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Розглянуто проблему контролінгу в молочному секторі з застосуванням математичних методів. Запропоновано рангову оцінку ефективності регіонального менеджменту молочних кластерів. Розроблено математичні моделі його вдосконалення шляхом найшвидшого поширення інновацій, оптимального скорочення витратної складової та обґрунтування залежності продуктивності від масштабів виробництва. Здійснено апробацію наведеного комплексу засобів стратегічного та оперативного контролінгу

Ключові слова: стратегічний та оперативний контролінг, математичні процедури контролінгу, молочний кластер, регіональне управління

Рассмотрена проблема контроллинга в молочном секторе с применением математических методов. Предложена ранговая оценка эффективности регионального менеджмента молочных кластеров. Разработаны математические модели его усовершенствования посредством наискорейшего распространения инноваций, оптимального сокращения затратной составляющей и обоснования зависимости продуктивности от масштабов производства. Выполнена апробация приведенного комплекса средств стратегического и оперативного контроллинга

Ключевые слова: стратегический и оперативный контроллинг, математические процедуры контроллинга, молочный кластер, региональное управление

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DEVELOPMENT OF THE CONTROLLING SYSTEM IN THE MANAGEMENT OF DAIRY CLUSTERS

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1. Introduction

Efficient management is the basis of competitive activity under conditions of market integration and increasing requirements to the quality of products. One of the most powerful tools in modern management is the controlling that provides comprehensive coordination and control over performance effectiveness. In addition to modern crisis factors, agribusiness has to respond to new global challenges related to supporting food security at the accelerated growth in population [1]. Maintaining food security by means of controlling implies sustainable intensification of agricultural sector with minimal impact on the natural environment and compliance with the norms of population rational nutrition [2].

Most European countries have sufficient and even deliberately restricted volumes of agricultural products from local manufacturers [3]. However, current situation in Ukraine, in terms of particular items, is fundamentally opposite. This applies to the clusters of fruits and berries, meat and milk, where, on the one hand, the levels of consumption are lower than the norms of rational nutrition due to a low purchasing power of the population. On the other hand, Ukrainian agriculture is not capable of satisfying domestic markets as a result of ineffective operation of agribusiness.

Development of the agricultural sector in Ukraine significantly varies over different regions. The differences are related to natural resources, climatic conditions, availability of agricultural machinery and technologies, volumes of funding, the level of qualification of the workforce. Hence it follows the need for consistent and continuous improvement of the regional agricultural management, adapted to the specifics of product clusters of crop and animal production. In fact, dairy clusters of Ukraine and in the regions, in particular, in Dnipropetrovsk region, have common, often negative, changes over 1990–2015. Statistical data [4], however, testify to a much worse situation at the regional level. First, the number of cows and gross milk production in Ukraine decreased by 3.9 and 2.3 times, respectively, but these indicators fell by 6.0 and 3.7 times in Dnipropetrovsk region. Second, annual production and consumption of milk per person in Ukraine dropped by 48 % and 44 %, respec-

tively, while regional decrease reached 3.1 times and 47 %. Finally, cow milk yield grew by 62 % in Ukraine but only by 55 % in Dnipropetrovsk region. In summary, there is an important scientific-practical task to evaluate and improve agribusiness management by regions and types of agricultural products.

2. Literature review and problem statement

Modern controlling sets the goal of comprehensive growth in the productivity and competitiveness of production, cost reduction, development of human resources, expansion of market segments for product sales [5]. An application of the controlling system is effective both for powerful corporate structures and for small businesses [6, 7]. Controlling proposes means for improving management in the range from strategic to operational level when planning the activities. In particular, strategic controlling provides tools and procedures for the analysis of external environment and calculating efficiency of management, as well as it generates strategic plans for further development. Operational controlling substantiates reserves in the internal environment of activity, along with bringing down costs and ensuring maximum tactical results [8]. A modern trend in forecasting, planning and management by the means of controlling is an active application of information-computer technologies [9]. Mathematical basis and the tools of cybernetics provide effective controlling in accounting, quality management, risk management and logistics [10]. However, the adaptation of controlling to the sectoral and regional features is still an open question.

