in fig. 8.7.

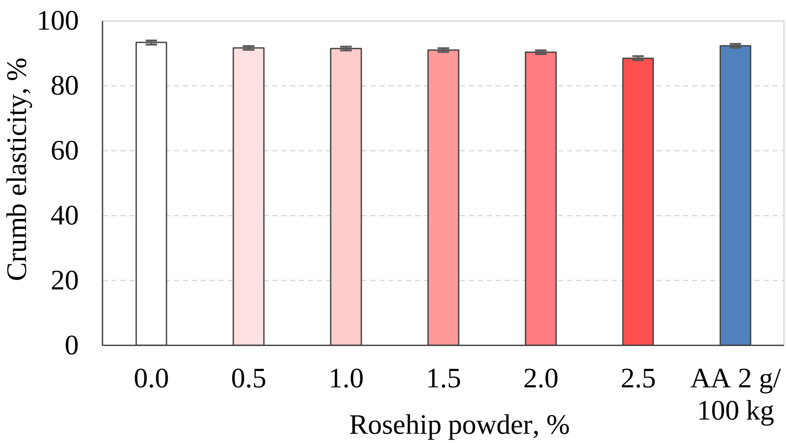

Fig. 8.7. Crumb elasticity as a function of Rp addition

The values obtained for the crumb elasticity are between 93.3 % for the control and 88.5 % for the bread from flour with 2.5 % Rp, meaning that they decrease with the increase of Rp addition. The differences are significant ($p < 0.05$).

8.3. The influence of Rp on the sensory attributes of the bread

8.3.1. Sensory analysis using the 20-point method

The 20-point test is based on the evaluation and awarding of points to the following sensory properties: shape, external appearance, volume (3 points), crust appearance (3 points), crumb appearance (4 points), consistency and chewing behavior of the crumb (3 points), smell (3 points) and taste (4 points) so that the maximum score is 20.

The most appreciated sensory properties are shape, appearance and volume, smell and taste (fig. 8.8). Thus, the shape, appearance and volume obtained average scores from a maximum of 3 points as follows: 2.9 points for bread with the 0.5%, Rp addition, 1.0 % and 1.5 % Rp, respectively 2.8 points for the rest of the bread. The smell received the maximum score for the control and the bread with 1.5 % Rp, 2.7 points for the bread with 2.5 % Rp and 2.9 points for the other breads. The taste obtained average scores from a maximum of 4 points between 3.4 for bread with 2.5 % Rp and 3.8 for 1.5 % Rp, the control and AA bread having 3.5 points.

