ЕКОНОМІКА ТА УПРАВЛІННЯ ПІДПРИЄМСТВАМИ

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MATHEMATICAL MODELLING OF THE PRODUCTION AND MARKETING OF PORK PRODUCTS AT THE ENTERPRISE LEVEL

Bezus R. M., Kobernyuk S. O. Mathematical modelling of the production and marketing of pork products at the enterprise level. Large changes in global market requirements and production environment, the reorientation of production and sales planning play a key role to support the optimization of the production and marketing of pork products. The adoption of separate decisions on production capacities and scale of sales may lead to lower profits. It is therefore proposed an integrated method for the simultaneous determination of two subtasks. The necessity of the economic-mathematical modelling usage in economics, including production activities of agricultural enterprises, is scientifically proved. Recommendations for the construction of a mathematical model taking into account the factors as model parameters are advised. The proposed mathematical model is a multi-disciplinary, multi-layer analysis, taking into account many variables, in particular, production lines, markets, sales prices, in order to copy with the large search space of solutions, applied the concept of genetic algorithm to effectively improve the performance of production and marketing of pork products.

Keywords: enterprise, agriculture, modelling, economic-mathematical modelling, mathematical model, production activities of agricultural enterprises, production, marketing.

Безус Р.М., Кобернюк С.О. Математичне моделювання виробництва і збуту продукції свинарства на рівні підприємства. Через великі зміни в глобальних потребах ринку і виробничого середовища, перепрофілювання виробництва і планування продажу відіграє ключову роль для підтримки оптимізації виробництва і збуту продукції свинарства. Прийняття окремих рішень щодо виробничих потужностей, і масштаб продажів можуть призвести до зниження прибутку. Тому пропонується комплексний метод одночасного визначення цих двох підзадач. Обґрунтована необхідність застосування економіко-математичного моделювання в економіці, в тому числі для виробничої діяльності сільськогосподарських підприємств. Надано рекомендації для побудови математичної моделі з врахуванням факторів, як параметрів моделі. Запропонована математична модель являє собою багатопредметний, багатошаровий аналіз з урахуванням багатьох змінних, зокрема виробничі лінії, ринки, ціни продажу, для того, щоб скопіювати з великого простору пошуку рішень, застосовується поняття генетичного алгоритму для ефективного підвищення продуктивності виробництва і збуту продукції свинарства.

Ключові слова: підприємство, сільське господарство, моделювання, економіко-математичне моделювання, математична модель, виробнича діяльність сільськогосподарського підприємства, виробництво, маркетинг.

Безус Р.Н., Кобернюк С.А. Математическое моделирование производства и сбыта продукции свиноводства на уровне предприятия. Через большие изменения в глобальных потребностях рынка и производственной среды, перепрофилирование производства и планирование продаж играет ключевую роль для поддержки оптимизации производства и сбыта продукции свиноводства. Принятие отдельных решений относительно производственных мощностей, и масштаб продаж могут привести к снижению прибыли. Поэтому предлагается комплексный метод одновременного определения этих двух подзадач. Обоснована необходимость применения экономико-математического моделирования в экономике, в том числе для производственной деятельности сельскохозяйственных предприятий. Даны рекомендации для построения математической модели с учетом факторов, как параметров модели. Предложенная математическая модель представляет собой многопредметный, многослойный анализ с учетом многих переменных, в частности, производственные линии, рынки, цены продажи, для того, чтобы скопировать с большого пространства поиска решений, применяется понятие генетического алгоритма для эффективного повышения производительности производства и сбыта продукции свиноводства.

Ключевые слова: предприятие, сельское хозяйство, моделирование, экономико-математическое моделирование, математическая модель, производственная деятельность сельскохозяйственного предприятия, производство, маркетинг.

Statement of the problem. In the mathematical modelling of production and marketing of pork products at the enterprise level the use of mathematical models in economics plays a leading role. Enterprise budgets were developed based on the use of input and output costs, as well as average production volumes and revenues, associated in particular with the allocation of land to alternative crops and livestock production, using previous production practices. When linear programming became practical with the growth of computing power, the enterprise budgets provided the data how advisable is it to implement this optimization tool.

In addition, a large number of alternative areas of production of agricultural activities, and various constraints related to land, labour, capital and technology showed possibilities to agricultural enterprises of the usefulness of mathematical modelling. Agricultural economists widely used programming tools, readily accepting and in some cases further innovation.

