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Economic analysis of the production process of targeted edible fats through post-addition hydrogenation and their market applications

Karim Sattarov*
Doctor of Technical Sciences, Dean of the Faculty
Gulistan State University
120100, 4 Microdistrict, Gulistan, Uzbekistan
https://orcid.org/0000-0002-3847-0660

Guljakhon Norimova
PhD in Pedagogical Sciences, Head of Department
Gulistan State University
120100, 4 Microdistrict, Gulistan, Uzbekistan
https://orcid.org/0000-0001-5955-054X

▸ **Abstract.** The fat production industry is one of the key and fast-growing components of the food sector of Uzbekistan, and therefore, it is relevant to analyse the economic part of its crucial elements. The purpose of this study was to examine the hydrogenation process from the standpoint of production cost features and pricing issues. The methods employed in the study were descriptive, systematisation, and dialectical. The study showed that the production and utilisation of targeted edible fats play a vital role in the food industry by achieving certain characteristics of other products. However, a hydrogenation procedure is often used to make the fats more efficient. The study described its essence in greater detail and evaluated the economic feasibility of the hydrogenation process. The significance of choosing the correct reactor and catalysts to maximise yield was highlighted, as well as the influence of some other characteristics on it. The study also addressed the disadvantages of the fat hydrogenation process, which has a negative impact on public health. Therefore, activities aimed at mitigating negative impacts in this industry should be carried out more actively. Furthermore, attention has also been paid to assessing the state of the edible fats market in Uzbekistan: the rapid growth rate of the industry has been noted due to the increasing revenues of enterprises engaged in the production of these products. The obtained findings can be applied by enterprises to change the principles of hydrogenation process, as well as by the state authorities to formulate a long-term policy for the development of the industry

▸ **Keywords:** chemical treatment; cost-effectiveness; hydrogenation reactor; healthcare; industry

▸ Introduction

As such, dietary fats play a vital role in the health and normal functioning of the human body: they are the most concentrated source of energy among food components (Ahmed *et al.*, 2021; Kolobe *et al.*, 2023). Some fats are part of cell membranes, neurons, and other structural components of the body. They also act as a protective layer for internal organs, which helps them avoid damage during physical impacts, and they also form an insulating layer that helps maintain optimised body temperature during c old weather (Nicholson & Marangoni, 2021). Hydrogenation allows achieving some special characteristics of the fats: it allows solidifying them, thereby increasing their resistance to oxidation, temperature, improving their taste and aroma (Su *et al.*, 2022). Although the hydrogenation process can produce trans fats, which can be harmful to health if consumed in excess, finding effective approaches to the process is still important. Furthermore, it stays important to assess whether it is still economically feasible to hydrogenate fats, as well as the market characteristics of these products in Uzbekistan.

In the current literature, there are few studies that have evaluated and examined the production of target edible fats in detail, including from the standpoint of economic analysis. D. Rakhimov *et al.* (2024) considered the possibilities of solving the problem of obtaining hydrogenated modified fats by hydrogen treatment with

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*Corresponding author

catalysts such as nickel, cobalt, and iron. There is a need to switch to health and environmentally safer catalysts, but this part of the problem has not been addressed in detail within the scope of the cited study.

N. Sabirova & M. Sadikova (2023) tried to increase the sustainability of the food industry by expanding the range of shortening fats with new types of fat sources. As a result, it was possible to create shortening fats in plastic, liquid, and granular forms, each designed for a specific food use. In the future, this could be used in practice to make more efficient use of fats in the food industry as a whole. Nevertheless, all the above-mentioned studies did not consider the economic component of food fats production, nor did they mention hydrogenation as one of the types of their processing.

Quite a few scientists have devoted their attention to evaluating different approaches to the processing of dietary fats. Thus, P. Albrand *et al.* (2021) proposed a new model for hydrogenation of sunflower oil using palladium catalyst. They noted that the proposed model should simplify the reaction mechanism based on key assumptions about the composition of sunflower oil. M.S.W. Lim *et al.* (2021) investigated the features of selected catalysts for the hydrogenation process. They proposed some original approaches to fat processing, specifically using catalysts synthesised using ultrasound. The researchers showed that ultrasound treatment altered the selectivity of the product, reducing the production of trans fats compared to catalysts not treated with ultrasound. Notably, the two studies cited above are tremendously important in the context of improving the quality situation of hydrogenation. Nevertheless, there are really few studies in the world that address the economic aspect of the issue of food fat production, which once again indicates the relevance of this study.

