Solid State Fermentation application in the study of peculiarities biotechnological potato used in panification

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Abstract

They highlighted the peculiarities biotechnological potato varieties, Impala and Orchestra grown in Romania. Flour-graphic technique was used for determining the solid composition of the fermentation medium and bioreactor for studying the amount of carbon dioxide that is released during 5 hours. Measurement of the amount of gas formed during the fermentation of the nutrient media is a significant indicator of the fermentation in bread manufacture. Bread was prepared in a nutrient medium composed of: white and brown wheat flour, Saccharomyces cerevisiae yeast for the cultivation medium. The amount of water added was determined using Flourgraph E6, to a consistency of 500 HE.

Hydration capacity decreases by 26% for white flour version (F1) and 31.2% dough from F2 (wheat brown flour) and potato pasta Orchestra variety (O-PP). If we use potato pulp and F2 flour, the maximum release is of 990 ml/h and it was recorded for the 30% working version, while 1185 ml/h for the mixture F2 and O-PP. At a potato concentration of 30% the gas release reaches its maximum towards the second hour of fermentation and in the first hour the fermentation is inhibited. By using this procedure, there may be the possibility of directing and orienting in placing the components in recipe, choosing the operational parameters, raw materials and their relation.

Keywords: bioreactor, flourgraph, rheology, yeast, CO2 release, wheat flour, potato

Abbreviation and Symbol

Material characteristics and methods used for analysis are shown in Introduction and Table 1, 2, 3, 4.

B1- vitamin B1-thiamine;
B2- vitamin B2-riboflavine;
B6- vitamin B6;
PP- vitamin PP-niacine;
CO2- carbon dioxide;
\( u \) - is the moisture, in %;
Glu - wet gluten, in %;
DI – deformation index, in mm;
Ig6 – glutenic index, in %;
FN – falling number;
TTA – titratable acidity, degree;
HD – hydration degree, %.
1. Introduction

Critical analysis of the literature shows that production of relevant compounds for the food processing industry by SSF (solid state fermentation) offer several advantages [1]. SSF is defined as any fermentation process performed on a non-soluble material that act both as physical support and source of nutrients in absence of free flowing liquid [2]. Recently, Wu and Shen [3, 4] used the different powder of plant for liquid and solid-state fermentation of ethanol.

Dough flour fermentation is an essential step in bread making. During this step, dough specific volume is increased due to bubble growth from yeast gas production [5, 6].

These problems have a negative effect on the cell-viability, growth and fermentation performance of the yeast, as shown by Srikantha [7]. High viscosity also leads to the incomplete hydrolysis of the starch, which decreases the utilization efficiency of the feedstock [8, 9,10,11]. S.cerevisiae cultivating environment generally contains, among others, sources of potassium, magnesium and ammonium, which add in the form of chemical synthesis substances [12]. The mineral salts P, K⁺, Mg²⁺, Ca²⁺ and Mg²⁺ influence the growth and fermentation performance of yeast [13]. Potato can provide some of these growing factors such as K, Mg, ascorbic acid, vitamin B₁, B₂, B₆, PP and source of carbon for microorganisms in a natural way, more than other nutritious media used in bakery. In panification, the yeast S. cerevisiae is used as production culture.

During yeast fermentation, the gas cell are filled mainly with CO₂ [14]. They create a pressure in the system. The modification of the chemical composition of the substratum influences the CO₂ quantity that is released [15].

For the fermentative potential study of the environment, the bioreactor may be used, where S. cerevisiae yeast is cultivated on a cultivation medium identical with the intermediary panification phase, namely the dough [16, 17]. The current study method of the environment fermentative potential has been changed through the modification of its chemical composition. At "International Conference of Applied Science, Chemistry and Chemical Engineering CISA-2010", presented a study about laboratory microprobes, which were used for the bioreactor and research in this way has proven to be efficient and attractive from an economic point of view, thus avoiding loss of time and raw materials with industrial samples[18].

Due to the fact that the nutritive environment contains potato pulp, whose humidity is different from that of the flour, the approach of a new way of calculating the mixture quantity has been imposed, with the purpose of studying the rheological dough characteristics. This is caused by the fact that the mixture has to contain 86 mg/100g of dry matter.

