CONTRIBUTIONS TO THE IMPROVEMENT OF GINGERBREAD MAKING TECHNOLOGY TO THE PURPOSE OF ENHANCING PRODUCT QUALITY

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Contributions to the improvement of gingerbread making technology to the purpose of enhancing product quality

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THESIS STRUCTURE

The PhD thesis was achieved using the technology and the plant laboratory within the Companies Extra Sib S.A. and Moara Cibin S.A., integral parts of the Boromir Group, and the experiments were complemented using the equipment from Lucian Blaga University from Sibiu, the Faculty of Agricultural Sciences and Environment protection.

The work is made up of 9 chapters, conclusions, biography, and annexes. It contains 218 pages, the documentary part representing 65 pages, presentation of the work methods and of the materials employed was achieved over 11 pages, and the experimental part is presented over 128 pages. The PhD Thesis comprises 91 illustrations and 17 tables, and the annexes are rendered in 6 pages. In the elaboration of the thesis, 121 bibliographical references were used. The dissemination of results is represented by the list of works published, within the area tackled as part of doctoral studies related to the PhD thesis theme.

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Before moving on to the presentation of the work, I would like to address acknowledgements and gratitude to the persons supporting me in the elaboration and completion of the doctoral thesis.

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I would like to take this chance to thank Professor Ioan Danciu, EngD, the scientific adviser for the PhD thesis, for his guidance and expertise in coordinating the entire activity carried out throughout the elaboration of the thesis.

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I would also like to thank the members of the committee for the evaluation and presentation of the PhD thesis, for doing me the honour of analysing my work.

I would also like to express my special gratitude to my parents and my child, to whom I dedicate the present work, for their support and consideration during the elaboration and completion of the PhD thesis.

PREAMBLE

The product "Gingerbread" is defined, according to DEX (The Explanatory Dictionary of the Romanian Language) as a "(crisp) pastry product, made of wheat flour, almonds, nuts etc. and a sugar syrup glaze".

The first evidence concerning the existence of this desert occur at the end of the first millennium, in the 10th century.

Gingerbread production is extremely diverse, and there is a wide range of gingerbread assortments. Variety results both from the technology used in the production of this product, and from the variety and availability of raw materials. The products have different shapes and sizes. One of the common points consists of the spices - this product's strong and specific flavour makes it a product widely appreciated and accepted by consumers. The strong and distinctive flavour is also relevant to the name of this product in other languages - the English "gingerbread" indicating bread and ginger, or the French pain d’épices meaning spice bread, whereas the name lebkuchen defines the German product made with honey and spices, specific to winter holidays. Another common point of all these products is the dark brown colour, due to the ingredients employed.

The equipment existing within the production unit and the need to obtain products with no additional investments sometimes entails the manufacturing of products on technological lines designed for other products. Thus, on the technological line dedicated to the production of spritz cookies, the manufacturing of gingerbread was also desired. There is a great difference between these types of products. Spritz cookies are a type of sugary cookie, with a high content of sugar and fats, the dough is very plastic and modelled by squirting and storing or by squirting and string cutting.
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Traditionally, gingerbread is obtained from a consistent, cohesive dough, modelled by rolling and then cut out. The extrusion of this dough requires modification of the manufacturing technology.

If the main ingredient in bread and pastry manufacture is flour, in the manufacturing of gingerbread the other ingredients combined represent more than the used flour, which compels a very rigorous analysis of the role of all ingredients and in particular of their interaction, to the purpose of obtaining a dough that is easily workable on the production line, but in particular to the purpose of obtaining a competitive product from the point of view of quality and of the quality-price ratio.

**Key words:** gingerbread, rye flour, water activity, sorption curve, moisture, kneading, maturation, toughness, elasticity, maximum force, texturometric characteristics.

**OBJECTIVES OF THE THESIS**

The main objective of the experimental research within this PhD work represents:

**The improvement of the manufacture technology for the product "gingerbread" to the purpose of enhancing product quality**

In order to attain the main objective of this research the sequential coverage and fulfilment of several complementary objectives was necessary:

1. **The analysis of the present stage of research and achievements in the area of technologies and equipment for the manufacturing of gingerbread;**
2. **Determining and elaborating the methodology for the performance of test baking for gingerbread;**
3. **Determining the influence of different factors on the rheological characteristics of dough:**
   3.1. The influence of rye flour addition;
   3.2. The influence of kneading, maturation times;
4. **Determining and assessing the work parameters in texture analysis**
   4.1. Setting the work protocol for the analysis of glazed and unglazed gingerbread;
   4.2. Establishing correlations between the different texture parameters
   4.3. Establishing the optimal moments for the achievement of texture analysis;
   4.4. Identification of the optimal number of texturometric parameters;
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4.5. Determining the intensity of compression;
4.6. Analysis of correlations between textural tests and sensory analysis;

5. **The influence of different factors on the physical-chemical properties of gingerbread**
   5.1. The influence of rye flour on the shape effect, on the H/D report, on the specific volume;
   5.2. The influence of different raw materials on the sorption-desorption properties of the product;

6. **The influence of different factors on texture characteristics**
   6.1. The influence of rye flour
   6.2. The influence of different sweeteners;
   6.3. The influence of maturation time;
   6.4. The influence of the aeration formula.

The abstract skims the PhD thesis in accordance with its structure:

**I. DOCUMENTARY STUDY**

Within the **documentary study**, the ingredients used within the manufacturing process for the product "Gingerbread" are detailed, following in particular their technologically significant components and the characteristics defining the finite product (physical-chemical, textural, sensory) to the purpose of attaining the proposed objectives:

1. **Raw materials**
   1.1 Flour
   1.2 Sweeteners
   1.3 Aerating agents
   1.4 Further ingredients

   Among flours, wheat flour was studied, with its characteristics such as extraction, origin (wheat type), protein content, starch, and rye flour.
   Among sweeteners, sugar, glucose, isoglucose, honey, inverted sugar, and polyols were comparatively studied.
Within the chapter "Other ingredients", shortening, enzymes, hemicelluloses, proteases, reducers, lecithin, colouring agents are presented.

2 Moisture content and water activity

For food products, the moisture content is a significant parameter and it is used in order to make different appreciations concerning their quality. The moisture content of the products has economic, as well as qualitative implications, but particularly concerning preservability of the products. Although the moisture content of certain products dictates their preservability, a relation cannot be established between them, except within certain product categories, having similar chemical compositions. The spoilage process depends on the air's relative moisture, but this term specific for air is not appropriate for food products. A new term was coined, water activity (a_w), which is equal to the relative humidity of air in equilibrium with a sample, for certain temperature conditions. If the relative humidity of air is expressed as a percentage, its value is divided by 100.

This term is not fully understood, but it can be successfully used in the characterization of food products. The term "water activity" is particularly used in relation with two aspects of a product's shelf life: microbiological spoilage and drying-dampening.

It may be said that the smaller the water activity in a product, the greater its tendency to absorb more humidity from the environment. According to this deduction, it may be said that products having low water activity are more hygroscopic. The greater the product moisture, the closer water activity gets to 1 and it shall have the ability to release moisture more easily. For an accurate description of the humidification and drying process, sorption and desorption curves are drawn.

3 Texture characteristics

The development of sensory analysis reached a standstill when the relativity and subjectivity of human sensory perception became an impediment in the way of scientific research objectivity. The identification of sensory analysis methods was in order, which also imposed the development of instruments measuring the food products' sensory (texture) characteristics in a systematic, objective, and repetitive manner. Among the first texture
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tests reproduced by a measuring device was the so-called "thumb test", in which an observer uses his/her thumb to test a product by pressing. These instruments were generically named texturometers and they are used for the mechanic characterization of products.

During the research undertaken, I have often noticed, within the sensory evaluation of gingerbread, a disparity of sensory assessments between different subjects. Following discussions with them, I reached the conclusion that they had created an idealized image of the product, which they used for comparison, so that products which had quite differing characteristics received very close assessments, due to the fact that they were perceived to be far from the ideal pictured and used as evaluation reference.

