Mathematical Modeling of Temperature in Bread Baking

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INTRODUCTION

This paper aims to obtain a mathematical model to describe the evolution of temperature during the baking of bread and pastry bakers, and how these developments affect the main qualitative characteristics of the finished product such as skin color, temperature heating of the product and weight loss in cooking.

MATERIALS AND METHODS

Considering the high temperatures, and lower side, the influence on quality indices was different. Temperature at the top has a greater impact on quality indices of the finished product. These data were used to determine the action of weight loss temperatures in each zone according to equation 1.

\[ x_i = p_{ts} \cdot T_s + p_{tl} \cdot T_l + p_{ti} \cdot T_i \]  

where:

- \( x_i \) – the temperature share of the four baking zones of the oven,
- \( p_{ts} \) - temperature share of superior part,
- \( p_{tl} \) - temperature share of the sides, \( p_{ti} \) - temperature share of inferior side,
- \( T_s \) - temperature of the superior side,
- \( T_l \) - temperature of the sides,
- \( T_i \) - temperature of the inferior side.

After we reviewed the experimental data of the temperature variation in each zone separately, we can say for a fact that equations 2 and 3 describe the best the relationship between temperature and baking time, the color of the crust, the weight loss and the temperature within the thermal centre of the product.

\[ y_i = f_i(x_1, x_2, x_3, x_4, x_5) \]  

and

\[ f_i = b_{0i} + \sum_{j=1}^{5} b_{ij} x_j + \sum_{j,k=1,j \neq k}^{5} b_{ijk} x_j x_k + \sum_{j=1}^{5} b_{ijj} x_j^2 \]  

where:

- \( y_i \) – quality index (weight loss \( y_1 \), internal temperature \( y_2 \), side crust’s color \( y_3 \), top crust’s color \( y_4 \), inferior crust’s color \( y_5 \), exterior aspect \( y_6 \))
- \( x_i \) - temperature share in the four stages \( i = 1, ..., 4 \)
i=5 – baking time
b_{io}, b_{ij}, b_{ijk} \text{ and } b_{il}(i=j=k=K) – modeling parameters

Fig. 1. Losses occurring during the process of baking bread

RESULTS AND DISCUSSION

Model can be properly assessed by calculating the average error (MCE) and correlation coefficients (R) between the actual results and the result expressed as a model for each quality attribute. To check the experimental data were used and about 50% of them check the model obtained..

<table>
<thead>
<tr>
<th>Model characteristics</th>
<th>Weight losses [%]</th>
<th>Internal temperature</th>
<th>Top crust's colour</th>
<th>Side crust's colour</th>
<th>Inferior crust's colour</th>
<th>Exterior aspect</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCE</td>
<td>0.32</td>
<td>3.11</td>
<td>5.72</td>
<td>6.50</td>
<td>5.9</td>
<td>3.40</td>
</tr>
<tr>
<td>R</td>
<td>0.92</td>
<td>0.91</td>
<td>0.93</td>
<td>0.92</td>
<td>0.83</td>
<td>0.95</td>
</tr>
</tbody>
</table>

Accuracy of models was reasonable, except for the lower crust color. According to correlation coefficients in Table 1 almost all quality attributes except lower skin color could reveal the link between temperature and quality parameter considered.

Accordingly, the weight ratio for lower temperature from the calculation of regression was a low value. Thus, the bottom of the oven temperature is less important than the top and temperatures considered for weight loss. Baking regime are all external parameters of the environment, changes in process parameters condition baking. In the framework of baking of the dough internal parameters are not included: dough composition, humidity, weight, shape, addition of chemicals or enzymes, etc.

Baking regime can be defined by parameters:
- ambient temperature baking (T_{CC});
- hearth temperature (T_v);
- baking chamber wall surface temperature, the energy radiates (T_{per});
- the relative humidity of the environment (u %).

Regime can be divided up cooking areas, on stages or moments. Cooking regime can be divided in two periods according to the baking process. The first includes a initial period with a fix duration of 2,3 - 3 minutes, period in which the moisture transfer process from the environment to the product by vapor condensation. The tunnel oven baking system is divided into zones leading to a breakdown of the baking process on five or six period . Each period being defined by different values of the cooking regime parameters T_{cc}, T_v, T_p and u% specific for each period.
**Baking temperature** ($T_{CC}$) varies between 120-270 °C in different areas and stages of ripeness, without this specific optimal regime impede the process. Between the environment and the product surface is heat exchanged by radiation, conduction, convection and condensation. Heat convective exchange is small, with values ranging from 3 to 4 W / m² °C, compared with other types of heat.

**Hearth oven temperature** ($T_v$). Some of the heat received of the dough piece in the baking surface is transmitted through the medium conductivity on temperature difference between surfaces. Heat flow received by the bottom of the product depends on thickness of dough to center of thermal conductivity and the differential temperature viscosity them $\Delta T$.

If $T_v$ is too much the crust is formed very quickly, becoming rigid, because the product obtained will have a conical shape, with thick crust. Placing the dough on cold hearth oven leads to sticking and cracking his side of the crust.

**Wall temperature of baking room** ($T_p$) is more important than the ambient temperature parameter influencing the flow of heat radiate intensity. The value of these temperatures is determined by calculation or experimentally, depending the product range, the dynamic exchange of heat and baking regime adopted.

Between $T_v$ and $T_p$ must be balanced, it influences the form of bread. For a normal oven with intense heating in the first period, will lead to a surface tension of spherical loaves. At low radiation, warming slowly, delaying the formation of the upper crust and get bread shaped widened.

Regime is given rudimentary oven baking the earth working steps in the accumulation of heat and the oven walls and cool gradually reduced due to conductivity of the material they are made. Baking regime is characterized by high initial temperatures, intense heating of the dough athe beginning and of long baking, fig. 2.

![Fig. 2. Diagrama regimului discontinuu de coacere](image)

Environmental humidity is very low at first and increases as products lose moisture. If there is a balance between dough mass and heat intensity, defects may occur in the figure, when the dough is extruded under pressure inside out.

The system of modern cooking in the first stage takes place fogging products (moistening with water vapor jet) without irradiation, heating the upper surface being made only by the heat of condensation of water vapor, Fig. 3.

At this stage toe has values between 160-180 °C, hearth temperature is higher, the products are heated to the bottom. After the first three minutes, the temperature of the upper crust is relatively low due to evaporation condensation which maintains its plasticity, deformation being produced without cracks or breaks. During operation temperatures rise, and finally heating is reduced and made their skin temperature decreases.
Fig. 3. Continuous baking

Profile of temperature and baking times obtained can be considered in making settings for tape or ovens for hearth ovens stacked because approximately 50% of the experimental data verifies the model obtained.

REFERENCES