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WORLD CORN MARKET: ANALYSIS, TRENDS AND PROSPECTS OF ITS DEEP PROCESSING

Purpose. *The purpose of the article is to determine the prospects of deep processing of corn in Ukraine, taking into account the restraining factors of development, on the basis of the analysis of the state and tendencies of functioning of the world market of corn.*

Methodology / approach. *During the research, general scientific and special research methods were used, in particular: analysis and synthesis, scientific abstraction – in determining the purpose and formulating conclusions; comparative, calculation, statistical and graphical ones – in the assessment, analysis, comparison and establishment of patterns of the current state and trends in the production of corn and its deep processing; program-target one – to substantiate the factors of intensification of deep processing of corn in Ukraine.*

Results. *The analysis was carried out and tendencies of world corn production were determined. The shares of countries-producers and countries-consumers of corn were calculated; their dynamics of changes were analyzed. Analysis of the dynamics of prices for corn grain on the Chicago Mercantile Exchange indicates that the price of raw materials is gradually declining, so agricultural enterprises that sell corn as a raw material, lose income from its production. The structure of corn use in different directions in the world was analyzed, and the structure of its use in the USA was considered in more detail. Factors of activation of deep processing of corn were identified. In Ukraine, deep grain processing as an industry is just beginning to develop, so it is worth processing corn, based on the experience of leading countries, such as the USA and China. Estimated costs for the construction of a modern plant for deep processing of corn and income from the implementation of this investment project were calculated.*

Originality/scientific novelty. *The scientific novelty of the study is a comprehensive analysis of the world corn market; economic substantiation of expediency of corn processing in Ukraine; improving the system of factors to intensify the development of deep processing of corn in Ukraine.*

Practical value / implications. *The practical value of the results of the study is that they will contribute to the formation of the concept of intensifying the development of deep processing of corn in Ukraine. The main results can be used by agro-industrial enterprises during the development of deep corn processing projects.*

Key words: *economic efficiency, investment process, sales of products, corn, deep processing, financing of deep processing, Ukraine.*

Introduction and review of literature. In the context of the global decline in corn prices, significant overproduction of this crop in Ukraine and the decline in profitability of this segment, new opportunities for the development of domestic processing are revealed. Today, 3 times more corn than needed for domestic consumption is produced in Ukraine, all other grain is exported as raw material.

Export of grain as a raw material brings quick currency earnings for the agricultural producer, but such earnings depend on demand in world raw material markets, which, taking into consideration the growth of domestic production costs, reduces the overall profitability of this crop growing. One way to maintain and increase profits is to develop the domestic processing industry and trade in value-added products. And one of the promising areas of development of the domestic corn processing segment is its deep processing.

Corn is the most popular cereal crop in the world, it is grown by most countries, but the United States and China provide half of the international market. In addition, the above-mentioned countries are the largest consumers and producers of deep-processed corn products. Thanks to many years of experience in the development of this segment in China, the products of corn deep processing have the longest technological chain, as well as the greatest diversity in the processing of food crops.

Today, after deep processing, corn is represented by 2000 different types of products, 100 of which are found in all aspects of human life [1]. Most of them are used in such areas as: food products, medical products, day-to-day goods, industrial production, animal foodstuff and others. International analysts have found that the global market of corn deep processing will grow by 25 % and reach 1.191 bln tons by 2026. The impetus for production growth will be an increase in the world's population by 3 bln people by 2050; in addition, the demand for corn products in Asian countries will increase by 53 % till 2026 compared with similar indicators in 2016. Also, the consumption of corn products in North and South America will increase by 38 % to 2026 [1].

In connection with optimistic forecasts of an increase in the consumption of products of corn deep processing and partial studies of domestic scientists on this topic, there is a need to study the experience of leading world producers for its application in Ukraine.

Many domestic and international scientists have studied the market of corn production and deep processing. L. W. Rooney та S. O. Serna-Saldivar [2] assert in their book that corn and wheat are some of the most important cereals in the world, giving the human body the greatest amount of protein and vitamins needed.In 2013, during the World Agricultural Outlook Conference, Y. Yang, Z. Zhou та F. Qin [3] proved that each country's national food security must be implemented through the diversification of importing countries and reducing the risks of foreign economic relations between consumer countries.In the studies of J. Michalczyk [4], T. Lang, M. Heasman [5], global challanges such as population growth and the food crisis were highlighted, the cultivation and processing of corn as one of the options for stabilizing food security was proposed. L. E. Baker [6] participated in the central debate in Mexico on food security and food sovereignty and concluded that corn products satisfy food needs and provide opportunities for its restoration. L. Cong-Xia [7] describes in his research the challenges associated with the deep mechanical processing of corn in the provinces of China and makes suggestions on the effectiveness of its implementation. In addition, he focuses on the fact that the

development of the corn industry is very important for the country's economy, as deep processing of corn improves the development of chemical, engineering and light industries, agriculture, construction industry, and also creates employment opportunities. Z. Guiyan [8] argues that the corn industry is one of the main industries contributing to the economic development of the provinces of China and the world.