4 The analysis of the present stage of research and achievements in the area of technologies and equipment for the manufacturing of gingerbread elaborates on the following:

4.1 Classical manufacturing technology

Initially the inverted sugar syrup and the caramel are prepared. The dough is obtained by kneading in a single stage. The classical technology for the achievement of this type of products presumes the rolling of dough, the achievement of a dough sheet which is to be cut out. The dough has to have sufficient consistency so as not to flow and become deformed under its own weight and it should be cohesive, its gluten structure should develop to a certain extent, so as to provide cohesion and continuity of the dough during the rolling operation, to be rolled out in the form of a sheet. To knead this type of dough, Z-arm kneading machines are used, and kneading time may reach 20-30 minutes. This time is long enough to provide for homogenization, as well as for the development of the dough's gluten structure. Dough maturation may last from a few hours to several days. The classic technology for this type of products assumes rolling out, obtaining a dough sheet that is to be cut out. Baking is achieved optimally in tunnel-ovens, and finishing occurs by glazing with a supersaturated sugar solution, followed by drying.
4.2 Adjusted manufacturing technology

On the technological line dedicated to the production of spritz cookies, the manufacturing of gingerbread is desired. There is a great difference between these types of products. Spritz cookies are a type of sugary cookie, with a high content of sugar and fats, the dough is very plastic and obtained by squirting and storing or by squirting and string cutting. In order to provide the optimal rheological characteristics for the dough, which has to be more fluid, without however increasing the water quantity, the kneading time may be reduced. In this manner, gluten protein shall not have sufficient time to become hydrated, and reduced hydration shall not allow for the optimal interaction for the development of a strong gluten structure. In order to obtain a homogeneous dough, but also with reduced consistency, it is necessary that the dough-kneading method be bi-phase. Homogenization is short-term and it is discontinued before the complete development of gluten.

Immediately following industrial kneading, the dough has a reduced consistency and it is sticky. The hydration process continues over the dough-maturation period (2.5 h), the dough consistency increases a little, and stickiness is reduced.

Dough extrusion is a technique used particularly for the formation of sugary biscuits, whose dough has a higher fat content. This dough is very plastic and sticky, and for this reason, it cannot be modelled by rolling out or with rotary moulds. As operating principle, the dough is pushed through different channels, of different sizes and shapes.

Upon coming out of these channels, the dough has taken their shape and the formed tube of dough is cut into slices of the desired thickness with the aid of a very well-stretched steel wire. For this reason, the technology bears the name "wire-cut". Baking is achieved in a tunnel-oven. The existing technological line is equipped with a glazing area, which consists of passing the products through a glazing curtain - sugar microcrystal suspension in a water syrup - sugar - gelatine, with added titanium dioxide as bleacher, and then through a glazing bath for the formation of the bottom. Drying is achieved on wire racks, in dryers, then the cooling in cold-air tunnel.
5 Materials and methods

5.1 Materials

The reactive chemicals used in laboratory assessments were of analytic or equivalent purity. The experiments were conducted over a longer period of time, which led to the fact that the materials used differ from one experiment to another. Given that this information is relevant, the characteristics of raw material as well as the manufacturing recipes are presented under every section, study, for better and easier interpretation of the result and of the experiment.

5.2 Methods

5.2.1 Elaboration of methodology for the performance of test baking

In specialized literature (Bordei 2007) (AACC 1995) several methods are described for the performance of test baking. Most of them refer to the manufacture of bakery products of the bread type, and only a few of them refer to the manufacturing of flour products. This is the main reason why the elaboration of a method for the achievement of test baking was in order. The starting point was the manufacturing recipe and the technology of modelling by extrusion. Table I.1 presents a recipe for the manufacturing of gingerbread, constituting the basis of work and reference in research for the improvement of gingerbread quality.

Table I.1. Standard manufacturing recipe

<table>
<thead>
<tr>
<th>No.</th>
<th>Raw matter</th>
<th>Quantity, kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Wheat flour</td>
<td>4.84</td>
</tr>
<tr>
<td>2</td>
<td>Rye flour</td>
<td>0.24</td>
</tr>
<tr>
<td>3</td>
<td>Starch</td>
<td>0.29</td>
</tr>
<tr>
<td>4</td>
<td>Sodium bicarbonate</td>
<td>0.071</td>
</tr>
<tr>
<td>5</td>
<td>Ammonium bicarbonate</td>
<td>0.035</td>
</tr>
<tr>
<td>6</td>
<td>SAPP 28</td>
<td>0.035</td>
</tr>
<tr>
<td>7</td>
<td>Clove</td>
<td>0.019</td>
</tr>
<tr>
<td>8</td>
<td>Cinnamon</td>
<td>0.077</td>
</tr>
<tr>
<td>9</td>
<td>Salt</td>
<td>0.017</td>
</tr>
<tr>
<td>10</td>
<td>Lecithin</td>
<td>0.036</td>
</tr>
<tr>
<td>11</td>
<td>Plant oil</td>
<td>0.36</td>
</tr>
</tbody>
</table>
Laboratory devices: laboratory mixer; technical scales; precision scales; worktable; modelling device (laboratory press with an evacuation diameter of 2 cm); temperature-controlled oven.

Work mode:

I. Preparation of dough: All the ingredients, except for flour, acidifier, and starch, weighed, were introduced into the kneading bowl and were kneaded for 2 minutes on speed level 1; the flours were added, and kneading continued for 1 min. on speed level 1. The bowl sides were cleaned; kneading continued for 1 minute at speed level 2.

II. Dough resting time - 2 h and 30 min. at room temperature;

III. Dough processing: a piece of dough was inserted in the laboratory press cylinder and then it was pressed. Pressing was achieved slowly, and when the extruded piece of dough reached a thickness of 2 cm, it was cut very quickly with the heated metal wire. The pieces of dough were set on baking trays covered with baking paper, leaving spaces between them;

IV. Baking - at 160°C for 14 min., without steaming, in previously heated oven. An empty tray was placed above the first product tray and below the last product tray.

V. Cooling - on racks.

Monitored technological parameters

- **the sensory characteristics of dough** (consistency, colour, stickiness, homogeneity) by feeling and visual examination;

- **Dough density**
  
  Assessed at the end of kneading and during the rest period, in particular concerning the assessment of aeration agents: approximately 150 ml of oil are introduced in a graded 250 ml cylinder, the initial volume is marked down, \( V_i \); from the kneaded dough, pieces

<table>
<thead>
<tr>
<th></th>
<th>Ingredient</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>Sorbitol</td>
<td>0.29</td>
</tr>
<tr>
<td>13</td>
<td>Glycerine</td>
<td>0.048</td>
</tr>
<tr>
<td>14</td>
<td>Honey</td>
<td>0.19</td>
</tr>
<tr>
<td>15</td>
<td>Inverted sugar syrup</td>
<td>2.86</td>
</tr>
<tr>
<td>16</td>
<td>Caramel</td>
<td>0.58</td>
</tr>
</tbody>
</table>

**TOTAL** 10
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of dough are cut out (not broken) and inserted in the graded cylinder previously tared, until the weight of approximately 75 grams is reached, and the level of oil in the cylinder is marked down $V_o$;

the level of the oil in the container is marked down every 10 minutes; dough density is calculated by the formula:

$$\rho = \frac{m_i}{V_a - V_i} \left[ \frac{g}{ml} \right]$$

- **average weight of modelled pieces** - 10 pieces of dough are weighed immediately following modelling;
- **average diameter of modelled pieces** - places in a row, next to each other, at least 10 pieces of modelled dough, and the row length shall be measured. By dividing to the number of pieces, the average diameter of a piece is obtained;
- **the average mass** of modelled pieces - at least 10 pieces of modelled dough are weighed and the arithmetic mean is calculated;
- **average diameter, average height and average mass of baked cakes** - similar steps shall be taken as in the determination of the average diameter and height of dough pieces, measuring and weighing the baked gingerbread pieces, 30 minutes after baking, following their cooling;
- **Sensory analysis** - the obtained gingerbread shall be assessed from a sensory point of view, according to the method;
- **Final gingerbread moisture** - by drying on the thermobalance, or in the stove, immediately after cooling;
- **Specific product volume**

Approximately 10 whole product pieces shall be weighed, not chosen, no selection is achieved; a bowl used for the measurement of the specific volume is filled with rape seed, it is levelled and excess is removed with the aid of a ruler (NOT TO BE SHAKEN - SEED BOWLS VIBRATE); the seeds are emptied from the used bowl, with no losses, and without mixing these with the remainder of the seeds; the gingerbread pieces are inserted, and over them the measured rape seeds are poured, the excess seed is removed with the ruler and then it is measured. The specific volume is calculated using the formula:
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\[ V_s = \frac{V}{m} \cdot 100 \]

where \( V \) - volume of rape seed

\( m \) - mass of measured gingerbread

- **Assessment of water activity**

The water activity of the assessed products was established with the help of the instrument LabMaster-aw (Novasina AG 2007), according to the instructions of the producer. The work conditions, confirmed in the study of several curves determining water activity, were: work temperature - 25°C; temperature stabilization period - 4 min.; water stabilization period - 10 min.

- **Drawing of sorption curves**

The sorption curves for different assortments were determined by the gravimetric method (Bajpai 2013). The triturated samples were dried for 24 hours at 65°C. The dried samples were placed in an environment where relative moisture was gradually increased, with the aid of a sulphuric acid with concentrations of 80% to 5%. The samples were maintained at a constant mass, at 30°C. The moisture content as determined by difference, and water activity measured at the temperature of 30°C and equilibrium time, until fulfilment of a water activity settlement period of 10 min.

