Deep processing of waxy corn as a promising direction for the use of plant raw materials

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Abstract. The paper analyzes modern methods of processing waxy corn to obtain starch and other products. The influence of the structural features of amylopectin starch on the technological process and the use of waxy corn in various industries is studied. The promising use of waxy corn starch in the production of food products, pharmaceuticals, biodegradable materials and biofuels is revealed. The main directions of development of waxy corn production in Russia are studied, allowing to reduce dependence on imports and increase the efficiency of the agro-industrial complex. Examples of the complex use of by-products of waxy corn processing are presented, which ensures increased production efficiency and the development of the bioeconomy.

1 Introduction

Plant materials play a key role in the development of many industries, including food, pharmaceutical, textile and biofuel. With the population growth and growing demand for environmentally friendly and efficient sources of raw materials, the processing of plant material is becoming increasingly important. Of particular interest is waxy corn (Zea mays ceratina) - a type of corn consisting almost entirely of amylopectin starch (up to 100%). Due to its unique properties, such as high viscosity, resistance to freezing and stability when heated, waxy corn is a promising raw material for deep processing.

Despite the growing global interest in waxy corn, its use and processing are poorly developed in Russia, which is due to the lack of adapted hybrids and low awareness of its potential. At the same time, the development of this area can significantly increase the economic efficiency of the country's agro-industrial complex and reduce dependence on imported starches and processed products. Waxy corn can become an important component in the production of high-value-added products, including food ingredients, biodegradable materials, and bioethanol.

The purpose of this article is to analyze modern methods of processing waxy corn, identify its prospects for various industries, and outline the main directions for the development of this type of raw material in Russia.

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2 Main part

2.1 Characteristics of waxy corn

Waxy corn (Zea mays ceratina) is a unique variety of corn, characterized by an almost complete content of amylopectin starch in the grain, which makes it especially valuable for industrial use. Unlike ordinary corn, where amylopectin makes up only 25-30% of the total starch content, waxy corn consists almost entirely of this component. This feature gives it high technological value and opens up wide opportunities for processing.

The main difference of waxy corn is the structure of the starch. Amylopectin in its grain is a branched molecule that has increased viscosity and the ability to form stable gels. Due to this structure, the grain acquires specific properties, such as stability when heated and cooled, which makes it ideal for use in technological processing. The resistance of amylopectin starch to retrogradation (loss of properties with repeated heating or cooling) is especially valuable for products that undergo heat treatment or long-term storage, such as frozen foods and sauces [7].

Waxy corn grain also contains a small amount of proteins, lipids, fiber and other biologically active substances, but their proportion is smaller compared to regular corn. This ensures the purity of the isolated starch and facilitates its further processing. High viscosity and the ability to gel make this type of amylopectin starch a sought-after ingredient in various industries, including the food, pharmaceutical and textile industries. It is these features that give waxy corn its unique value as a raw material for further processing.

2.2 Processing of waxy corn starch

The process of processing waxy corn to obtain starch is a sequence of stages, including grinding the grain, separating the starch from other components, cleaning and drying it. First, the grain is mechanically ground, which destroys the structure and allows the release of starch granules. Then the starch is separated from the fiber, proteins and other components using washing, centrifugation and filtration. Additional enzymatic treatment allows removing residual protein and fat inclusions, which improves the quality of the resulting starch.

Amylopectin starch extracted from waxy corn is widely used in various industries in Russia. The demand for it is due to its unique properties, which make it indispensable in the production of food, medicine and technical products. The pie chart (Figure 1) shows the distribution of the use of amylopectin starch by key industries.

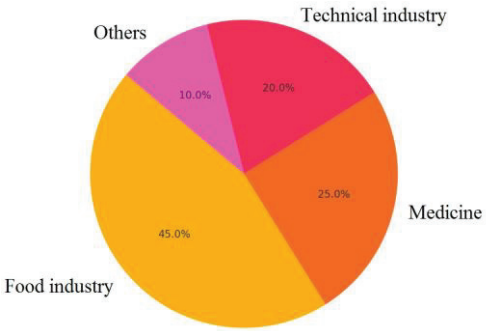

Fig. 1. Shares of industries in the consumption of amylopectin starch.

The food industry accounts for the largest share of use (45%), where amylopectin starch is valued for its ability to stabilize products, provide the necessary texture and improve freezing properties. Its use in the food industry is particularly effective for the production of products that require a thick consistency, such as sauces, puddings and creams, as well as in frozen products, where stability during freezing and thawing is important. The medical industry accounts for 25%, where the starch is used to create biocompatible and biodegradable materials, as well as in the production of drugs, including the role of a binder and filler for tablets and capsules, and as a thickener for syrups and suspensions. The technical industry accounts for 20% of use, where amylopectin starch serves as an adhesive and thickening agent in the production of paper, textiles and other goods, and also allows fabrics to be given the desired density and structure. The remaining 10% are from other industries, demonstrating the versatility of this product [9].