Used a new experimental model for the application of the flour-graphic technique to the study of the mixture of flour and hydro thermally processed potato obtained. The higher substitution percentage of the flour is higher than PP, with both the the mixture is higher humidity [19, 20, 21].

In panification, there are different equipments that facilitate the study of the dough rheological behaviour [22, 23]. The dough formation characteristics are studied with the Brabender Farinograph [24], the mixograph [25, 26] and lately with E6 Haubelt Flourgraph. The compatibility of the Brabender Farinograph with the E6 Haubelt Flourgraph and the equivalence of the Brabender units of measurement with the Haubelt units of measurement have been demonstrated [27].

In this study, micro samples of dough formed out of white wheat flour, 650 type, with additives (F₁) or out of brown flour, 1250 type, with additives (F₂) have been prepared. The potato varieties that replaced flour in proportion of 5%, 10%, 20% and 30% were: Impala potato pasta (I-PP) and Orchestra- potato pasta (O-PP).
The chemical composition of the environment cultivated with breading yeast was done by using the flour-graphic technique. The CO₂ release was monitored and measured with the volumetric method. The influence of the potato varieties on the potential evolution of the fermentative environment has been compared, with consequences in the fermentative panification process. The batch operating system was used. The potato samples have been compared with the control sample and the influence of the potato varieties were considered.

2. Materials and methods

For analysis the next equipments were used: Bioreactor, Haubelt Flourgraph E6, moisture analyzer and ML-50, analytical balance type WPS 210/C/1 Partner, mixer HV4 with sieve diameter at 2 mm. Drinking tap water was used to prepare the nutrient media.

### Table 1. Physico-chemical characteristics for the raw material (flour).

<table>
<thead>
<tr>
<th>Raw material</th>
<th>Characteristic of raw material</th>
</tr>
</thead>
<tbody>
<tr>
<td>White flour, type 650, additivate (ascorbic acid, L-cisteina, α-amylose, hemicellulase, xylanase)</td>
<td>u=13.9%; Glₖ=32%; ID = 4 mm; Iₒ₉₅=55.7; FN = 290-330 s; TTA = 2.2 degree, ash 0.649 %</td>
</tr>
<tr>
<td>Brown flour, type 1250 additivated (ascorbic acid, L-cysteine, α-amylose, hemicellulase, xylanase)</td>
<td>u=12.9%; Glₖ=30%; ID = 8 mm; Iₒ₉₅=44.4; FN = 280 s; TTA =3.3 degree, ash 1.25 %</td>
</tr>
</tbody>
</table>

### Table 2. Physico-chemical characteristics for the raw materials yeast and potato pasta.

<table>
<thead>
<tr>
<th>Raw material</th>
<th>Characteristic of raw material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potato Impala variety</td>
<td>u = 83.5 %</td>
</tr>
<tr>
<td>Potato Orchestra variety</td>
<td>u = 81.3 %</td>
</tr>
<tr>
<td>Yeast bakery</td>
<td>Power of growth = 10 minutes; u = 68.9%,</td>
</tr>
</tbody>
</table>
Methods for CO₂ measuring

The device used in this study measures the amount of gases released from the fermenting dough at the temperature 30°C, from 5 hour, expressed as volume of NaCl solution. The volume of NaCl solution gathered outside the fermentation vessel is the released volume in milliliters of CO₂. To measure the fermentation intensity (from 1 to 1 hour) we used a precision 0.1ml.

The mash preparation

The mash preparation recipe and the chosen operational parameters are a hybrid version of the existing recipes at macro process level, where battered the mash simulating the mechanical action during dough processing in the industrial technological processes at a laboratory level.

The amount of water

The amount of water that is added at the preparation of fermented mash in the bioreactor was calculated using Flourgraph E6 according to the hydration capacity of the flour and potato pulp hydrothermally treated or raw mixture. Mixture consistency was of 500 HE. Amount of fresh yeast is added in constant quantity of 10 g/ 86 g medium (dry basis), so for 100g mixed with humidity 14%.

