SUMMARY OF THE DOCTORAL THESIS

RESEARCH ON THE INFLUENCE OF BIOLOGICAL FACTORS AND OF MANUFACTURING TECHNOLOGY ON THE QUALITY OF CONFECTIONERY PRODUCTS MADE OF CEREAL GRAINS

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INTRODUCTION

In food industry, *extrusion* represents a process of compressing raw materials under pressure and then forcing them through a small aperture. Extrusion is particularly adequate for vegetal raw materials, mainly coarse flour such as wheat and corn semolina, wheat, rice and rye flours. Other vegetal materials are legumes, potatoes, protein products (wheat gluten, oleaginous coarse grits), separately or blended with other raw materials or additives (sugar, salt, spices, emulsifiers) for amelioration of their sensory qualities (IOANCEA, L și KATHERINE I., 1988).

In our research, we plan a comparative study of grain genotype influence in conjunction with technological manufacturing factors on the quality of extruded products, in order to broaden the choice of raw materials for manufacturing wheat and corn flakes and their optimal use in the process of obtaining bars.

In a volume of 183 pages, this PhD thesis is structured in six chapters that include 138 tables, 39 charts and 6 figures grouped into two main parts.

The general part deals with current knowledge, history and general technology of manufacturing cereal flakes, grains as source of raw materials and our research objectives. (Chapters I-II).

Our research is structured in four chapters covering the biological material, additives and machinery used in production of cereal flakes and bars, the experimental method (III), results and discussion of our research (IV), the economic efficiency of variants of manufacturing snacks with added wheat and corn flakes (V) and general conclusions and recommendations. (VI).

The orientation and contents of this PhD thesis was done under the guidance of distinguished professor Dr. Alexandru Salonta, whom I wish to address in this way my most sincere thanks and my gratitude for his highly competent scientific guidance, for his permanent support, as well as generous advice and suggestions.

My thanks to the leadership of the University of Agricultural Sciences and Veterinary Medicine Cluj - Napoca and to the Department of Agriculture for their support in carrying out his doctoral thesis.
I also thank the management of S.C.D.A. Turda who generously provided me the necessary biological material and to the management of SC Perffetti Van Melle Romania for its support in carrying out experiments and record experimental data. I am grateful to my family for their permanent support and encouragement offered throughout the completion of the doctoral theses.

CHAPTER I. CEREAL GRAINS, MAIN SOURCE OF RAW MATERIAL IN THE CONFECTIONERY INDUSTRY

In the classification of main food groups, according to GONŢEA I. (1970), cereals and their derivatives are part of Group VI, representing the most important source of energy due to high intake in the diet and with a high calorific value. The nutritional value of cereal grains is determined by their chemical composition, which after BILTEANU, GH. et al. (1991) include: 57 to 75.1% non-nitrogen substances, 7.7 to 24% protein, 1.5 to 4.1% fat, 1.9 to 4.85% cellulose and 0.5-2.78% mineral substances. The ratio of these chemical components is considered to be very balanced for a rational human nutrition, especially for wheat and maize, the main cereals consumed in the world and our country.

1.1. CEREAL GRAINS AS SOURCE OF ORGANIC SUBSTANCES

Although cereal grains have a relatively low content of protein, due to their extended use in food preparation, they represent the most important source of human protein, providing about half the protein consumed by humans. Food proteins, through the process of digestion, release amino acids, which are the main source of body feed. Proteins are involved in cell growth and in enzyme formation; they control many metabolic processes and participate widely in the formation of antibodies. (SEGAL, B. et al., 1982).

Non-nitrogen substances are found in high proportion in the endosperm of cereal grains and are composed of starch, about 90%, 2-3.5% sugar and 2.3% dextrin.

In cereal grains, there are 1.5 - 6% fatty substances with higher proportion in the embryo, which in maize represents 30 - 35% and for wheat only 1.5%. In corn, out of the total fat content, the embryo detains about 83.2% and 15% in the endosperm. (SALONTA, AL., Muntean, L. 1982).
Cereals contain vitamins B1, B2, B6, E, D, and PP. Although small, the embryo contains 50% thiamin (B1), and 30% niacin (PP). (SEGAL, B. et al., 1982). Aleuronic and other outer layers contain 50% niacin and 35% riboflavin (B2). The endosperm, which is the paramount part of the grain, contains 1/3 or less of vitamin B. The dry form of cereal grains are devoid of vitamin C; with the exception of yellow maize, they are also free of carotene (Provitamin A) (SEGAL, B. et al., 1982).