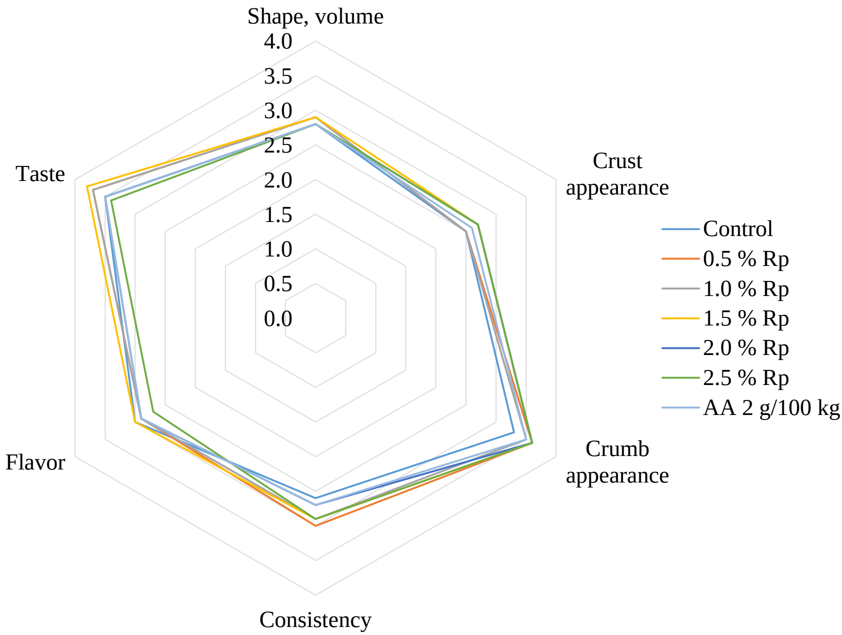

Fig. 8.8. Sensory profile for bread with Rp addition

The fact that the control bread received the lowest score shows that the bread with the addition of Rp was accepted and appreciated by the tasters. The addition of Rp improved the rheological properties of the dough so that the bread obtained also had good physico-chemical properties. The colour shades did not bother, consumers being accustomed to the commercial existence of wholemeal or black bread, even if rosehip powder has induced reddish colours due to the carotenoid pigments it contains.

8.4. Partial conclusions – the influence of Rp on bread attributes

The study of the influence of the Rp addition on the bread properties allows the following findings:

– The volume of bread with Rp addition shows higher values than the control, except for the sample with 0.5 % Rp, with significant differences (*p* < 0.05) and the highest increase for 1.0 % Rp and 1.5 % Rp;
– The specific volume has the same evolution as the bread volume, higher values than the control being obtained for the Pm addition except for the addition of 0.5 % Pm;
– The moisture of the bread increases compared to the control for all samples with the Rp addition, with significant differences (*p* < 0.05);
– The acidity increases with the increase of the Rp addition with insignificant differences (*p* > 0.05);
– The breads have high porosity, with significant differences (*p* < 0.05);
– The crumb elasticity decreases by significant values (*p* < 0.05) compared to the control, with the increase of the Rp addition;
– The most appreciated sensory properties are shape, external appearance and volume, smell and taste;
– Breads with the Rp addition received a higher score than the control, which means that they were accepted by the tasters;
– In the hedonic test, the most appreciated sensory properties were the external appearance, the appearance and color of the crust and the color of the crumb, followed closely by elasticity and porosity, smell, respect for taste and aroma;
– The general acceptability, evaluated by the manifestation of the purchase intention, received lower scores, but the averages are still above 7.

In conclusion, bread with Rp addition has good physico-chemical and sensory properties, appreciated when tasting, the influence of AA from rosehip powder added to flour being indisputable when kneading the dough.

9. Colorimetry and image analysis of bread

9.1. Introduction. The importance of studying the colour of bread

The colour of the food surface is the first quality parameter evaluated by consumers and is critical in the acceptance of the product, even before it enters the mouth. Thus, the observation of colour allows the detection of certain anomalies or defects that food items may present (Abdullah *et al*., 2004; Du & Sun, 2004; Hatcher *et al*., 2004; Pedreschi *et al*., 2000).

The appearance of the food determined mainly by the colour of the surface is the first sensation that the consumer perceives and uses as a tool of acceptance or rejection of food (Leon *et al*. 2006).

The method used is based on colour image analysis (CIA) of bread with the rosehip powder addition scanned at the end of the technological process. The CIE L*a*b* trichromatic space was used for color coding and discrimination in the pixel classification process.

The main purpose was to find a fast and non-invasive method to evaluate the quality of bread from a quantitative and hygienic point of view (Teusdea *et al*., 2010; Fumiere *et al*., 2004). The method had to be suitable for industrial application and for biochemically or microbiologically aggressive environments.

The classification process was based on the conversion of digitally scanned images for bread with the rosehip powder addition into CIE *L*a*b** colour space which has the advantage of being a linear space.

9.2. Materials and methods

9.2.1. The analysis of bread crumb colour

The method of analysis used to highlight the change in the colour of the bread to various rosehip powder additions was the ***colour images analysis*** (CIA). This method uses the CIE trichromatic space *L*a*b**, instead of the native one for encoding digital images, namely RGB. An indepth analysis of the reliable RGB to CIE conversion L **a*b** is discussed by Leon *et al*. (2006).

