

Optimization model of production and product sales within profit maximization

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Abstract—Demand for some food differs from day to day. For example, a sharp increase in demand for poultry meat on weekends and holidays is notable. In such conditions, companies need to answer the following question: how many products and what kind of products shall be produced and sold to meet the demand of buyers under limited resources and, at the same time, to obtain the maximum profit. To answer this question, a model for optimizing production and products selling within profit maximization was developed. The main advantages of the proposed model is the creation of a production structure that will provide the maximum profit, while several types of products, sale price, limited resources are taken into account. The proposed model was tested on the materials of the operating company. The model included 14 types of finished products, their sale price, the rate of consumption of raw materials, restrictions on the available raw materials, technical and labor resources. As a result of the application of the model, the structure of production and the maximum forecast profit with minimum and maximum demand were obtained. Practical application of the model is realized using the Microsoft Office application package (Excel).

Keywords—*optimization model, profit maximization, poultry meat production.*

I. INTRODUCTION

In market conditions, supply often exceeds demand, which adversely affects producers, as it leads to overstocking of the warehouse. If a company is engaged in the production of short shelf life products, overproduction and additional costs for maintaining finished products can lead to a loss due to natural damage to products.

To provide the population with quality food, as well as to increase the efficiency of their own production, agricultural

companies do the research of demand for manufactured products.

Thus, the demand for various types of poultry products (whole carcass, cuts, minced meat, ends of cuts) differs from day to day. For example, on weekends and holidays there is a significant increase in demand for poultry meat. In this regard, the authors believe that the output should depend on the consumption habits.

To increase the efficiency of production and sale of poultry meat, as well as to improve the supply of poultry products to the population, an economic and mathematical model was developed to optimize the production and sale of poultry meat. The task of this model is to determine such structure of production and sale of poultry meat which will provide maximum economic benefit, taking into account the availability of production resources and turnover. As a criterion of optimality, the authors used the maximum profit level in the model, since this indicator objectively characterizes the efficiency of production and marketing activities of the company and is also the main objective of the business entity activity.

II. BRIEF LITERATURE REVIEW

The development of optimization models for maximizing profits was done by such scientists as Y. Jiang, J. Shang, Y. Liu, J. May, M. Moghaddam, S.Y. Nof, M. Natter, A.-M. Ozimec, J.-Y. Kim, A.V. Prokopyeva, A.S. Nechaev, K. Puranam, M. Katehakis, R.W.Seifert, J.-S.Tancrez, I. Biçer, M. Tyapkina, E. Ilina and E. Domanova.

Optimization modeling of agricultural production is reflected in the works of S. Robinson, H. van Meijl, D. Willenbockel, H. Valin, S. Fujimori, T. Masui, R. Sands, M.

Wise, K. Calvin, P. Havlik, D. Mason d'Croz, A. Tabeau, A. Kavallari, C. Schmitz, J.P. Dietrich, M. von Lampe, S. Shrestha, T. Hennessy, M. Abdalla, D. Forristal, M.B. Jones, Ya. M. Ivano, V. R. Elohin, T. N. Medvedeva.

However, the problems of modeling the optimization of production and sales of products in order to maximize the profit of a particular enterprise have not been adequately studied.

III. MATERIALS AND METHODS

The optimization model for the production and sale of poultry meat takes into account various processing options: the whole carcass, cuts (thigh, drumstick, breast, round cut, wing, fillet, ends of cuts); giblet (gizzard, liver, heart, heads, paws); minced meat. Let us take y_v as an amount of a v product where $v=1, 2, \dots, 14$.

In this case, carcasses of different weight categories are used for the production of different types of products. Carcasses of the first and second weight categories can be used to produce all four considered options for poultry products depending on market demand, non-categorized carcasses are used to produce minced meat and ends of cuts products.

The authors introduced a_{iq} factor for each weight category which reflects the ratio of the whole carcass of a q weight category in the i production option, i.e. $q = 1, 2, 3$ – weight categories of the poultry; $i = 1, 2, 3, 4$ – poultry processing option. For the q weight category, the following condition is fulfilled:

$$\sum_{i=1}^4 a_{iq} = 1 \quad (1)$$

Then, the quantity of finished products (y_v), represented by separate parts of the poultry carcass (breast, thigh, drumstick, fillet, wing, etc.), is determined by the following equation:

$$y_v = \sum_{i=1}^4 a_{iv} x_i \quad (2)$$

where a_{iv} – ratio of the v part of the carcass in the i production option, x_i – amount of the produced products in the i production option, kg.