1.2. CEREAL GRAINS AS SOURCE OF MINERAL SUBSTANCES

Cereal grains contain between 1.4 and 3% mineral substances (K, P, Mg), concentrated largely in grain shells, substances that are removed during further processing of cereals.

CHAPTER II. CURRENT KNOWLEDGE ON MANUFACTURING CEREAL FLAKES AND BARS IN THE FOOD INDUSTRY

2.1. HISTORY OF MANUFACTURING CEREAL FLAKES AND BARS IN WORLD FOOD INDUSTRY

Flakes industry consists of companies engaged in the manufacture and sale of prepackaged food products made mainly from cereals. The consumer should not prepare the product before use and can consume it dried or by adding food products such as milk, yoghurt. From a consumer perspective, some of the advantages of flakes are ease of use in meeting their food needs. Products are predominantly consumed at breakfast, but are also used as snacks.

Flakes industry has a turnover of $4 billion and is composed of several large companies that dominate the market. Led by Kellogg, flakes industry includes General Mills, General Foods, Quaker Oats, Ralston Purina and Nabisco.

2.2. HISTORY OF MANUFACTURING CEREAL FLAKES AND BARS IN ROMANIAN FOOD INDUSTRY

Extrusion in our country is in research phase, with the exception of modified starches for the production of oil wells. For the food industry in our country, there have been produced extruders Sotex 135(according to documents prepared by ICPIAF Cluj-Napoca)
and granulator extruder type 15X60 EG-1, produced by CCSITMUIU-Bucharest. (IOANCEA, L și KATHERINE I., 1988).

Before 1989, in Romania there were only two factories producing corn flakes: Titan SA Bucharest and Constanta Dobrogea. In Cluj, the factory Feleacul-produced “pufarin" cereals, obtained by expanding wheat and corn in expanding guns and then pelleted with sugar syrup, were the only product of this kind on the Romanian market.

2.3. RESEARCH OBJECTIVES

In Romania, there is no scientific research on grain extrusion, so we considered our investigations necessary with the following objectives:
• Broadening the basis of extrusion raw materials;
• Establishing cereal genotype influence on extrudate quality and determining optimal technological factors;
• Determining the influence of storage on the quality of extrudates;
• Enhancing valorisation of extruded cereals as sugary foods;
• Creating opportunities for diversification of extruded cereal confectionery.

CHAPTER III. MATERIALS USED AND EXPERIMENTAL METHOD

3.1. BIOLOGICAL MATERIAL AND EXPERIMENTAL METHODS

To achieve the objectives, we studied grains belonging to two major cereals, wheat Triticum aestivum (L) ssp.vulgare (Vill), respectively varieties Turda 95, Arieșan, Turda 2000 and maize, Zea mays (L), respectively genotypes Turda Favorit, Turda 200, Turda Super approved and created at the SCDA Turda.

Experiments were carried out using a two-Worm extruder type CLEXTRAL BC - 21, with capacity of 12.1 kilograms / hour, screw diameter of 25 mm and 3 mm diameter mold nozzle. The following factors and graduations were considered:

To obtain wheat flakes:

Factor A = genotype (variety) with graduations:
  a1 = Turda 95, a2 = Turda 2000, a3 = Arieșan;

Factor B = mixture humidity (%) with graduations:
b1 = 21, b2 = 23, b3 = 25;

Factor C = feed flow (kg/hr) with graduations:
   c1 = 3.5, c2 = 5.4, c3 = 7.2.

To produce corn flakes:

Factor A = maize genotype (hybrid) with graduations:
   a1 = Turda Favorit; a2 = Turda 200; a3 = Turda Super;

Factor B = mixture humidity (%) with graduations:
   b1 = 21, b2 = 23, b3 = 25;

Factor C = feed flow (kg/hr) with graduations:
   c1 = 3.5, c2 = 5.4, c3 = 7.2.

Factors B and C are similar to those of wheat flakes.

The combination of factors and graduations for each species resulted in a trifactorial experience of type 3 x 3 x 3, with 27 variants, as follows:

V1 = a1 b1 c1;  V 10 = a2 b1 c1;  V 19 = a3 b1 c1;
V2 = a1 b1 c2;  V 11 = a2 b1 c2;  V 20 = a3 b1 c2;
V3 = a1 b1 c3;  V 12 = a2 b1 c3;  V 21 = a3 b1 c3;
V4 = a1 b2 c1;  V 13 = a2 b2 c1;  V 22 = a3 b2 c1;
V5 = a1 b2 c2;  V 14 = a2 b2 c2;  V 23 = a3 b2 c2;
V6 = a1 b2 c3;  V 15 = a2 b2 c3;  V 24 = a3 b2 c3;
V7 = a1 b3 c1;  V 16 = a2 b3 c1;  V 25 = a3 b3 c1;
V8 = a1 b3 c2;  V 17 = a2 b3 c2;  V 26 = a3 b3 c2;
V9 = a1 b3 c3;  V 18 = a2 b3 c3;  V 27 = a3 b3 c3;