The captured image is a bitmap image that consists of many pixels, each pixel being assigned a specific place and color value. Software converts values from RGB to CIE *L*a* b** (Teusdea *et al*., 2010).

The samples were studied through a digital image analysis with their own software, the code being written in the Matlab R2015 programming environment. The images were captured with a CanoScan 9000F scanner (300 dpi resolution) from three central areas of 20 mm thick slices of bread cut from each loaf. The scan was repeated for three consecutive days.

The optical resolution of the scanned bread sections was 300 × 300 dpi (1 pixel = 0.0846 × 0.0846 mm), and the background was chosen black. The samples, meaning the slices of bread, were scanned on both sides (duplicate samples) on the first day, the second day and the third day, so that 36 images were scanned.

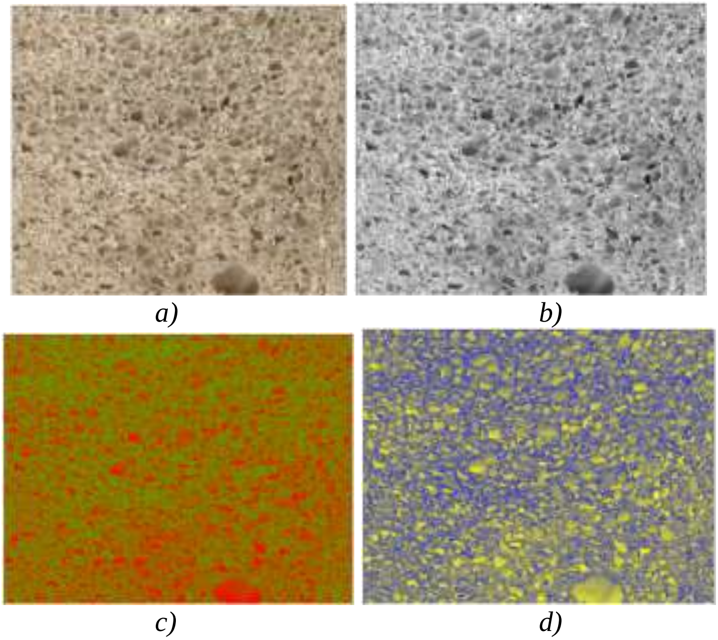

Fig. 9.2. Colour transformation of a bread sample, from the trichromatic system RGB (*a*) in CIE *L*a*b** (example): *b)* – Image coded in luminance L*; *c)* – Image coded in chromaticity a*; *d)* – Image coded in chromaticity b*.

The total porosity of the bread samples was evaluated by classifying the crumb and pore pixels using chromatic CIE *L*a*b** histograms (1D and 2D).

The univariate statistical analysis was used to determine the statistical differences between the samples for the factors of the Rp addition and the storage time (days). All multivariate samples highlighted how the Rp addition alters the preservative properties of white bread.

Multivariate sequences for principal component analysis (PCA), multivariate analysis of variation (MANOVA) and hierarchical cluster analysis (HCA) were used to establish the grouping of samples, using chromatic parameters and bread porosity.

9.4. The results of the two-factor ANOVA test

The ANOVA analysis of variance for the analyzed bread samples included two factors (bifactorial). The first factor is the percentage of rosehip powder added, Addition, with the levels: 0.0 %, 0.5 %, 1.0 %, 1.5 %, 2.0 % and 2.5 %. The second factor is the analysis period in days, Day, with the levels: Day_0, Day_1 and Day_2.

The ANOVA test (p = 0.05) for bread samples was performed for the chromatic parameters CIE *L*a*b* and the browning index, BI.

