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TECHNICAL AND TECHNOLOGICAL SUPPORT FOR GRAIN STOCKS MANAGEMENT OF AGRICULTURAL PRODUCERS IN THE CONDITIONS OF ELEVATOR CAPACITY DEFICIENCY IN UKRAINE

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Abstract

The article proves the prospects of grain production in Ukraine and defines that the implementation of the production potential of the industry is slowed by insufficient technical and technological parameters as well as outdated grain storage facilities. The problem of disproportion between the potential volume of grain production and the certified grain storage facilities in Ukraine requires the search for alternative options of technical and technological support for grain stocks management. The method of identifying territorial reserves for the construction of elevator facilities is proposed based on the integral estimation of the proportions between the parameters of the grain offer and the possibilities of its storage across different regions of Ukraine with the corresponding mapping visualization. Alternative options for grain stocks storage based on producers' point of view are considered, and the use of Argentine grain storage technology is proposed for domestic agricultural enterprises that are unable to provide themselves with their own modern grain silos. Feasibility study on the use of Argentine technology has been carried out and its benefits for enterprises with limited financial resources have been identified.

Key words**:** *grain, stocks management, grain storage capacities, financial resources, Argentine technology*

INTRODUCTION

The chosen by Ukraine path towards European integration means that the country's economy has to focus on those sectors that determine its international specialization and the development of which can give a hefty boost to the country's economic rebirth. Agroindustrial complex is among these priorities and, in particular, the grain production, which is the basis of the country's food security and the raw material base for many other sectors of the economy. The grain industry has a significant export potential and, accordingly, makes provision for an increase in foreign exchange earnings in the country. Specifically, in 2014, among the countries of the world, Ukraine ranked second in terms of grain export volumes, stepping back only to the USA, while domestic agro-industrial complex was the first in terms of the size of foreign exchange earnings to the state budget, leaving behind the traditionally export-oriented metallurgical industry. But if Ukraine exported 33.4 million tons of grain and products of its processing in 2014, and 38.3 million tons in 2015, already in 2016 export volumes increased to 41.5 million tons [1, p.36], while at the same time the potential of domestic grain production in 2018 estimates to 70.2 million tons, compared with 66.1 million tons collected in 2016, which was a record for Ukraine.

Enhancement of grain crops yields and efficient grain logistics, as well as improving of the state-owned enterprises management and renewing the storage facilities, transportation and port trans-shipment of grain masses - all this can increase grain production parameters to 90-100 million tons, and in some strategies - up to 120 million tons per year. However, unless a systematic approach is used for the development of this industry these ambitious strategic programs aimed to increase annual grain production in Ukraine will remain just a populist call.

Among the most obvious problems ranks the disproportion between the existing capacity of certified elevators with an annual storage volume of 31.5 million tons and the declared grain offer parameters.

Theoretical and methodological foundations of the stocks management systems were studied in foreign works by Bowersox and Closs [2], Linders and Firon [8], as well as in the works of Ukrainian scholars Velychko [14], Perebyinis [10] and others. These studies are mostly of a general scientific nature and do not reflect the peculiarities of stocks management in a sectoral way.

On the other hand, well-grounded researches of the development problems of the agrarian and grain economy in Ukraine, implemented by Boyko [3], Lobas [9], Shpychak [11], Yurchyshyn [15] and other scientists contributed to the creation of a powerful domestic grain industry with significant potential for dynamic growth. Yet, the issues of technical and technological support for grain stocks management, the parameters of which have recently considerably increased, remain beyond the attention of researchers.

MATERIALS AND METHODS

The purpose of this article is to look for alternative grain storage technologies and their feasibility study in the grain management system of agricultural producers in view of the objectively existing elevator capacity deficiency in Ukraine.

In the furtherance of this goal, the following tasks have been tackled: developing a methodology for identifying territorial reserves for the construction of elevator facilities on the basis of an integral estimation of the proportions between the parameters of the grain offer and the capacities of its storage across different regions of Ukraine with the corresponding cartogram vizualization and propose an estimated indicator.