In order to compare the experimental results, we set a control (standard) variant that is the average of all variants ($\bar{X}$). (SĂULESCU N., 1959). As physical attributes, the expansion index and bulk density were determined, and as chemical, the starch and protein content. All these features were determined in three stages: at the start of storage, at six months and 12 months.
The expansion index was determined by the method of RAYAS - DUARTE (1988), by measuring the diameter of ten extrudates with callipers, after which an arithmetical mean was calculated, which was divided by the diameter of the mold nozzle.

The volumetric mass in g/l was determined by a hectoliter balance with capacity of 1 liter, the protein content was determined by the Kjeldahl method and the starch with the Evers method. To obtain wheat flakes bars, Turda 95 wheat variety was used, and for corn flakes bars the Turda Favorit hybrid was used, with different content of flakes 5%, 6%, 7%, 8% and 9% resulting in a monofactorial experience: Tables 3.1. and 3.2.

Table 3.1.

<table>
<thead>
<tr>
<th>No.</th>
<th>Variants % wheat flakes</th>
<th>M.U.</th>
<th>Raw materials</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Fondant</td>
</tr>
<tr>
<td>1.</td>
<td>5 % Kg</td>
<td>66</td>
<td>4.5</td>
</tr>
<tr>
<td>2.</td>
<td>6 % Kg</td>
<td>66</td>
<td>4.5</td>
</tr>
<tr>
<td>3.</td>
<td>7 % Kg</td>
<td>66</td>
<td>4.5</td>
</tr>
<tr>
<td>4.</td>
<td>8 % Kg</td>
<td>66</td>
<td>4.5</td>
</tr>
<tr>
<td>5.</td>
<td>9 % Kg</td>
<td>66</td>
<td>4.5</td>
</tr>
</tbody>
</table>

Table 3.2.

<table>
<thead>
<tr>
<th>No.</th>
<th>Variants % corn flakes</th>
<th>M.U.</th>
<th>Raw materials</th>
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<tr>
<td></td>
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<td>8 % Kg</td>
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<tr>
<td>5.</td>
<td>9 % Kg</td>
<td>66</td>
<td>4.5</td>
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</table>
The experiments were performed within the company SC Perfetti Van Melle Romania, Cluj - Napoca, with the following equipment used to obtain bars with added cereal: duplex boiler for boiling fondant syrup, fondant pouring machine, mixer, extruder, icing machine and bar packaging machine.

The bars with added wheat and corn flakes obtained from experiments were analyzed by five tasters by means of sensory methods with score scales, the average of the features being the organoleptic characteristics of each variant.

3.3. EQUIPMENT USED AND TECHNOLOGICAL FLOW

In cereal flakes manufacturing there are several production lines with manufacturer-specific equipment, which ultimately fulfill the operation for which they were designed. Extrusion technology can manufacture cereal flakes with fully developed flavour and specific crunchy texture. As a result of combining different grains, it is possible to obtain flakes with texture and taste and a better balance of nutritional composition. Special coating systems can use sugar, honey, cocoa powder. Figure 3.1. shows a possible scheme of production lines for producing sweet snacks and breakfast cereals.

![Schematic view of a possible plant configurations for making sweet snacks & breakfast-cereals](image)

Figure 3.1. : Schematic view of possible plant configuration for making sweet snacks and breakfast cereals (By Internet, Clextral company profile)
To obtain bars with added cereal flakes the following equipment was used: duplex boiler for boiling fondant syrup, fondant pouring machine, mixer, extruder, icing machine and bar packaging machine.

The technological scheme of manufacturing bars with added cereal flakes is shown in Figure 3.2.

![Technological Scheme](image)

Fig. 3.2. Technological scheme of manufacturing bars with added cereal flakes (adapted from Fundy Hungary specifications)
CHAPTER IV. RESULTS AND DISCUSSION

4.1. RESEARCH RESULTS FOR OBTAINING WHEAT FLAKES

4.1.1. Results of research on the influence of the interaction of genotype, humidity and feed flow on the expansion index of wheat flakes

The expansion index of wheat flakes at start of storage, 6 months and 12 months under the influence of the studied factors is presented in figures 4.1, 4.2, 4.3.

