Fermentation of an oat drink enriched with sunflower root inulin

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Abstract. The use of secondary raw materials to obtain useful products is a relevant direction of research. So sunflower root remains in large quantities after harvesting sunflower. For example, in 2021, after harvesting sunflower, about 67 million tons of dry organic residues of this plant remained in the fields. The possibility to use sunflower roots for inulin production is interesting, so earlier sunflower roots were examined for the presence of inulin in it. Studies have shown that up to 10% of inulin can be found in sunflower roots. Inulin is a dietary fiber and a prebiotic and has a beneficial effect on the microbiome of the gastrointestinal tract. The development of fermented oat drinks will provide a combination of the functional properties of probiotic cultures with the prebiotic properties of inulin from sunflower root. In this article, two technological schemes for the production of a functional oat drink containing inulin extract from sunflower root are investigated. For the fermentation of the drink, lactic acid bacteria of the species Lactobacillus acidophilus were chosen. Several variants of beverage formulations were investigated. The dynamics of changes in the content of inulin during fermentation for 24 hours is presented.

1 Introduction

The growing prevalence of various diseases associated with unbalanced nutrition has encouraged scientists in the pharmaceutical and food industries to innovate and look for additional alternatives for the development of new medicines and food products. The decline in the quality of lifestyle and eating habits has increased the prevalence of digestive disorders among consumers, which has led to an increase in the demand for dietary fiber. Dietary fibers such as inulin have health benefits and are therefore increasingly used to treat various diseases. Inulin is a polysaccharide with a wide range of therapeutic uses, such as a drug delivery vehicle, as a diagnostic tool, or as dietary fiber, which have a number of beneficial properties. With many health benefits, inulin is primarily used in medicines to support the immune system and treat digestive problems.

Improvement in the condition of patients with diabetes, obesity and lowering cholesterol levels through the consumption of inulin has led to an increase in demand for dietary fiber.

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Inulin is also known to stimulate the bowels. Eating enough inulin and other dietary fiber can prevent or relieve constipation. The use of inulin is relevant not only in the daily diet, but also in the production of sports nutrition. Because soluble fiber helps soften stools and support muscle performance, endurance, and muscle repair before, during, and after exercise, dietary fiber such as inulin is very beneficial. Thus, products with dietary fiber open up opportunities for manufacturers of functional and sports nutrition. The increase in consumption of energy supplements by athletes will drive the growth of the inulin market during the forecast period [1].

Inulin is an excellent fat substitute and is used in moist or semi-moist foods. Inulin as a fat substitute is used to provide some or all of the functional properties of fat while providing fewer calories than the fat being replaced. Inulin is used in a variety of foods, from baked goods to frozen desserts. It is ideal for low-fat products where it can improve texture and mouthfeel, reduce the calorie content of products without sacrificing taste or texture, and improve the stability of milk mousse and foams [2].

The growing popularity of prebiotic ingredients coupled with an increased awareness campaigns to reduce fat and calories are expected to drive the global inulin market. What's more, inulin has been recognized as a safe food ingredient by government-authorized food and drug organizations in several countries [3].

The main products in which inulin is used are: clinical nutrition, dietary supplements, functional foods and drinks, dairy products, baby food, breakfast cereals and cereal bars, meat products, animal nutrition (Fig. 1). An important driver of growth in the global inulin market is the growing dairy industry. Inulin is widely used in dairy products such as cheese, yogurt, ice cream and fermented milk products. The market value of dairy products in the world is growing rapidly. Among various dairy products, yoghurts and drinking yoghurts are growing applications in which the content of prebiotics is very high. Inulin is primarily used in dairy products as a texture modifier and as an alternative to sugar and fat. In fact, inulin and oligofructose are among the most widely tested prebiotic fibers available, providing soluble dietary fiber. The threat of substitution by other prebiotic ingredients and the high cost of scientific research are the main factors holding back the global inulin market. The growing market for prebiotics such as pectin and beta-glucans is also a major deterrent to the global inulin market [4].

![Fig. 1. The ratio of segments of the inulin market in Europe.](image)

The global inulin market is valued at US dollars 1.9 billion in 2020. In the following years of the COVID-19 pandemic and the economic crisis, consumers have started to pay more attention to their health. Therefore, there is an increased consumer interest in functional products.
The health shift of consumers creates better opportunities for manufacturers of inulin for nutritional supplements and functional foods. In addition, the growth of the inulin market is being driven by consumer spending on health food due to health trends. Inulin also tends to have a higher nutrient content, which includes fiber and minerals such as potassium and calcium, proteins and vitamins, including vitamin C. The rise in inulin consumption is likely to attract new consumers to the inulin market.