In the research of V. M. Savkin and V. M. Honcharova [9], the situation of consumption of corn grain is analysed and the need to increase the volume of domestic processing of corn, which is one of the important areas of its effective implementation, is emphasized. N. O. Duhiienko, O. O. Pidopryhora [10], V. M. Nelep, O. M. Vysotska [11], N. S. Tanklevska [12], V. S. Petrenko [13], A. S. Karnaushenko [14] emphasize that countries with developed economies prefer to export deep processing products with high added value, as opposed to Ukraine, which exports raw materials. V. Ya. Mesel-Veseliak [15], O. R. Polishkevych [16], N. V. Pryshliak, V. M. Baldyniuk [17] consider the corn processing as one of the main crops for biofuels.

The research works of the above-mentioned Ukrainian scientists relate to the export and prospects of increasing the production volume of corn as a raw material, but do not sufficiently reveal the state of world production of deep processing of this crop. The research works of international scientists are of a technological and social nature, which emphasize the solution of food security, but do not sufficiently cover the economic essence of deep processing of corn.

Purpose. The purpose of the article is to determine the prospects of deep processing of corn in Ukraine, taking into account the restraining factors of development, on the basis of the analysis of the state and tendencies of functioning of the world market of corn.

Results and discussion. According to the Food and Agriculture Organization of the United Nations (FAO) [18] and the United States Department of Agriculture (USDA), rapid increase in consumption and production of corn has began since 2013. Positive trends were observed both in the area of corn plantations and in gross harvest per hectare (c/ha). By 2021, while maintaining a positive trend, a double increase in corn production should be expected compared to 2000 (Fig. 1).

After analysing figure 1 it was found that the world corn production keeps restrained, but stable growth in gross yield and tends to increase, and taking into consideration the given forecast, the volume of grown corn of 1143 mln t should be expected in the agricultural year 2024/2025, which is by 7.73 % more than was harvested in the agricultural year 2018/2019. According to the results of the agricultural year 2017/2018 and 2016/2017, the growth rate of the gross yield of corn in the world was 1.95 % and 1.85 %, respectively.

The largest producing countries are also the largest exporters and consumers of corn. Geographically the corn market is segmented to North American, South American, European and Asia-Pacific regions. The popularity of the corn cultivation in these regions is caused by favourable climatic conditions. It is expected that on a

global scale among all regions high demand will continue in the countries of North America and the Asia-Pacific region. The main reason for the increase in demand will be scheduled high volume of the corn harvest and its processing for animal foodstuff.
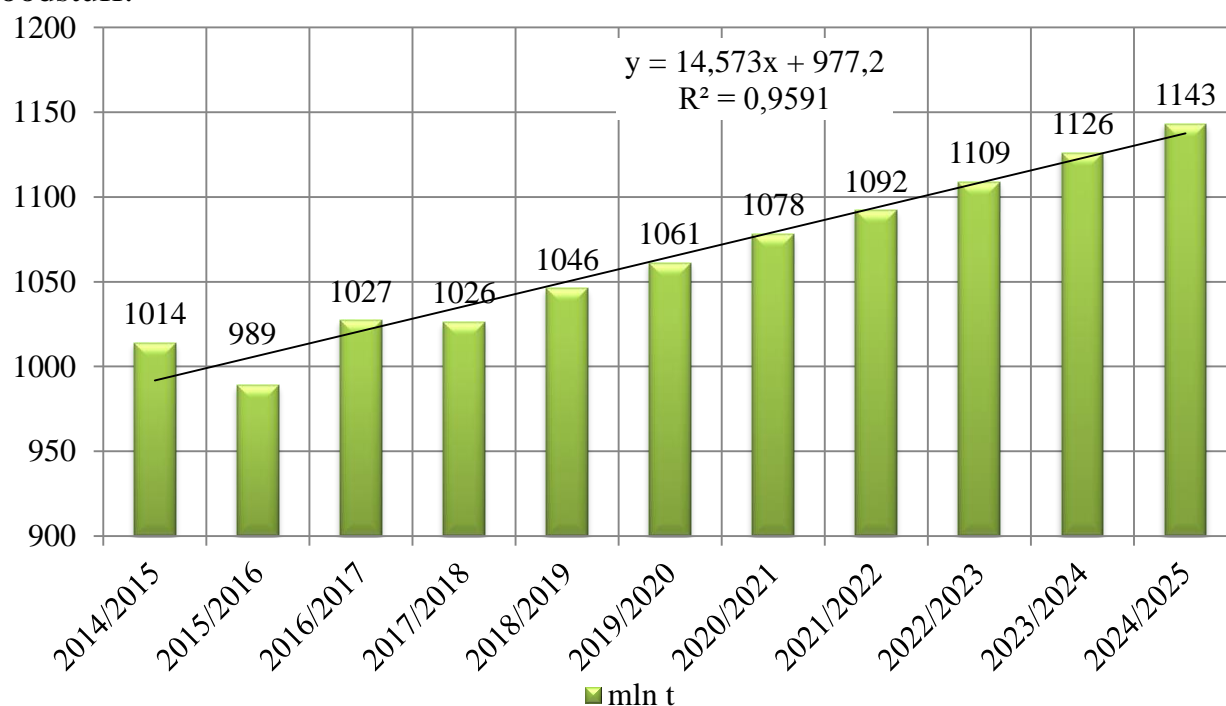
Fig. 1. World corn production, taking into consideration the forecast to the 2024/2025 agricultural year, mln t