Fig.4.1. Influence of genotype, humidity and feed flow on the expansion index of wheat flakes at start of storage
Fig. 4.2. Influence of genotype, humidity and feed flow on the expansion index of wheat flakes at six months

Fig.4.3. Influence of genotype, humidity and feed flow on the expansion index of wheat flakes at 12 months
On examining the research results on the index of wheat flakes expansion at start of storage, six months and 12 months, we concluded the following:

The most favorable extrusion of wheat at the start of storage is done in Turda 95 variety in interaction with 21% and 23% humidity and feed flows of 3.5 and 5.4 kilograms per hour, the deviations from (\(\overline{X}\)) being very significant; it is followed by Turda 2000 variety at humidity of 21% and 23%. The worst results were obtained from Arişan (a3) variety for all variants with very significantly negative differences.

At six months of storage, the expansion index increased slightly, and the most favorable extrusion is also made for the Turda 95 variety (a1) at the same humidity of 21% and 23%, respectively at the feed flow of 3.5 kilograms/ hour and 5.4 kilograms/ hour. The lower values were also obtained in the Arişan variety to increased moisture and feed flow rates.

At 12 months of storage, the data clearly confirmed the data obtained at six months, meaning that by increasing storage time, extrusion is improving and that varieties are classified, with slight differences in the following order: Turda 95, Turda 2000, Arişan, with varying degrees of significance. Moisture and feed flow factors interact most favorably at small and intermediate values, respectively at humidity of 21% and 23%, and feed flow of 3.5 kilograms/hour and 5.4 kilograms/ hour.

4.1.2. Research results on the influence of the genotype, humidity and feed flow interaction on the bulk density of wheat flakes.

Bulk density of wheat flakes at the start of storage, six months and 12 months under the influence of factors considered for the study is shown in Figures 4.4, 4.5 and 4.6.
Fig. 4.4. Influence of genotype, humidity and feed flow on bulk density of wheat flakes at start of storage

Fig. 4.5. Influence of genotype, humidity and feed flow on bulk density of wheat flakes at six months
Fig. 4.6. Influence of genotype, humidity and supply flow on bulk density of wheat flakes at 12 months

On examining the results on bulk density of wheat flakes at start of storage, at six months and 12 months, the following can be noticed:

In terms of qualitative characteristics (shape, size, taste), it is desirable that bulk stored flakes have a density of (g / l) as low as possible.

Storage revealed that the lowest density of wheat flakes was recorded in the Turda 95 variety, gradually increasing in Turda 2000 and Arieșan varieties, very significantly as to the \( \bar{X} \).

At six months of storage wheat flakes bulk density values are slightly lower, \( \bar{X} \) is lower with 1g / l, but the order of the varieties and interactions between factors are generally the same. The Turda 95 variety is highlighted once again.

Bulk density of wheat flakes at 12 months of storage is similar to that at six months storage and the order and variety interaction with flake moisture and extrusion flow is generally the same for each variety, including differences and significances to \( \bar{X} \). In all phases of storage, the influence of humidity on the bulk density of wheat flakes shows
significantly positive variations with humidity of 21% and decreases with increasing humidity towards very significantly negative values at 25% humidity.

Feed flow of the mixture in interaction with genotype and moisture on bulk density has a very significant positive influence at 7.2 kilograms/hour, decreasing relevantly significant at a flow of 5.4 kilograms/hour and significantly at the flow of 3.5 kilograms/hour.

4.1.3. Research results on the influence of the interaction of genotype, humidity and feed flow on the starch content of wheat flakes

The starch content of wheat flakes at start of storage, at 6 and 12 months from storage under the influence of the variables taken into account is presented in Figures 4.7, 4.8 și 4.9.

Fig.4.7. Influence of genotype, humidity and feed flow on the starch content of wheat flakes at start of storage
Fig. 4.8. Influence of genotype, humidity and feed flow on the starch content of wheat flakes at 6 month-storage.

Fig. 4.9. Influence of genotype, humidity and feed flow on the starch content of wheat flakes at 12 month-storage.
Results on starch content of wheat flakes in storage, at 6 and 12 months:

The content of starch flakes at start of storage has values very significantly above average variations ($\bar{X}$) in Turda 95 varieties in all combinations, and in Turda 2000, the differences being very significantly positive. The lowest starch content occurred in the Arieșan variety of flakes with very significant differences as compared with the average variations and to other varieties.

After six months storage, wheat flakes starch content had values above ($\bar{X}$), being significantly close to wheat at start of storage and very significantly high in Turda 95 variety, in all combinations, and Turda 2000 in combination with minimum humidity (b1), with significantly positive differences. The lowest starch content occurred in the Arieșan variety of flakes in all combinations, with very significant negative differences as to ($\bar{X}$) and the other varieties.