The economic efficiency of waxy corn starch processing is due to its high added value in the international market, where it is valued significantly higher than regular starch due to its unique properties. The use of such starch in production allows to reduce the cost of finished products, improve their quality and increase competitiveness. There is significant potential for the development of waxy corn production in Russia, which will reduce dependence on imports and provide the domestic industry with high-quality raw materials. Given the shortage of waxy starch and its importance for strategic industries, it is necessary to consider the issue of developing and supporting domestic production. This will make it possible to strengthen Russia's position in the international starch products market, meet the growing demand for this product in key sectors of the economy and expand the use of waxy corn in various industries [2]

The waxy starch market in Russia has faced serious challenges since the introduction of sanctions in 2022. This product plays a key role in the food, pharmaceutical and technical industries due to its unique properties, such as high viscosity and freeze resistance. Import restrictions have significantly reduced access to waxy starch, leading to an increased shortage in the domestic market (Figure 2).

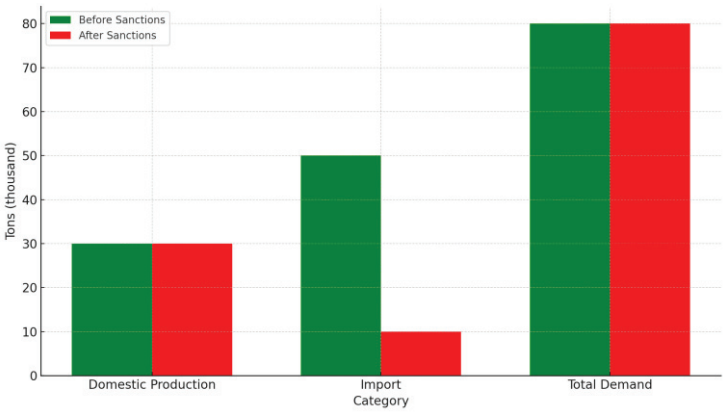

Fig. 2. Changes in import volumes and domestic production of waxy starch in Russia due to sanctions, 2022.

The diagram compares domestic production and import volumes of waxy starch before and after the sanctions were imposed. As can be seen, the import volume, which previously amounted to 50 thousand tons, fell to 10 thousand tons, which created a critical deficit with a total demand of 80 thousand tons. Domestic production remained at 30 thousand tons, which is clearly insufficient to meet market needs. Such a deficit puts pressure on prices

and can lead to increased costs in industries using waxy starch, as well as disruptions in production. Thus, the situation requires immediate attention and investment in the development of domestic waxy starch production [4]

Thus, waxy corn starch processing is a promising area that can ensure a stable supply of high-value-added products to the industry, increase production profitability and improve product quality in various market segments.

2.3 Production of syrups and molasses

The production of syrups and molasses from waxy corn is one of the most promising areas of processing this type of raw material due to its high properties and wide range of applications in various industries. One of the main products obtained from waxy corn is glucose-fructose syrup, which is widely used in the food industry. The process of producing glucose from starch includes several stages, including enzymatic hydrolysis, filtration, crystallization and subsequent centrifugation [11].

According to the study by V. V. Ananskikh and L. D. Shlein (2016), up to 109.81 kg of dry matter of glucose syrup can be obtained from 100 kg of starch during enzymatic hydrolysis of high-purity starch. After filtration and removal of impurities, the yield can decrease to 105.61 kg. This process allows achieving a concentration of glucose syrup up to 73-75% of dry matter, which is then sent for crystallization [1].

The use of glucose-fructose syrup on the Russian market is gradually growing, and its consumption volumes are increasing annually (Figure 3).

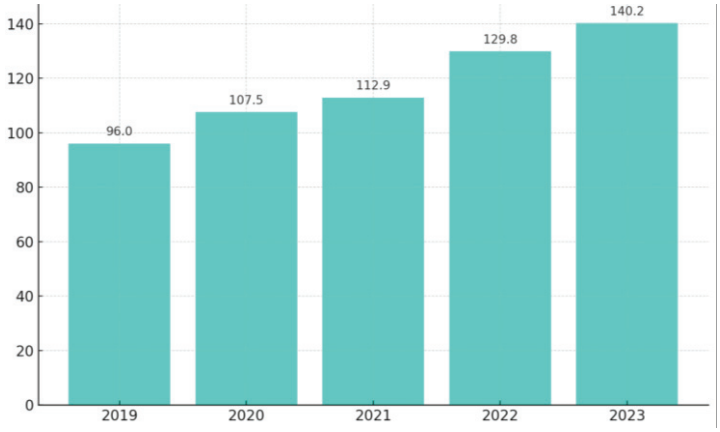

Fig. 3. Dynamics of consumption volumes of glucose-fructose syrup in Russia.