Thus, the purpose of this study was to analyse all aspects of hydrogenation from an economic standpoint (assessing the level of profitability of enterprises that are engaged in this type of activity, as well as the current situation in this market). This allowed developing some recommendations for enterprises on the formation of the specific features of conducting their activities from both technical and economic standpoints.

Materials and methods

The study evaluated the economic feasibility of fat hydrogenation. In other words, opinions were formed on whether it was advantageous to hydrogenate fats in terms of benefits. Nevertheless, there are many difficulties in these assessments. The price of this type of product is not publicly available due to the specificity of the goods needed for the hydrogenation process: therefore, it is difficult to determine a clear market price for it without direct negotiations with manufacturers and suppliers. In this regard, the values assumed within the framework of this study, albeit presumably close to the real values, may differ from the real values obtained by entrepreneurs directly in their work.

Considering the specific features of finding and performing analytics on the information found, many indicators were calculated based on the small amounts of data that could be found, e.g., an approximate estimate of 20 litres of cotton oil based on data on five; an approximate estimate of the wage of a worker servicing the fat production process based on approximate wage estimates for this kind of specialists. Nevertheless, some indicators were also employed, which are used to assess the financial condition of the enterprise, namely ROI (return on investment), which within the framework of the study was calculated as net profit (before or after tax) in relation to the level of investment in equipment for the production of products. Formula 1 is presented below, which illustrates how the calculation is carried out:

$$\text{ROI} = \frac{\text{Profit}}{\text{Investments}} * 100\%, \quad (1)$$

where ROI – the return on investment; Profit – the net profit; Investments – the volume of invested investments.

Therewith, as already noted, the study employed two approaches to estimating ROI: with and without tax deductions, which initially affects Profit, and thus profitability. The study also assessed the overall state of the edible fats industry in the country. For this, some statistical data were used, namely regarding the income received by entrepreneurs in Uzbekistan in this sphere, as well as the level of offline and online sales of edible oil. Thus, data were used from the Oils & Fats – Uzbekistan (n.d.). Notably, it provides data up to 2017 to 2029: accordingly, information from 2024 to 2029 is projected, and while it may provide some information on likely future trends in the industry, it is not entirely reliable.

Certain scientific methods were also employed within the framework of the study. The systematisation of information within the study (regarding the state of the hydrogenated fats market, prices and costs of production) helped to simplify the analysis process, making it more unified and holistic. Abstraction made it possible to analyse certain concepts and variables outside any systems, i.e., in isolation. The dialectical method helped to analyse different sources of information to form a single conclusion on them based on the negative and positive components of each side. Separate approaches to assessing the financial performance of an enterprise were also used.

Results

Unlike conventional hydrogenation, which leads to the formation of harmful trans fats, step-by-step hydrogenation considerably reduces their content, which is caused by the specific features of the technology, the essence of which is the gradual addition of hydrogen at several stages. Stage-hydrogenated fats also have a better resistance to oxidation, which makes them more resistant to spoilage and extends their shelf life, which is especially significant for food manufacturers, because it allows them to produce products with a long shelf life without the addition of artificial preservatives. The texture quality of such products is also better. Furthermore, the stepwise hydrogenation process can be tuned to produce fats with different properties, namely hardness, plasticity, and stability (Puprasit *et al.*, 2022). This reduces the risk of product spoilage and increases shelf life. All this shows the clear advantages of using the stepwise hydrogenation approach over any other methods.