Source: compiled by authors based on the data from Food and Agriculture Organization of the United Nations [18].

The world leaders in growing corn for 2015–2018 are presented in table 1. After analysing table 1 it was found that there is both reducing and increasing the gross yield of corn on the background of changes in general global gross yieldover during the period 2015–2018 in some countries. Throughout the years, the United States is the absolute leader among producers; 366.3 mln t of corn were grown in 2018. The country's share made 31.3 % in 2018. China took the second place (257.3 mln t were grown in 2018), its share made 22 % in 2018. But in the USA, a decrease in the gross yield of corn in 2018 and 2017 was due primarily to natural disasters – the hurricanes that swept across the country during this period. In general, there is a decrease in corn grown in many countries in 2018 including the USA, China, Brazil, Argentina, India, Mexico. But the decrease in grown corn did not affect the decrease in consumption of this crop (Table 2).

It is expected that the constantly growing world population will stimulate the growth of the global corn market over the next years. Moreover, increased awareness of population about proper nutrition and healthy lifestyle results in change of the people's preferences in the diet towards products that are rich in protein. In its turn, this implies an increase in the demand for food grain of various crops, including corn, which stimulates the growth of the world market of this crop. However, the constant fluctuation of corn prices and growing consumer concerns in relation to genetically

modified products, leads to additional costs in the total supply chain, which hinders the growth of the world market.

Table 1

Shares of the countries-producers of corn for 2015-2018 by volume, mln t

Years		Producing countries									Total
		USA	China	Brazil	Argentina	India	Indonesia	Mexico	Ukraine	Other	
2015	Mln t	345.5	265	85.3	33.8	22.6	19.6	24.7	23.3	232.2	1052
	%	32.8	25.2	8.1	3.2	2.1	1.9	2.3	2.2	22.1	100
2016	Mln t	384.8	263.6	64.1	39.8	25.9	23.6	28.3	28.1	241.8	1100
	%	35.0	24.0	5.8	3.6	2.4	2.1	2.6	2.6	22.0	100
2017	Mln t	371	259.1	97.7	49.5	28.7	28.0	27.8	24.7	247.5	1134
	%	32.7	22.8	8.6	4.4	2.5	2.5	2.5	2.2	21.8	100
2018	Mln t	366.3	257.3	94.5	46.0	26.0	36.0	25.6	35.5	281.8	1169
	%	31.3	22.0	8.1	3.9	2.2	3.1	2.2	3.0	24.1	100
Relative deviation 2018 up to	2015	106.0	97.1	110.8	136.1	115.0	183.7	103.6	152.4	121.4	111.1
	2016	95.2	97.6	147.4	115.6	100.4	152.5	90.5	126.3	116.5	106.3
	2017	98.7	99.3	96.7	92.9	90.6	128.6	92.1	143.7	113.9	103.1
Absolute deviation 2018 up to	2015	20.8	-7.7	9.2	12.2	3.4	16.4	0.9	12.2	49.6	117
	2016	-18.5	-6.3	30.4	6,2	0.1	12,4	-2.7	7.4	40	69
	2017	-4.7	-1.8	-3.2	-3.5	-2.7	8	-2.2	10.8	34.3	35

Source: compiled by authors based on the data from Food and Agriculture Organization of the United Nations [18]