At 12 month-storage, the starch content of the flakes had values generally similar to previous determinations, the most favorable extrusion occurring in Turda 95 variety, in all cases, followed by Turda 2000, and lowest in the Arieșan variety, with gradually very significant negative differences.

The influence of humidity in conjunction with genotype and feed flow on the starch content of wheat flakes is significantly positive at 21% humidity and significantly negative at 25% humidity.

The influence of feed flow in interaction with genotype and humidity on the starch content of wheat flakes at start of storage, six months and 12 months have insignificantly equal values at all power flows.

4.1.4. Research results on the influence of the interaction of genotype, humidity and feed flow on the wheat flakes protein content

The protein content of the wheat flakes at start of storage, at six months and 12 months under the influence of the studied variables is presented in figures 4.10, 4.11 and 4.12.
Figure 4.10 Influence of genotype, humidity and feed flow on the protein content of wheat flakes at the start of storage

Figure 4.11. Influence of genotype, humidity and feed flow on the protein content of wheat flakes at six months
Fig. 4.12. Influence of genotype, humidity and feed flow on the protein content of wheat flakes at 12 months

On examining the protein content of wheat flakes at the start of storage, at 6 months and 12 months, we can conclude the following:

Protein content of the flakes at the start of storage indicates that the Arieșan variety comes first, followed by Turda 2000, the last being Turda 95, containing less than 8%, the variations are very significantly negative as to both ($\bar{X}$) and relative to the other varieties. All varieties responded more favourably to the maximum humidity (b3) and average (b2).

At six months of storage, wheat protein content decreased to the lowest value recorded in variety Turda 95, with values similar to the moment of storage.

At 12 months of storage, protein content values did not change significantly from those registered at the start of storage and of six months; the highest percentage also occurred in the Arieșan variety, with significant variations compared to ($\bar{X}$). In Turda 2000, content was situated halfway in relation to the two varieties, and the variations related to ($\bar{X}$) are insignificant.
The influence of humidity in conjunction with genotype and feed flow on the protein content of wheat flakes shows insignificant variations for 21% and 23% humidity.

4.2. RESEARCH RESULTS FOR OBTAINING CORN FLAKES

4.2.1. Results of research on the influence of the interaction of genotype, humidity and feed flow on the expansion index of corn flakes

The expansion index of corn flakes in storage, at 6 and 12 months under the influence of the studied variables is presented in Figures 4.13, 4.14 and 4.15.

Fig. 4.13. Influence of genotype, humidity and feed flow on corn flakes expansion index at the start of storage
Fig. 4.14. Influence of genotype, humidity and feed flow on corn flakes expansion index at six months

Fig. 4.15. Influence of genotype, humidity and feed flow on corn flakes expansion index at 12 months
On examining the results on the corn flakes expansion index at the start of storage, six months and 12 months, we can conclude the following:

At the start of storage, the expansion index is significantly higher with the Turda Favorit hybrid in which, except for variant 9 (a1, b3, c3), deviations from ($\bar{X}$) are very significantly higher. Similarly, values are very significantly higher for hybrid Turda 2000, in variant 14 (a2, b2, c2). The lowest results are obtained from variant a3 b3 c1 and a3 b3 c3, respectively Turda Super hybrid, at 25% humidity and supply flow of 3.5 and 7.2 kilograms/ hour where the index of expansion of cornflakes was the lowest.

At six months of storage, the expansion index of the median ($\bar{X}$) variations, increased significantly in relation to the time of storage (3.36 cm to 2.95 cm). The most favourable extrusion was carried out at Turda Favorit hybrid, followed by Turda Super. The lowest results were obtained from hybrid Turda 200, variant a2 b2 c 3, at 23% humidity and feed flow of 7.2 kilograms/ hour, where the corn flakes expansion index was the lowest.

At 12 month-storage, the expansion index of the flakes have virtually equal values to the average ($\bar{X}$) at the start of storage, but lower than the values at six months, with Turda Favorit ranking first, followed by Turda 200, and Turda Super hybrid on the last position, with very significantly negative variations. The influence of humidity in interaction with genotype and feed flow on the index of expansion of corn flakes recorded very significant positive variations at a 21% humidity mixture and very significant negative values at 25% humidity.

The influence of the feed flow in interaction with genotype and humidity on the index of expansion of corn flakes at start of storage showed significant variations in variant (c1), significantly positive at a flow of 5.4 kilograms/ hour and distinctly negative at a flow of 7.2 kilograms / hour and insignificant values at 6 and 12 months.