In the period from 2019 to 2023, the consumption of glucose-fructose syrup in Russia increased from 96 to 140 thousand tons per year and continues to grow every year. This is due to the replacement of sugar in the production of drinks, jams, canned goods and other products with more affordable and cost-effective glucose-fructose syrup, which improves the stability of products and preserves their taste. Unlike sucrose, glucose-fructose syrup is not subject to crystallization and ensures a long shelf life of products [3].

2.4 Production of Biodegradable Materials

Biodegradable materials derived from waxy corn are becoming increasingly important in the production of environmentally friendly products. The graph (Figure 4) shows the distribution of production volumes of biodegradable and non-biodegradable materials based

on bio-based raw materials in 2021 and 2022. The total production volume increased from 2,060 thousand tons in 2021 to 2,112 thousand tons in 2022. At the same time, the share of biodegradable materials increased from 885 to 912 thousand tons, indicating a trend towards replacing traditional plastics with more environmentally friendly alternatives. The amount of non-biodegradable materials also increased, but at a slower pace - from 1,175 thousand tons in 2021 to 1,200 thousand tons in 2022. This indicates the continuing development of the bio-based materials market and the need for further implementation of biodegradable solutions [8, 10].

Fig. 4. Dynamics of production of biodegradable and non-biodegradable materials.

Figure 5 shows the structure of global production of biodegradable polymers in 2022.

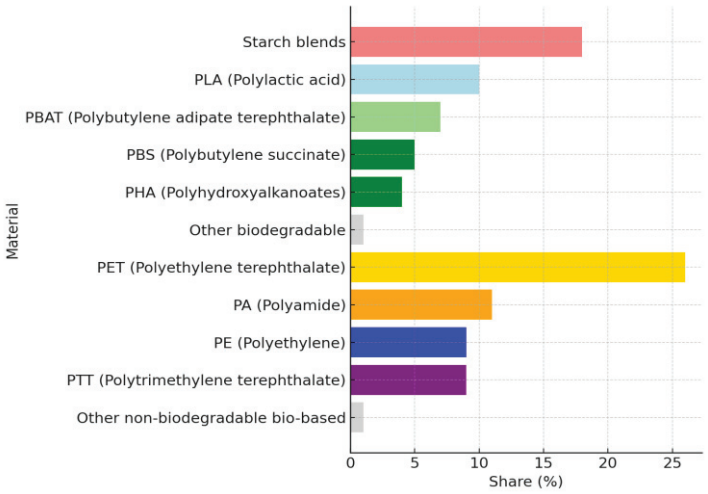

Fig. 5. Structure of global production of biodegradable polymers, 2022.

The main contribution to the production of biodegradable materials was made by starch mixtures (18%), which confirms the importance of waxy corn starch in the creation of environmentally friendly materials. PLA (polylactide) accounts for 10%, PBAT (polybutylene adipate terephthalate) - 7%, and PBS (polybutylene succinate) - 5%. The main part of non-biodegradable materials based on bio-raw materials is made up of PET (26%), PA (11%), PE and PTT (9% each). Such a market structure demonstrates the

potential for further expansion of the use of starch mixtures and other biodegradable materials, especially in the context of the introduction of waxy corn into production.

For Russia, the prospects for development in this area lie in the possibility of introducing advanced technologies for processing waxy corn and increasing the production of biodegradable materials. This will help meet domestic demand for environmentally friendly packaging and products, as well as strengthen positions in the global market for biodegradable polymers, which is especially important in the context of the global transition to sustainable technologies [6].

2.5 Bioethanol and biofuel production

Bioethanol production from waxy corn is a promising area for the development of alternative energy sources in Russia. Bioethanol production technologies include wet and dry milling, in which waxy corn starch is converted into ethanol using fermentation processes. In 2021, global bioethanol production reached 103.3 billion liters, and in 2022 it increased to 106.4 billion liters, indicating a steady growth in demand for this type of fuel. Despite the presence of significant raw material potential, Russia is still lagging behind in the development of the bioethanol market due to the abundance of hydrocarbon resources. However, the introduction of bioethanol production from waxy corn can be an important step towards the country's energy independence. In the context of the transition to environmentally friendly fuels, the development of this area will reduce dependence on imported fuel sources, strengthen energy security and create new jobs in the agricultural sector and processing industry [5, 12].

3 Conclusion

Waxy corn is a valuable raw material for deep processing, possessing unique physical and chemical properties. The high content of amylopectin in the grain makes it in demand for the production of starch, syrups, biodegradable materials and bioethanol. The use of modern processing technologies allows for the maximum use of the potential of waxy corn, ensuring the production of products with high added value and promoting the development of environmentally friendly technologies. Further research and improvement of waxy corn processing technologies will open up new opportunities for the efficient use of this raw material in various industries, increasing the economic efficiency and sustainability of the agro-industrial complex.

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