Analysis of recent research and publications. In the literature there are numerous documents related to the production and promotion of agricultural products in the market. These documents were distributed in three dimensions on the basis of manipulative variable: (1) the solution to the problems of production, (2) the solution to the problem of promotion of agricultural products in the market, and (3) the solution to problems of production and promotion of agricultural products in the market. A significant contribution to the development of practical economic and mathematical modelling in Economics, Finance was made by scientists, such as: Burkinsky B. V., Vitlinsky V. V., Galaeva L. V., Vasyuk I. V., Volk V. M., Priyma S. S., Shish I. M., Gedelevich E. V., Demchuk N. I., Kuzmenko E. V., Pavlova V. A., Kholod S. B., Makarenko P. M., Samarska D. O., Domaskina M. A., Sergeeva O. R., and others [1-8].

First, the solution to the problems of production occurs when the decision variables on the basis of industrial activities, such as production capacity of the facility/equipment, production volumes and production cycle/series, etc. There are a lot of studies of integration of subprocesses, but really only to coordinate them in the form of the cost function, not the manipulation of variables between multiple processes. From the point of view of controlled variables, it is possible to name these types of problems, problem solving of production. There are one-product models, multiproduct models and models of one company. In addition, there are studies of multi-product, multi-companies and multi-market problems [6].

Second, the solution of the problem of promotion of agricultural products on the market occurs when the demand between the markets and the agricultural enterprise is well-known and it entails a decision on distribution activities, such as distribution of existing equipment, modes of distribution number of distribution and routing. This is a problem of planning development of the logistics network.

Thirdly, another problem is the production and promotion of agricultural products in the market, that is the simultaneous solution to this problem, this means that there is at least one manipulative variable in production and distribution activities. With these types of studies it is discussed the promotion of agricultural products in the market, how to manipulate the variables that relate to production activities. They make decisions on distribution, such as the number of transport for internal distribution. In addition, the problem of route selection, you can use direct distribution or multiple distribution routes through other warehouses. These types of studies are rare but important in the strategy and tactical decision support systems decisions in real agricultural enterprises.

Key business processes are the production, promotion and sale. There are very few studies that discuss the production and solution of marketing problems. There are two points of view on the long-term capacity management for manufacturing of pork products and sales strategies that say about the importance of simultaneous decision making on production and sales problems. However, there is no modelling work. The advantage of an integrated model has been proven by numerous experiments. However, the amount of reserves is a variable solution for sales process model, which is the operational level of the factor in the decision of planning problems of sales and financial-economic operations of agricultural enterprises. As the objective function in the maximize profits model of agricultural enterprises, in particular, include the price in the market. One of the disadvantages of the model is that sales prices are given in advance. When planning the production of pork products, we believe that the sale price as a decisive factor in the sales process is very important in modern medium-and long-term solutions for agricultural enterprises.

Task formulation. The purpose of the article is to offer a comprehensive method to solve simultaneously the problems of production and sales planning of pork products to support tactical decisions for agricultural enterprises.

Main material exposition. After an initial focus on the management of an agricultural enterprise the urgent advanced marketing study, with the aim of improving the welfare of farmers is becoming increasingly, more efficient procurement of materials and sales of products. The markets of grains and livestock are so interrelated that it led to the modelling of the market supply and the demands of the system of equations, and to the need to evaluate these systems. At the same time, we must recognize that some budgets are focused more on maximizing production, not profit maximization. This leads to the estimation of production functions specifying the initial value as a function of factor input levels and other characteristics of the production environment, including human capital. The need to evaluate relationships in production and marketing is resulted in the application of statistical methods in economics, now called econometrics. In turn, this has led to a new regulatory class,

seeking to optimize social welfare through the development of agricultural policy. The use of welfare economics as a tool of analysis of agricultural enterprises activity became the main goal of mathematical modelling.

Thus, the application of mathematical modelling continues to increase to the extent that the activity of enterprises devoid of serious mathematics is unlikely to be as effective as possible.

For the mathematical modelling of production and marketing of pork products at the enterprise level it is expedient to use such tools:

– simulation models and normative modelling;
– linear programming;
– integer programming;
– quadratic risk programming;
– nonlinear programming.

The global market environment can be described as such that has global factors those are external to the management of the production farm, but can significantly affect business planning. Currently, we see that the market is growing worldwide. To continue to grow, agricultural enterprises should learn to act in the global and regional markets. Traditional production planning in agricultural enterprises, which are engaged in mixed farming, namely the cultivation and production of pork products, was concentrated separately by optimizing production and sales planning in different departments with different goals at the end of the year. The production department strives to minimize production costs, and the activities of the sales department are dedicated to maximizing revenue from sales. However, revenue maximization from the sale of products does not mean that production costs are minimized. In addition, in many cases it is accompanied by an incorrect decision-making associated with full capacity utilization. This leads to increased production costs and reduced investment. Therefore, integrating these subprocesses in optimization economic and mathematical model it is necessary to provide a compromise between them.