Table 2

Shares of the countries-consumers of corn for 2015-2018 by volume, mln t

Years		Countries-consumers										Total
		USA	China	Brazil	Argentina	India	Indonesia	Mexico	Ukraine	EU	Other	
2015	Mln t	288.5	255.8	67.8	8.7	18.7	12.8	27.7	6.5	73.8	274.3	1034.6
	%	27.9	24.7	6.6	0.8	1.8	1.2	2.7	0.6	7.1	26.5	100.0
2016	Mln t	289.9	265.3	65.4	9.0	19.1	13.4	30.9	7.5	76.0	296.1	1072.6
	%	27.0	24.7	6.1	0.8	1.8	1.3	2.9	0.7	7.1	27.6	100.0
2017	Mln t	291.3	289.8	76.3	9.3	19.5	14.1	32.4	7.9	78.2	291.9	1110.7
	%	26.2	26.1	6.9	0.8	1.8	1.3	2.9	0.7	7.0	26.3	100.0
2018	Mln t	304.5	301.3	73.1	10.6	19.9	15.0	34.5	8.2	80.4	301.2	1148.7
	%	26.5	26.2	6.4	0.9	1.7	1.3	3.0	0.7	7.0	26.2	100.0
Relative deviation 2018 up to	2015	105.6	117.8	107.7	122.3	106.8	117.3	124.6	126.2	108.9	109.8	111.0
	2016	105.0	113.6	111.6	118.1	104.4	111.8	111.7	109.3	105.8	101.7	107.1
	2017	104.5	104.0	95.7	114.1	102.2	106.8	106.5	103.8	102.8	103.2	103.4
Absolute deviation 2018 up to	2015	16.0	45.5	5.3	1.9	1.3	2.2	6.8	1.7	6.6	26.9	114.1
	2016	14.6	36.0	7.6	1.6	0.8	1.6	3.6	0.7	4.4	5.1	76.1
	2017	13.2	11.5	-3.3	1.3	0.4	1.0	2.1	0.3	2.2	9.3	38.0

Source: compiled by authors based on the data from Food and Agriculture Organization of the United Nations [18].

The formation of corn prices depends on supply and demand on commodity exchanges. The most popular and active commodity exchange for the trading of futures contracts on corn is the Chicago Mercantile Exchange, namely its individual SWOT unit. Data of the exchange testify to the collapse of corn prices (Fig. 2).

Fig. 2. Corn futures at the Chicago Mercantile Exchange

Source: data from equity.today [19].

The future trade agreement between the USA and China will be the catalyst that will lead to serious consequences for corn producers, in consequence of which the demand for this crop will increase, and the processing sector will fill the markets with different goods: products for animal foodstuff, food products and deep processing products (Fig. 3) [20].
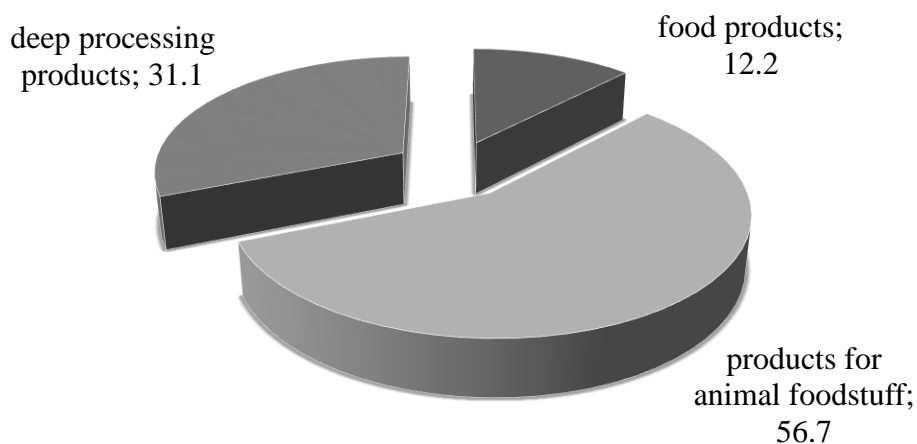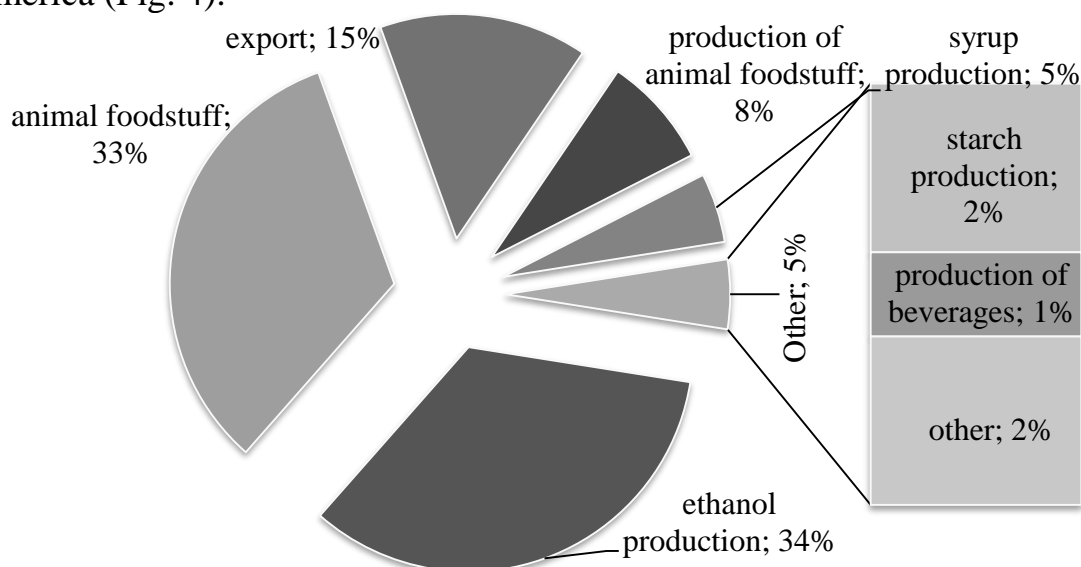
Fig. 3. Structure of corn use in sectors in the world in 2018, %