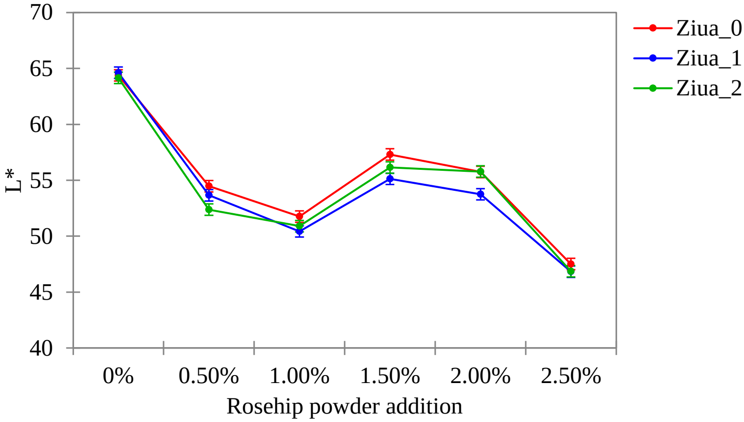

Fig. 9.13. Average of L* luminance values in bread samples for Addition * Day factor levels (option 1**)**

Naturally, the evolution of the luminance with the increase of the rosehip powder addition would be a monotonically decreasing one, but in the analyzed case the addition samples 0.5 % and 1.0 % show lower values than those of the samples of 1.5 % and 2.0 %. An identical evolution is also present for the a* chromaticity.

The evolution of the chromaticity b* and of the browning index, BI, presents only one syncope for the 1.5 % bread sample.

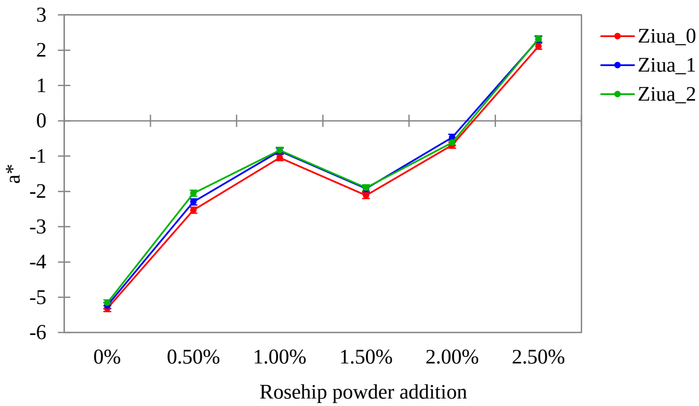

Fig. 9.17. Average of a* chromaticity values in bread samples for Addition Factor levels * Day (option 1)

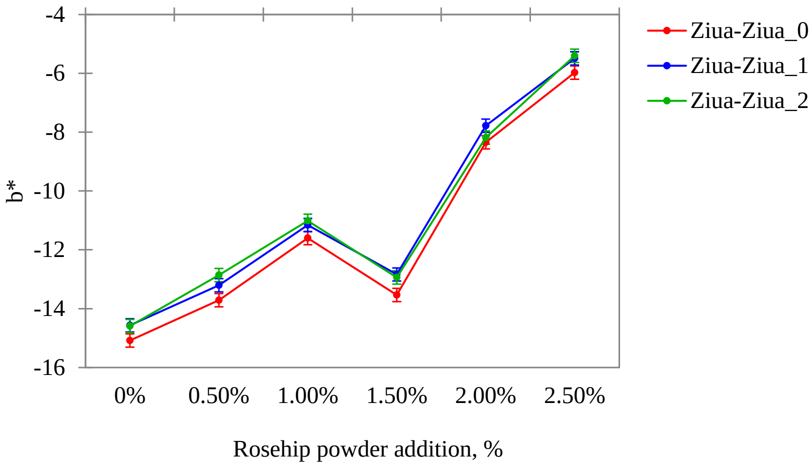

Fig. 9.21. Average of b* chromaticity values in bread samples for Addition Factor levels * Day (option 1

The general trends of the analyzed parameters evolutions are those expected at the addition of Rp, which by the presence of a significant amount of anthocyanins lead to the change of chromaticity to a reddish brown color. As a result, with the increase of the addition, the color of the bread samples has lower luminance (L*), chromaticities a*, b* and browning index, BI, higher.