4.2.2. Results of research on the influence of the interaction of genotype, humidity and feed flow on the bulk density of corn flakes

The corn flakes bulk density at the start of storage, at 6 and 12 months under the influence of the studied variables is shown in Figures 4.16, 4.17 and 4.18.
Figure 4.16. Influence of genotype, humidity and feed flow on corn flakes bulk density at start of storage

Figure 4.17. Influence of genotype, humidity and feed flow on corn flakes bulk density at six month-storage
Fig. 4.18. Influence of genotype, humidity and supply flow on corn flakes bulk density at 12 month-storage

*On examining the results on the corn flakes bulk density on storage, six months and 12 months, we can conclude the following:*

The lowest density at the start of corn flakes storage was recorded in variant a1, b1, c2, respectively Turda Favorit hybrid, with 21% humidity mixture and feed flow of 5.4 kilograms/hour.

At six months of storage, the influence of genotype in conjunction with humidity and feed flow shows very significant positive variations in Turda Super hybrid, distinctly significant in Turda 200 and again very significantly negative in Turda Favorit hybrid.

At 12 months of storage, the humidity influence in conjunction with genotype and feed flow on the bulk density of corn flakes is very significantly positive at 25% humidity, significantly positive at 23% humidity and very significantly negative at a flow of 21%. The influence of the feed flow in conjunction with genotype and moisture on the bulk density of corn flakes recorded very significant positive variations at a flow of 7.2 kilograms/hour and very significant negative at a flow of 3.4 kilograms/hour and 5.4 kg/hour.
At 12 months of storage, the influence of the supply flow in interaction with genotype and moisture on bulk density of corn flakes recorded insignificant variations.

4.2.3. Results of research on the influence of the interaction of genotype, humidity and feed flow on the starch content of corn flakes

The starch content of corn flakes at the start of storage, at 6 and 12 months after storage under the influence of the variables taken into account is presented in Figures 20 – 22.

Fig.20. Influence of genotype, humidity and supply flow on the starch content of corn flakes at start of storage
Fig. 21. Influence of genotype, humidity and feed flow on the starch content of corn flakes at 6 month-storage.

Fig. 22. Influence of genotype, humidity and feed flow on the starch content of corn flakes in 12 month-storage.
On examining the starch content of corn flakes at the start of storage, at 6 months and 12 months, we can conclude the following:

At the start of storage, the starch content of corn flakes and the interaction of factors are influenced largely by the hybrid. In comparison with the others, which have average variation values situated between 68 and 52 %, Turda Favorit stands out with values ranging from 68.73 to 70.21 %, the variations being extremely significant. The lowest values occur in Turda Super hybrid, with only 65.81 – 69.84 %, compared to 68.73 – 70.21 in Turda Favorit hybrid.

The influence of feed flow in interaction with genotype and humidity on the starch content of corn flakes at the start of storage has similar values.

After 6 month-storage, the starch content of corn flakes shows values similar with the storage start time, the order of the genotypes being the same in the interaction with minimum humidity (21 %).

After 12 month-storage, genotypes are noticed to be determinant with Turda Favorit coming first at 21 % humidity, followed by Turda 200, and Turda Super on the last position.

In variable interaction, humidity has a negative influence: the higher it is, the lower the starch content. Thus, the starch content decreases from minimum humidity (b1) to maximum humidity in all hybrids. The feed flow has a minimum influence on starch content.

4.2.4. Research results on the influence of the genotype, humidity and feed flow on the protein content of corn flakes

The protein content of corn flakes at the three stages of storage in interaction with the variables studied is presented in Figures 23 – 25.
Fig. 23. Influence of genotype, humidity and feed flow on the protein content of corn flakes at the start of storage

Fig. 24. Influence of genotype, humidity and feed flow on the protein content of corn flakes at six months
Fig. 25. Influence of genotype, humidity and supply flow on the protein content of corn flakes at 12 months

*On examining the protein content of corn flakes at the start of storage, at 6 months and 12 months, we can conclude the following:*

At the start of storage, the average protein content ($\bar{X}$) of corn flakes was 7.48% with very significant variations between hybrids. Turda Super ranked first (7.51% - 7.58%), followed by Turda 200 (7.36% - 7.55%), with Turda Favorit on the last place (7.34% - 7.39%). All three hybrids responded most favourably in interactions with a feed flow of 7.2 kg / hour (c3), followed by flow 5.4 kilograms / hour (c2).

After six months of storage, the average protein content of the 27 variants ($\bar{X}$), decreased slightly to 7.41% whereas the order of values was similar to those registered at the start of storage, respectively Turda Super (7.44 to 7.78%), Turda 200 (7.30 to 7.45%) and Turda Favorit (7.29 to 7.32%). All hybrids responded most favourably to interactions with the feed flow of 7.2 kg / hr (c3), followed by flow 5.4 kg / hour (c2).