Source: built by A. Karnaushenko based on data from the Food and Agriculture Organization of the United Nations [18] and inventure.com.ua [20].

After analysing the structure of corn use in consumption sectors it was found that there were no significant changes in the structure within 2017–2018, however, it is worth noting that the change of 0.01 % on the global market scale indicates that this is more than 1 mln t of corn. In 2018, the use of corn as food increased by 0.5 %, the use of corn as animal foodstuff increased by 0.2 %, and as deep processing products increased by 0.3 %.

As the leader and largest supplier of corn in the world is the United States of America, and one second of the harvest of this crop is cultivated in its fields, it is advisable to consider the processing structure of this crop in the United States of America (Fig. 4).

Fig. 3. Structure of corn use in the USA in 2018, %

Source: built by V. Petrenko based on data from the Food and Agriculture Organization of the United Nations [18] and inventure.com.ua [20], landlord.ua [1] and agrotimes.ua [21].

Technologies of deep processing, that meet the demand of the final consumer for quality products are actively developing all over the world. Currently, 78 plants for deep processing of grain crops, located in 20 countries operate in Europe [27, 28, 30]. In the USA, these plants are only 21, but each plant has higher production capacity than in Europe [31; 32]. Development of the industry of deep processing of grain is at a faster pace in China, so starch products, spirits, glutamine acid, lysine, citric acid are produced in the processing of corn. In addition, production of corn oil and polyol is organized. Production of corn starch as the main product of deep processing industry is developing rapidly. In 2017, the corn starch production in China reached 29.2 mln t, which was 26 % more than in 2013 (Table 3). In 2017, China has increased corn processing from 104 to 137 mln t, in 2018 positive trend continued [33].

For Ukraine, deep processing of corn is a new direction of development of the agricultural sector, which will boost the growth of the economy with its added value. At the same time, when Ukraine's processing is only developing, in the USA, about 36 % of the corn crop, or 145 mln t is deep processed [23; 26; 29].

Table 3

Development of the main products of corn deep processing

No.	Deep processing products	Countries leading in production	State of development
1	Glucose	USA	Currently, the most popular sweeteners are sweeteners made of corn – they occupy at least 55 % of the market. Their consumption continues to grow. In 2012, the average American consumed almost 50 kg of HFCS per year. Corn syrup with high content of fructose is used in soft drinks, fruit juices and other sweetened beverages (including sports and energy drinks).
2	Starch	USA, India and China	As a result of 2018, the World market for corn starch is estimated at 25.9 bln USD and has a tendency to increase on average by 4.8 % per year. High yield of corn with high starch content is an important factor stimulating the growth of world market of corn starch. Currently, the global corn starch market is segmented into food products and beverages, animal foodstuff, pharmaceuticals and chemicals, textiles, paper, corrugated board etc. Within 2016–2018, the segment of food products and beverages had the second largest share of global corn starch market, and it is expected that the share will increase over the next years.
3	Gluten	China, USA	Due to the high protein content, corn gluten is used as an additive in the feed industry, especially for feeding pigs and poultry. In recent time, it is widely used as feed for feeding fish and in production of corn-based food products. In recent years, interest in using corn-gluten flour as an herbicide for agriculture has increased in the world owing to its properties, which suppress the growth of weeds, however, the share of corn gluten, which is used for this purpose does not exceed 1% of the total volume.
4	Flour	Great Britain, Germany, China	The corn flour market is rapidly developing and has the potential to become the fastest growth market where high level of average annual growth rates is expected. Growing population, increasing consumption of basic food products, high demand for fast food and increase of available income of consumers are the main factors for future growth of this market.