On the basis of the dialectical approach of objective reality cognition and using the comparison technique, we can assess the availability of elevator capacities and the efficiency of grain storage in Ukraine based on qualitative and cost criteria. Estimated-constructive method was used to determine the cost of implementing the Argentine technology of grain storage. Using monographic research method in assessing the technical and technological support of grain stocks management for agricultural farmers, the abstract logical method of research was used for theoretical generalization of scientific research results and the formation of opinions and suggestions.

RESULTS AND DISCUSSIONS

In terms of the logistical chain, which provides the transfer of grain flows, considerable attention should be paid to the structural provision of the grain storage system. As an integral part of the logistical process, it determines the nominal capacity of the logistical system, since the implementation of grain production potential in Ukraine (at the level of 100-120 million tons per year), as indicated, is slowed by insufficient parameters of grain storage capacities.

In Ukraine, grain storage is provided by the following structural divisions that, based on their subordination, can be grouped into enterprises: the State Joint Stock Company "State Food and Grain Corporation of Ukraine" (PJSC "DPSKU"), the State Agency of Ukraine Reserve (SARU), the State Joint-Stock Company (DAK) "Khlib Ukrainy" ("Bread of Ukraine"), as well as private owners of specific elevators and elevator networks. It should be noted that the grain storage system will be analyzed in terms of certified facilities that have passed the state procedure of compliance with certain standards. Without doubt, most elevators outlived its usefulness, their equipment does not fit into European and world estimates, but for effective and real changes, it is necessary to objectively assess the condition of the whole system. It is practically impossible to consider all grain storage capacities that are not certified, but still used by agricultural producers, since they can include a simple canopy over an asphalt-like site, where grain

is stored in bulks in some remote farm. Obviously, there are no statistics of such "capacities".

As of December 1, 2018, Ukraine has 761 certified enterprises belonging to the above-mentioned organizational structures. A significant number of elevators have been operating since the Soviet Union and now outlived their usefulness. Because of improper storage of grain, losses account for about 15% of the yield, and storage costs are substantially increasing [7]. At the same time, most elevators have predominantly floor storage containers for grain (54%) and can provide much less shipment volumes than enterprises equipped with modern vertical silos (46%) [6]. Thus, the average grain loading volumes in railway carriages on large elevators in Ukraine can serve about 12 carriages a day, while the optimal number shall comprise 54 carriages and more.

In order to study the proportionality between the formation of grain offer and the provision of its storage across territories, we have to calculate the grain production volumes in the regions of Ukraine. However, for this purpose, there's no sense to use absolute indicators of grain production volumes, but rather relative - production per unit of the region's area. Similarly, it is possible to calculate also the region's provision with grain storage capacities. By comparing the relative values of grain production we obtain ***the coefficient of local provision of grain storage capacities (Ks):***

$$Ks = \frac{Ne}{Pg}$$

where *Ne* stands for the number of certified grain storage capacities per 1 km^2 of the territory, t/km^2;

Pg – the amount of grown grain per 1 km^2 of the territory, t/km^2.

This indicator helps to integrally assess the existing potential of elevator capacities in the regions and identify "bottlenecks" or the priority investment directions. Output data for calculation and the direct calculation of the coefficient of local provision of certified grain storage facilities across different regions of Ukraine are presented in Table 1.

If the value of the *Ks* coefficient is equal to one, this means that all the grain within the region has appropriate provision of certified facilities for its storage. At the same time, it is necessary to allow a certain convention of such assumption, since the logistics of grain flows is not limited to administrative boundaries of the regions, and the grain producers that are territorially located on the border of the region can use the services of the closest elevators, including those located in the neighboring region.

The comparative analysis of the total volumes of grain production and certified containers for its storage shows a significant lack of the latter, since all coefficients are considerably lower than one, except for the Mykolaiv and Odesa regions, where the main port transshipment capacities of Ukraine are located. While analyzing the indicated ratio, it is necessary to take into account the uncertified warehouses, which in the vast majority do not provide the proper conditions for the storage of grain stocks.

For visualization of the territorial provision of Ukraine's regions with grain storage capacities we shall use the corresponding cartogram, but before that we will group the regions according to the calculated values of the *Ks* coefficient.