Solving the task of food security on a global scale requires efficient management of agribusiness in separate clusters of crops and animal husbandry [11]. Mathematical methods for improving dairy production in line with national features of activities are successfully applied in assessing the competitiveness of dairy producers in Slovakia [12], in comparing profitability of specialized dairy and mixed farms in the Czech Republic [13], in predicting wholesale and retail prices for milk in Hungary [14]. However, the current state of milk production in Ukraine and in regions leads to a conclusion that the employment of mathematical apparatus for improving management in agriculture is among the unsolved issues.

Thus, the research we conducted was aimed at obtaining mathematical estimates and searching for reserves of efficiency improvement in the regional clusters of Ukrainian agribusiness.

3. The aim and objectives of the study

The purpose of present research is to propose substantiated mathematical procedures for strategic and operational controlling, which would make it possible to take into account special features of management in the regional clusters of dairy sector.

In order to achieve the set goal, it was necessary to solve the following tasks:

1. To develop a mathematical procedure for the analysis of external environment and to evaluate effectiveness in the management of milk production.

2. To propose mathematical procedures for the substantiation of internal reserves in the management of regional dairy clusters through the implementation of innovations, cost reduction, and performance efficiency improvement.

3. To examine calculating aspects in the application of the controlling system under conditions of actual realities of the dairy sector in Ukraine.

4. Mathematical framework for controlling the regional management in dairy clusters

Estimation of agricultural clusters and markets is appropriate by using indices and coefficients of elasticity of demand and supply indicators, prices by the categories of farms, labor productivity [15, 16]. Therefore, in order to improve the adequacy of rating score of strategic controlling in the agricultural management, first we suggest including into its structure 8 indicators of business, technological and social effectiveness of the regional dairy clusters. For the purpose of evaluating business and technological results of activity in the dairy sector, it is expedient to analyze:

e_1 – wholesale price of milk;

e_2 – profitability of the regional dairy production;

e_3 – income per cow;

e_4 – milk yield per cow;

e_5 – milk output per feeding unit;

e_6 – milk output per milking plant.

Food safety in a dairy cluster performs an extremely important social mission of providing the country's population with one of the basic products of healthy nutrition. Therefore, the proposed ranking model should include indicators that assess not only entrepreneurial achievements in the regional agricultural management, but those that define their social effectiveness. This thesis was represented by considering a number of indicators:

e_7 – annual regional milk production per person;

e_8 – annual regional milk consumption per person.

The proposed rating assessment of efficiency E of the regional management in a dairy cluster is calculated from formula

$$E_j = \sum_{k=1,...,8} rank(e_{kj}) / 8, \ j=1,...,J, \quad (1)$$

where through $rank(e_{kj})$ we denote a rank of indicator e_k in region j among the indicators relative to other J regions, given in ascending order.

The second part of the present study was devoted to determining the reserves of operational controlling in the regional milk production in accordance with 3 methodological theses: "follow the leader" + "reduce costs" + "improve productivity". Implementation of the first option of controlling designed to improve regional management in the dairy sector by the principle "follow the leader" was linked with spreading agricultural innovations, established by the selected indicators of business, technological, and social effectiveness. The second option of controlling in terms of optimizing the regional management implied reducing the cost of milk through bringing down the most expensive expenditures for feed. The third reserve of controlling on the examined issue had to do with the integration of households to ensure optimal capacities for efficient milk production [17].

Innovative modernization exerts a significant positive impact on the improvement of management of dairy clusters and can form a basis for the effective procedure of operational controlling [18, 19]. The shortest ways to spread innovations from region i to region j can be determined in the following form. We shall denote through $L=\{link(i,j)\}_{i,j=1,...,J}$ a Boolean matrix of territorial links between regions, that is, $link(i,j)=1$ in the case of existence of a territorial link between regions i and j, otherwise $link(i,j)=0$. Then it is required to determine such a chain of distinctive numbers

$$n_1,...,n_{T+1}\in\{1,...,J\}, \tag{2}$$

that satisfies constraints

$$n_1=i,\quad n_{T+1}=j,\quad link(n_k,n_{k+1})=1,\quad k=1,...,T, \tag{3}$$

and has the smallest length

$$T\to\min. \tag{4}$$

The specified approach makes it possible to adapt optimization problems on the shortest path to the tasks of improving operational controlling in the regional dairy clusters. Optimal solutions of the model (2)–(4) can be found by means of the Dijkstra's algorithm. The advantage of its application is the ability to consistently search for the shortest chains among all attainable pairs of regions with determining those pairs of regions where territorial links are absent.