- **Assessment of water content**

The samples' water content was assessed by means of the indirect method, drying in the stove, at 130°C for 60 min. (Bordei 2007)

- **Assessment of rheological behaviour of gingerbread dough**

For the study of dough behaviour upon kneading, the AACC 54-21 Farinograph Method for Flour (AACC 1995) was used, the method of the dough's constant mass. This option was selected because the gingerbread dough is very complex, it contains a great number of ingredients which are added to a greater extent than in the bread manufacture dough. Consequently, in order to minimize the influence of the kneaded dough mass on dough consistency, this method was preferred, where the dough mass is always of 480 grams. The flour mixture is always of 258.07 g, with the moisture of 14%. If the used flour
had a different moisture content, a correction was performed, so that the dry substance quantity was always the same. The flour and acidifier were introduced in the kneading machine's container following its calibration, and left to anneal for 1 minute, and the remainder of ingredients were added under the form of a premixture obtained by mixing the ingredients. The work was achieved at 30°C, which is the regular work temperature for this assessment.

The results were processed with the software specific for the instrument.

5.2.3 Texture analysis of gingerbread

Instruments: For texture tests, the TexVol TVT-300XP/XPH texture meter manufactured by the company Perten Instruments, Sweden, was used, equipped with a 15 kg load cell.

The used testing devices were: testing device by penetration of the rod type, with a straight end and a diameter of 5 mm, used to test the hardness of gingerbread glazing; testing device by penetration, with spherical tip, sphere diameter of 1 inch. The device was used to imitate the mode in which gingerbread is tested by thumb pressing, the sphere imitating the human thumb in shape and size; testing device by means of cutting (blade), the device imitates a bite, the clipping of the product between the teeth.

Texture characterization:

For testing by penetration with the cylinder device and for testing by shearing, the method of a single cycle was used, because under the action of the two devices, the tested sample was destroyed to a high extent, and subjecting it to a new testing was not relevant. The circulation speed of the device was of 10 mm/s, and penetration depth of 10 mm.

For testing with the spherical device, due to limited destruction of the sample, a second successive test was also performed to assess the disruption degree and the hardness of the product. The relatively large size of the sphere and the product's limited compression caused the limited mechanical damaging of the product. For this reason, a test containing two compression cycles was selected. The device's circulation speed was of 10 mm/s, the
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recession speed 10 mm/s, the compression distance 30% of the height, the period of recovery between the two successive tests 10 seconds. This test was defined by several researchers using compression tests and they bear the generic name of Texture Profile Analysis (A.J. 1999) (Bourne 2002).

Illustration 1 presents the curve registered during such a test with two compression cycles.

Illustration 1 Texture Profile Analysis

Following the processing of data obtained, several texture characteristics for the product may be defined:

- hardness - force necessary to the compression of the product to the set dimensions;
- hardness 2 - force necessary to compress the product to the dimensions set in the second cycle;
- resilience, recovery - product capacity to regain initial dimensions following contortion (area 5 / area 4);
- cohesion - strength of inner forces leading to product recovery (the surface below the curve of the second compression / surface below the curve of the first compression);
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- elasticity, flexibility - relation between the circulation distance of the testing device in the two cycles. The closer the report is to the value 1, the more elastic the body, it suffers an elastic contortion, less plastic;
- gumminess - the energy necessary to the disintegration of a product, so that it can be swallowed (cohesion * hardness);
- masticability - the energy necessary to chew a product until swallowed (gumminess*elasticity= cohesion*hardness*elasticity);
- adhesiveness - area 3
- energy necessary to the distortion of samples (Area 4).

These characteristics can describe the sensory characteristics of the product quite well, and they can be used to complete a full picture of the product.

The latter test could not always be used, given that during storage, certain products became very hard, and the load cell that the device was equipped with could no longer be used. In order to test the product, the cutting knife was used, because the forces necessary to cutting are smaller, taking into account the fact that the surface for the distribution of forces (contact surface with the product) is much smaller.
II. RESULTS AND DISCUSSIONS

6. Assessing the influence of different factors on the rheological properties of the dough (rye flour proportion, kneading and maturation time)

The wheat flour dough is drier, more elastic, less sticky and therefore more easily processable by mechanical means, whereas the dough made from rye flour are stickier, but the products tend to have a more fragile and tender structure due to smaller gluten protein quantities, and in particular due to the limited development of gluten during kneading because of the presence of pentosans in large quantities. Dough was prepared with a proportion of 100, 80, 70, 60 and 50% wheat flour, the rest being rye flour, using the previously presented recipe and a kneading time of 60 minutes, The experiments were carried out on a Farinograph with electronic registration, Farinograf-E, from the company Brabender. By studying the kneading curves, it can be noted that the formation of gingerbread dough is not very difficult, the maximum dough consistency is only reached at very high kneading times, higher than 40 minutes. The reduced water quantity causes the dough to have greater consistency, and the sugar addition reduces hydration speed and, consequently, the complete formation of dough, the achievement of maximum consistency is greatly delayed. It can be noticed that the minimum value of the maximum dough consistency is reached in dough with a 30% proportion rye flour. A very close value is also the dough with an addition of 40% rye flour. The smallest development time was registered for these dough, 54, respectively 44 minutes. Dough with wheat flour to the greatest proportion also had the greatest consistency and the longest development time, practically it could not be registered during performance of rheological measurements, of 60 minutes. Dough with a high contents of wheat flour is formed with more difficulty, a 13 minute time is needed to reach the consistency of 500 UB. As the rye flour percentage grows, the time needed to reach the 500 UB consistency decreases, from 7 minutes for the dough with 30% rye flour to 5 and even to 3.5 minutes for dough with an addition of 40, respectively 50% rye flour. With the increase of the rye flour percentage, the formation of the dough is faster. This dough shall also require shorter kneading times, to reach the consistency of 1000 UB.

The formation of dough with a higher rye flour proportion is slower, while dough with a greater wheat flour addition are formed more rapidly, dough consistency increases
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rapidly and afterwards it has the tendency to become stabilized, undergoing smaller modification.

The analysis of kneading curves indicates that these curves tend to widen as kneading occurs, and the variations of the minimum and maximum measured consistency, measured at the moment, are increasingly large. These indicate an increase in dough stickiness. The dough having a greater wheat flour proportion present a more emphasized widening towards the end, whereas dough with added rye flour have a wider curve in the first part of the kneading than in the cases of wheat flour, and the curve width increases slightly emphasized with kneading. For a proportion of 50% rye flour, its rheological behaviour became predominant. Hydration was achieved rapidly, and dough consistency was increased due to the greater hydration capacity in the case of rye flour as compared to wheat flours.

To the purpose of analysing the rheological modifications of dough, suffered during kneading, 480 grams of dough obtained with flour 650 prepared on the industrial line, was inserted in the farinograph container. The variation of dough consistency was monitored over 20 kneading minutes. The following were analysed: the initial consistency of the dough, minimum and maximum consistency, as well as the time necessary to reach the minimum consistency after 0, 60 and 150 minutes of maturation. A significant consistency diminution is noticed, followed by its appreciation. The appreciation continues over the entire period of dough kneading. In doughs undergoing a maturation process, a sudden increase in consistency is noticed at the beginning of kneading, followed by its diminution. The doughs—during maturing/rest suffered a relaxation, which causes sudden increase in dough consistency immediately after kneading, and then it drops. After reaching a minimum level of consistency, an increase in dough consistency was noticed during the kneading process. Increase of consistency proves that the industrially manufactured dough was not kneaded sufficiently to completely develop the gluten network and to appropriately absorb water. For the three types of dough, the minimum consistency had much closer values, 309, 347, and respectively 367 UB. In order to reach the minimum consistency, 4 minutes were necessary in the case of dough without maturing, and dough with 60 and 150-minute maturing needed 7, respectively 8 minutes to reach the minimum.
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During maturation, under the action of the gases formed in the dough, following neutralization of aerating agents, the development of the gluten network is completed.

Given that the solutions making up the dough are very concentrated due to high sugar concentrations, they have higher viscosity. The viscosity of these solutions also contributes to the general dough consistency. These solutions may very well be thixotropic, and consequently their viscosity may drop, as a consequence of the churn occurring during kneading. The longer the kneading time, the higher the viscosity. These two processes (relaxation of gluten proteins and thixotropy of sweetener solutions), due to their superposing, may explain the initial behaviour of the dough. If these hypotheses are taken into account, the time needed to reach the minimum consistency and the dough’s minimum consistency are rheological parameters describing the rheological transformations suffered by dough during maturation in a much better way.