So in a number of marketing studies analyzed for the period 2020-2027. By the end of the analysis period, the Food & Beverage Supplement sector is predicted to have the compound annual growth rate (CAGR) of 7.9% to reach US dollars 1.9 billion. After a preliminary analysis of the impact of the pandemic on this sector, the average annual growth rate was revised to 9% by the end of the analysis period. As a result, the global inulin market will reach a revised size of 3.3 billion US dollars by 2027, while the average annual growth rate will be 8.2% for the analyzed period 2020-2027 (Fig. 2).

Europe holds the bulk of the inulin market and is likely to dominate the market in the near future. The existence of a favorable regulatory policy for the use of functional ingredients, mainly in food and beverages, is one of the main reasons for the strong growth rate in the region. However, due to an increase in the elderly population and increased consumption of baby food, the inulin market in Asia-Pacific and North America is expected to experience notable growth during the forecast period. In established markets such as Europe and North America, consumers are more inclined to buy value-added products, preferably clean label, natural ingredients, organic, plant-based and other alternatives, which are increasingly part of a healthy diet. With increasing consumer health awareness in the region, the demand for organic inulin is also on the rise [2].

The U.S. market for inulin is valued at 518.1 million US dollars in 2020. China, the second largest economy in the world, is projected to have a market size of US dollars 755.4 million by 2027 and a CAGR of 12.3% over the analyzed period from 2020 to 2027. In Europe, Germany is predicted to grow at around 5.3% per annum. By 2027, the Asia-Pacific market, led by countries such as Australia, India and South Korea, is expected to reach 462.6 million US dollars, while in Latin America the average annual growth rate during the analyzed period will be 9.7% [6; 7].

Currently, inulin enters the Russian market through imports (Fig. 3). Every year the import of inulin is growing (Fig. 4). For the period up to 2030, the consumption of inulin per year for Russia will approximately be 255-260 thousand tons [8].

![Fig. 2. Global inulin market (billion US dollars) [5].](image-url)
Inulin is present in tubers, bulbs and tuberous roots of over 36,000 plants belonging to both the monocot and dicot families [10]. The main sources of inulin for global companies are chicory, Jerusalem artichoke and agave [11].

Most of the commercially available inulin worldwide are obtained from the roots of chicory (*Cichorium intybus* L.). Chicory is a plant rich in inulin, its fleshy roots contain 15-20% inulin. However, in recent years, agave fructans have been studied in Mexico [12; 13]. Agave contains on average 7-10% inulin [10]. Jerusalem artichoke is a promising source for the production of inulin in Russia. Jerusalem artichoke is an important raw material, which accumulates about 12-19% of inulin. The content of inulin is 80% of the total amount of carbohydrates present in the tuberous roots of Jerusalem artichoke [10; 14].

The limiting factor for the development of the Jerusalem artichoke market in Russia is:
- unformed demand for culture;
- lack of Russian raw materials on an industrial scale;
- short shelf life;
- shortage or complete absence of a complex of - machines for mechanized technology of cultivation and processing,
- limited technologies for complex processing, as well as technologies for semi-finished products for public catering and retail trade [15].

There are other plant sources of inulin. Sunflower belongs to the same *Asteráceae* family as chicory and Jerusalem artichoke. Previously, sunflower roots were examined for the presence of inulin in them, and studies have shown that sunflower roots contain up to 10% inulin [16]. Sunflower root remains in large quantities after sunflower harvesting. In 2021 the total area of sunflower fields in Russia amounted to 9.6 million hectares, and after sunflower harvesting, about 67 million tons of dry organic residues of plant residues remained in the field.
The use of sunflower root containing inulin for the production of functional products is relevant in the context of the development of population diseases associated with unbalanced nutrition. An interesting possibility is the creation of a product that also contains probiotic lactic acid bacteria. The development of fermented oat drinks will combine the functional properties of probiotic cultures with the prebiotic properties of inulin from sunflower root. However, it is necessary to take into account the degree of consumption of inulin by lactic acid microorganisms in order to create a balance of prebiotics and probiotics and use the benefits of these two components [17, 18].

Thus, the aim of the work was to establish the possibility of using an oat base with inulin extract from sunflower root for fermentation with lactic acid bacteria.

2 Materials and methods

As the main research material, a plant base of crushed oatmeal was used. With a degree of flattening 20%. The source of inulin was the sunflower root of the Voronezhskij 638 variety. As a probiotic, a commercially available culture of microorganisms Lactobacillus acidophilus sold in a retail trade network, was used. In the literature it is noted that I consume inulin and bifidobacteria better, but in our study, less active consumption of inulin was important [19]. Therefore, lactic acid bacteria were chosen, which will probably have a probiotic effect, but consume inulin less actively [20].