The application of optimization methods identified their benefits while reducing transportation cost of cooperatives in the milk supply chains, as well as it contributed to substantiating a dependence between profits of milk farms and the size of herd, milk productivity of cows and an indicator of the number of animals per a farm worker [20, 21]. In order to implement operational controlling in line with the principle "reduce costs", we proposed an optimization model of the following form. Namely, let the unknown variables define:

x_1 – crop area under concentrated feed crops;

x_2 – crop area under rough feed crops;

x_3 – crop area under succulent feed crops;

in this case, $x_1\geq 0$, $x_2\geq 0$, $x_3\geq 0$.

We shall denote through S a total area of arable lands in the region, a – a share of arable lands under feed crops. Then a constraint on the distribution of arable lands for feed crops will take the form:

$$\sum_{i=1,...,3} x_i\leq a\cdot S. \tag{5}$$

Each type of feed crops was characterized by the mean expected yield y, cost of production c, output of feed units f, acceptable weight range lw and uw, maximum share of feed units b. Based on the listed parameters, the following inequalities were obtained:

$$y_j x_j\leq uw_j\sum_{i=1,...,3} y_i x_i,\quad j=1,...,3, \tag{6}$$

$$y_j x_j\geq lw_j\sum_{i=1,...,3} y_i x_i,\quad j=1,...,3, \tag{7}$$

$$f_j x_j\leq b_j\sum_{i=1,...,3} f_i x_i,\quad j=1,...,3. \tag{8}$$

We shall denote through F a consumption of feed per a centner of milk, then let M be a gross production of milk required for supporting the regional food security according to the rational standards of nutrition with an annual consumption of 330 kg per person. Then the corresponding model's constraint will take the form

$$\sum_{i=1,...,3} f_i x_i / F\geq M. \tag{9}$$

Let P be a regional wholesale price of milk, while C is the proportion of feed in the structure of costs of the dairy sector in a region. Hence, an objective function that determines maximum profitability R of the regional milk production will take the form:

$$R=100\cdot\left(\frac{P\cdot\sum\limits_{i=1,...,3} f_i x_i / F}{\sum\limits_{i=1,...,3} c_i x_i / C}-1\right)\to\max. \tag{10}$$

It should be noted that a negative value of R will indicate the unprofitability of production. Applying the methods of mathematical modeling has to identify the ways to overcome this phenomenon. Thus, model (5)–(10) provides second reserve of operational controlling in the management of a regional dairy cluster by bringing down the cost of feed production for cows.

At last, international experience shows that effective milk production can be achieved both by large private enterprises and small family-owned farms or households. This effect is, however, explained by a growing cooperation among small business structures [22]. For the operational controlling of increase in the productivity, related to producers' capacities, it is appropriate to employ statistical methods. Given a small sample size (up to 24 elements based on the number of regions in Ukraine), it is mathematically correct to apply a Wilcoxon signed-rank test and a nonparametric Kruskal-Wallis H-test in order to compare milk yields from cows based on regions with different shares of large industrial production.

5. Approbation of the controlling system in the regional dairy clusters

The proposed mathematical procedures for the controlling of management were tested and illustrated by calculations based on statistical data from the Ukrainian dairy clusters in 2016 (Table 1). Assessments of effectiveness of the regional management, obtained from formula (1), are given in Table 2 that contains E_j, j=1,..., 24, and the corresponding ranks, sorted in descending order. As shown in Table 2, the highest rating of regional management among the Ukrainian dairy clusters was obtained by Ternopil region, while Odesa region received the worst rating. Overall, rating estimates E_j are in the range from 3.13 to 20.25 with an average value of 12.45 and a variation of 34.5 %. Rating estimate of Dnipropetrovsk region reached 10.5, which corresponds to the almost critical 19th place. This indicates that the regional management of Dnipropetrovsk dairy cluster requires immediate controlling improvement even compared only with the Ukrainian regions.