In addition, the agreement between subprocesses is the best method to obtain the corresponding production plan. Cost functions must be well-formed with the use of mathematical models because of faulty design business model deviates from the actual production operations and no opportunities to use accurate data of real businesses. In the end, the shortcomings of the cost management system cannot provide the decision-makers, convincing advice when making business decisions.

Therefore, you must rebuild the planning of production of pork products through an integrated sub-processes and the reconstructed cost function to obtain the best system decision support to help managers of agricultural enterprises.

In this paper we consider an optimal design and operation of multi-production of pork products, product lines, markets and selling prices of production, problems of pork products promotion to the market and sales. In general, each product belongs to a product group and each product group is allocated for one or several production lines at different farms.

The location of the farm is important and each farm consists of several production lines. Each production line has a fixed assets value and fixed cost of work. If the allocations of market demand in a standard production capacity of the production line, then the cost of making the line is permanent. However, the unit production cost of this line decreases, output increases, and overtime labour costs are increased if the distribution of demand in the market is higher than standard production capacity, but not above the maximum production capacity. Another situation is the distribution of market demand that exceeds the maximum production capacity; in this case, there must be capacity building in the form of a new production line.

Let's consider the demand for the types of products and quantity for each region. It is possible to get the sale price and the value of the dynamics of demand curve price-quantity (PQ) on each market and each product has multiple prices associated with a corresponding number. For example, the demand in some economic regions is very sensitive to sales price. However, as constraints, there are absolute minimum selling price and maximum demand for each product in each region.

Let's study the connection between agricultural enterprises and distribution channels of pork products that use transportation. In practice, several types of distribution can be selected. Because of the complexity and long time logistics outsourcing is considered to be the best for the process of distribution. We can get the delivery cost of pork products with an outsourcing transport company, which could indicate the unit of delivery cost from the enterprise to the market for each product.

In this mathematical model, we define production capacity for each product from farms to the markets and sale price of each product in each market as our manipulative variables. The objective function is to maximize the total annual income from the production network, considering both fixed and variable costs. In this article we consider the stationary form of the problem, according to which the price of sale, production and distribution flows are determined by optimization.

The mathematical model of the production-distribution-sales is considered.

After the problems described above, we formulate the production-marketing-sales using the model of mixed integer programming. It is necessary to make the optimal planning for private agricultural enterprises.

Hypotheses:

(1) each production unit has the ability to produce relevant groups of the products;

(2) each production unit has a production standard and maximum capacity but it can be expanded at the expense of variable or fixed costs;

(3) there is a changing distribution of costs between each company and the market;

(4) the demand for each market comes from the final consumers of the region;

(5) there are several pricing options for each product in each market;

6) there are several options in the demand for each product in each market;

(7) no stock limits on markets;

(8) the storage capacity may be changed due to the increase in rent for warehouse space.

Indicators and sets:

i animals (pigs) $i \in I$ $(i = 1, 2,, I)$.

l processing lines $l \in L$ $(i = 1, 2,, L)$.

k type of product $k \in K$ $(k = 1, 2,, K)$

g product groups $g \in G$ $(i = 1, 2,,G)$

j market segments $j \in J$ $(i = 1, 2,, J)$

p sales prices $p \in P$ $(i = 1, 2,, P)$

l_i production line on the farm i.

k_l products that can be produced on the line l.

Parameters of products:

$PCap^l$ standard production capacity of the farm and for the line l (time).

$PCap_i$ i_l maximum production capacity of the farm for the line l.

$PAss^l_i$ the rate of return of fixed assets for the line l on the farm i.

$PLab^l_i$ return of fixed labour cost for the line l on the farm i.

$PSun^l_i$ other annual costs for the line l on the farm i.

CTK_i^k the expended man-hours amount to manufacture product k on the farm i.

Ck^{materi} material costs unit for the production of a product k.

INV^l the annual investment costs for the line l.

$a^{overtime}{}_{i\,l}$ ratio of overtime labour costs for the line l on the farm i.

Parameters of marketing (distribution and sale):

$C^{trans}{}_{ij}$ unit of transportation cost from farm i to market j.

$p^j{}_k$ possible sales prices of product k in the market j.

d_k^j possible volume of demand of product k in the market j.

