Technologies of obtaining concentrated molasses from cereal grain raw material

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Abstract. Results of the studies of processes involved in obtaining concentrated molasses from the grain raw material (wheat) are reported. One of the methods to enhance grain concentration for obtaining molasses is the introduction of the stage of additional treatment of grains. Grain irradiation by the infrared light was used as the preliminary treatment. It is established that IR irradiation of grains causes a decrease in strength-related characteristics, violation of the integrity of grain hulls, as well as partial destruction of starch granules in grains. These transformations simplify subsequent enzymatic hydrolysis of cereal starch, which makes it possible to increase the concentration of grain raw material during production of molasses. Concentrated molasses have a higher carbohydrate content, which enables to decrease the amount of molasses per animal for feeding, and reduce the feed expenditures. Concentrated molasses can be stored for a long time. All these measures enhance the profitability of molasses production from grains. Enzymatic conversion of grains was carried out in a mechanoenzymatic reactor of original design. A conclusion is made that it is reasonable to apply the results obtained in the development of the improved technology of manufacturing concentrated molasses from different kinds of cereal grain raw material subjected to preliminarily IR treatment.

1. Introduction

The steady growth of the world prices for cereals is followed by increased prices of meat, milk, fat, and butter [1]. So, development of new technologies for processing grain raw material and upgrading of the existing ones based on the newest scientific and technological achievements are among the most essential goals of processing industry in the area of agriculture. These innovative technologies include ecologically safe, energy and resource saving technologies of mechanoenzymatic and biotechnological conversion of renewable agricultural raw materials. These raw materials include commercial grain starch-bearing plants: corn, wheat, barley, rye, triticale, etc. [2,3]. In the recent years, the production of molasses with the high concentration of free carbohydrates, with glucose as the major component has become an interesting direction in grain processing [4-10].

In our opinion, the use of molasses from grain raw material is the most efficient, economically reasonable and technologically implementable measure to achieve the recommended carbohydrate-protein ratio to eliminate the chronic lack of saccharides in the
ration of cattle, which is observed almost in all farms over Russia. The deficit of saccharides in the ration of cattle averaged over the cattle breeding branch in Russia is 40%, while in some livestock enterprises it reaches 70% [11].

It is generally accepted that carbohydrates play essential roles in all physiological processes in animals. On the one hand, carbohydrates are one of the main sources of energy for animals; on the other hand, they are a nutrient medium for the synthesis of microbial protein. The lack of carbohydrates in the ration of large cattle (LC) causes worsening in digestibility and accessibility of nutrient substances in forage, leads to misbalance of biochemical processes in animals and to a decrease in milk productivity and productive longevity of the animals. The negative phenomena manifest themselves especially strongly in the case of the chronic lack of carbohydrates in the ration of highly productive animals, which does not allow them to completely realize their genetic potential of productivity and causes a substantial decrease in the productive longevity.

Various methods and technologies of the treatment of grain raw materials are used to increase their digestibility and nutritional value. These methods include grain wetting, grinding, extrusion, flaking, and others. The above-listed technologies are energy-intensive and poorly governable, while high treatment temperature causes destruction of vitamins and other biologically active compounds, and leads to the side chemical reactions between proteins and carbohydrates. In addition, low conversion of cereal starch into saccharides at a level of 5-7% is observed.

One of the ways to improve the process of obtaining molasses is the use of grains subjected to the infrared thermal treatment. It is recognized that moisture present in the grains is not only released outward as a result of this treatment but also passes along capillaries and pores inside the caryopses [12,13]. The IR radiation density is rather high, so moisture concentrated in the grains is heated to 110-150 °C, which causes a rise of water vapor pressure inside the grains and the loss of hull integrity. This is accompanied by a decrease in the strength of grains, which promotes a decrease in energy consumption for subsequent treatment (grinding, flaking, etc.) and simplifies chewing by animals. This may cause an increase in the availability of biopolymers present in starch (amylose and amylpectin) for enzymes, which promotes a decrease in energy consumption for subsequent biochemical conversion.

The existing industrial technologies of starch bioconversion into saccharic starch products are complicated and multistage processes [14-16]. The morphological features of native starch, especially the semi-crystalline structure of starch granules, essentially define the accessibility for water and enzymes to amylose and amylpectin molecules. The limiting stage of the biochemical treatment of starch is the stage of its gelatination, which involves upswelling and destruction of starch granules, resulting in an increase of the viscosity of the reaction mass by three to five orders of magnitude. Efficient mass and energy transfer in highly viscous media is one of the major problems in starch industry. For this reason, it is urgent to decrease the viscosity of the starch colloidal solution and, as a consequence, to reduce energy consumption for starch bioconversion into glucose molasses. This is the subject of the current research.

The currently existing technologies for the production of grain molasses use the grain to water ratio of 1:2.5 - 4 [4-6]. The carbohydrates content in these grain molasses is 8-18% at high water concentration, which results in a decreased storage time. For instance, at a temperature above 25 ºC, low-carbohydrate molasses can be stored not longer than for 4 hours, because lactic-acid fermentation starts and carbohydrate content decreases by 1% every hour.

The current study was aimed to increase the amount of carbohydrates in grain molasses and storage time. It is also known that bacteriostatic effect is observed if carbohydrate content in solutions exceeds 38%.
2. Materials and Methods

The studies were carried out using the wheat variety Novosibirskaya 16. This is a soft summer wheat variety. It is early-ripening, with the growing period of 67-88 days. It is resistant to lodging; its resistance to droughts is standard. The average crop productivity is 0.242 t/ha. The mass of 1000 grains is 36.8 g, the grain-unit is 732 g/l. Protein content is 10-12%, starch content is 59-64%.