Table 1

Statistical sample of dairy clusters in Ukraine [4]

Region	Indicators							
	e_1 (€)	e_2 (%)	e_3 (€)	e_4 (kg)	e_5 (t)	e_6 (t)	e_7 (kg)	e_8 (kg)
Vinnytsya	143.3	12.5	736.2	5137	1.05	280.5	521.9	214.0
Volyn	143.7	20.8	586.8	4082	0.79	231.2	407.7	221.3
Dnipropetrovsk	146.7	–8.2	643.8	4387	1.09	216.7	105.5	194.7
Donetsk	141.6	0.2	626.5	4426	1.18	281.4	53.2	171.2
Zhytomyr	145.6	12.0	710.1	4877	0.81	207.0	462.1	230.8
Zakarpattya	174.2	14.9	633.0	3634	0.80	81.4	284.3	223.0
Zaporizhya	138.6	–1.5	591.2	4266	0.95	140.1	148.1	186.4
Ivano-Frankivsk	132.6	18.4	577.3	4354	0.88	167.0	342.9	259.3
Kyiv	151.1	13.0	913.7	6048	1.05	213.9	96.4	222.8
Kirovohrad	140.1	–0.6	698.5	4984	1.20	262.6	317.9	207.8
Luhansk	131.8	8.1	553.2	4197	0.95	187.9	71.7	144.8
Lviv	144.3	16.2	603.4	4180	0.94	113.8	225.2	235.5
Mykolayiv	145.8	7.4	599.0	4110	1.16	216.0	296.0	206.8
Odesa	129.1	–4.7	452.0	3502	0.86	173.2	161.0	194.5
Poltava	148.5	16.4	893.2	6016	0.95	287.0	550.2	223.6
Rivne	145.2	14.0	610.7	4206	1.03	189.8	376.1	213.1
Sumy	137.6	15.8	679.8	4940	1.09	381.5	373.4	203.5
Ternopil	152.3	21.7	694.6	4561	1.15	408.3	431.4	235.1
Kharkiv	142.5	17.0	781.5	5483	0.98	306.9	192.5	228.3
Kherson	148.6	14.4	618.6	4163	0.95	256.4	281.7	195.6
Khmelnytski	144.1	12.8	601.7	4175	1.01	347.6	448.0	233.0
Cherkasy	148.1	16.2	847.6	5724	1.04	335.6	425.0	226.9
Chernivtsi	143.1	0.9	681.8	4764	1.00	170.6	323.1	243.9
Chernihiv	140.3	13.7	664.1	4735	0.93	239.2	526.1	239.2

According to the principle "follow the leader", the first reserve for efficiency controlling of the regional dairy clusters implies the application of organizational, technological and marketing innovations from the leading producers of Ukraine. Namely, Ivano-Frankivsk and Poltava regions have the highest annual indicators of consumption and production of milk per person (259.3 kg and 550.2 kg, respectively). Kyiv region dominates by annual milk yield and income per cow (6,048 kg and €913.7 on average). This is, however, 25 % lower than that in Germany, the Netherlands and Finland, and is almost 50 % worse than that in Canada, Denmark, Sweden and the USA [25]. Ternopil region prevails by profitability and milk output per milking plant (21.7 % and 408.3 tons per year, respectively). Finally, Kirovohrad and Zakarpattya regions are the best by the indicator of milk output per feeding unit and by the wholesale price for milk (on average, 1.2 t of milk per feeding unit and €174.2 per ton of milk). However, it should be noted that the average wholesale prices in the developed countries of Eastern Europe are €343 per ton of milk, in Western Europe – €473 per ton of milk, and in North America they reach even €615 per ton of milk [25].

Minimum time periods T for spreading the specified best results by indicators e_1–e_8 are found from the formulated model (2)–(4) and are compiled in Table 3. As shown in Table 3, consistent regional spread of innovations in the Ukrainian dairy sector lasts up to 7 periods, according to the indicator's content. In particular, the periods for a wholesale milk price, its output per feeding unit, and per milking plant is one month. Time periods for profitability of the regional milk production, income, and milk yield per cow may comprise a quarter, while one year should be a time period for the annual regional production and milk consumption per person.