At the heart of the fat hydrogenation production process is the reactor. It is equipped with a special stirrer,

called a combined gas supply system, which is the basis for carrying out the hydrogenation process. In the hydrogenation reactor, hydrogen is fed to a high-efficiency impeller at the bottom where it is dispersed in tiny gas bubbles (Cho *et al.,* 2021). Additionally, a gas turbine, which has a self-flushing mechanism, circulates unreacted hydrogen, which accumulates in the free space of the reactor, back to the reaction mixture via a hollow shaft. This ensures that there is always enough dissolved hydrogen available for the chemical reaction and provides the appropriate conditions for hydrogenation. The price of this kind of reactors can vary greatly depending on the individual parameters, namely maximum filling volume, design temperature, pressure, as well as some other characteristics.

The price of a reactor can vary considerably depending on what features it has. Moreover, this information is rather non-public, as it is quite difficult to find any data in the public domain regarding how much generators of this kind cost. Their price is formed based on personal agreements between the manufacturer and the potential buyer. Nevertheless, the study still managed to form some price frames, at around USD 10,000 for a 20-litre reactor, considering all possible associated costs. In this case, the hydrogenation process can take 6-24 hours; thus, it is assumed that only one portion of fats that have undergone the hydrogenation procedure can be obtained within one working day (Lee *et al.*, 2021).

However, to carry out this process, other elements are also required, namely the fats themselves (the raw material for hydrogenation), hydrogen (the gas that is added to the reactor to react with the double bonds in the fats) and catalysts (it is to be assumed that the additional equipment that may be needed to carry out the hydrogenation process is already available or was purchased with the purchase of the generator). On one of the Uzbek marketplaces, the price for 5 litres of cotton oil is UZS 92,000, i.e., about USD 7.26; for 20 litres one will have to pay USD 29; the catalyst will cost about the same amount. Therewith, the price of hydrogenated cottonseed per 1 litre is at USD 4.2, i.e., USD 84 for 20 litres. Considering energy costs of about USD 2 per day, as well as a minimum of 1 employee with an average salary of USD 350/month, one obtains a production cost price of about USD 72, while its selling price is USD 12. A net profit per year is USD 4,380 before taxes, which is about 43.8% per annum, with a payback period of 2 years and 4 months, or USD 3,504 at a rate of 20%: in this case the rate of return is 35% per annum, and payback will occur in 2 years and 11 full months.

Notably, the above calculations are rather approximate, and in reality, the yield may turn out to be somewhat higher or lower. A description of the variables affecting possible changes in the profitability of hydrogenated fats production is presented in Table 1.

Table 1. Estimation of the impact of individual variables on the profitability of fat hydrogenation

No.	Variable	Influence
1	Reactor volume	Within the framework of the study, the evaluation was based on a 20-litre reactor. However, better results will be achieved if larger fixtures are used
2	Decrease in reactor cost per litre with volume increase	While a 20-litre reactor may cost around USD 10,000, if the volume of the apparatus to be purchased increases by n times, its price will increase at a comparatively lower rate, resulting in a faster payback period
3	Number of employees	One worker is more than enough to handle a reactor with a capacity of 20 litres. In this regard, when working with a larger sized equipment, e.g., 50 or 100 litres, hiring even an additional 1, 2, or 3 workers (if required) will allow for higher incomes overall
4	Additional costs	Estimates of product delivery, service, and other operating costs were not used as part of the calculations. Still, they should not be so noticeable in terms of their impact on the cost of production at high volumes
5	Catalyst cost	The estimated cost of the catalyst for the hydrogenation process is approximate, and in real conditions may turn out to be both higher and lower

Source: compiled by the authors of this study

Table 1 shows that there are both variables that can actually have both positive and negative effects on the resulting returns. Nevertheless, due to the scalability of this business, it is worthwhile to generally expect more positive results from this type of business due to the economies of scale generated by the purchase of a larger scale reactor.