Source: compiled by N. Tanklevska based on the data from inventure.com.ua [20], hipzmag.com [22].

Competitive advantages of the enterprises of deep processing consist in the fact that they have the possibility to regulate the volume of goods produced at various stages of its production that allows adapting the production process to the existing requirements of the market. In addition, it allows increasing economic efficiency of enterprises [34; 35]. Investments are needed for re-equipment of existing silos and processing plants. Therefore, there are two powerful investment projects in Ukraine

for the development of this direction (Table 4).

Table 4

Investment projects for corn processing in Ukraine

No.	Country-investor	Amount to be invested	Capacities	General description
1	China	200 mln USD	100 thsd. t	There are plans to build three plants for corn processing on an area of 75 hectares in Ternopil region. The plant will produce fructose, lysine (a natural feed additive for animals) and glutamic acid. The finished products will be exported to the EU and China.
2	USA and Spain	14 mln USD	100 thsd. t	The plant will produce flour and grits of durum corn. The durum corn grain that is grown by Ukrainian farmers will be used for processing. It is assumed that 80 % of the finished products will be exported all over the world. Breakfast cereals will be supplied to the domestic market.

Source: compiled by K. Melnykova based on data from naas.gov.ua [24] and latifundist.com [25].

In the process of corn processing, plants produce significant amount of products with high value added: starch, gluten, glucose, glucose-fructose syrups, sweeteners, amino acids, vitaminsand bio-ethanol [36; 37]. Typical raw material balance of the corn processing plant is as follows (Fig. 4): the plant recycles within the year about 100 thsd. t of kernels, 21 thsd. t of which is animal feed, 64 thsd. t – corn, 5 thsd. t – gluten, 6 thsd. t – corn germ, and 4 thsd. t – waste.

Almost 91 mln EUR are necessary to spend for construction of an elevator for grain deep processing and production of high-protein feed of DDGS-standard, corn starch, corn gluten and corn germs (Table 5), but the revenues that will be received (Table 6), will cover completely the costs incurred within 5 years.

Table 5

Costs needed to build a plant for corn deep processing

| No.	Description	Estimated cost, mln EUR
1	Construction of buildings and structures	21.3
2	Purchase of equipment and other assets	66.1
3	Deferred costs	0.9
4	Other costs	3.4
5	Total	91.7

Source: calculated by authors.

The average operational profitability of agriculture in Ukraine makes 23 %, with the established price of corn, the profit would average about 40–50 EUR/t. After corn processing, the producer will be able to get additional profit of about 70–80 EUR/t. Total profit of Ukrainian agricultural producers under the processing conditions will increase from 7.5 mln EUR to 20.0 mln EUR.

Table 6

Revenues from the sale of products of corn deep processing

No.	Deep processing products	Amount, thsd. t per year	Price for 1 t, EUR	Revenue from sales, thsd. EUR
1	Animal feed	21	98	2058
2	Corn starch	64	420	26880
3	Corn gluten	5	392	1960
4	Corn germs	6	150	900
5	Waste	4	36	144
6	Total			31942