Table 2

Evaluation of effectiveness of the Ukrainian dairy clusters calculated from formula (1)

Rank	Region	Rating assessment
1	Ternopil	20.25
2	Poltava	19.00
3	Cherkasy	19.00
4	Vinnytsya	16.00
5	Kharkiv	16.00
6	Kyiv	15.63
7	Sumy	14.75
8	Chernihiv	14.25
9	Zhitomyr	14.00
10	Khmelnytskiy	14.00
11	Kirovohrad	13.50
12	Chernivtsi	12.75
13	Rivne	12.00
14	Kherson	11.13
15	Ivano-Frankivsk	10.75
16	Mykolayiv	10.75
17	Volyn	10.63
18	Lviv	10.63
19	Dnipropetrovsk	10.50
20	Donetsk	10.13
21	Zakarpattya	10.13
22	Zaporizhya	5.25
23	Luhansk	4.75
24	Odesa	3.13

Table 3

Minimal time periods for spreading innovations in the dairy clusters of Ukraine by indicators e_1–e_8, calculated from model (2)–(4)

Region	Time periods T by indicators							
	e_1	e_2	e_3	e_4	e_5	e_6	e_7	e_8
Vinnytsya	3	2	1	1	1	2	2	3
Volyn	2	2	3	3	4	2	4	2
Dnipropetrovsk	5	4	2	2	1	4	1	5
Donetsk	6	5	3	3	2	5	2	6
Zhytomyr	3	2	1	1	2	2	2	3
Zakarpattya	–	2	4	4	4	2	5	1
Zaporizhya	6	5	3	3	2	5	2	6
Ivano-Frankivsk	1	1	3	3	3	1	4	–
Kyiv	4	3	–	–	2	3	1	4
Kirovohrad	4	3	2	2	–	3	1	4
Luhansk	7	6	3	3	3	6	2	7
Lviv	1	1	4	4	4	1	4	1
Mykolayiv	5	4	3	3	1	4	2	5
Odesa	4	3	2	2	1	3	2	4
Poltava	5	4	1	1	1	4	–	5
Rivne	2	1	2	2	3	1	3	2
Sumy	6	5	2	2	2	5	1	6
Ternopil	2	–	3	3	3	–	4	1
Kharkiv	6	5	2	2	2	5	1	6
Kherson	6	5	3	3	2	5	2	6
Khmelnytskiy	3	1	2	2	2	1	3	2
Cherkasy	4	3	1	1	1	3	1	4
Chernivtsi	2	1	2	2	2	1	3	1
Chernihiv	6	4	1	1	2	4	1	5

Certainly, acquiring the best domestic and international experience does not exhaust all relevant options for improving efficiency in the regional dairy clusters. To prevent further degradation of the Ukrainian dairy sector, it is required to find internal reserves of agricultural management. In particular, regional natural potential should be implemented to the fullest, that is, related to large arable lands, favorable climatic conditions and fertile soils. Second option for the controlling in the examined issue will contribute to a reduction in the cost of milk production by growing own feed crops. Such an approach will provide essential strategic environmental benefits. In fact, crop production is a profitable area of the agrarian sector in Ukraine, demonstrating profitability in the range from 8 to 42 % [23]. However, the opposite side of this achievement is a dangerously high level of soil plowing, systematic violation of the crop rotation, and neglecting the techniques to restore soil fertility [24]. Namely, a part of arable lands in Ukraine reaches 56.2 %, which is the third indicator globally, after Bangladesh and Denmark, while these indicators in Poland, Germany, France, and the USA are 35.7 %, 34.0 %, 33.5 %, and 16.9 %, respectively [28]. According to data from the State Statistics Service of Ukraine [4], structural shares of industrial crops, especially sunflower, increased from 15.4 to 31 %, which gradually destroys Ukrainian fertile black soil. At the same time, structural share of feed crops decreased from 26.0 to 7.4 %, and even to 3.2 % in Dnipropetrovsk region [4]. This tendency ranks among the most dangerous causes of the crisis state of domestic livestock.

Optimization model (5)–(10), proposed in order to solve this problem, was implemented using the spreadsheets LibreOffice Calc and verified on data from Dnipropetrovsk dairy cluster.