The number of groups (*n*) will be determined by the Sturges approximation formula [6]:

$$n = 1+3{,}322 \log N,$$

where *N* stands for the number of observations (regions).

The resulting value of n is 5.64 groups, or ≈ 6 groups.

To determine the interval (*i*) we shall use the following formula:

$$i = (x_{max} - x_{min})/n,$$

where x_{min} - the minimum value of the sign;

x_{max} – the maximum value of the sign.

Substituting in the corresponding formula the maximum value of *Ks* (1.153) for Odesa region (Table 1) and the minimum value for Transcarpathian region (0.074), we will get an interval that equals to 0.18. Using the method of equal intervals, based on this characteristics we can group together the six groups that are included in the formed closed intervals (Table 2) with a subsequent illustration of these regions on the cartogram (Figure 1).

Table 1. Output data and the calculation of the coefficient of local provision of grain storage capacities in the regions of Ukraine

Region	Territory area, thousand km^2	Average grain production (all categories of households), thousand tons (2013-2015)	Maximum value of grain production, thousand tons.	Number of grown grain in the calculation for 1 km^2 of territory *Pg*, t / km^2	Total capacity of certified grain storage facilities in 2017, thousand tons.	Number of certified grain storage facilities in the calculation for 1 km^2 of territory *Ne*, t / km^2	**Coefficient of local provision of grain storage capacities, *Ks***
AR Krym	26.1	1,256.1	1,988.2	48.13	988.1	37.86	**0.787**
Vinnytska	26.5	2,953.0	4,852.3	111.43	2,376.5	89.68	**0.805**
Volynska	20.1	753.1	922.0	37.47	272.0	13.53	**0.361**
Dnipropetrovska	31.9	2,578.3	3,710.3	80.82	2,139.4	67.07	**0.830**
Donetska	26.5	1,800.8	2,551.2	67.95	1,155.0	43.58	**0.641**
Zhytomyrska	29.8	1,260.6	2,108.6	42.30	574.2	19.27	**0.456**
Zakarpatska	12.8	266.9	325.0	20.85	19.8	1.55	**0.074**
Zaporizhska	27.2	1,828.0	3,093.7	67.21	1,356.5	49.87	**0.742**
Ivano-Frankivska	13.9	450.4	677.6	32.40	112.9	8.12	**0.251**
Kyivska	28.1	2,272.4	3,343.0	80.87	1,498.8	53.34	**0.660**
Kirovohradska	24.6	2,504.8	3,781.4	101.82	1,621.8	65.93	**0.648**
Luhanska	26.7	1,149.7	1,876.5	43.06	947.9	35.50	**0.824**
Lvivska	21.8	836.9	1,186.1	38.39	328.0	15.05	**0.392**
Mykolaivska	24.6	1,904.8	2,803.8	77.43	1,977.5	80.39	**1.038**
Odeska	33.3	2,479.9	3,670.8	74.47	2,860.1	85.89	**1.153**
Poltavska	28.8	3,123.3	5,639.6	108.45	2,696.5	93.63	**0.863**
Rivnenska	20.1	768.1	1,108.6	38.21	366.5	18.23	**0.477**
Sumska	23.8	1,847.6	3,588.1	77.63	1,515.4	63.67	**0.820**
Ternopilska	13.8	1,423.1	2,228.9	103.12	709.8	51.43	**0.499**
Kharkivska	31.4	2,327.2	4,201.5	74.11	2,201.7	70.12	**0.946**
Khersonska	28.5	1,646.6	2,792.4	57.78	1,470.9	51.61	**0.893**
Khmelnytska	20.6	1,945.3	3,039.5	94.43	1,053.4	51.14	**0.542**
Cherkasska	20.9	2,538.6	4,068.5	121.46	1,829.8	87.55	**0.721**
Chernivetska	8.1	506.6	625.5	62.54	203.7	25.15	**0.403**
Chernihivska	31.9	1,856.2	3,123.6	58.19	1,196.7	37.51	**0.645**
Ukraine	**603.5**	**42,278.8**	**63,051.3**	**70.06**	**31,473.0**	**52.15**	**0.744**

Source: Own calculation on the basis of data [13].