9.6. Partial conclusions – colorimetry and image analysis of bread

Recent advances in image acquisition and high-power computing make it a future reality.

The luminance of the bread samples presented indicates that their evolution is almost constant after the second day of preparation. Naturally, the evolution of the luminance with the increase of the addition of rosehip powder would be a monotonically decreasing one, but in the analyzed case the addition samples 0.5 % Rp and 1.0 % Rp show values lower than those of the samples by 1.5 % and 2.0 % Rp. The evolution of the chromaticity b* and of the browning index, BI presents only a single “syncope” for the 1.5 % Rp bread sample.

The general trends of the evolutions of the analyzed parameters are those expected at the addition of rosehip powder which, due to the presence of a significant amount of carotenoid pigments, lead to the change of chromaticity to a reddish brown color. As a result, with the increase of the addition, the color of the bread samples shows lower luminance (L*), chromaticities a*, b* and browning index, BI, higher.

10. Final conclusions, original contributions and perspectives

10.1. Final conclusions

The basic concern of bakery specialists is the application of the latest methods to ensure the industrial production of high-quality products, well-leavened, with high porosity, pleasant taste and aroma, high nutritional value and long-lasting fresh.

The use of improvers is part of this concern because the addition of an improver to flour in small quantity positively influences the quality and freshness of bread and bakery products.

Ascorbic acid (AA) or vitamin C is an improver used both to accelerate the maturation of flour and to process weak flours, respectively for intensive and fast kneading.

The role of AA in baking is to mediate oxidation reactions that stabilize the dough for preserving its elastic and viscous properties so that the dough can retain gases produced during fermentation and proofing. In addition to the improvement of the ability of gluten to retain gases, AA contributes to a faster fermentation, to obtain a bread with a larger volume, finer crumb, smaller and many pores, evenly distributed and to reduce the thickness of the crust. These changes result in a softer crumb, and the bread will look fresh longer. AA used in breadmaking comes mainly from chemical synthesis, thus it is classified as a chemical compound with the number E300.

Current trends in the use of bioactive compounds from natural sources have led research to replace synthetic compounds with natural materials. Many vegetable products, especially fruits, contain large amounts of AA naturally, for example rosehips, cranberries, acerola and kakadu plums. Of these, the acerola extract was used as a substitute of AA in breadmaking, and good results have paved the way for other uses.

Rosehip fruits are used in food due to their rich content of bioactive compounds such as polyphenols, essential fatty acids, galactolipids, folates, antioxidants, vitamins and minerals, especially for vitamin C that varies between 100 and 1400 mg/100 g, with average values in the range of 400–800 mg/100 g.

The idea to use rosehips in the study of synthetic AA replacement in bread making is based on the high content of vitamin C in these fruits and the fact that the shrub that produces them is widespread in Romania. This idea generated the general objective and the specific objectives of the doctoral thesis.

The results obtained in the research aimed **to determine the influence of the rosehip powder addition**, as a natural substitute of AA, **on the dough rheology and the bread quality** were interpreted and discussed to establish conclusions and verify the achievement of objectives.

A summary of the conclusions reached with a view to achieving the specific objectives are presented below.

- **Obtaining and characterizing the rosehip powder**

Rosehip powder (Rp) was obtained from the pulp of rosehips harvested by hand, mild dried in atmospheric conditions (t = 20°C, φ = 60%), finely grinded and sifted to separate the particles with the size of 180 µm, similar to the granulometry of wheat flour. Rp was stored in the dark in airtight glass jars and stored until use.

The composition of rosehip powder was: moisture 13.40 ± 0.15 %, ash 6.50 ± 0.07 %, proteins 4.89 ± 0.11 %, lipids 0.76 ± 0.01 %, carbohydrayes 73.66 ± 0.19 % from which reducing sugars 65.03 ± 0.21 %, fibers 8.63 ± 0.03 %, and vitamin C 820 ± 37.75 – 200 ± 24 mg/100 g.