In particular, Dnipropetrovsk region has 2 082 600 hectares, or nearly 7 %, of all arable lands in Ukraine. Hence, overall recovery of soil fertility and livestock industry is a regional priority in the view of providing food security and environmental protection. A share of the arable lands under feed crops at a 5-year crop rotation for natural restoration of soil fertility is 20 %, that is, we accepted a=0.2 for calculations.

The most common concentrated feed in Dnipropetrovsk region are grain crops, rough – alfalfa, succulent – corn silage and root crops. According to the summary of agricultural production in Dnipropetrovsk region from the Main Statistics Department in Dnipropetrovsk region for 2016 [26], model characteristics of the specified feed crops took the following values:

– crop yield y_1=38, y_2=80, and y_3=200 centners per hectare;

– production cost c_1=383.3, c_2=110, and c_3=280 € per hectare of crops;

– outputs f_1=50, f_2=24, and f_3=40 feed units per hectare;

– permissible weight ranges from lw_1=0.1 to uw_1=0.2, from lw_2=0.25 to uw_2 =0.4, from lw_3=0.55 to uw_3=0.65;

– maximum shares of feed units b_1=b_2=b_3=0.5.

According to data from the State Statistics Service of Ukraine [4], other model parameters of the dairy cluster of Dnipropetrovsk region equaled:

– feed consumption F=0.92 centners per centner of milk;

– desired annual regional milk production M=10 778 957 centners;

– regional wholesale price P=17.2 € per centner of milk;

– feed share in the structure of cost of the regional milk production C=0.6.

Based on the conducted author's calculations, it is established that the reserves for controlling the improvement of regional management, defined using model (5)–(10), involve increasing the profitability of Dnipropetrovsk dairy cluster up to 72 %. Calculations that employed tools of the LibreOffice Calc software and model (5)–(10) showed that this result is attainable in the case of growing own feed crops at 13.4 % of the regional arable lands, and by dividing 27 %, 45 %, and 28 % of cultivated areas to the concentrated, rough, and succulent crops. At the same time, the remaining 6.6 % of the ecologically reasonable 20 % of arable lands are expedient to allocate for feed crops for the meat cluster of Dnipropetrovsk region.

In the future, in order to provide regional food security, milk producers of Ukraine have to apply management techniques that ensure the highest performance efficiency of dairy sector in the world. In this case, the USA, Denmark, Canada, Sweden, and Finland should be included in the list of such countries-leaders, where the average annual milk yield of cows are 9 902, 8 766, 8 739, 8 459, and 8 222 kg of milk [25]. The performed analysis of statistical data has revealed the third option for improving the efficiency of dairy sector in Ukraine based on a positive effect from a large-scale production.

On the one hand, Table 2 indicates that the Ternopil milk cluster is ranked first among other regions, although its dominant producers of milk are the households with a share of 87.2 % [4]. At the same time, agricultural enterprises in Poltava and Cherkasy regions produce 53.5 and 55.5 % of milk, respectively [4]. And these are the Poltava and Cherkasy dairy clusters that took the second and third places, according to the regional rating (Table 2). In addition, based on the rating assessments (Table 2) and by the structural shares of regional milk production at agricultural enterprises in Ukraine [4], a Spearman rank correlation coefficient was found, which is only 0.53 with a significance level of 0.01. Thus, the given facts illustrate potential competitiveness of both large and small milk producers in Ukraine.

On the other hand, according to data from the State Statistics Service of Ukraine [4], 10 % of large agricultural enterprises that keep more than 500 cows and produce more than 3 000 tons of milk annually, account for more than 51 % of its gross production in Ukraine. In this case, 60 % of small farms, which keep less than 100 heads of cows and produce less than 500 tons of milk annually, provide only 7.6 % of products. Currently, 55 % of milk is produced by 19 % of highly effective agricultural enterprises whose annual milk yield from cows exceeds 6 000 kg. At the same time, only 14 % of products are made by 56.1 % of small farms whose annual milk yield of cows is less than 4 000 kg [4].