3. Results and discussions

The fermentation mediums have been prepared outside the system (the fermentation area of the bioreactor). The water quantity has been added by taking into consideration the mixture’s hydrating capacity, which has been determined with the E6 Haubelt Flourgraph.

Various water quantities shown in Table 5 have been added, which are influenced by the replacement proportion of the flour with the hydrothermally processed potato pulp. The diagrams selectively presented in Figure 1 show that the mixture viscosity is modified. The water quantity is added for all samples up to a 500 HE consistency.

<table>
<thead>
<tr>
<th>Potato variety and degree coking</th>
<th>F1 Water absorption (%)</th>
<th>F2 Water absorption (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potato variety</td>
<td>I-PP</td>
<td>O-PP</td>
</tr>
<tr>
<td>Control</td>
<td>56.9</td>
<td>56.7</td>
</tr>
<tr>
<td>5%</td>
<td>56</td>
<td>55.3</td>
</tr>
<tr>
<td>10%</td>
<td>53.1</td>
<td>53</td>
</tr>
<tr>
<td>20%</td>
<td>47.6</td>
<td>48.4</td>
</tr>
<tr>
<td>30%</td>
<td>42</td>
<td>40.9</td>
</tr>
</tbody>
</table>

The hydrating capacity decreases depending on the replacement percentage of flour with potato pulp. The potato variety and the flour type influence the water absorption capacity. At a small replacement percentage, irrespective of the flour type, there are no significant differences in the hydrating capacity value. At 20%-30% potato added, the differences between the water absorption values given by the potato variety are greater. The relation between the solid, liquid and gaseous phase has been modified. In the new used structure, the

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hydrothermally processed and minced potato pulp is hydrated and the corresponding water quantity is smaller.

The dough formation time is influenced by the flour replacement percentage with potato pulp and by the flour type. It is influenced in a smaller degree by the potato variety (Table 6).

Table 6. The forming characteristic of mixture (dough). The dough development time.

<table>
<thead>
<tr>
<th>Flour type</th>
<th>F1</th>
<th>F2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potato variety and degree coking</td>
<td>I-PP</td>
<td>O-PP</td>
</tr>
<tr>
<td>Control</td>
<td>2.7</td>
<td>2.7</td>
</tr>
<tr>
<td>5%</td>
<td>2</td>
<td>1.7</td>
</tr>
<tr>
<td>10%</td>
<td>1.3</td>
<td>1.3</td>
</tr>
<tr>
<td>20%</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>30%</td>
<td>1.1</td>
<td>1.2</td>
</tr>
</tbody>
</table>

Due to the decrease of protein content, especially of proteins that produce gluten, the dough development time decreases especially for the 20% - 30% work variants.

Dough preparation cultivated with yeast and monitored in batch system has not been made in sterile conditions. It has been opted for this work variant in order to be as close as possible to industrial conditions. The constant values of the system were the 30°C temperature, the pressure and time. The system variables have been the fermentation mediums (their composition).

Figure 1. Presentation selective: influence of potato pulp processing degree and of added materials on the profile of the flourgraphic curves of the F1 or F2 and Impala potato-pasta or Orchestra potato-pasta that replaced flour in 30% proportion comparative with control.
Figure 2, shows that for the control sample the maximum CO₂ release has been registered in the first fermentation hour (750 ml/h). At the same time with the increase of the replacement percentage of flour with potato, the maximum release quantity is displaced towards a second fermentation hour (Figure 3 and 4). The maximum CO₂ released quantity for the F₁-I-PP mixture has been registered for the work variant of 30% (990 ml/h), in the second fermentation hour. The same CO₂ released quantity for the F₁-O-PP mixture has been registered for the work variant of 30% (990 ml/h). For the F₂ flour mixture with a small potato pulp quantity, 5% stimulates the fermentation process in the first hour. The maximum CO₂ released quantity is given by the mixture with Impala potato variety in the second fermentation hour and it is 1185 ml/h and for the Orchestra potato variety it is 1000 ml/h. The quantity is smaller for the Orchestra potato variety as compared with the Impala potato variety, even if the same flour type and yeast quantity has been used. These values have been obtained for the work variant of 30%. For the F₂ flour mixture, the more its replacement percentage with potato pulp increases, the more the fermentation process is inhibited, with the exception of the work variant of 5% (Figure 3). This aspect is not valid for the mixture with F₁ flour (Figure 2).