In Uzbekistan, the oil and fat industry is one of the main industries in the food production sector. It covers oilseed production, vegetable oil processing, and the production of various products such as edible oils, margarines, and industrial fats. With the transition to a market economy, Uzbekistan has made considerable progress in diversifying the processing of oilseeds, especially soya beans, and developing local cultivation of oilseeds such as safflower, sunflower, and sesame. The internal market for oil and fats products in Uzbekistan is sustainable, fuelled by growing consumption by households, food producers, and a growing population. To better understand the current state of the edible fats market in Uzbekistan, it is worth evaluating the individual data that can describe them. Thus, Figure 1 shows the profits earned by the industry representatives. As Figure 1 shows, the income earned by producers of edible fats in Uzbekistan is constantly increasing. Thus, between 2023 and 2017, revenues increased by 53.5%, which equates to an annual growth rate of 7.4%. The projection of the subsequent change in income presented in Figure 1 also suggests a probable improvement in the subsequent situation. Another characteristic is the sales volumes in the offline and online segments, data which is presented in Figure 2.

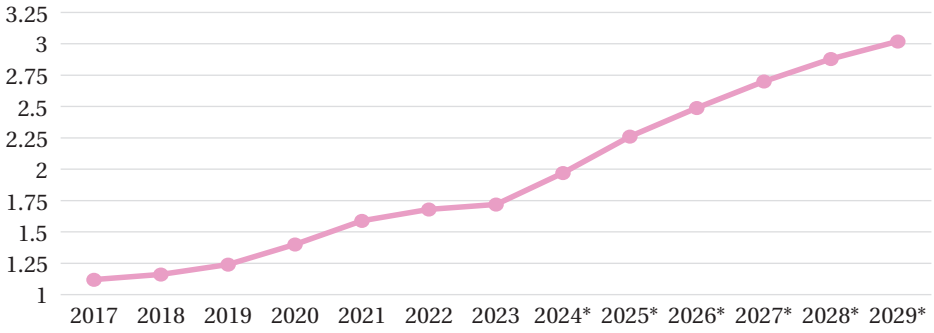

Figure 1. Revenue generated by the edible fats industry in Uzbekistan in 2017-2029, USD mln
Note: * – data from 2024 to 2029 are projections
Source: made by the authors of this study based on data from Oils & Fats – Uzbekistan (n.d.)

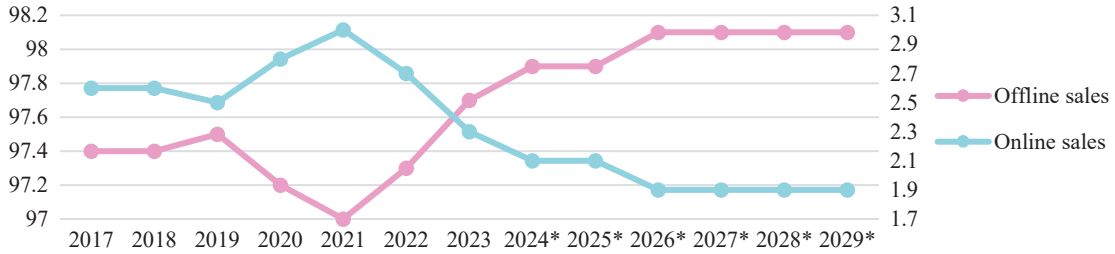

Figure 2. Share of offline and online sales of hydrogenated fats in Uzbekistan from 2017 to 2029, %
Note: * – data from 2024 to 2029 are projections
Source: compiled by the authors of this study based on data from Oils & Fats – Uzbekistan (n.d.)

As Figure 2 shows, the share of offline sales in the country in this sphere is significant: almost all sales take place in this way. The situation stays unchanged and is likely to remain so in the years to come. Nevertheless, it would be more effective to develop specifically online sales as this allows for a considerable increase in sales and therefore has a positive impact on the development of the industry. However, it is challenging to make such an assessment separately for hydrogenated fats. This is caused by the fact that this is a rather niche product, for which it is virtually impossible to find data in the public domain, which means that real niche research is required. Furthermore, such fats are most often used in B2B rather than B2C business models, which also makes it more difficult to collect information and analyse it.

Hydrogenated fats can be utilized in the production of confectionery products such as margarines, candy fillings, biscuits, and pies. They are also used in the bakery industry for baking fats, in the sauce industry, and in the creation of milk substitutes like vegetable creams and cream. Additionally, they serve a role in the creation of feed fats as additives to enrich feed and enhance its nutritional value. Thus, their application is broad yet niche-specific.