At 12 months of storage, the average protein content ($\bar{X}$) of corn flakes was 7.43%, slightly lower than at the start of storage time, with same order of values in the three hybrids, respectively Turda Super (7.41 to 7.82 %), Turda 200 (7.32 to 7.45%) and Turda Favorit (7.29 -7.32), in interaction with high and medium flow of 7.2 kilograms / hour and
5.4 kilograms/ hour. The influence of genotype in conjunction with humidity and feed flow on the protein content of corn flakes is very significantly negative in Turda Favorit and Turda 200 and very significantly positive in Turda Super hybrid in relation to the mean of the variants.

The influence of the feed flow in interaction with genotype and humidity on the protein content of corn flakes registered insignificant values in all variants and storage stages.

Research results on the comparative study of cereal genotype influence on extrudate quality under the influence of technological factors with the purpose of broadening the base of raw materials for the manufacture of wheat and corn flakes and their valorisation in the process of obtaining bars lead us to the following conclusions:

4.3. RESULTS OF RESEARCH CARRIED OUT TO OBTAIN BARS WITH ADDED WHEAT AND CORN FLAKES

4.3.1. Results on the influence of interacting factors on characteristics of bars with added wheat flakes

Based on results of impact assessments of the five tasters as to the influence of wheat flakes content on the organoleptic characteristics of bars taken to study, the averaging criteria are presented in table 4.1.

Analysing the organoleptic characteristics of bars with added wheat flakes our study has found that the appearance of bars with wheat flakes is essentially equal for all variants considered for the study, the criteria average ranging between 3.20 and 4.00.

As to the bar flavour, we noticed that the lower the flake content in the recipe, the lower the average of the criteria, namely from 4.00 to 2.20. The lowest values were recorded in version 1, where the content of cereal flakes was 5%. Significantly higher values were recorded in variants 4 and 5, where the content in cereal flakes was 8%, respectively 9%.

The consistency of the studied bars, especially crispiness, was largely influenced by the amount of cereal flakes. For variants 1 and 2, we considered a hard consistency, because of the lesser amount of flakes, respectively semi-hard for variants 4 and 5 with higher content of flakes.
Taste is significantly superior in variants 4 and 5, with a high flake content in comparison with variants 1 and 2 where the content of flakes in the recipe was 5% and 6%.

Table 4.1. Tasters’ average values regarding the organoleptic characteristics of bars with wheat flakes

<table>
<thead>
<tr>
<th>Variant % flakes</th>
<th>Questionnaire</th>
<th>Appearance</th>
<th>Flavour</th>
<th>Consistency</th>
<th>Taste</th>
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4.3.2. Results regarding the influence of variable interaction on characteristics of bars with added corn flakes
The criteria average was calculated based on data from questionnaires on the organoleptic characteristics of bars with corn flakes. The data are shown in Table 4.2:

Table 4.2. Tasters’ average values regarding the organoleptic characteristics of bars with corn flakes

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<tr>
<th>Variant</th>
<th>Questionnaire</th>
<th>Appearance</th>
<th>Flavour</th>
<th>Consistency</th>
<th>Taste</th>
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On analysing the mean values of tasters on the organoleptic characteristics of bars with added corn flakes, we noticed that the appearance of bars with corn flakes is relatively equal to the bars with added what flakes.

According to the results given by tasters, the flavour of the bars studied differed, with variants 3, 4 and 5, with a higher percentage of flakes being the most appreciated.

The consistency of bars in variants 1 and 2 was harder because of lower flake content, respectively semi-hard and crisp in variants 4 and 5, with a higher flake percentage.

The taste of bars is significantly superior in variants 4 and 5, with a high content of corn flakes.

**CAPITOLUL V.**

**ECONOMIC EFFICIENCY IN MANUFACTURING VARIANTS OF BARS WITH ADDED WHEAT AND CORN FLAKES**

For the variants of bars considered in the study, the specific consumption per 100 kg of finished product in five different manufacturing variants was drawn up, to which were added the purchase prices for raw materials, packaging and labour force.

A cost price was established for each variant, which was compared with the sales price, thus establishing the profit. Further, based on the profit, the profit rate was calculated for each bar variant.

Variants considered in our study are bars with added wheat and corn flakes weighing 50 grams / piece.

**5.1. ECONOMIC EFFICIENCY OF MANUFACTURING VARIANTS OF BARS WITH ADDED WHEAT FLAKES**

The changes in the cost, profit and profit rate for the variants of bars with added wheat flakes are shown in Figures 5.1, 5.2, and 5.3.
Figure 5.1. Evolution of cost (euro) of variants of bars with added wheat flakes.