Source: calculated by authors.
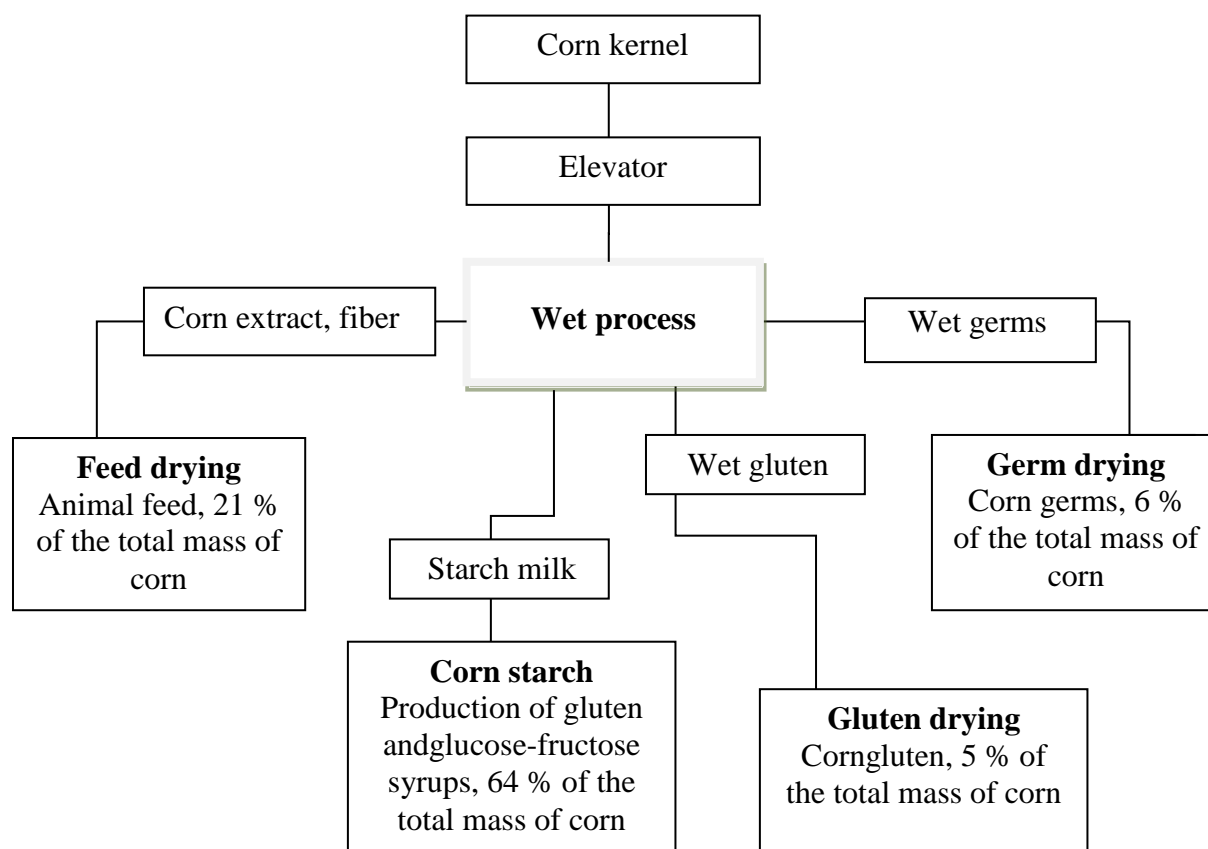
Fig. 4. Typical raw material balance of the corn processing plant
Source: complieled by authors based on datafrom processing plants.

Despite the obvious advantages of corn deep processing for enterprises, there are certain constraining factors (Table 7).

It should be noted that most of the projects for deep grain processing is implemented in the context of the import substitution concept. The implementation of these projects is slow due to high capital expenses for construction of facilities with a long payback period [38; 39]. Therefore, financing and obtaining capital from investors, state venture funds, business angels and other persons who have the resources and desire to invest in the processing sector play a decisive role in these projects.

Table 7

Pros and cons of running the corn processing plant

Advantages of launching deep processing of corn	Constraining factors
Social: provision of districts and communities with new jobs.	Financial: the lack of temporary free funds for re-equipment of capacities; few investors who are ready to invest in Ukrainian enterprises; high interest rates on bank loans to raise debt capital; deferred profit as opposed to the sale of raw materials.
Economic: the additional income for agricultural producers; tax payments to the community budgets and establishment of enterprises with closed cycle, integrated production processes, low cost of raw materials for production.	Technological: it is difficult to introduce foreign technologies in production, lack of personnel with required training; looking for distribution channels; bringing the finished products to European standards.

Source: summarized by authors.