One more clarification regarding the content of the coefficient of local provision of grain storage capacities is the objectively existing dynamics of stocks, according to which the grain of different types of crops comes into storage and is used gradually during the marketing year. This means that proportionality (*Ks* = 1) can be ensured only at the time of filling the elevators with the harvested yields, and the first use of grain will cause an increase of the coefficient (*Ks* > 1), thus creating an excess capacity. However,

despite of the warnings in general, Fig. 1 shows proportionality between the grain raw material base and the available capacities for its storage. The analysis of cartogram illustrates the lack of modern certified elevator complexes on the state level, especially in the western regions of Ukraine (Table 2, Fig. 1).

Table 2. Ukraine's regions grouping by the coefficient of local provision of grain storage capacities, *Ks*

Group	Legend	Group interval	Regions in closed intervals
I		0,074 – 0,254	Zakarpatska. Ivano-Frankivska
II		0.255 – 0.434	Volynska. Lvivska. Chernivetska
III		0.435 – 0.614	Zhytomyrska. Rivnenska. Ternopilska. Khmelnytska
IV		0.615 – 0.794	AR Krym. Donetska. Zaporizhska. Kyivska. Kirovohradska. Cherkasska. Chernihivska
V		0.795 – 0.974	Vinnytska. Dnipropetrovska. Luganska. Poltavska. Sumska. Kharkivska. Khersonska
VI		0.975 – 1.153	Mykolaivska. Odeska

Source: Own calculation.

Fig. 1. Cartogram of Ukraine's regions grouping according to the coefficient of local provision of grain storage capacities, *Ks.*
Source: created by authors.

In the agriculturally developed European countries, as well as in the USA and Canada, up to 80% of the yield is kept by its producers in silage grain storage facilities with active

ventilation, while in Ukraine this figure comprises only 1%. Some domestic producers with the sufficient financial capabilities have all conditions for using this experience, as in Ukraine, according to our estimates [6], approximately 50 enterprises offer mini-elevators predominantly of foreign manufacture (Poland, Germany, China, Italy, Spain, France, USA, Turkey) and of five domestic producers. The customers of these elevators are mainly farms with a land bank of up to 10 thousand hectares that specialize in crop production and have the resources to create their own elevator base, as well as grain traders that use them for the consolidation of grain lots at the transshipment points. However, for the vast majority of agricultural enterprises, mini-elevators are unpurchasable, since their construction costs about 3-4 million US dollars (one-time storage volume of up to 5 thousand tons of grain).

Within the grain stocks management system, compliance with the storage standards becomes of paramount importance, which in turn provides opportunities for the integration of the national grain product subcomplex of AIC into the world grain market. Certification in Ukraine also does not guarantee the use of global grain storage standards, since subjective factors and corruption element are often grounds for granting permits with violations of the Technical Regulations on Grain Composition [12].

The introduction of a procedure for grain storage facilities certification, adapted to the conditions of EU and the countries - potential grain importers, and recognized by them, will significantly increase the export potential of Ukraine, and existing local farms have to use modern technologies for yields storage that have been tested and proved efficient in world practice. As an example - the storage technology in polymeric grain sleeves, which we offer for small and medium-sized grain producers - as an alternative to powerful elevators, which can not provide storage of all volumes of grain produced in Ukraine, and as an alternative to silage grain storage facilities of agricultural producers, which also requires considerable one-time investments and quite large grain stocks for their economically feasible storage.

The choice of grain storage technology and related equipment is individual for each entity, but ultimately, the following tasks must be executed:

(i)ensuring the compliance of the grain storage system with the current sanitary standards specified by the Technical Regulations on Grain Composition [12];

(ii)protecting the conditional properties of the grain from the influence of meteoclimatic factors;

(iii)protecting the grain from pests and diseases during storage;

(iv)providing ventilation and cooling of the grain to inhibit the physiological activity of biological components;

(v)preventing mixing of different lots of grain;

(6)creating conditions for the consolidation and reduction of lots of grain;

(7)creating technical and technological preconditions for the grain accounting and remote control of its temperature. The grain storage system must ensure continuous monitoring of grain temperature, humidity, contamination by pests and diseases, and also control the smell and color of the grain and, in case of deviations, to take adequate measures.