The total volume of released gas has proved to be greater so as the replacement percentage of flour with potato increases. For the mixture with F₁ the maximum quantity has been obtained if, for flour replacement, the Impala potato variety 2445 ml CO₂/5h has been used, as compared with the mixture with F₂ and the same potato variety for which the maximum is 2720 ml CO₂/5h. For mixtures with Orchestra potato variety there are smaller values (Figure 3).

![Figure 2](image-url)

**Figure 2.** Diagram of CO₂ intensity release, F₁ -control, F₁ -I-PP and F₁ -O-PP, that replace flour in proportion of 5%, 10%, 20% and 30%.
The fed-batch SSF process, with gradual feeding of pre-hydrolysed medium, carried out in two bioreactors, enabled to increase the final ethanol concentration and to eliminate problems associated with high concentrations of inhibitors in batch mode and high viscosity of the medium [28].

Screening number 4 shows that the influence factor of the values of total released gas volume is also the initial environment potential (the control sample) that is also greater for F2 flour type as compared with F1 flour type. The correlation indexes between the total released CO2 and the percentage of flour replacement with hydrothermally treated potato pulp is 0.9466 in the case of F1 and Impala potato variety mixture. The fermentative potential is given by this variety and it has been proven to be higher in comparison with Orchestra potato variety (Figure 4) for which the correlation with the replacement percentage is smaller, i.e. 0.8846. In the case of the mixture of F2 brown flour, the values of the correlation indexes are smaller. It seems that are also other factors that influence the fermentation process (Figure 4).

Solid fermentation medium is a natural environment for breeding of microorganisms. The most important technological acquiring yeast bread is its ability to ferment. The ability to form gas is one of the most important technological properties of flour. Capacity mixture to form gas is the new layout of this study. Because it can provide strength fermentation mixture (Figure 2, 3), raising the volume level assessment leavening bread and taking into account that the higher percentage of replacement of flour with potato decreases the amount of gluten.

Correlations between the values of the variables measured that characterize the rheometer as: forming dough, dough forming properties and its viscoelastic properties contributed to the calculation of the chemical composition of the fermentation medium (Table 5, 6, Figure 1). It was based on an experimental model to study the application of the flourgraphic technique on...
the behavior of flour mixture and raw potato or treated hydrothermally [21]. Combination flourgraphic studies, clearing provides information about the influence of nutrients immersion of the treated potatoes, compressed yeast species *Saccharomyces cerevisiae* for the production and direct fermentative activity using the activity-stimulating factors, such as the biotechnological features of potato varieties with the aim to improve fermentative ability mixture or fermentative ability of microorganisms to improve the quality of bread with potato.

**Figure 4.** Correlation between the total quantity of CO2 measured for 5 hours, at fermentation with batch cultivating system, on a hydrating nutritive medium, out of flour F1 or F2 and the replacement percentage with Orchestra and Impala potato variety.

**Conclusion**

By using this procedure (volumetric method determination to release gas in a solid state, using a bioreactor), there may be the possibility of directing and orienting in placing the components in recipe, choosing the operational parameters, raw materials and their relation. Potato pulp addition, hydrothermally processed and minced generally stimulates fermentation, improving the ‘mixture’s capacity to form gases’. Choosing the variety shall not be random, but in concordance with the aimed purpose.

Once with the increase of the replacement percentage of the flour with potato paste fermentation’s maximum is directed towards the second hour of fermentation, CO2 release being stopped in the first fermentation minutes. The same potato variety behaves differently mixed with different flours.
If one opts for a potato percentage higher than 20% then it is recommended to prolong the fermentation time. If one works in fed-batch system, it is well that the added paste to replace flour from the leaven, not in dough phase.

In this study, the method used for estimating the fermentative potential is a modified variant. The modification is represented by the calculation method of component parts of the nutritional substratum and the purpose in which it is used.

The CO2 volume that is released is or not always correlated with the replacement process of flour with potato, which implies the existence of other influence factors of the process.

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