Revenues are defined as the difference between the sale revenues of produced goods and the cost of production. Sale revenues of products (T_v) are calculated by the following formula:

$$T_v = \sum_{v=1}^{14} p_v y_v \quad (3)$$

where p_v – sale price of the v type of the finished goods, rub.

The cost of production depends on the rate of resources consumption and their cost. Let us denote the used resources

as R_j . For the production and processing of poultry meat, it is required as followed: resource R_1 – the volume of primary raw materials in the amount of b_1 kg; R_2 – manpower in the amount of b_2 people; R_3 – equipment in the amount of b_3 machines. The resource unit cost is d_j , RUB. Therefore, the cost of production (C_i) is calculated as follows:

$$C_i = \sum_{j=1}^3 d_j \sum_{i=1}^4 a_{ij} x_i \quad (4)$$

where d_j – the resource unit, RUB; a_{ij} – R_j resource consumption rate for the i option product, x_i – the amount of the i option product output.

The production of x_i products is demand-based, which is determined in the amount of S_i kg ($i = 1, 2, 3, 4$); therefore, S is the total demand for finished products, kg.

Thus, the mathematical model of production and sale plan optimization of poultry meat is as follows:

$$f = \sum_{v=1}^{14} p_v y_v - \sum_{j=1}^3 d_j \sum_{i=1}^4 a_{ij} x_i \Rightarrow \max \quad (5)$$

limited by:

- 1) Market demand - based products output, kg:

$$\sum_{i=1}^4 x_i \leq S_i$$
- 2) The product sales volume not less than the specified volume, kg: $\sum_{i=1}^4 x_i \leq M$, where M – volume of products sold, kg;
- 3) Actual expenditure of raw materials, manpower and equipment:
 - $a_{11}x_1 + a_{12}x_2 + a_{13}x_3 \leq b_1$ (kg);
 - $a_{21}x_1 + a_{22}x_2 + a_{23}x_3 \leq b_2$ (people);
 - $a_{31}x_1 + a_{32}x_2 + a_{33}x_3 \leq b_3$ (units).
- 4) Total whole carcass production, kg: $y_1 = x_1$
- 5) The amount of finished products which are separate parts of the poultry carcass (breast, thigh, drumstick, fillet, wing, etc.), kg: $y_v = \sum_{i=1}^4 a_{iv} x_i$
- 6) Implementation of conditions for each weight category: $\sum_{i=1}^4 a_{iq} = 1$
- 7) The condition that the variables are not negative: $x_i, y_v, a_{iq} \geq 0$

The described production and sale optimization model of poultry meat within profit maximization is applied with Microsoft Office package (Excel).

IV. RESULTS AND DISCUSSION

In the described model of production optimization and sales of products, one of the limitations is the magnitude of demand for products. In this regard, an analysis of demand in the poultry meat market was conducted using the example of the Irkutsk region. For a more complete analysis of demand, it is necessary to consider the dynamics of meat consumption including poultry meat in the region as compared to that in Russia (fig. 1).

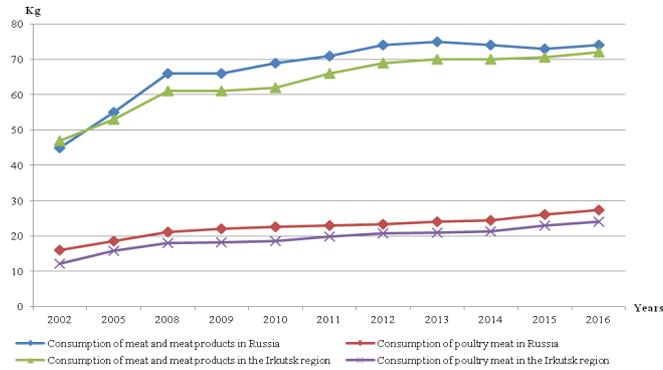


Fig. 1. Consumption of meat, meat products and poultry by the population of Russia and Irkutsk region for 2002-2016

The data of Figure 1 show that the consumption rates for both meat in general and poultry meat in particular in Irkutsk region lag behind those observed in Russia.

The dynamics of consumption of meat and meat products over 12 years in Irkutsk region and Russia is positive. Such dynamics of consumption of poultry meat in the investigated region indicates an almost 2-fold increase in the consumption of poultry meat and processed products.

It should be noted that the level of per capita consumption of meat in various regions of the country varies considerably and depends on the availability of this product, national characteristics, traditions and the level of monetary incomes of the population.