The idea of storing grain in special flexible hermetic polyethylene sleeve-bags appeared quite recently in Argentina, where there was a considerable lack of grain storage capacities. Today, one third of the cultivated Argentinean grain is stored in this way. Subsequently, the so-called “Argentine technology” of grain storage was adopted by the countries of North America and Europe, as well as Australia and India [5].

Compared with traditional ways of grain storage, sleeve-bags have a unique advantage in terms of humidity. In a closed environment, that is a polyethylene sleeve, oxygen is gradually consumed by breathing of living organisms (O2) and therefore the concentration of carbon dioxide (CO2) increases. As a result, the microclimate inside the polymer bag changes and becomes unfavorable for the development of pathogens

and harmful organisms, so the grain can be stored for a longer time without the quality loss. Hermetic environment provides for decreasing of biological activity inside the grain mass, which is the main reason for self-heating of the grain. The placement of grain in the sleeve-bags takes place directly on the field and the preservation of wet grain during cold temperatures, that is, during the late autumn and winter times, naturally contributes to its cooling due to the large surface area of 4-5 thousand square meters for the grain weight of 150-200 tons.

Sleeve-bags, the length of which comprises approximately 60 m, are made of five opaque layers of polyethylene (sometimes of three), each of which has its own properties. This is necessary to ensure that the grain does not break the film with its own weight, and also so that the bag can stretch uniformly. The inner layer of the sleeve is made of black polyethylene, and the outer one is white so that the grain does not overheat in the sun. The diameter of the bag after filling is 2.7 m and it can store about 200 tons of grain. Given the minimum allowable distance between the sleeves for 1 hectare of the field, this way it is possible to store 5 thousand tons of grain.

The applicability of using sleeve-bags from logistical management options is related to the seasonality of grain production, since the peak loads on carriers and the excess offer of a new yield increase accordingly transportation tariffs and reduce purchasing prices for grain. It is not always possible to dry the grain to the necessary level due to weather conditions, since harvesting of many types of grain falls in the autumn period and the natural drying of grain is considerably complicated, and the use of drying equipment is associated with expensive heat carriers. In fact, by storing the grain directly on the field, there's no need for traditional monitoring of grain in elevator facilities, mixing it in order to avoid self-heating, as well as energy consumption for active ventilation, etc.

Costs for the introduction of Argentinean technology (Table 3) include the purchase of a corresponding set of machinery and equipment and the very sleeve-bags. According to studies [5], sleeves can be used for two years, after which polyethylene is destroyed under the influence of ultraviolet rays and the bag needs to be replaced. The package also includes a sticky tape, which allows to carry out minor repair of the sleeve sections damaged by rodents or other physical actions.

Table 3. Estimated cost of equipment, works and materials for grain storage in sleeve-bags in Ukraine

One-time investments in new equipment	**Cost**
Loading machine	$ 18,750
Discarging machine	$ 31,250
Conveyer-hopper, trailer	$ 81,250
Conveyer-hopper like "dump pit"	$ 31,250
Total one-time investments	***$ 162,500***
Annual expenses	
One bag for 150-190 t	$ 3.13 / t (given the cost of the bag $ 563)
Grain Loading Department, 6 people including mechanics	$ 0.08 / t / person is set individually in each farm
Grain Discharge Department, 3 people	$ 0.08 / t / person
Fuel costs per 1 tonne of loaded / discharged grain	$ 0.16 (given the calculation of 80 liters of diesel fuel for a full day and processing of 800 tons of grain)
The cost of storing 1 ton of grain	***Not less than $ 3.75 / t***

Source: Own calculation on the basis of data [5].

Table 3 shows the estimated costs of using the Argentine grain storage technology in Ukraine, excluding the costs associated with security, lighting of the territory, ensuring bags integrity and the purchase of consumables (ropes and strips that are used when the bags are filled). Moreover, it is necessary to carefully prepare the field for

laying sleeves, selecting perfectly plain areas with proper drainage and free it from stones, stumps, drills, metal objects, etc., which can cause the rupture of the sleeve bag. It is recommended to apply anhydrous ammonia at the chosen field to destroy rodents, and to plant grass, which will allow using the field many times without extra costs.