7. Determining and assessing the work parameters in texture analysis

7.1 Setting the work protocol for texture analysis of glazed and unglazed gingerbread;

Within the production activity, often the recipes are tested immediately following manufacturing or within several days, and the issue is raised whether these projects reached "maturity", at the stage where texture characteristics vary greatly or not at all, due to internal structural transformations. Immediately following baking, modifications of gelified starch occur, as well as of protein gel, and crystallizing of sugar solutions. These processes are accelerated by temperature diminution. The purpose of this experiment is to monitor the texture modifications of gingerbread immediately following baking and at the beginning of storage, in order to establish the time interval when sensitive modifications of product characteristics occur. Also, the verification of the hypothesis according to which these transformations can be accelerated by decreasing temperature was also pursued.

The cookies, glazed and unglazed, were divided into two lots. One lot was kept in the laboratory at an average temperature of 24°C, and the other lot was refrigerated and kept at 6°C. In order to reduce moisture exchange with the environment, they were kept in high-density, double polyethylene packages.

The refrigerated samples were taken out of the refrigerator 30 minutes before being tested. The cold cakes were tested after only 3 hours from manufacture and immediate
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refrigeration. Testing was performed at 3, 6, 24, 48, 96 and 120 hours from manufacturing. The cakes kept in the laboratory were also tested at 0,1, and 2 h from manufacturing. The texturometric testing was achieved with the 1 inch-diameter ball device. The protocol with two testing cycles was used (compression). Compression was achieved down to 30% of the initial height, a 1-minute break was inserted between compression cycles, for recovery of the tested samples. At least 6 samples were analysed from the point of view of texture. For the selected work protocol, toughness is equal to maximum force (Force A).

7.2 Texture characteristics of gingerbread, connections and correlations
Areas 1 and 4 are differentiated on the one hand by the variation curve of the distortion force and the graphic axis on the other hand (the graphic axis is represented by the achieved distortion). Thus, a good correlation of these texture parameters is noticed. Correlation is better with area 4, given that area 1 contains area 4, as well as area 3. These correlations prove that the samples present better homogeneity and there are no great differences in the mode of variation of force as distortion occurs. Recovery of unglazed cakes does not register values as high, in comparison with the toughness of the samples, and it remains contained between 0.19 and 0.16. The smaller values of this parameter indicates the fact that gingerbread presents smaller elasticity, and the low variability during the experiment indicates that it is not a relevant parameter to the characterization of gingerbread. A contrary situation was noted in the case of glazed gingerbread. The linear regression coefficients registered markedly smaller values, 0.4511 and 0.6519 for areas 1 and 4. This proves a greater variability of glazed samples and modifications in the texture behaviour, as well as the fact that the testing protocol with two or more compression cycles is not the most appropriate for the testing of glazed gingerbread.

7.3. Establishing the optimal moments for the achievement of texture analysis;

Modification of time duration

Toughness seems to be the most representative texture characteristic for gingerbread. The premise for this study is the fact that in time, the texture of products undergoes a modification, independently from the modification of water activity. This modification occurs particularly in the first part of storage, immediately following baking, and then
stabilization is registered. Unglazed gingerbread suffers an emphasized hardness increase, and 48 hours later stabilization of hardness occurs. Unglazed gingerbread kept in cool conditions confirmed the supposition that was the basis for this study. Major modifications occurred within the first 24 hours. In the case of glazed gingerbread, an accentuated growth is noticed in the first hour, followed by a diminution of hardness, and 48 hours later, certain stabilization is achieved. The glazed gingerbread kept in cool conditions had greater hardness than the glazed gingerbread, kept in warm conditions. 48 hours later, a similitude occurs in the behaviour of products. Glazed gingerbread has lower toughness than unglazed gingerbread. 48 hours later, the toughness of glazed gingerbread is approximately twice as small as in the case of unglazed gingerbread.

The conclusion of the experiment is that for the texture study of products obtained in the baking tests, it is necessary that at least 48 hours pass for texture testing. Glazed gingerbread confirms the model of the curve specific to a logarithm function, with a regression coefficient $R^2$ of 0.9285 and 0.8501 for unglazed gingerbread, kept in cool, respectively warm environment. In the case of the cool environment, the model is not as predictable, as is in the case of warm environments. In the case of glazed gingerbread also, the regression coefficient had smaller values with samples kept in cool places. Even more so, glazing led to the drastic modification of the model varying the time duration, the logarithm curve is no longer appropriate, as the regression factors have much smaller values, 0.5610 and respectively 0.0533. It is proven that maintaining the product at lower temperatures accelerates the processes within the product, but promotes others, leading to differences in its behaviour.

**Modification of distortion energy during storage** following the logarithmic model of hardness, taking into account the good correlation between the 2 sizes, in particular for the gingerbread kept at room temperature. The samples kept in a cool place do not verify the model. Unglazed samples, kept at cold and at room temperature present curves which only become intersected after 24 hours, then the variations are reduced.

**Modification of elasticity in time**

Elasticity can be expressed by means of two factors, Resilience and Springiness. The first one, as ratio of areas 5 and 4 measure intrinsic elasticity, the energy incorporated in the
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material upon compression, whereas springiness measures the distortion effect, the extent to which the body recovers following distortion. These sizes are expressed as a ratio of energies, respectively of distortions, and they should be equal to less than 1. For unglazed gingerbread, this condition is observed in time, as elasticity, in both of its forms of quantifications, is less than 1. In the case of glazed gingerbread, assessment errors occur, pertaining to the nature of glazing interaction with the testing device, respectively to the fact that it sticks to the worktop and the testing device. The value of elasticity is more than a unit, which proves that the test was vitiated by an assessment error. A first conclusion is that the glazed product should be prepared, prior to being testes, either by removing the glaze (which aspect may affect the properties of the product) or by using a non-stick layer to cover the contact surfaces between the testing device and the sample to be analysed.

For a perfectly elastic body, these sizes are equal to 1, namely the entire energy taken up to the purpose of distortion is stored in the material as tensions and then released upon loosening the distorting device. In the case of the second size, the body regains its initial sizes to the full, and for the second distortion of the cycle, the device must follow the same course as in the case of the first device.

For unglazed gingerbread, this condition is observed in time, as elasticity, in both of its forms of quantifications, is less than 1. In the case of glazed gingerbread, assessment errors occur, pertaining to the nature of glaze interaction with the testing device, respectively to the fact that it sticks to the worktop and the testing device. The value of elasticity is more than 1, which proves that the test was vitiated by an assessment error. A first conclusion is that the glazed product should be prepared, prior to being testes, either by removing the glaze (which aspect may affect the properties of the product) or by using a non-stick layer to cover the contact surfaces between the testing device and the sample to be analysed.

This behaviour was particularly noticed in the case of gingerbread kept in a warm environment. We preferred the logarithm scale for the representation of time and in order to better emphasize the values within the first storage hours. Unglazed gingerbread does not have great elasticity results, the relation of energies being contained, in most cases, between 0.2 and 0.15. For the elasticity of unglazed gingerbread, the storage temperature
did not hold great importance. The values had approximately the same evolution in time and they present very little variety. Upon cooling, the starch gel is reduced and it becomes more rigid, elasticity drops. In geometric terms, the evolution of elasticity (Springiness) is similar. From a geometrical point of view, the samples present better elasticity, the samples recover better from the point of view of height. The value of elasticity is contained between 0.9 and 0.6. Samples kept in warm environments seems to suffer a loss of elasticity in time, and the samples kept in cool environments maintain their elasticity rather constant, but we must emphasize the fact that the differences are small. The variation of glazed samples' elasticity is smaller than in the previous formula expressing elasticity.

The elasticity of gingerbread suffers minor modifications 12 hours after storage, and therefore, from the point of view of elasticity, we believe that a 24-hour preservation period, prior to testing, is sufficient.

Cohesiveness refers to the properties of bodies to maintain their integrity. In the case of gingerbread, it is a rather important parameter, given that gingerbread that crumbles is not appreciated by the consumers, and their consumption is not pleasant, because the bite generates large quantities of crumbs.

As in the case of elasticity, cohesion is also expresses as a ratio of the surfaces contained between the curves of the distortion force and the axis representing distortion, for two successive distortions. In the case of gingerbread, this distortion is compression.

From the analysis of the presented data, the fact results that cohesiveness of unglazed gingerbread does not seem to be affected by the temperature regime or by the storage time.