- **Study of the influence of Pm on the physico-chemical properties of flour**

Several wheat flour assortments, namely white, intermediate, wholemeal and black flour were analized and based of the physico-chemical properties one assortment of each type was selected to prepare mixtures with Rp addition as 3, 6, 9, 12, 15, 18, and 21 %. A number of 28 mixtures of wheat flour with Rp resulted. All the mixtures were chemically analysed to determine the moisture, ash content, protein content and wet gluten content. The chemical composition of mixtures has been significantly (p < 0,05) modified as a result of Rp addition: misture, protein and wet gluten decreased and ash content increased. White flour (WF) was selected for future studies.

- **The selection of the Rp addition range and the right flour for the study**

Mixtures of white flour with rosehip powder (WF-Rp) were obtained with the addition of 1.0%, 2.5% and 5.0% Rp which were physico-chemically analyzed and with the help of farinographic, extensographic, amylographic and reofermentographic tests obtaining the following conclusions:

- WA of flour increased significantly ($p < 0.05$) through fibre intake from Rp;
- AA from Rp significantly decreased ($p < 0.05$) DDT and significantly increased ($p < 0.05$) DS for additions below 2.5 %;
- The dough has a very high resistence to extension and is less extensible for 2.5 and 5.0 % Rp additions;
- The effort required to stretch the piece of dough decreases significantly ($p < 0.05$) for additions greater than 2.5 % Rp;

– The Rp addition determines the increase of maximum gelatinization temperature and maximum viscosity with significant differences ($p < 0.05$);
– The maximum height and the final height of the dough increase significantly ($p < 0.05$) with the Rp addition up to 2.5 % Rp after which they decrease;
– The volume of gases retained in the dough increases with the Rp addition.

The Rp addition had a positive influence on the rheological parameters, especially on WA, DDT, DS, dough energy, tensile strength, gelatinization temperature, maximum and final dough height, fall percentage, volume of gases lost during fermentation and volume of gases retained in the dough. Rheological tests have shown that the addition of Rp must be up to 2.5 % to obtain a suitable dough and bread crumbs, with good porosity and elasticity.

- **The study of the Rp influence on the dough rheological characteristics**

To study the influence of Rp addition on dough rheology white wheat flour (WF) 550 type, untreated with AA or other improvers and Rp addition in the proportion of 0.5 %, 1.0 %, 1.5 %, 2.0 %, and 2.5 % were used. Untreated WF and WF with the addition of 2 g AA / 100 kg flour were used as controls.

The mixtures obtained were characterized physico-chemically and with the help of specific rheological tests for flour and dough (farinographic, extensographic, amylographic and reofermentographic). The following conclusions were obtained:

- The addition of Rp to WF influenced the composition of mixtures through the insignificant decrease ($p > 0.05$) of moisture, significant increase ($p < 0.05$) of ash content, significant decrease ($p < 0.05$) of protein and wet gluten content and insignificant ($p > 0.05$) variation of lipid and carbohydrate content.
- Farinographic parameters were influenced as follows:
  – WA increases significantly ($p < 0.05$) with the Rp addition likely due to the contribution of the fibre intake of WF-Rp mixtures;
  – DDT varies insignificantly ($p > 0.05$) with the Rp addition;
  – DS varies significantly ($p < 0.05$) with the Rp addition;
  – Relevant degree of softening obtained at 12 min after reaching the maximum increases significantly ($p < 0.05$) with the Rp addition;

  The farinographic analysis did not allow to establish if there is an optimal Rp addition, respectively what Rp additions can be recommended for use as a substitute for ascorbic acid in bread making.
- The addition of 0.5–2.5 % Rp in wheat flour influences the extensographic parameters as follows:

  - R_{50} increases with significant differences ($p < 0.05$) with the Rp addition and resting time, at 2.0 % Rp reaching the maximum values the apparatus can record;
  - The extensibility of the dough decreases with the addition of Rp, at the beginning insignificant ($p > 0.05$), then significant ($p < 0.05$);
  - Extensographic quality indices increase indicating a good dough;
  - The energy required to dough extension until break increases compared to the control but does not show significant differences ($p > 0.05$).