The population of the Irkutsk region is a set of buyers that are characterized by the volume of solvent demand and consumer preferences. Aggregate demand for poultry meat is a real volume of product that individuals and legal entities are ready to purchase at the current level of prices. Despite the positive performance indicators, consumer demand for poultry meat of its own production in Irkutsk region is not fully provided. This indicates that local agricultural producers of poultry meat have the potential for developing poultry meat production and providing aggregate demand.

One of the main issues in the production of poultry meat is the improvement of the production and marketing activities of the commodity producer by identifying the main factors affecting the motivation of the consumer when selecting, buying and consuming meat products of poultry farming. In our opinion, these factors include the price for poultry meat products, the volume of production (supply) of poultry meat, the average per capita income of the population and the price of substitute products.

TABLE I. FACTORS AFFECTING THE DEMAND FOR POULTRY MEAT IN IRKUTSK REGION FOR 2002-2016

Parameters	Year					Growth ratio, times
	2002	2013	2014	2015	2016	
Price for 1 ton of poultry meat, RUB	24121	62483	67562	69430	81790	3.4
Production of poultry meat, thousand tons (slaughter weight)	12.8	33.9	37.1	37.4	40.8	3.2
Price for 1 ton of cattle meat, RUB	21731	76361	92551	86290	97096	4.5
Price for 1 ton of pork meat, RUB	41951	168220	183263	192398	177967	4.2
Average per capita monetary income, rubles / month.	3609	16017	17720	19276	21763.3	6

Over the analyzed period, the pork meat price growth rate (4.2 times) is observed over the growth rate of poultry meat prices (3.4 times), which, in the authors' opinion, should lead to an increase in demand for poultry meat. At the same time, a 4.4 times increase in the price of cattle meat can stimulate its replacement with poultry meat. It also can not be asserted that the population with the growth of its income completely excludes poultry from consumption. The production of poultry meat in Irkutsk region increased 3.2 times during the analyzed period, while the price for poultry meat increased 3.4-fold, which is quite logical.

In the authors' opinion, it is advisable to consider the main social and economic indicators of the development of Irkutsk region, which to some extent will influence the formation of demand for poultry meat (Table II).

TABLE II. THE MAIN INDICATORS OF SOCIAL AND ECONOMIC DEVELOPMENT OF IRKUTSK REGION FOR 2002-2016

Parameters	Year					Growth ratio, %
	2002	2012	2014	2015	2016	
Population, thousand people.	2691	2428	2424	2422	2418	90
Including rural population	557.2	495.6	495.3	496.4	495.6	89
The retired, thousand people.	663.5	725.9	732.8	739.5	741.5	111.7
Average retirement benefits for 1 person, rubles / month	851	8504	9425	10319	11298	13276
Average per capita monetary income, rubles / month	3609	16017	17720	19276	20968	581

Parameters	Year					Growth ratio, %
	2002	2012	2014	2015	2016	
Commodity bundle, RUB	955	1822	1966	2184	2424	229
Living wage, rubles / month	1357	6609	6370	7067	8295	611
Rate of the population having the income below the living wage, % of the total population	35.5	19.2	16.8	17.1	17.8	50
Expenditures of the population including those made outside the house on average per capita, rubles / month.	642.8	3303	3577	3756	3944	613

During the analyzed period, the total population of the region decreased by 10%, rural - by 11%, and the number of the retired increased by 11.7%. This dynamics can negatively affect the demand. At the same time, data indicate a significant increase (13 times) in the average retirement benefits and average per capita monetary income of the population (5.8 times), which taking into account the price index for poultry meat for this period to some extent indicates an increase in the purchasing power of the population including the retired. The number of people with incomes below the living wage decreased by 50%, and the living wage increased by 6. It should also be noted that per capita expenditure on food increased by 6 during the analyzed period. Thus, most of the indicators of social and economic development of the region indirectly confirms the presence of a set of factors that favorably affect the demand for poultry meat in the region.

In addition, to protect the interests of the most disadvantaged population in Irkutsk region, "Social Price" project continues to be implemented, within which a "social commodity bundle" was agreed and approved and included 15 items sold at socially low prices, the majority of which is produced by the companies of Irkutsk region including products of poultry farming. This aspect, combined with the high nutritional value of poultry meat, is an additional factor that positively affects the increased demand for poultry from regional producers.

To determine consumer preferences in the poultry meat market and its products, a survey of 400 respondents was conducted representing households in Irkutsk region, cumulative number of more than 1500 people, and 40 sellers of poultry meat and processed products from the retail network.