**Gumminess and masticability**

Other texture characteristics that can be measured in this test are gumminess and masticability. Gumminess is a factor derived from two other factors, which are already established, it is the composition of hardness and cohesiveness. Unglazed gingerbread seems to have, from the point of view of gumminess and masticability, the same behaviour, irrespective of the temperature regime that they are subject to. It may be noted that the variation model for these values falls quite well in the shape of a logarithm curve, the regression coefficients having superior values, higher than 0.9000. In the case of
masticability, no distinctions can be made between the curves traced for gingerbread kept in warm or in cool environments. After 48 hours, these values seem to become balanced. The variation model for these values is very similar to the hardness curves (for unglazed gingerbread). This fact is perfectly normal, given that these values are obtained by multiplying hardness and cohesiveness in the case of gumminess and hardness with cohesiveness and elasticity (Springiness). Hardness had a logarithm curve of variation in time, whereas elasticity (Springiness) and cohesiveness were relatively constant in time. The general conclusion is that the texture analysis at 48 hours from manufacture is relevant.

7.4 Identification of the optimal number of texturometric parameters;
we performed a number of 16 mechanical tests on 16 pieces of glazed gingerbread with sprinkles. This assortment was selected because glazing, and in particular chocolate surrogate sprinkles present quite large validities from the point of view of thickness, which caused the samples to non-homogeneous from the point of view of structure and texture. The samples were subject to a testing regime consisting of two successive compressions, of 30% from the height of the samples. 3, 4 to 16 tests were randomly selected. The Average was calculated, as well as the standard deviation of samples (STD%). A larger variety of statistical parameters is noticed when the number of tests performed is reduced, which is statistically normal. For a better appreciation of the size of standard deviation, it was expressed as a percentage as compared to the arithmetic mean if the measured value. In the case of these measurements, it may be noticed that the reliability interval (standard deviation) in which 95% of the measured values are found, is quite large for this product. Only for product cohesion, the standard deviation shall have values representing 10% of the measured average. For mechanical work, hardness, and elasticity, the standard deviation also has close values of 25% of the average of measured values. The high value of standard deviation indicates a non-homogeneity of the samples or the presence of measuring errors, whatever they may be. From the analysis of the data, it is noticed that the average of the measured sizes presents quite a small variety, and its stabilization is noticed if 6 or more samples are taken into account. We appreciate that the minimum number of tests to be run is 6, in order to obtain representative results.
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**7.5 Determining the intensity of compression**

Given that the purpose of this experiment is to determine only the compression distance, the testing protocol with a single testing cycle was used. The 1 inch-diameter ball device was used in the experiment. The testing device's speed was of 1 mm/s. Industrially manufactured gingerbread was used, prepared according to the same recipe. Some were simple (coded TD), others were coated in glaze (TDG), whereas the last ones were glazed and decorated with chocolate sprinkles (TDGS). The movement of the device into the product was set at 25, 30, 40, 50, 60, and respectively 70% of the product height. The testing was achieved on 8 samples. In order to identify the compression distance for the sample, several texturometric parameters were evaluated: hardness, elasticity, and mechanical work. The fact is noticed that the texture parameters hardness and surface present a similar variations, and elasticity presents a different variation model. The hardness and surface of the graphic presents a continual increase with compression, the increase as emphasized as the compression is more intense. Conversely, elasticity remains constant, and only on very high distortion values (70%) does elasticity register major appreciation. Both hardness, and curve surface presents small variations, to a 30% distortion, and then they increase. Upon large distortions, the entire sample material is caught under the pressing device and it shall oppose sample advancement. For small distortions there is also a lateral slippage, due to the device’s spherical shape. The elasticity of samples varies very little proportional to the size of the distortion. Elasticity, as a ratio of surfaces delimited by the curves traced upon withdrawal and insertion of the testing device, has small values, of approximately 0.1 to a 60% compression. On higher compression, the material shall be caught between the device and the sample worktop, and upon recovery, it shall push the device with greater energy. In this case, the material shall surely modify its behaviour and measurement errors occur.

Following this analysis, we reached the conclusion that a 30% compression ensures a compression level similar to the one achieved by people, and the material does not suffer internal fractures, and the movement of the device is reproducible.
7.6 Analysis of correlations between textural tests and sensory analysis

For this test, gingerbread prepared according to different manufacturing recipes were used, kept for different time periods, so that a large diversity of textures is ascertained. The samples were analysed from the point of view of texture with a cutting knife. The knife insertion distance was of 10 mm into the sample. The knife was used for testing, because some of the analysed samples presents great resilience, exceeding the limit of measurement for the load cell, if the sphere or another device is used, with larger contact surface. The samples were also analysed from the point of view of texture by a group of persons who were instructed and who are familiarized with the sensory analysis of the products. The samples were only analysed from the point of view of hardness, by feeling the samples and slightly pressing them between the fingers. The 10 point scale was used for quantification. The softest product, which crumbles most easily, is marked with 10 points, while the very hard product, requiring a special effort for fracturing shall be graded with 1.

For the cutting test, the following were taken into account: hardness (force registered after the blade entered 10 mm into the sample body), the maximum force (FORCE A - maximum registered force during testing), as well as Area 4, representing the area contained under the curve) and the composition between hardness and the distance crossed by the cutting device in the sample. Sufficient correlation is noticed between the grades obtained upon sensory evaluation and the measured texture characteristics, only in the case of maximal force, the linear regression coefficient being a little smaller than 0.8, namely 0.7992.

8. The influence of different factors on the physical-chemical properties of gingerbread

8.1 The influence of rye flour addition

The rye flour provides for the manufacture of products having a superior texture, softer, somewhat gully, but the dough is more difficult to process, is stickier, less cohesive. Wheat flour was replaced by rye flour in different percentages and the dough obtained was left to mature for 30 and 150 minutes.
Materials: Rye flour had a mineral content of 0.950 % and a moisture content of 13.9%. The inverted sugar syrup and the caramel syrup were industrially manufactured (64% s.u. and respectively 80% s.u.). Wheat flour type 650 was used.

The sensory characteristics of dough
The dough without rye flour addition, after 30 minutes of rest, has a homogeneous, non-sticky aspect, it was easily processable. These characteristics remained similar also after 150 minutes of rest, the dough was more consisted and drier upon feeling. As the rye flour proportion increased, the dough became stickier, somewhat more cohesive, having a viscous appearance. The dough which had 150 minutes of rest were more consistent. These notes are in agreement with the previous rheological experiments, indicating that, with the increase of rest time, dough consistency is increased due to the sorption of water by the flour components. Reduction of the gluten quantity in the dough by diluting wheat flour with rye flour leads to less cohesive and stickier dough.

The shape effect
The widening of the cookies during baking is expressed as a percentage as the difference between the final and the initial value of the diameter, reported to the initial diameter of products. The gingerbread cookies prepared with different proportions of rye flour had different behaviours during the baking process. Initially all samples had the same dimensions, 3.1 cm in diameter and 2 cm in height. It is noticed that with the increase of rye flour proportion, the widening of products upon baking is ever more reduced. The differences between samples of differing textures are more reduced for the 30-minute maturation time. The gingerbread prepared only with wheat flour had a 25.8% widening, whereas replacement with 50% rye flour led to a widening of only 16.1%. The same samples, after 150 min. of relaxation had a widening of 29, respectively 11.3%. If the results obtained are statistically analysed, a rather good correlation is noticed between the widening of gingerbread and the proportion of used rye flour. In the case of dough with 30-minute maturing time, the linear regression coefficient has a smaller value, 0.8275, whereas for
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cookies prepared from matured dough for 150 minutes, the linear regression coefficient has a greater value, 0.8275. The larger the rye flour proportion, the greater the dough consistency (according to rheological studies previously presented, the dough is not sufficiently kneaded for full development of dough, and dough with more rye flour, at the same kneading time, has a greater consistency, leading to a more reduced widening of dough pieces.

The gingerbread cookies prepared with wheat flour had an initial mass of 18.4 grams, whereas the cookies with 50% rye flour had an initial average mass of 15.55 g. If the fact is taken into account that widening, flow is conditioned by the weight of the piece of dough, it is very possible that this widening also depends on the mass of the pieces. In order to verify this, the percentage widening of dough pieces was related to the average mass of the samples. The rate of the curves does not change, which indicates the fact that weight has an ever more reduced role on widening and it depends much more on the rheological modifications of dough.

H/D Ratio

In order to characterize bread products from a geometrical point of view, one other parameter is used, the ratio between height and diameter. For chemically aerated products, this indicator is significant, because it also describes the mode in which products develop during baking, preponderantly on the vertical, horizontal, or both direction. No notable differences are noticed between maturation samples for 30 minutes or 150 minutes. With the growth of the rye flour proportion, the ration between sample height and diameter also increases. The obtained values indicate the fact that, during baking, the dough with a greater wheat flour proportion are more fluid, they tend to become more widened. Although a constant increase of the H/D ratio is noticed with the increase of rye flour proportion in gingerbread dough, correlation is very weak, the linear regression coefficients have values smaller than 0.4000. The slope of linear tendency curves is very small, 0.026 and respectively 0.018. This indicates low variableness, practically a preservation of proportions, of product shape is noticed, although an obvious widening was noticed, of 11 and 29%. The almost unchanged preservation of the ratio between height and diameter indicates the fact that samples with greater widening also suffered an appropriate height increase.
Specific volume

The tendency is for the specific volume of products to grow with the increase of the rye flour percentage.