  From the extensographic analysis it results that the Rp addition must be made so that the resistance to extension increases very much; under the experimental conditions of the study, the optimal values of the Rp addition are up to 2.0 %.

- The addition of 0.5–2.5 % Rp in wheat flour influences the amylographic parameters:
  - Temperature at the beginning of gelatinization and the maximum gelatinization temperature increase with significant differences ($p < 0.05$) with the Rp addition;
  - Maximum gelatinization viscosity shows significant differences ($p < 0.05$) with the Rp addition and indicates the obtaining of a more viscous flour gel at high Rp additions.
- The addition of 0.5–2.5 % Rp in wheat flour influences the reofermentographic parameters:
  - The maximum height of the dough varies significantly with the control;
  - The doughs are stable because the height of the dough at the end of fermentation has values almost identical to H_m, except for the control;
  - The T_x time at which the loss of CO_2 from the dough begins has higher values than the control for the additions of 0.5–1.5 % and AA, respectively lower for the rest of the samples;
  - The total gas volume has relatively close values for all samples;
  - The volume of gas lost from the dough during fermentation has lower values for samples with the Rp addition compared to the control;
  - The gas volume retained in the dough increases to the Rp addition 2.0 %, then decreases.

In conclusion, the Rp addition in wheat flour improves the rheological properties of the dough in a similar way to synthetic AA, even if there are some differences that are caused by other components of Rp. These differences are relatively small as the addition does not have to be done in large quantities. In addition, some differences are beneficial, for example increasing the water absorption of the dough most likely due to the intake of fibre by the Rp addition. According to the experimental results, flour parameters and vitamin C content of Rp, additions up to 2.0 % Rp could be recommended, mentioning that there is necessary to know the vitamin C content of Rp at use.

- **The study of the influence of Rp on the physico-chemical and bread sensory properties**

To determine the physico-chemical and sensory of bread properties, from the flours analyzed in the rheological tests bread was obtained by the direct method. After modeling the dough was placed in trays for leavening and baking. After cooling, the bread was analyzed physico-chemically (size, volume, specific volume, moisture, acidity, porosity and elasticity) and sensory (20-point test and hedonic test). The main findings and conclusions were:

– The volume of bread with Rp addition showed higher values than the control, except for the sample with 0.5 % Rp, with significant differences ($p < 0.05$) and the highest increase for 1.0 % Rp and 1.5 % Rp;
– The moisture of the bread increased compared to the control for all samples with the Rp addition, with significant differences ($p < 0.05$);
– The acidity increased with the increase of the Rp addition with insignificant differences ($p > 0.05$);
– The breads had high porosity, with significant differences ($p < 0.05$);
– The crumb elasticity decreased by significant values ($p < 0.05$) compared to the control, with the increase of the Rp addition;
– The most appreciated sensory properties were shape, external appearance and volume, smell and taste;
– Breads with the Rp addition received a higher score than the control, which means that they were accepted by the tasters;
– In the hedonic test, the most appreciated sensory properties were the external appearance, the appearance and color of the crust and the color of the crumb, followed closely by elasticity and porosity, smell, respect for taste and aroma;
– The general acceptability, evaluated by the manifestation of the purchase intention, received lower scores, but the averages were still above 7 (out of 9).

In conclusion, bread with Rp addition has good physico-chemical and sensory properties, appreciated when tasting, the influence of AA from rosehip powder added to flour being indisputable when kneading the dough.

The bread analysis was supplemented with colorimetry and imaging studies with color analysis of images using the CIE L*a*b* trichromatic space, instead of the native one for encoding digital images, namely RGB.

Colour is an important attribute of food quality that influences consumer choice and preferences. Colour can be correlated with other quality attributes, such as sensory, nutritional and visual or non-visual defects and helps to control them immediately.