According to Irkutskstat, in 2016, the population of the region was about 2.4 million people; the proportion of urban population is 79.5%. Irkutsk region is divided into 33

municipal districts (6 of them are an administrative and territorial unit with a special status - the Ust-Ordynsky Buryat District) and 9 urban districts.

Geographically the survey covered the territory of 7 urban districts and 25 municipal districts, or more than 50 settlements in Irkutsk region. Among the respondents, there were citizens temporarily residing on the territory of Irkutsk region from the republics of Buryatia, Altai and Tyva, the Trans-Baikal Territory and Mongolia.

The largest share in the number of respondents was held by citizens residing in Irkutsk (18.5%), Irkutsky (14.75%), Kuytunsky (10.5%), Ekhirit-Bulagatsky (9.75%), Usolsky (8%) districts.

On average, each interviewed respondent represented a family of 4 people. More than 100 respondents living in Irkutsk, Kuytunsky, Usolsky, Chunsky, Ust-Kutsky, Ust-Udinsky, Slyudyansky, Nizhneudinsky, Ekhirit-Bulagatsky districts, the number of family members was 5 people and more.

Proceeding from the summary data, the most popular types of meat in the region are pork, beef and poultry, which occupy first, second and third places respectively.

Preference for poultry meat is given by the population of the Balagansky and Zalarinsky districts, and also by the city of Bratsk. In other municipalities, with the exception of 6 districts of the Ust-Orda Buryat Okrug (UOBO), poultry meat plays almost the same role as pork and beef.

Despite the ambiguous choice in favor of poultry meat, the question "Do you consume the products made from poultry meat (with the addition of poultry meat)?" was answered by almost all the respondents as "Yes". Among the population of the region covered by the survey, only in 8 municipalities a small number of citizens refused to consume poultry products.

In order to identify the most significant factors considered by consumers when buying poultry products, respondents were asked to choose the main criteria that influence the choice (price, producer, packaging, appearance, composition and date of manufacture). Summary data of the questionnaire revealed that, first of all, consumers when buying poultry products were guided by information about the date of manufacture, the producer and the appearance. The price in this case is inferior to the listed criteria.

It follows that almost all consumers preferred to buy and consume fresh products of proven producers, despite the price, composition and appearance of the product.

An important marketing tool in the expansion of poultry meat consumption both in foreign countries and in Russia is the production of semi-finished and ready-to-eat products that meet the end-use requirements

The main reason why citizens bought semi-finished products is to save time on cooking. This opinion was shared by the majority of city dwellers, as well as in Balagansky, Bokhansky, Irkutsky, Kuytunsky, Nizhneudinsky, Nukutsky, Slyudyansky, Tulunsky and other districts.

Unlike semi-finished products and sausages, to a lesser extent, poultry giblets are popular in the region's markets. About 55% of the polled citizens did not buy this product.

In Irkutsk region, giblets were in demand in 15 municipalities. At the same time, a large number of citizens who bought giblets live in Irkutsk, Irkutsky, Kuytunsky, Tulunsky and Usolsky districts.

The question "Would you like to see more poultry products in stores (with the addition of poultry meat)?" was answered by the majority of the respondents as "Yes".

According to respondents, leaders in the market of poultry meat and products of its processing in the Irkutsk region are LLC Sayan Broiler and Agricultural Joint Stock Company Belorechenskoye which collected 47% and 38% of the votes, respectively. More than 11% of respondents' votes were given to CJSC Angarsk Poultry Factory and 4% noted other manufacturers.

LLC Sayan Broiler produces 55.3% and sells 57.6% of poultry meat in the region. In this regard, one considers it expedient to test the proposed model for optimizing the production and sale of poultry meat within profit maximization based on the materials of this company. Table III provides information on the types of products sold by the company in 2016.

TABLE III. TYPES OF PRODUCTS SOLD BY CUTTING OPTIONS AND SALES VOLUME OF LLC SAYAN BROILER IN 2016

Product	Cutting options for the whole carcass of chicken								Sold per year, tones
	1		2		3		4		
	Price, RUB	Output out of 100 kg of raw materials	Price, RUB	Output out of 100 kg of raw materials	Price, RUB	Output out of 100 kg of raw materials	Price, RUB	Output out of 100 kg of raw materials	
Carcass	-	-	-	-	65	29.31	-	-	8550
Thigh	-	-	92	31.2	-	-	-	-	1578
Drumstick	-	-	102	11.6	102	11.62	-	-	1166
Breast	108	27.6	108	27.6	-	-	-	-	2673
Round cut	89	45.2	-	-	-	-	-	-	951
Wing	99	9.9	99	9.9	99	9.9	-	-	815
Fillet	-	-	-	-	160	16.22	-	-	735
Ends of cuts	-	-	-	-	30	8.9	-	-	1335
Gizzard	-	-	-	-	155	3.05	-	-	315
Liver	-	-	-	-	155	3.05	-	-	495
Heart	-	-	-	-	155	3.05	-	-	138
Minced meat	-	-	-	-	-	-	65	29.3	503
Heads	-	1.8	-	1.8	-	-	-	-	695
Paws	-	1.8	-	1.8	-	-	-	-	660

The amount of each resource unit, required for the production of poultry meat by cutting options, is in Table IV.