If curve rates for the two series of results are traced, corresponding to the 30 and 150 minutes of kneading, it is noticed that these are almost identical, which indicates that maturation time has no effect in the products' specific volume. The specific volume depends on the proportion of rye flour from the mixture. Correlations with the rheological characteristics of dough.

No correlations can be established between dough consistency and the physical-chemical characteristics of products. Much better characteristics were obtained when the physical-chemical characteristics of gingerbread were placed in relation with the time needed to reach the consistency of 500 UB.

The variation of dough volume during maturation

In the experiment achieved, the only variable was the proportion between rye flour and wheat flour, which means that the gas release speed is identical in all these. If differences occurred in gas release, they are owed to the different retention capacity of gases, such as the pressure exerted on them. It was noted that dough with a greater proportion of rye flour had an easier development, their volume increases faster.

8.2 The influence of different raw materials on the sorption-desorption properties

The present study proposes to study water activity in products of the gingerbread type in the relation with their composition and particularly with their behaviour during storage. For this purpose, 11 gingerbread types were achieved, manufactured in different periods, using different recipes, kept in the same conditions, wrapped in laminated polypropylene foil of 40 microns and sealed until use. The product storage period varied from 95 to 208 days. Some products lost 6%, whereas one sample suffered no moisture modifications in time for 199 days, and another sample, after 200 storage days, registered moisturising, the moisture increase being of only 0.1%. The conclusion may be drawn that the storage period is not
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defining for the drying-moisturising process. The greater water activity is, the smaller the moisture losses, however, the correlation between these values is very small ($R^2 < 0.500$).

Sorption curves

The sorption isotherms for the gingerbread samples, shaping the product’s hygroscopic features, were determined at the temperature of 30°C.

The sorption isotherms of a 0.65 water activity or at the 12% moisture, common values for this type of products. On the same water activity, 0.65 sample 1 has a 13% moisture content, whereas sample 6 only has a moisture content of 7. This aspect is particularly significant for the quality of this type of products, as the sensory characteristics of the product are profoundly dependent upon moisture. The smaller the moisture of the products, the more breakable, crumbly the product, and even harder, which makes for a negative sensory perception of the product.

The factor that varied for all these samples was the loss of moisture during the storage process, much greater for the samples kept in bulk, as compared to the ones mentioned previously. From this point of view, it is more desirable that the products be as hygroscopic as possible, to have water activity as high as possible for a certain moisture level. In this way, the loss of moisture shall be smaller during the storage process. If, in the case of products, moisture needs to be as high as possible for them to as high as possible for them to be as tender and as soft as possible, there could be a tendency to increase the moisture of these products and also to increase the product hygroscopic features by adding wetting agents, reducing the loss of moisture. This aspect could reach to the attainment of certain values of water activity, only allowing for preservability of these products. The products shall be studied from the point of view of texture, for different water activities, in order to follow their texture profile.

It is noticed that, at desorption, on the same value of product moisture, the product’s water activity is smaller than in the case of sorption. This fact needs to be taken into account because, as it also resulted from the experiment, during storage dehydration, desorption takes place. **The influence of ingredients on sorption isotherms**

The samples with an identical manufacturing recipe present close behaviours, but not identical. The differences may result from the fact that upon manufacturing invert syrup
produced in different batches was used, and the hydrolysis degree may be different. The greatest differences occur with the addition of sweeteners. Sample 1 contains 2% honey and 29.5% inverted sugar syrup, whereas sample 9 contains 20% honey and only 6% inverted sugar. This confirms the similarity existing from the point of view of composition and function between honey and inverted sugar.

The sorption curves prove to be particularly efficient instruments for the analysis of product behaviour during storage, and they may allow for the selection of the most efficient raw matter to the attainment of certain objectives.

8.3 Factors influencing water activity for products of the gingerbread type

Objective: The study of the influence of different sweeteners on the physical-chemical properties of gingerbread, more precisely on the sorption-desorption properties.

This behaviour is particularly significant for the quality of gingerbread due to moisture losses in the product during storage in inappropriate conditions, which leads to the loss of certain sensory characteristics and the depreciation of product quality. The basic recipe was the same, and the quantity of sweeteners identical in 8 samples, but the sweeteners were different. The products were analysed in order to establish moisture content, water activity, and sorption characteristics. Gingerbread with the highest and lowest water activity have close moisture contents, 11.2 and respectively 12. It is noticed that products prepared with honey or with inverted sugar practically have an identical behaviour. These results confirm the observations from the previously-presented experiment, and they prove that from this point of view inverted sugar and honey are not different concerning the technological effect. The use of sugar seems to be more efficient from the point of view of the effect upon sorption than the use of glucose.

The effect of sorbitol and glycerine addition into products prepared with sucrose.

The sorption curves are presented comparatively for gingerbread prepared with sucrose, in which a part of the sucrose was replaced with sorbitol. The replacement was made so that the sweetener quantity is the same for all products. Sorbitol is used as wetting agent in the food industry, but also as a sweetener. As a sweetener it has the same
sweetening power as sucrose, but from the point of view of hygroscopicity, it is 4 times stronger than sucrose. No notable differences were found in the used quantities.

The effect of sorbitol and glycerine ingredients in products prepared with inverted sugar.

If only the graphs are analysed, no notable differences concerning moisture sorption can be noted. The analysis of experimental data reveals that 100 g of dry product from the sample only using inverted sugar absorbed 9.80 g of water, when water activity increased from 0.558 to 0.740. Replacement of one part of the inverted sugar syrup (sucrose equivalent 1.4) with sorbitol (sucrose equivalent 4) led to an increase of water sorption to 9.80 grams. 100 grams of dry matter from gingerbread prepared with glycerine ingredient led to the sorption of 10.01 grams of moisture. The modifications induced by sorbitol and glycerine are very small, due to the small proportion that they are added in and to the much greater proportion of inverted sugar.

Glycerine and sorbitol induce a slight increase of products' hygroscopic features.

9. The influence of different factors on the texture properties of gingerbread

9.1 The influence of rye flour

Rye flour was replaced to variable proportions, from 0 to 50%. Gingerbread, after a 60-day preservation, was analysed from the point of view of texture by cutting with the blade device. Given that product dehydration occurred during storage, it was resorted to rehydration by placing it into a relative moisture environment of controlled water. Two water activities were provided, 0.555 and 0.672. The products stored in the warehouse were also analysed, their water activity being indefinite. The gingerbread prepared with different relaxation times were tested, 30 min., respectively 150 min. of relaxation.

The more rye flour proportion increases, the more significant the reduction of hardness is, of resilience opposed upon insertion of texturometer's cutting knife. The diminution of hardness is visible starting with the gingerbread in whose recipe wheat flour was replaced with rye flour to a proportion of 20%, the drop being the most visible in this percentage. For large proportions of wheat flour, the relaxation time led to significant increase of product hardness. If we relate to product hardness without conditioning (without wetting) and with the same rye flour proportion, in almost all cases increases in hardness are
noted, with the increase of relaxation time. It was thus resorted to the moisturising of gingerbread so they can be compared taking into account all the factors which could influence the process. The data obtained confirms the fact that gingerbread moisture influences the moisture characteristics of products to a great extent. The differences between gingerbread conditioned and unconditioned to a water activity level of 0.555 are not great. Subsequent laboratory assessments confirmed that water activity for these samples is very close to the one of conditioned samples (contained between 0.480 and 0.560). Much greater differences were noticed when the conditioning was achieved up to water activity of 0.670. Sample hardness increased for almost all samples with the increase in relaxation time.

If the hardness of conditioned gingerbread is analysed up to a water activity level of 0.555 and 0.670, prepared with a 30-minute resting time, it is noticed that for a water activity of 0.555 hardness decreased, as compared to the 100% wheat flour sample, insignificantly for gingerbread with 10% rye flour, but with values contained between 31.5 and 42.3% for gingerbread in which the rye flour proportion increased from 20 to 50%. If the same reference is maintained in water activity increase to 0.670, hardness decreased even more, with values contained between 46.5 and 73.8%. In principle, a decrease by almost half of the hardness in the case of samples which were wetted more can be noticed.