In the context of a better understanding of the current state of the market, some additional assumptions can be made about the above assessments of the calculations of the economic viability of fat hydrogenation. Thus, it is worth addressing the specific features of the pricing policy, which can be adopted by the company: in fact, there can be two of them, either based on the market, or based on the formed markup. The study assumed that the market price of non-hydrogenated fats is at USD 84 per litre. The company is not obliged to set its own price at that level, but above, or below. This affects demand, because if the price is lowered, it is likely to sell more products, and vice versa (Ivashura *et al.*, 2022). In this context, it is worth initially trying to estimate the demand for the product at the market price and then changing the price according to the magnitude of demand. Notably, considering the gradual growth of income received by representatives of the edible fats industry in Uzbekistan, as well as the forecasts that were formed, an increase in demand for products can be anticipated. While this could lead to an increase in price, it should not be very rapid, considering that the increase in demand will be offset, among other things, by an increase in production levels (Yousaf *et al.*, 2022). The company can then either focus on the market price, which will change dynamically, or it can change its rate of return depending on market conditions: for instance, in the valuation exercise, producers should receive approximately 16.7% return for each litre of hydrogenated fat produced. Thus, the generated rate of return may be at the level of 15-16%; however, as market performance changes, it may gradually increase to 18%, 20%, 25%.

Still, hydrogenated fats have their problems, which is why scientists are trying to find other methods of processing fats for later use. The principal reason is trans fats, which have a negative impact on people's health. They cause cardiovascular diseases, can cause diabetes, inflammation of the immune system, adversely affect human growth and development. The fact is that during the hydrogenation process, unsaturated fatty acids

(which have one or more double bonds between carbon atoms) are converted into saturated fatty acids (without double bonds) (Czwartkowski *et al.*, 2022). However, trans-isomers can form when the double bond stays but hydrogen atoms are added to the molecule from opposite sides. Trans-isomers of fats have a different structure from natural fats, which affects their physical and chemical properties (Kopytets & Voloshyn, 2022). They can be more resistant to oxidation, which has a positive effect on the shelf life of products, thus the risk of diseases of all kinds. Apart from the hydrogenation process, trans fats can also be formed in nature, in small amounts, such as during processing of animal products or during fermentation of some foods; however, their concentration is not significant (Sivakanthan & Madhujith, 2020). In this context, legislation is emerging in many countries to regulate the use of trans fats, to minimise their content in products. Thus, in the current environment, it is essential to find new approaches that are aimed at either minimising the occurrence of trans fats in products due to the hydrogenation process or new approaches to fat processing.

▸ Discussion

The production of target fats in Uzbekistan was considered in a fairly comprehensive manner in the presented study. Nevertheless, there are quite a few difficulties in this area in Uzbekistan despite its significant role for the economic well-being of the state and the industry. Thus, considering the health risks associated with trans fats, it is crucial to implement strict regulations to minimise their presence in food products. The Uzbek authorities should consider reviewing existing legislation to determine whether it is effective in the current context of global trans-fat restrictions. Furthermore, it is still effective to stimulate innovative development to create and implement the latest technologies that could improve the quality of reproducible hydrogenated fats or use a different processing technology (Borsolyuk & Verbytskyi, 2023). Grants, tax incentives, and cooperation with academic institutions and industry experts should be the state's tools for this purpose. This should especially apply to small and medium-sized enterprises, providing them with both technical and financial support.