The development of deep processing of corn should be approached comprehensively by attracting state support, improving tax loyalty, simplifying insurance conditions, taking into account the international experience of enterprises in this industry, reducing lending rates, improving leasing contracts. To quickly fill the processing industry with investment, the following factors should be taken into account (Fig. 5).
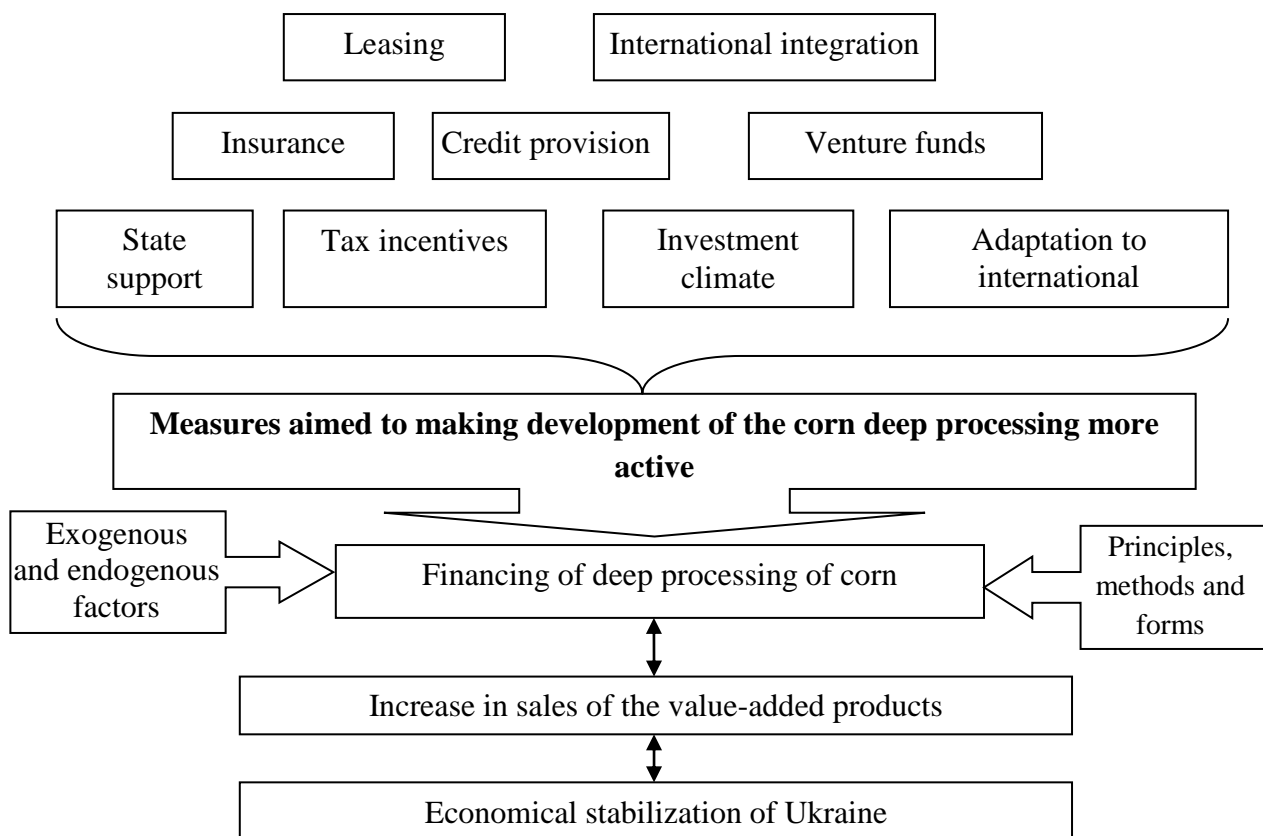
Fig. 5. Factors of activation of deep processing of corn in Ukraine
Source: developed by authors.

Therefore, the factors that intensify the development of deep processing of corn should be based on their effective interaction, which is influenced by exogenous and endogenous factors, methods, forms and principles of financing, taking into account and adherence to which create preconditions for processing [40; 41].

Conclusions. Thus, the advanced economies will stimulate and support the development of the processing industry, because the streamlined process of agricultural crops processing renders the country's economy a lot of advantages, the main of which are more jobs, taxes paid, an increase in the consumption of domestic products. Today, the corn deep processing is a promising direction of development of Ukraine. In analysing the current state, it is established that global production of corn has anincreasing tendency; according to the forecast made in the agricultural year 2024/2025, it will be 9 % more than in the agricultural year 2018/2019. Considering the share of the producers, it is determined that the production of corn has a tendency of decreasing their share in the world market, thanks to this fact, Ukraine increases its volume. However, the consumption of corn processed products is growing in the world.

The prices of corn on the Chicago Mercantile Exchange indicate that the price of raw materials is gradually reduced. Thus, agricultural producers who sell corn as raw material lose the income from its production. Therefore, it is necessary to be involved in processing of this crop following the example of leading countries such as the USA and China. The current state of development of products of the corn deep processing in the world has established that this index has increased as compared to previous years.

The concept of forming a mechanism of intensification of the development of deep processing of corn in Ukraine can be taken into consideration in the practice of agricultural enterprises to improve the deep processing industry through the interaction of the state, external and domestic investors and producers. The development of deep processing of corn should be approached comprehensively by involving state support, improving tax loyalty, simplifying insurance conditions, taking into consideration the international development experience of enterprises in this industry, reducing loan interest rates, improving the terms of leasing contracts. A promising area of future research of functioning world market of corn is to determine the efficiency of producing of its products of deep processing.

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