TABLE IV. COSTS AND RATES OF RESOURCE CONSUMPTION FOR POULTRY MEAT PRODUCTION BY CUTTING OPTIONS IN LLC SAYAN BROILER IN 2016

Parameter	Processing options			
	1	2	3	4
The rate of consumption of "Raw materials" resource (a_{11})	1	0.9976	0.071	0.2931
Cost of "Raw materials" resource (d_1)	95	95	95	95
The rate of consumption of "Manpower" resource (a_{12})	0.000875	0.000938	0.0012	0.001
Cost of "Manpower" resource (d_2)	1500	1500	1500	1500
The rate of consumption of "Equipment" resource (a_{13})	0.000188	0.000219	0.00025	0.00021
Cost of consumption of "Equipment" resource (d_3)	3400	3400	3400	3400
Production unit cost, RUB.	96.95	96.92	9.40	30.06

At the same time resources available in the company are limited. Thus, raw material expenditures should not exceed 56,000 kg, manpower are limited to 320 people, equipment amounts to 80 units.

The proposed optimization model of production and sale of poultry meat within profit maximization allowed us to obtain a structure of production and sales volume of products within minimum and maximum demand (see Table V).

TABLE V. RESULT OF MODELING: RECOMMENDED SALE VOLUME OF POULTRY MEAT BY TYPES OF PRODUCTS FOR LLC SAYAN BROILER WITHIN MAXIMUM AND MINIMUM DEMAND, KG

Product	Production output	
	Minimum market demand	Maximum market demand
Carcass	9209	18180
Thigh	4593	9066
Drumstick	1614	3186
Breast	3890	7680
Round cut	1717	3390
Wing	1353	2670
Fillet	1401	2766
Ends of cuts	593	1170
Gizzard	63	125
Liver	13	25
Heart	13	25
Heads	414	817,8
Paws	46	90
Minced meat	46	90

One will get the maximum profit (see Table VI), if one sells the volume of poultry meat specified in Table V under the condition of coincidence of the sale price, consumption rates and cost of used resources with the values used in the model.

TABLE VI. PROFIT FORECAST OF LLC SAYAN BROILER UNDER MINIMUM AND MAXIMUM MARKET DEMAND

Demand for finished products	Proportion of products of the q weight category in the i production option			Type of products, kg				Profit, RUB
	categories			1	2	3	4	
	Options							
Minimum demand	0.21	1	0	9209	15161	180	414	965819
	0.31	0	0					
	0.48	0	0.29					
	0	0	0.71					
Maximum demand	0.38	0	0	18180	29928	355	818	1814306
	0.62	1	0					
	0	0	0.21					
	0	0	0.79					

In the days when the maximum demand for the company's products is projected, it is recommended that only 38% of the first category be sent to the carcass production, and 62% to the carcass cutting. Broilers of the second weight category should be fully used for carcasses cutting. Poultry carcasses of the third weight category will be used as follows: 21% for the production of the ends of cuts, 79% for the production of minced meat.

Demand structure in the model will change with a decrease in demand for the goods due to the changed factors that show the share of q -type production in the i -th option of poultry meat processing.

Thus, the implementation of the proposed model will allow the company's management to respond quickly to changes in demand for products sold on the market and make reasonable management decisions on production volumes planning to maximize profits.

V. CONCLUSION.

Thus, the proposed optimization model of production and sales of products within profit maximization allows one to determine the structure of products, taking into account not only the cost and rate of resources consumption, but also to establish restrictions on their use depending on the number of employees, capacities, etc.

Using the described model in market conditions allows avoiding overproduction and natural damage to products, as the model is oriented to demand changing, which is important for the companies engaged in the production of seasonal products or products the demand for which dynamically changes depending on objective factors.

In summary, the main task of the described model is to answer to the following question: how many products and what type of products shall be produced under the limited resources and changing demand, to get the maximum profit. In order to obtain a more consistent profit, it is necessary to consider the fact that the sale price can vary from buyer to buyer and on days of maximum and minimum demand.

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