Figure 5.2. Evolution of profit (euro) of variants of bars with added wheat flakes.

Figure 5.3. Evolution of profit rate (euro) of variants of bars with added wheat flakes.
The analysis of researched variants makes clear that 4 and 5 manufacturing variants of bars with added wheat flakes (8 and 9%) that generate lower costs also have highest profit and profit rate. Variants 1 and 2 generate the highest costs and lowest profit and profit rate, and the cost of ingredients is the highest per same amount of finished product.

5.2. ECONOMIC EFFICIENCY OF MANUFACTURING VARIANTS OF BARS WITH ADDED CORN FLAKES

The evolution of cost, profit and profit rate at bar variants with added corn flakes is presented in Figures 5.4., 5.5 and 5.6.

**Fig.5.4. Changes in the cost (euro) of variants of bars with added corn flakes**

**Fig.5.5. Evolution in the profit (euro) of variants of bars with added corn flakes**
Fig. 5.6. Evolution in the profit rate of variants of bars with added corn flakes

On analysing the variants, we can notice that variants with 8% and 9% added flakes, respectively V 4 and V 5, generate lower costs and the highest profit and profit rate.

CAPITOLUL VI.

GENERAL CONCLUSIONS AND RECOMMENDATIONS

The research results on the manufacturing technology of cereal flakes out of cereal grains and of cereal bars with added cereal flakes, which were the object of this doctoral thesis, entitle us to formulate the following general conclusions:

6.1. CONCLUSION ON THE MANUFACTURING OF WHEAT AND CORN FLAKES

6.1.1. The grains of the three wheat varieties (Turda 95, Turda 2000, Arieșan) and of the three maize hybrids (Turda Favorit, Turda 200, Turda Super) considered in our research are suitable for obtaining cereal flakes for consumption or as raw materials in confectionery industry.

6.1.2. Due to the anatomy and chemical composition of grains, the cereal flakes obtained have particular features regarding the expansion index, bulk density, starch and protein content.
6.1.3. The particular anatomy and chemical structure of grains belonging to the three species determined the extrusion process and the technology during the interaction with humidity and the feed flow of the mixture.

6.1.4. Following extrusion, Turda 95 and Turda Favorit hybrid registered the highest expansion index, with values ranging between 2.74 cm and 3.91 cm.

6.1.5. The most favourable extrusion in terms of expansion index and bulk density of flakes was definitely that obtained at 6 months after wheat and corn storage.

6.1.6. As regards the genotype (wheat or corn), the moisture of grains fed into process had a significant influence, with values being different and the most favourable mixture humidity being 21%.

6.1.7. The variable feed flow had a relatively weak influence; the variations among the three graduations are not significant but in terms of quality, minimum and average flow rates are preferable.

6.1.8. Grain extrusion determined an insignificant reduction of protein content, which results from our measurings, enabling a better digestibility by starch and protein degradation into lower molecular weight compounds.

6.2. CONCLUSIONS REGARDING THE MANUFACTURE OF BARS WITH ADDED WHEAT AND CORN FLAKES

6.2.1. The wheat flakes obtained from Turda 95 variety and corn flakes obtained from Turda Favorit hybrid considered in our research are suitable for manufacturing bars in various proportions.

6.2.2. In the recipes used to manufacture bars with added wheat and corn flakes, the flake content was the determining factor in relation to the organoleptic characteristics of the finished product, so that the variants with highest amount were the most appreciated.

6.2.3. Bars made with added corn flakes were much more appreciated in terms of taste as compared to those obtained with added wheat flakes.

6.2.4. In terms of economic efficiency, we concluded that manufacturing variants with 8% and 9% added wheat and corn flakes generate lower costs and maximum profit and profit rate.
6.3. RECOMMENDATIONS

Based on the results recorded in our research on the extrusion of wheat grains (three genotypes) and corn grains (three hybrids), we consider appropriate the following recommendations:

6.3.1. Introducing extrusion in the manufacturing of wheat and corn extrudates using technological parameters that allowed the best results in terms of qualitative characteristics:

- Using the Turda 95 wheat variety at 21% humidity mixture and feed flow of 5.4 kg/hour;
- Using the Turda Favorit corn hybrid at 21% humidity mixture and feed flow of 5.4 kg/hour.

6.3.2. Introducing in the manufacturing process of bars with added wheat and corn using technological options that have obtained the best organoleptic qualities, respectively those with added 8% flakes of Turda 95 variety, and those with added 8% corn flakes of Turda Favorit hybrid.
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