In the work, two technological schemes were used for the production of a functional drink. The difference is that in the first scheme, the extraction of inulin from the sunflower root was carried out in an oat base, in the second scheme, a ready-made inulin extract from the sunflower root was added to the oat base. The amount of sunflower root powder or inulin extract from sunflower root used was determined based on the content of inulin in the food product recommended in regulatory documents (Table 1) [21].

Table 1. Theoretical background for the development of a fermented oat drink enriched with inulin contained in sunflower root.

<table>
<thead>
<tr>
<th>Theoretically justified content of inulin in the drink after fermentation, mg/100g</th>
<th>The content of the sum (average) of fructosides and fructosans in terms of inulin in the drink before fermentation in the studied samples, mg/100g</th>
</tr>
</thead>
<tbody>
<tr>
<td>500 ± 50</td>
<td>690 ± 50</td>
</tr>
</tbody>
</table>

The content of inulin was determined according to the method described in an earlier article [16].

Thus, the production process of a functional drink was carried out in the following steps:
1. Oat flakes are mixed with hot water 90 °C and held for 1 hour;
2. Grinding oatmeal;
3. Sunflower root is crushed to a powder with a particle size of up to 1 mm;
4. Sunflower root powder is added to the oat base and extraction is carried out at 60 °C for 1 hour;
5. Filtering oat through gauze;
6. Cooling the resulting oat base with sunflower root powder to 35 °C and determining the content of inulin in the oat base;
7. Preparation of culture of lactic acid bacteria. To activate the preparation of lactobacilli and obtain starter cultures, the recommendations of the manufacturers were used, according
to which the vial of the preparation was added to 25 ml of a pre-sterilized oatmeal base. Incubation was carried out at 37°C for 12 hours.

8. 0.25% of the starting culture is added to the oat base containing sunflower root inulin. Fermentation was carried out at 35°C for 24 hours.

9. Cooling of the fermented drink to 3-7 °C;

10. Filling drink.

Schematic diagram of a fermented oat drink with sunflower root is shown in the Figure 5.

**Fig. 5.** Proposed technology of fermented oat drink.

Another way to add inulin from sunflower root has been suggested (Fig. 6). Inulin was extracted from the sunflower root for an hour at 75°C. The resulting extract was evaporated in a vacuum evaporator. The resulting inulin extract concentrate was added to the oat base of the drink.

**Fig. 6.** Modified technology of fermented oat drink.
3 Results

The studied formulations of the fermented oat drink are presented in the Table 2. The ratio of water and crushed oats was chosen by previous experiments. The choice of application dose of sunflower root powder or inulin extract from sunflower root was determined on the basis that it is necessary to take into account the recommended levels of inulin intake and at the same time not significantly change the oat taste and aroma of the drink. The dose of lactic acid organisms is in accordance with the manufacturer's recommendations.

Table 2. Fermented oat drink recipe options.

<table>
<thead>
<tr>
<th>Recipe №</th>
<th>Crushed oats, g/dm³</th>
<th>Sunflower root, g/dm³</th>
<th>Type of inulin applied (from sunflower root)</th>
<th>Type and dosage of lactic acid bacteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>№1</td>
<td>150</td>
<td>20</td>
<td>powder</td>
<td>1*10⁶ KOE Lactobacillus acidophilus</td>
</tr>
<tr>
<td>№2</td>
<td>150</td>
<td>30</td>
<td>powder</td>
<td></td>
</tr>
<tr>
<td>№3</td>
<td>150</td>
<td>40</td>
<td>powder</td>
<td></td>
</tr>
<tr>
<td>№4</td>
<td>150</td>
<td>20</td>
<td>concentrate</td>
<td></td>
</tr>
<tr>
<td>№5</td>
<td>150</td>
<td>30</td>
<td>concentrate</td>
<td></td>
</tr>
<tr>
<td>№6</td>
<td>150</td>
<td>40</td>
<td>concentrate</td>
<td></td>
</tr>
</tbody>
</table>

The results of determining the content of inulin in the drink before fermentation and after fermentation are shown in Figure 7.

Fig.7. The dynamics of changes in the content of inulin during fermentation for 24 hours.

4 Conclusion

The results obtained generally indicate that it is possible to use oatmeal as a nutrient medium for the development of lactic acid microorganisms. Lactobacillus acidophilus consumes inulin from oatmeal drink, with enough inulin remaining in formulations 3 and 6 to meet regulatory requirements [21].
As previously suggested, the addition of sunflower root powder allows the extraction of inulin from sunflower root slightly more, but the use of concentrated sunflower root inulin extract is more convenient in production.

5 References

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