$dlot_k^j$ demand variety of product k in the market j.

α_{ijk}^{proc} ratio of procurement to production k from farm i in the market j.

β_{ijk}^{duty} coefficient of taxes value on products k from farm i in the market j.

$C^{inter}{}_j$ loan interest rate in banks in the market j.

Sp_k production value of product k.

$wp^a{}_j$ cost of a warehouse renting in the market j.

$\hat{c}^k_j$ level of service in the market j for product k.

α standard deviation of demand.

I_0^{kj} initial inventory of product k in the market j.

Variables that agricultural enterprise can manipulate.

Production:

$x^k{}_{i\,j}$ production volume of product k from the farm i for the market j.

Sales:

y^k_j 1 – if the sale price of product k in the market j is selected, and 0 otherwise.

The problem of optimization of pork production and promotion of products in the market by agricultural enterprises is formulated with the objective function to maximize total profit:

Max

$$\sum_j \sum_k p^k{}_j y^k{}_j * d^k{}_j y^k_j - \text{production costs} - \text{marketing costs} - \text{sales costs} \quad (1)$$

Subject to:

$$\sum_l CTK_i^k * x_{ij}^k \geq \sum_l \sum_k d \quad (2)$$

$$k_j \sum_l CTK_i^k * x_{ij}^k \geq 0 \quad (3)$$

$$\sum_j \sum_k d^k j\, y^k j \leq \sum_i \sum_k xij^k \quad (4)$$

Maximization of total profit in the objective function includes the total revenue and total production cost. Total production cost includes production costs, marketing costs and cost of sales. In particular, it includes the cost of standard products manufacturing, the cost of overtime and the capacity increase of the production line. Distribution costs include delivery costs from the farms to the market. Cost of sales includes taxes, marketing expenses and other costs.

Task (1) is to maximize total profits, minimize production-related expenses, marketing cost and cost of sales. Constraints (2) are limited production capabilities, which ensure that production volume should not be less than the amount of demand for the products of a particular farm. Constraint (3) provides the minimum value of production for each selected line l. Constraint (4) is the limited demand for the market j, which shows that the demand for the products k should not exceed the production quantity at each enterprise. Constraint (5) is the limitation of warehouse space for the market j, show that the value of stocks in each market shall not exceed the warehouse capacity.

Production costs:

Situation 1: annual fixed costs + material costs

If $0 \leq \sum_l CTK_i^k * x_{ij}^k \leq PCap_i^l$

$\sum\sum(PAss_i^l + PLab_i^l + PSun_i^l) + \sum\sum C_k^{materi} * x_{ij}^k$

Situation 2: annual fixed costs + material costs + overtime costs

If $PCap_i^l \leq \sum_l CTK_i^k * x_{ij}^k \leq PCap\hat{}_i^l$

$\sum\sum(PAss_i^l + PLab_i^l + PSun_i^l) + \sum\sum C_k^{materi} * x_{ij}^k$

Situation 3: annual fixed costs + material costs + costs of capacity expansion

If $PCap\hat{}_i^l \leq \sum l\ CTK_i^k * x_{ij}^k$

$\sum\sum(PAss_i^l + PLab_i^l + PSun_i^l) + \sum\sum C_k^{materi} * x_{ij}^k$

i -l $\qquad$ i- k

Distribution costs:

$$\sum\sum\sum C^{trans} * x^k$$

ij $\quad$ ij

Cost of sales = total taxes + marketing expenses + other expenses

The proposed mathematical model shows that significantly more difficult to solve the problem using mathematical methods, when the scale of the problem grows. There are studies tha t review the decisions of supply chain optimization models using genetic algorithms. Genetic algorithms proved to be effective enough for complex optimization problems, towards methods of

stochastic search and can easily find good solutions in a shorter period of time. Therefore, in this study, we use the concept of a genetic algorithm for the development of the planning system of the production of pork products.

Conclusions and recommendations for further researches. The article suggests a comprehensive study of the problems of production and planning methods of sales using manipulative variables as the cost function. For easy construction of the model to be as close to the real activity of the agricultural enterprise, production function of process cost using the operation timing, including fixed hardware costs and variable costs of labour. We built a cost function of the sales process due to the change in tariffs with routing, by changing inventory costs due to the scale of sales by other costs. Using the proposed mathematical model, numerical experimental results proved the advantage of integrated method in comparison with the method of the interchange for the development of the economic environment. Also it is stressed that the market has become more sensitive, which made the efficiency of the proposed method more obvious.

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