Bread was scanned in section, in duplicate, in three successive days, than the images obtained were processed, converted to CIE L*a*b* and analyzed.

The luminance of the bread samples indicated that their evolution is almost constant after the second day of preparation.

Naturally, the evolution of the luminance with the increase of the addition of Rp would be a monotonically decreasing one, but in the analyzed case the addition samples 0.5 % Rp and 1.0 % Rp show values lower than those of the samples with 1.5 % and 2.0 % Rp. An identical evolution was obtained for the chromaticity of a*.

The evolution of the chromaticity b* and of the browning index, BI presents only a single “syncope” for the 1.5 % bread sample

The general trends of the evolutions of the analyzed parameters are those expected at the addition of Rp which, due to the presence of a significant amount of carotenoid pigments, lead to the change of chromaticity to a reddish brown color. As a result, with the increase of the addition, the color of the bread samples shows lower luminance (L*), chromaticities a*, b* and browning index, BI, higher.

- **Submission of a patent application *Bread with rosehip powder addition and process for obtaining the same***

The patent application with the title *Bread with rosehip powder addition and process for obtaining the same*, having Turtoi Maria and Vartolomei Nicoleta as authors received the number A/0069 of 19.09.2018. Its summary has been published in BOPI no 3/2020.

10.2. Original contributions

The original contributions of the doctoral thesis are the following:

- ✓ Obtaining the rosehip powder (Rp) under natural conditions without forced drying and its physico-chemical characterization;
- ✓ Obtaining flour mixtures with Rp and physico-chemical analysis to establish the influence of the Rp addition on the composition of the mixtures;
- ✓ Performing rheological tests specific to flour and dough (farinographic, extensographic, amylographic and reofermentographic) to study the influence of Rp on the rheology of the dough;

- ✓ Obtaining bread from mixtures of flour with Rp in the range of 0.5–2.5 % and analysis of bread to determine the influence of the addition of Rp on the physico-chemical and sensory characteristics of the bread;
- ✓ Analysis of the colour of the bread crumb by scanning the bread in section and converting the images from the RGB space into the CIE L * a * b * space;
- ✓ Deposition of a patent application entitled *Bread with rosehip powder addition and process for obtaining the same.* The patent application was registered at OSIM with no. A / 00697/2018, with the date of deposit 19.09.2018 and regular national deposit with no. of 2018 00697, and the summary was published in the Official Bulletin of Industrial Property - Inventions Section, no. 3 of 2020, p. 16.

10.3. Perspectives and future research directions

The completion of the doctoral thesis is just a moment of balance that will materialize in the doctoral degree diploma, the prospects for continuation and diversification of research remaining open. Thus, the following future research directions are proposed:

- ➢ To use the rosehip powder in combination with other types of flour;
- ➢ To obtain a rosehip extract, characterize it and study its use in bread as a substitute for chemically synthesized ascorbic acid;
- ➢ To identify other native plant materials high in vitamin C and study the replacement of synthetic AA in breadmaking.

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List of published and presented papers

Patent – application

1. Turtoi M. & **Vartolomei N**. **2018**. *Pâine din făină de grâu cu adaos de pudră de măceșe și procedeu de obținere a acesteia*, Cerere de brevet de invenție nr. A/0069 din 19.09.2018; rezumat publicat în BOPI nr. 3/2020.

Publications Web of Science

1. Pircu Vartolomei N., Aruș V.A., Moroi A.M., Zaharia D. & Turtoi M. **2020**. Influence of rosehip powder addition on quality indicators of mixtures obtained with different types of wheat flour. *Scientific Study & Research Chemistry & Chemical Engineering, Biotechnology, Food Industry*, 21(3), ISSN 1582-540X, 379-393. http://pubs.ub.ro/?pg=revues&rev=cscc6&num=202003&vol=3&aid=5166

Participation at international conferences (poster included)

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