Similar behaviour was also noticed in the case of gingerbread prepared with 150 minutes of rest. It can be noticed that with the increase of water activity, for samples with 30-minute rest and for the ones with 150-minute rest, an increase of cutting depth occurs, for which maximum force is registered. It is noticed that for small water activities the curves have a sudden début, reaching a maximum, and then the registered values decrease until the maximum cutting depth is attained. The more reduced water activity is, the more cohesive and compressible the product is, which makes the maximum force increase gradually and the maximum cutting depth is reached. Elasticity is first of all influenced by resting times, as well as by water activity. From the analysis of these figures, the fact results that it is not a possible elasticity of samples that determines the increase of the distance for the attainment of maximum force. This parameter is influenced by product brittleness. It is noticed that the curves with high distance for attaining the maximum force have a more
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regular aspect, whereas the other ones are more regular, due to small fractures occurring in the product.

The elasticity of products with smaller rye flour proportion is greater for more reduced dough resting times and for small water activity. With the increase of water activity, elasticity decreases.

Conclusion: products with a lower rye flour content are more crumbly and with the increase of water activity product brittleness decreases.

9.2 The influence of different sweeteners and of water activity on the texture characteristics of gingerbread

The samples were wetted until water activity levels of 0.590, 0.630 and 0.71. The samples were analysed from the point of view of texture with the help of the knife device. The following were monitored: hardness, maximum distortion force (ForceA), energy needed for distortion (Area4) and the cutting distance on which the maximum force was registered.

Force needed for cutting

It was noticed that in the case of gingerbread texture analysis by cutting with a maximal force, hardness does not coincide. The samples registered the highest cutting force values in the case of samples with the most reduced water activity. Water activity increase from 0.59 to 0.71 led to a decrease of cutting forces by 50 and even more than 50%.

Sample 7 had the highest hardness degree, which is prepared with glucose syrup with DE64, and sample 1, prepared only with sugar. The smallest values were registered in the case of sample 8 and of sample 2. Sample 8 was prepared with a premix, whereas sample 2 was prepared with sugar, sorbitol, and caramel. A weak correlation may be noticed in the case of hardness with moisture, and in the case of maximum force, correlation is even more reduced. This data suggests that hardness is however influenced by the ingredients, it does not depend completely on moisture.

Cutting energy

Area4 can be associated to the energy needed to the purpose of cutting the samples. The variation model is very similar to the one of the maximal force. The correlation between the energy needed for cutting and moisture is very weak, the linear regression coefficient, \( R^2 \), being of 0.569.

The cutting distance on which maximum force is reached.
In the case of samples 7, 1 and 2, the maximum force is attained after a few millimetres from insertion in the product. This suggests that the product is somewhat crumbly, it does not suffer from elastic distortions, but rather only plastic distortions. A general tendency is noticed to increase the distance for the attainment of maximum force with the increase of water activity (and of product moisture). With the increase in moisture, the products become more elastic and less brittle, Samples with added inverted sugar, honey, and sorbitol present a more reduced crystallizing tendency.

9.3 The influence of kneading time on the texture characteristics of gingerbread

Materials and methods: 6 kg of industrially, following two different recipes, with premix (R2) and without premix (R1) were introduced into a laboratory mixer. The dough was then kneaded for different times, of 1 to 5 minutes. Following kneading, the re-kneaded dough and the industrially prepared dough (which was not additionally kneaded) were left to rest for 150 minutes and then modelled and baked. After being baked, the products were kept in airtight recipients for 24 h and then texturometrically tested with the 1 inch diameter spherical device to determine the determination of the textural profile, a test with two compressions.

The effect of kneading time on hardness and compression resilience force

The maximum force registered on first compression coincides with hardness (the force registered on the set insertion depth). This is also valid for the second compression cycle. Very large differences are not noticed with the increase in kneading time. For gingerbread prepared with a premix, a slight tendency of the compression force is noticed with the increase in kneading time, but also large variations are noticed between the analysed samples. In the case of the dough without premix, the same great variableness of the registered values, as well as a slight tendency for compression force increase. The products have similar resilience to compression.
Effect of the kneading time on elasticity and cohesion.

Elasticity and cohesion are texture characteristics of the product and they are defined in the texture profile by the ratio between the compression distance between the two cycles and, respectively, the area below the graph in the two compression cycles. From the point of view of recovery, the two samples have similar characteristics and they have quite a good recovery rates, contained between 62 and 83%. A much reduced tendency is noticed for elasticity decrease for premix gingerbread with the increase of kneading time, whereas for the samples without premix, the extended kneading led to the increase of elasticity. The premix-added gingerbread are sensitively more cohesive, the values are almost double as compared to the samples prepared without added premix. In both cases, product cohesiveness seems to increase very easily with the increase of kneading time.

The effect of kneading time on resilience.

Another texture characteristic of the product is elasticity defined as a ratio of the area below the graph at compression, during the first cycle. The greater the product-pushing force, the more elastic it is. The greater the distance that the device is pushed on, the greater the elastic distortion and area below the graph for the product. Resilience of premix products is greater by approximately 1/3 of the resilience of products prepared without premix. Resilience of samples with premix presents a very slight increase with the increase of kneading, whereas for samples with no added premix, there is a reduced tendency for elasticity increase.

The effect of the kneading time on gumminess and masticability

Increase of kneading time led to the decrease of masticability of the products without premix (R1) and to the increase of masticability of products with premix (R2). Products with no premix are more easily masticable than the ones with premix.

9.4 The influence of dough maturation time and of aeration formula on the texture characteristics of gingerbread

Materials and methods: The recipe (presented in table II.9) was modified taking into account the following premises: the gradual replacement of ammonium bicarbonate with sodium bicarbonate and the addition of sodium acid pyrophosphate, so that a 95% neutralization of the sodium bicarbonate within the recipe is achieved, 5 samples were made, matured for different times, 0, 60, 120 and respectively 150 minutes, at room
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temperature, the baked gingerbread was kept for 14 days in sulphuric acid solutions until constant water activities were reached. The blade device was used for cutting. Cutting was achieved at a speed of 1 m/sec, down to a depth of 10 mm.

A good correlation was noticed (the linear regression coefficient $R^2$ is 0.9062) between hardness and maximum registered force. The correlation between hardness and energy is smaller, $R^2$=0.8649. A very good correlation is also noticed between curve area and maximum force, $R^2$=0.9801. This indicates that, for tested samples, irrespective of the recipe or the work parameters, the curves had a similar form and cutting to a 1 cm depth ensured the fact that analysed texture sizes were measured in similar moments, when the analysed samples were not destroyed. This indicates that the analysis of the mode of variation for the maximum distortion force is sufficient. From this data, the following conclusion can be drawn: for the texture characterization of gingerbread by means of this type of test, cutting to a constant depth, the analysis of hardness and of the maximum distortion force is sufficient.

Both hardness and distortion energy have a very similar variation model, demonstrated also by the very good correlation of these values.

Another aspect is the increase of hardness as water activity decreases. This mode of variation is specific for all gingerbread assortments and it was also noticed in previous experiments. The smaller water activity is, the smaller the sample moisture. An increase of gingerbread hardness is ascertained with the increase of maturation time. Short maturation times (of the 1-2 hour order) does not influence the texture of the products in a positive way. The increase of maturation time may lead to texture improvement, but it is possible that longer maturation times are needed, 24-48 hours, recommended in traditional recipes for obtaining gingerbread. There is a significant correlation between maturation time and gingerbread hardness.

Gingerbread hardness decreases as the proportion of ammonium bicarbonate replaced by sodium bicarbonate increases. The effect is stronger as the resting time is longer.

It is noticed that there is no correlation between product hardness and its elasticity. Elasticity is not a textural measure that can be used in cutting tests for gingerbread. Most likely, the cutting test induces permanent distortions, leading to the destruction of sample integrity. For the characterization from the point of view of elasticity, the use of other devices and work protocols is needed, such as compression with two or more cycles.
9.5 Correlations between the physical-chemical and texturometric characteristics

Laboratory-obtained gingerbread was also analysed from the point of view of physical-chemical characteristics, respectively dimensions and specific volume.

Height, diameter, specific volume - these are characteristics that relate to each other. The specific volume is defined by the diameter and height of the samples, and diameter increases with height, and therefore the weight leading to extrusion, the widening, is greater. Even more so, a high specific volume means that the samples have higher porosity. The presence of larger pores would have to lead to smaller product hardness. In order to confirm this, it was statistically attempted to identify a correlation between hardness and these geometric characteristics. No statistical correlation is established, the linear regression coefficients have very low values.

No correlation can be established between the specific volume and the increase in diameter or in height. A possible relation was also investigated between the final height, final diameter, and specific volume of samples. The linear regression coefficients had values smaller than 0.3000.