A Wilcoxon signed-rank W-test on a sample of 24 regions of Ukraine, calculated by authors of the present paper at a significance level of 0.05, has confirmed the dominance of the average milk yields from cows in agricultural enterprises in comparison to the indicators of households:

$$87=W_{calc}<W_{crit}=91.$$

In addition, a nonparametric Kruskal-Wallis H-test was verified on 4 samples of the average milk yield from cows by regions with shares of milk production by agricultural enterprises below 10 %, from 10 to 20 %, from 20 to 40 %,

and over 40 %. It was confirmed with a significance level of 0.01 that there are advantages in the productivity for regions with more powerful milk manufacturers:

$$11.79 \approx H_{calc} > H_{crit} \approx 11.34.$$

Thus, the outlined trends substantiate the third encouraging option for controlling in order to improve management over regional clusters in Ukrainian agriculture.

6. Discussion of practical aspects in the application of controlling system for the regional management of dairy sector

Computed approbation of research results allowed us to establish the following features of practical application of the controlling system in regional dairy clusters.

First, the proposed rating estimation of the controlling in dairy clusters is a quantitative cumulative index whose structure combines 3 groups of business, technological, and social indicators of regional management. The specified mathematical modification enables to implement a function of strategic monitoring over the state and prospects for improving regional milk production and contributes to increasing interregional competition.

Second, a characteristic feature of the mathematical model for operational controlling over the innovative improvement of regional management is that its constraints are formalized in line with the requirements for territorial links between dairy clusters, and the minimum duration of spreading key innovations is chosen as the optimality criterion. The advantages of the specified mathematical procedure for operational controlling include the availability of its information support from the official sources of statistical data in Ukraine.

Further innovative improvement of regional management in Ukrainian dairy clusters implies their arrangement using the examples of Denmark, the Netherlands, Switzerland, Finland, and Austria. These are the countries that have the highest volumes of annual milk production per person, 908 kg, 742 kg, 499 kg, 429 kg, 403 kg, respectively [25]. At the same time, to join the global system of food security, regional management of Ukrainian dairy sector should be reorganized using the model of New Zealand, Germany, the Netherlands, France, and the USA, which held 18.9 %, 11 %, 8.1 %, 6.5 %, and 6.1 % of the world milk export market in 2016 [27].

Third, optimization model of the operational controlling by the criterion of increasing profitability of milk production differs from other analogues by its including the constraints by the types of own feed crops and conditions for ensuring milk consumption in accordance with standards of healthy nutrition. It should be noted that quantitative recommendations for reducing production cost in a dairy cluster are of short-term character only and thus require annual adjustment for the result of changes in the market parameters of the model.

Four, when choosing statistical tests for the appropriateness of operational controlling based on the attribute of production capacity, limited volumes of the analyzed data should be taken into account. In comparison with the analogues, a Wilcoxon signed-rank W-test and a nonparametric Kruskal-Wallis H-test make it possible to substantiate the prospects of integration and cooperation in dairy clusters in a mathematically correct technique. Practical significance of the given approach is proven by the fact that at present agricultural enterprises produce more than 40 % of milk in only 5 regions of Ukraine. The dairy cluster of Dnipropetrovsk has substantial reserves for building the capacities of production, taking into account the fact that the share of households in the dairy sector of the region reaches 76.3 %.

Finally, the application of mathematical methods proved a positive impact on the regional management of dairy clusters. Therefore, in the future, it is expedient to continue development of the controlling systems over food security for other sectors of agricultural production.

7. Conclusions

1. The generalized mathematical procedure for strategic controlling in the regional management is modified and supplemented with a set of business, technological, and social indicators of rating assessments for clusters in the dairy sector. By using this technique, it becomes possible to define priorities for the trajectory of further development of regional milk production.

2. Mathematical apparatus of the optimization theory allowed us to perform formalization of procedures for operational controlling, adapted to the criteria and constraints of regional management in the dairy clusters. A complex of developed mathematical models and the selected statistical tests for calculating the reserves of efficiency in the dairy sector will make it possible to:

– to spread agricultural innovations from the regional leaders;

– to reduce cost and improve milk profitability under conditions of cultivating own feed crops;

– to improve productivity due to the effect of a large-scale production.

3. During practical test, we have proven adequacy of the mathematical formalization of procedures for strategic and operational controlling and established their positive impact on effectiveness of the regional management over a dairy cluster. Mathematical support for controlling by the means of quantitative assessments, optimization models and statistical tests will contribute to the saturation of domestic market according to the rational standards of nutrition, and eventually – to increase export of excessive milk abroad.

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