Although long-term experiments conducted both in Argentina and in other countries have shown that during storage in the bag no changes were reported as to the moisture content of seeded grain, it is advisable to dry the grain to the standard norms, which will guarantee a longer shelf-life. Grain humidity is optimal in the range of 14-15%, although Argentinean and American farmers consider that in the case of urgent need, it is possible to set in polyethylene bags grain maize with a high humidity up to 20%, and for feeding animals - up to 40%. Based on these data, the completely safe moisture content of grain maize is 13.6% (equal to a relative humidity of 67%), since this indicator correlates with the limit of the required condition for the development of fungal organisms at the temperature of +25 ºC [5].

The advantages of Argentine grain storage technology are as follows:

(i)relatively low investment costs for the introduction of technology with the possibility of cooperative use of machinery and equipment;

(ii)reduction of logistical costs for storage and transportation of grain masses;

(iii)the possibility of storing both dry grain and grain with high humidity, which ensures saving costs for heat-carriers in case of artificial drying;

(iii)independence from transport companies and elevator enterprises, which saves time and money;

(iv)lack of depersonalization and underestimation by elevators of grain quality (loss in price);

(v)avoidance of mixing of lots of grain, which reduces the total cost of the offer;

(vi)improvement of quality, as well as price characteristics of grain after storage due to after harvesting maturing in the sleeves;

(vii)avoiding stopping of the harvest due to lack of vehicles and free grain storage facilities;

(viii)better visualization of products in case of mortgage transactions with a bank or presentation to the insurance company's agent of a collateral for obtaining a loan.

The feasibility and economic calculations of using alternative technologies for grain stocks management of agricultural producers have shown that the use of certified elevators's services, such as PJSC "DPSKU", for grain owners at least costs $ 19.5/t/year [4], which is significantly more expensive than current costs associated with the use of Argentine technology ($ 3.75/t/year). In addition, taking away transportation costs and adding a seasonal price increase at the time of the reboxing of the bag, it is easy to calculate the expected benefits for the grain owner. Our calculations have shown that taking into account the one-time investments made (Table 3) for the purchase of machinery and equipment (corresponding depreciation charges), as well as all organizational and operating costs for the use of Argentine technology, ultimately provide up to three times lower cost of grain storage, compared to the use of certified elevators services, and also solve many organizational problems within the stocks management system of agricultural producers.

CONCLUSIONS

Ukraine is increasing grain production volumes and demonstrating its record-breaking yields in recent years, but the realization of the industrial potential of the industry is slowed by insufficient technical and technological parameters as well as outdated grain storage facilities. Ukraine has 761 certified enterprises, the total capacity of which is 31.5 million tons of grain. A comparative analysis of the total volumes of grain production and certified containers for its storage, based on the calculation of the coefficient of local support of grain storage capacities, indicates a significant shortage of the latter ($Ks<1$) in all regions of Ukraine,

except for Mykolaivska and Odesa regions, where the main state's transshipment capacities are located. At the same time, the modern silage capacities for grain storing account for only 54% of their total volume, the rest belongs to primitive storage technologies (floor and bags).

In the conditions of advanced growth rates of raw materials offer over the commissioning of new grain storage capacities, the use of non-traditional technologies for preserving the conditional properties of grain becomes a crucial issue. We recommend small and medium-sized grain producers, who have no sufficient funds to purchase own silos-based grain storage facilities, to use the so-called Argentine grain storage technology in the polyethylene sleeve-bags, which is an effective alternative for their stocks management system. Today it is the best among all known technologies of storing wet grain, not only for feeding, but also for food purposes, and the cost of storage is approximately 2-3 times lower than that of an elevator. Due to the high sealing capacity of the bag, the grain mass is self-condensed by reducing its biological activity, and storage of grain at zub-zero temperatures contributes to the natural cooling of the bag's content.

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