10. THESIS CONCLUSIONS

10.1 Conclusions on the modification of gingerbread manufacturing technology by using extrusion technology and wire-cut

The following alterations are needed as compared to classical technology:

- Reduction of kneading time;
- The kneading method is bi-phase: all the other ingredients, except for flours, are first homogenized and then the kneading proper is carried out, after adding flour. Homogenization is short-term and it is discontinued before the complete development of gluten;
- In order to prevent neutralizing of aeration agents prior to adding flour, it is necessary that sodium bicarbonate and ammonium bicarbonate are not added at the same time as the acidifiers. The addition of sodium and ammonium bicarbonate in the initial stage was preferred.
Dough maturation is achieved by means of a few hours' rest; during resting time, the dough increases in size and it becomes more porous, more easily processable;

- For the processing of the dough characterized by plasticity and stickiness, for better control of the size of debited dough pieces, a carrier system similar to pumps is used;
- Glazing, drying, are achieved continuously, by passing through glaze curtain and bath, drying at controlled temperature on wire rack.

10.2 Conclusions of rheological study

- rye flour inhibits the development of gluten;
- rye-flour added dough requires shorter kneading timed to reach certain consistencies;
- the optimal proportion for rye flour addition is of 25-35%, dough stickiness is not very great and dough consistency is minimal, ensuring easier processing;
- the defining elements of the maturation process are relaxation, water sorption and degradation of the dough's gluten structure;
- industrially manufactured dough is kneaded long enough to assure the complete development of gluten structure;
- the 2.5 h maturation time is not long enough to notice a "worsening" of the rheological characteristics of the dough, no major modifications are noticed in dough rheology;
- in order to maintain dough consistency sufficiently low for industrial processing, the extension of the resting time is recommended, as well as the manufacturing of the dough at higher temperatures, so that the physical-chemical processes defining the kneading and particularly the maturation process develop at high speeds.

10.3 Conclusions concerning the work protocol within texture analysis

- elasticity is not a relevant parameter to the characterization of unglazed gingerbread;
- glaze induces a variableness of the glazed product behaviour;
- the testing protocol with two or more compression cycles is not the most appropriate for the testing of glazed gingerbread cookies, or the identification of methods
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preventing adherence of glaze to the testing device and/or the sample worktop during testing is needed;

- glazed gingerbread has lower hardness than unglazed gingerbread; 48 hours later, the hardness of glazed gingerbread is approximately twice as small as in the case of unglazed gingerbread;
- maintaining the product at low temperatures hastens the processes occurring within the product, but it also promotes others, leading to differences in behaviour;
- glazing is a factor having a major impact on the hardness of gingerbread, which renders the textural study of cores only inadequate, ignoring glazing;
- the samples should be assessed from the point of view of texture after at least 48 hours from manufacture;
- that the minimum number of tests to be run is 6, in order to obtain representative results;
- a 30% compression provides a compression level similar to the one achieved by human subjects within product testing, and the material does not undergo major internal fractures, and the circulation of the device is reproducible;
- there is good correlation between the sensory and texture assessment;
- in selecting the testing devices, the geometry of the samples and their shapes shall be taken into account;
- the selection of assessed texture characteristics shall be carried out attentively, depending on the forms and sizes of the analysed samples.

10.4 Conclusions on the influence of different factors on the physical-chemical characteristics of gingerbread

- The greater the rye flour proportion, the greater the dough consistency, which leads to reduced widening of dough pieces by means of baking, and therefore of the finite product;
- maturation time has no effect on the products' specific volume;
- the specific volume depends on the proportion of rye flour in the mixture, but there are, however, other factors also influencing this parameter;
- the dough with a greater rye flour proportion presents better extensibility;
• the storage period is not defining for the sorption-desorption process. The chemical composition, the storage conditions, the nature of the wrapping are much more significant for the process;
  • the use of glucose syrups with a small DE (probably smaller than 90) is not efficient for the replacement of honey in the preparation of gingerbread;
  • sugar and glucose syrup with a small DE have a reduced hygroscopic character, the sugar seems to be more hygroscopic than the glucose syrup with DE 64;
  • The inverted sugar syrup and honey have similar hygroscopic features, the inverted sugar may replace honey in the fabrication recipe, if only the finite product's hygroscopic character is taken into account;
  • glycerine and sorbitol induce a slight increase of products' hygroscopic features.

10.5 Conclusions on the influence of different factors on the texture characteristics of gingerbread

• products with a lower rye flour content are more crumbly and with the increase of water activity product brittleness decreases.
• texture characteristics are influenced both by the moisture content and by the ingredients used;
  • the use of sugar has a negative impact on product texture;
  • the replacement of sweeteners in the recipe with DE 64 glucose syrup has a negative effect on texture, stronger than the use of sugar. It is possible that sugar syrups with high DEs have better results due to the higher glucose content and to the more reduced dextrin content;
  • the maintenance of high moisture (water activity) is essential to keep products soft;
  • the maximum cutting force (ForceA) is a superior texture parameter for the assessment of gingerbread texture as compared to the texture parameter Hardness;
  • the cutting energy (Area4) and the distance on which the maximum force is reached (Max. dist.) are texture characteristics which may be successfully used to assess gingerbread;
  • increase of kneading time has led to a decrease in hardness, elasticity, cohesion, masticability and resilience of gingerbread prepared without added premix, whereas for the
products manufactured following the premix-added recipe, these texture characteristics suffered increases, however minor, with the increase of kneading times;

- product moisture is more important than the maturation time from the point of view of product texture;
- short maturation times (of the 1-2 hour order) does not influence the texture of the products in a positive way. The increase of maturation time may lead to texture improvement, but it is possible that longer maturation times are needed, 24-48 hours, recommended in traditional recipes for obtaining gingerbread;
  - there is a significant correlation between maturation time and gingerbread hardness;
  - the dough maturation time has a greater influence on product texture than the formula selected for aeration;
  - as the proportion of ammonium bicarbonate is replaced with sodium bicarbonate, the hardness of gingerbread decreases; The effect is stronger as the resting time is longer, suggesting that the processing carried out upon maturation, which influence the texture of gingerbread imply, in one way or another, transformations of these aerating agents, it is possible that in fact the real variable is the acidifying agent, rather than the aerating agent;
  - for the textural characterization of gingerbread by means of the cutting test to a constant depth, the analysis of hardness and of the maximum distortion force is sufficient;
  - elasticity is not a textural measure that can be used in cutting tests for gingerbread;
  - the manual process for gingerbread formation is reproducible to a small extent, and the texture characteristics obtained within the thesis experiments are owed particularly to the properties of the composition and less to product porosity.

**10.6 Industrial application contributions**

The following application contributions were presented within the work:

- The possibility to manufacture gingerbread using the "wire-cut technology", state-of-the-art extrusion and wire-cutting technology, allowing for high quality products to be obtained, presenting the modifications imposed;
  - The work protocol for test baking for the product "gingerbread";
  - The work protocol for the performance of texture analysis for the product "gingerbread";
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- The use of certain raw materials to the detriment of others, of the recommended quantities, to the purpose of obtaining the superior quality finite product, at an optimal quality-price ratio;
- The recommendation to use certain texturometric sizes for the analysis of the finite product "gingerbread", the presentation of interferences between the rheological, physical-chemical, texturometric and sensory characteristics.

10.7 Future research directions

Within the present work, the importance of the accurate assessment of the advantages incurred by the use of certain ingredients in the elaboration of fabrication recipes was highlighted, of laboratory test performance to the purpose of optimizing the manufacturing recipe, of laboratory device employment to the purpose of analysing the product's texture profile, correlated with the sensory analysis performed with the taster-fnal consumer team.

The improvement of the work protocol for the texturometric analysis, setting optimal work parameters in motion (kneading times and speeds, maturation times and temperatures etc.) depending on the particularities of technological processes within production units, setting target work values for texturometric characterization - these are significant research directions.

To these, the following themes are added: the monitoring of the efficiency of different type of wrapping, to the purpose of maintaining humidity and texture characteristics, such as the study of the influence of certain ingredients (such as proteases, metabisulphite, amylases on the characteristics of gingerbread, as well as the deeper understanding of the relation between the core of gingerbread and their glaze.
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10.8 Scientific disseminations

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• Water Content and Water Activity of Bakery Products

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• Rye Flour and Resting Effects on Gingerbread Dough Rheology

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• Sorption Properties of Some Romanian Gingerbread

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LUCRĂRI PREZENTATE LA CONFERINȚE INTERNAȚIONALE

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AGRI – FOOD SCIENCES, PROCESSES AND TECHNOLOGIES”, SIBIU, 14-15 MAI 2014

- Effects of storage temperature on textural properties of gingerbreads

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