Work needs to be done on the consumer side as well. Public awareness campaigns, seminars, and educational materials can empower consumers to favour healthier fat options and stimulate demand for trans fat-free products (Tkach *et al.*, 2023). The same applies to the promotion of sustainable practices in the edible fats industry, such as responsible sourcing of raw materials, optimising production processes to minimise waste and emissions, and promoting environmentally friendly packaging, can contribute to a healthier environment and increased consumer confidence (Yemchenko, 2022). Promoting cooperation between industry stakeholders, including producers, manufacturers, and regulators, can facilitate the sharing of best practices, standards, and technological advances. Establishing industry-wide guidelines on fat processing methods, labelling transparency, and quality standards can improve consumer confidence and product integrity (Shahini *et al.*, 2023). By implementing these policy recommendations, Uzbekistan will be able to overcome the challenges of the targeted edible fats industry, address the public health problems associated with hydrogenated fats, promote innovation and sustainable development, and ultimately improve the well-being of its population. In the present study, the role of fats, their uses, and applications were described in sufficient detail. A. Zbikowska *et al.* (2023) evaluated current trends in fat modification. The researchers described the significance of solid fats in food production and their importance for both practical use and nutritional value. Within the framework of the study, the researchers noted that conventional methods of fat modification, such as partial hydrogenation, are known for reducing nutritional value, therefore suggesting other approaches such as enzymatic transesterification. It was concluded that it is crucial, first of all, to ensure better health levels in countries, to utilise newer methods of fat modification.

F. Troncoso & G. Tonetto (2023) reached analogous conclusions in their economic analysis of sunflower oil hydrogenation. Researchers have pointed out the importance of hydrogenation in modifying fats and oils for various applications including food and non-food industries. However, they also noted that conventional hydrogenation methods using nickel-based catalysts often produce undesirable trans fatty acids, requiring expensive filtration and bleaching processes to remove traces of nickel and ensure product quality. The researchers proposed the use of platinum monolithic catalysts as a solution to reduce processing costs by eliminating filtration stages. In their conclusions, they note the significance of switching to this kind of technology, both to preserve the health of citizens and for environmental and economic reasons. The present study also indicated that there are problems caused primarily by the negative effects of hydrogenated fats on human health, which may make their subsequent use hazardous. Therefore, public authorities should adopt policies that aim to introduce innovative technologies that can reduce the level of harm caused by this process or introduce new types of edible fats processing.

W. Wongjaikham *et al.* (2022) investigated the production of low trans-fat margarine. The researchers pointed out that the importance of fats in the diet is really high. However, conventional hydrogenation methods often result in the formation of trans fatty acids, which is a health hazard. In this regard, the researchers also suggested that the pilot plant could be used to produce low trans-fat margarine. In other words, the implementation of the technology described in this study, or any other technology, will considerably improve the situation in terms of the level of health quality among the citizens of the country. K. Sattarov (2023) reviewed the production of target edible fats in step hydrogenation technology and their utilisation. He pointed out that the quality of the catalyst, activity, durability, and stability in isomer formation during hydrogenation are essential for the efficient performance of this process. The study revealed the problem of trans-isomer formation due to hot temperatures, catalyst specificity, and feedstock composition rich in unsaturated fatty acids. The researcher believes that a critical need in the industry is the development of catalysts: despite considerable progress in this area, the problem is still not fully solved. The present study did not focus so much on issues that address the need for the development of new catalysts. Still,

since it is an approach to harm reduction in terms of harm to public health, it is effective.

F. Menaa *et al.* (2013) noted the need to create innovative technologies in this area. The researchers outlined three key strategies to focus on creating healthy edible oils that are low in saturated fatty acids. They recommended the use of fat substitutes for this purpose to mimic the functional and sensory properties of fats while reducing calories, the use of chemical or enzymatic processes in the creation of structured lipids, and the genetic modification of fatty acid composition. However, the researchers also noted the need for more long-term research on this topic to fully assess the impact of all these changes on health outcomes. This study also observed the need for improvement in the context of utilisation of dietary fats to improve the standard of living of the population. Thus, the use of this type of technology is relevant to achieve this goal. Z. Wang (2020) analysed the edible oil market in China. The study described many features of this market in the country. Specifically, it was shown that individual firms attempt to gain competitive advantage by lowering prices below market prices. The researcher generally considers this strategy to be quite effective in attracting new users. In this regard, he recommends more active application of various marketing tools, changing the development strategies of their enterprises to increase the efficiency of their companies. The present study described the specific features of the existence of the edible fats market in Uzbekistan. It was shown that this market is developing quite rapidly in the country, with many opportunities for expansion. In China, the situation is a bit different, with more problems with the competitive situation, among other things. Nevertheless, in the future, the situation in the Uzbek market may come to a state that is currently observed in China. In this regard, these recommendations can also be used in Uzbekistan in the future.