The effect of the parameters of IR treatment of grains on the yield of saccharides in molasses obtained by enzymatic hydrolysis of irradiated grain was studied in a mechanoenzymatic reactor (MER). These devices are hydromechanical converters of mechanical energy into acoustic, thermal and other kinds of energy, Fig 1. It is used to intensify of hydromechanical, heat and mass exchange processes in non-stationary flows during the treatment of heterogeneous media.

Fig. 1. The flowchart for obtaining concentrates molasses

The following process parameters were controlled:
- The rotor frequency, r.p.m.;
- Hydromodulus;
- Treatment time, min;
- Process temperature, °C.

3. Results

Irradiated grains are supplied into the mechanoenzymatic reactor containing the necessary amount of water. The grains are subjected to destruction and homogenization passing many times through the working units of the reactor. Simultaneously with the destruction of grains in the MER, the grain mass is heated. The stages of enzymatic bioconversion of grains (gelatination, enzymatic liquefaction and saccharification of starch) follow each other while the grain suspension is heated in the MER. Gelatination and liquefaction proceed at a temperature of 75-80 °C, while saccharification is carried out at 60-65 °C. The overall duration of the process of obtaining concentrated molasses is up to 8 hours.

Experimental data on the IR treatment of wheat grains are presented in Table 1.
Table 1 – Experimental data on the infrared treatment of wheat grains.

<table>
<thead>
<tr>
<th>Grain humidity, %</th>
<th>Duration of IR irradiation, s</th>
<th>Amount of glucose, mg/g of the dry substance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>125</td>
<td>25.32</td>
</tr>
<tr>
<td>2</td>
<td>150</td>
<td>25.63</td>
</tr>
<tr>
<td>3</td>
<td>200</td>
<td>26.73</td>
</tr>
<tr>
<td>4</td>
<td>125</td>
<td>34.05</td>
</tr>
<tr>
<td>5</td>
<td>150</td>
<td>43.56</td>
</tr>
<tr>
<td>6</td>
<td>200</td>
<td>47.45</td>
</tr>
<tr>
<td>7</td>
<td>125</td>
<td>43.67</td>
</tr>
<tr>
<td>8</td>
<td>150</td>
<td>44.56</td>
</tr>
<tr>
<td>9</td>
<td>200</td>
<td>48.93</td>
</tr>
</tbody>
</table>

It can be seen that higher grain humidity promotes higher starch dextrinization, while irradiation time has a less significant effect of starch dextrinization.

The physical essence of the process is as follows: the smaller moisture content in the grains results in the lower internal pressure of evaporated moisture inside the grains. The destruction of grain structure becomes less and dextrinization of starch in the irradiated grains becomes lower.

In the case of high humidity of grains, the degree of starch dextrinization increases, which promotes its higher availability for amylolytic enzymes during subsequent processing of irradiated grains, which causes a decrease in the time necessary for molasses production.

Table 2. Carbohydrate content in grain molasses as a function of hydromodulus

<table>
<thead>
<tr>
<th>No.</th>
<th>Hydromodulus, Grains:Water</th>
<th>Carbohydrate content in molasses, %</th>
<th>Humidity of molasses, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.0:2.5</td>
<td>18.1</td>
<td>71.5</td>
</tr>
<tr>
<td>2</td>
<td>1.0:2.0</td>
<td>21.8</td>
<td>69.6</td>
</tr>
<tr>
<td>3</td>
<td>1.0:1.5</td>
<td>30.1</td>
<td>60.2</td>
</tr>
<tr>
<td>4</td>
<td>1.0 :1.0</td>
<td>38.4</td>
<td>50.4</td>
</tr>
</tbody>
</table>

4. Discussion

Analysis of the obtained experimental data (Table 1) shows that grain humidity has a stronger effect on the level of grain starch destruction (Table 1, No. 3 vs. Nos. 6 and 7) than the duration of IR treatment. For instance, for 12% grain humidity, with an increase in irradiation time from 125 s to 250 s, the difference in the extent of destruction was 1.41%. For 15% grain humidity, this difference was 13.4% (Table 1, Nos. 4-6). With an increase in grain humidity to 18%, the difference of the amounts of glucose after IR treatment was 5.34% (Table 1, Nos. 7-9). Comparison of the effect of grain humidity for identical treatment time gave the following results. For irradiation time of 125 s, the difference in glucose content in the grains with 12% and 15% humidity was 8.73 mg/g (Table 1, No. 1 vs. No. 4), while the difference between glucose content in 15% and 18% humidity grain was 9.62 mg/g (Table 1, No. 4 vs. No. 7).
5. Conclusions

Thus, the obtained result provide evidence that preliminary IR treatment of grains may be used as a stage of preliminary treatment, which results in a decrease in grain strength. In this connection, the necessary time and energy consumption for obtaining molasses from irradiated grains through subsequent crushing decrease, and shorter time is required for obtaining molasses. This is explained by the increase in the availability of substrate molecules for amylolytic enzymes after IR treatment of grains. Low microbiological contamination provides long-term storage of molasses. So, IR treatment of grains makes it possible to obtain concentrated suspensions with long storage time.

References

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