▸Conclusions

The study concluded the role of quality production of edible fats for better functioning of the entire food industry. Targeted edible fats are generally designed for specific uses, whether for margarines, cooking oils, confectionery, or food additives. The hydrogenation process, the key aspect discussed, alters the molecular structure of fats, increasing their stability, shelf life, and suitability for industrial applications. However, this transformation also produces trans fats, which are known for their adverse health effects. In modern environment, regulatory frameworks around the world are evolving to change the way trans fats are regulated to ensure better health outcomes for countries.

The economics of hydrogenation, particularly in Uzbekistan, are highlighted through cost analyses and market trends. The profitability of hydrogenated fats is affected by a range of factors, including production costs, raw material prices, and market demand. The study provided information on profitability calculations with potential income and payback periods. Although the calculation was made with some assumptions, it makes it clear that running such a business in the current environment is still effective in terms of profitability. It costs USD 72 to produce 20 litres of hydrogenated fats in Uzbekistan. Furthermore, the study described selected trends related to the development of this industry in the country. Thus, the evolution of the oil and fat industry of Uzbekistan was presented, demonstrating the achievements in diversifying the processing of oilseeds and meeting the needs of the internal market. Revenues of the oil and fats industry in Uzbekistan totalled USD 514.5 mn in 2023 and are forecast to grow annually by 7.4%.

Nevertheless, the trans fats that arise from the hydrogenation process are still a significant problem for their subsequent increased production. Therefore, it is relevant for future research to propose innovative approaches to reduce health hazards due to the hydrogenation of dietary fats.

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▸Conflict of interest

None.

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Економічний аналіз процесу виробництва цільових харчових жирів через постадійну гідрогенізацію та їх ринкове застосування

Карім Саттаров
Доктор технічних наук, декан факультету
Гулістанський державний університет
120100, 4 Мікрорайон, м. Гулістан, Узбекистан
https://orcid.org/0000-0002-3847-0660

Гюльжахон Норімова
Кандидат педагогічних наук, завідувач кафедри
Гулістанський державний університет
120100, 4 Мікрорайон, м. Гулістан, Узбекистан
https://orcid.org/0000-0001-5955-054X

► **Анотація.** Галузь виробництва жиру є однією з важливих і швидкозростаючих складових харчової сфери Узбекистану, у зв'язку з чим проведення аналізу економічної частини найважливіших її елементів є актуальним. Метою цього дослідження стало розглянути процес гідрогенізації з точки зору особливостей витрат на виробництво та питань ціноутворення. Методами, що застосовувалися в рамках дослідження, стали описовий, систематизація та діалектичний. У рамках дослідження було показано, що виробництво та використання цільових харчових жирів відіграють життєво важливу роль у харчовій промисловості, оскільки дають змогу досягти певних характеристик інших продуктів. Однак, для більш ефективного застосування жирів, часто використовується процедура гідрування. У роботі більш детально було описано її суть, а також проведено економічну оцінку доцільності проведення процесу гідрування. Було підкреслено важливість вибору правильного реактора і каталізаторів для максимізації прибутковості, а також вплив деяких інших характеристик на неї. У рамках дослідження також зверталася увага на недоліки процесу гідрогенізації жирів, який негативно впливає на здоров'я населення. У зв'язку з цим, діяльність, спрямована на зниження негативного впливу в даній галузі, повинна проводитися більш активно. Крім того, увага приділялася й оцінці стану ринку харчових жирів в Узбекистані: було відзначено стрімкі темпи зростання галузі, що було відзначено завдяки збільшенню доходів підприємств, які займаються виробництвом цієї продукції. Отримані результати можуть бути застосовані підприємствами для зміни принципів проведення процесу гідрогенізації, а також державною владою для формування довгострокової політики розвитку галузі

► **Ключові слова:** хімічна обробка; рентабельність; реактор гідрування; охорона здоров'я; промисловість