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. Özimec, 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.
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 \( v = 1, 2, ..., 14 \).

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 \( a_{i,v} \) 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:

\[
\sum_{i=1}^{4} a_{i,q} = 1. \tag{1}
\]

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:

\[
y_v = \sum_{i=1}^{4} a_{i,v} x_i \tag{2}
\]

where \( a_{i,v} \) – 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:

\[
T_v = \sum_{v=1}^{14} p_v y_v \tag{3}
\]

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 \( R \). 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:

\[
C_i = \sum_{j=1}^{3} d_j \sum_{i=1}^{4} a_{i,j} x_i \tag{4}
\]

where \( d_j \) - the resource unit, RUB; \( a_{i,j} \) - \( R_j \) 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:

\[
f = \sum_{v=1}^{14} p_v y_v - \sum_{j=1}^{3} d_j \sum_{i=1}^{4} a_{i,j} x_i \Rightarrow \max \tag{5}
\]

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:

\[
\sum_{i=1}^{4} x_i \leq M, \ (i = 1, 2, 3, 4)
\]

where \( M \) – volume of products sold, kg.

3) Actual expenditure of raw materials, manpower and equipment:

\[
a_{i,1} x_i + a_{i,2} x_i + a_{i,3} x_i \leq b_1 \text{ (kg)}; \\
 a_{i,2} x_i + a_{i,3} x_i + a_{i,4} x_i \leq b_2 \text{ (people)}; \\
 a_{i,3} x_i + a_{i,4} x_i + a_{i,5} x_i \leq b_3 \text{ (units)}.
\]

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: \( y_v = \sum_{i=1}^{4} a_{i,v} x_i \)

6) Implementation of conditions for each weight category: \( \sum_{i=1}^{4} a_{i,v} = 1 \)

7) The condition that the variables are not negative:

\[
x_i, y_v, a_{i,v} \geq 0
\]

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).

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 2002 | Year 2013 | Year 2014 | Year 2015 | Year 2016 | Growth ratio, times |
|----------------------------------------------------------------------------|-----------|-----------|-----------|-----------|-----------|---------------------|
| 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 2002 | Year 2012 | Year 2014 | Year 2015 | Year 2016 | Growth ratio, %      |
|----------------------------------------------------------------------------|-----------|-----------|-----------|-----------|-----------|----------------------|
| 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                  |
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 Borechenskoye 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          | 5          |
|                 | Output of 100 kg raw materials, Price, RUB | Output of 100 kg raw materials, Price, RUB | Output of 100 kg raw materials, Price, RUB | Output of 100 kg raw materials, Price, RUB |
| Carcass         | -                      | -          | 65         | 29.31      | -          | 8550      |
| Thigh           | -                      | -          | 92         | 31.2       | -          | 1758      |
| Drumstick       | -                      | 102        | 102        | 11.6       | 1166       |
| Breast          | 108                    | 27.6       | 108        | 27.6       | -          | 2673      |
| Round cut       | 89                     | 45.2       | -          | -          | -          | 951       |
| Wing            | 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     | -                      | -          | 155        | 3.05       | 65         | 29.31     | 503       |
| Heads           | 1.8                    | 1.8        | -          | -          | -          | 605       |
| Paws            | 1.8                    | 1.8        | -          | -          | -          | 660       |

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 | 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.
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.

**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                                      |                     |            |
| Minimum demand              | Options                                         |                     |            |
|                             | 0.21 1 0                                        | 9209                | 15161      |
|                             | 0.31 0 0                                        | 180                 | 414        |
|                             | 0.48 0 0.29                                     | 0                   | 0.71       |
|                             | 0 0 0.71                                       |                     |            |
| Maximum demand              | Options                                         | 18180               | 29928      |
|                             | 0.38 0 0                                        | 355                 | 818        |
|                             | 0.62 1 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.

**References**

[1] A.M.T. Hussain, J. Tschirhart, Economic/ecological tradeoffs among ecosystem services and biodiversity conservation. Ecological Economics, 93, pp. 116-127, 2013.

[2] D. Ilyashevich. Entity and conditions of formation of the market of meat of a bird. NGAU bulletin, 2 (35), pp.142-146, 2015.

[3] Y. Jiang, J. Shang, Y. Liu, J. May, Redesigning promotion strategy for e-commerce competitiveness through pricing and recommendation. International Journal of Production Economics, 167, pp. 257-27, 2015 0.

[4] M. Moghaddam, S.Y. Nof, Combined demand and capacity sharing with best matching decisions in enterprise collaboration., International Journal of Production Economics, 148, pp. 93-109, 2014.

[5] M. Natter, A.-M. Ozimec, J.-Y. Kim. ECO: Entega’s profitable new customer acquisition on online price comparison sites. Marketing Economics, 2015, 34 (6), pp. 789-803.

[6] A.S. Nechaev, D.A. Antipin, O.V. Antipina, Efficiency estimation of innovative activity the enterprises. Journal of Mathematics and Statistics, 10 (4), pp. 443-447, 2014.

[7] A.V. Prokopjeva, A.S. Nechaev, Key features of risks of company innovative activities. Middle East Journal of Scientific Research, 17 (2), pp. 233-236, 2013.

[8] K. Puranam, M. Katehakis, On optimising taboo criteria in Markov decision processes. International Journal of Applied Decision Sciences, 7 (1), pp. 33-43, 2014.

[9] 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, Comparing supply-side specifications in models of global agriculture and the food system. Agricultural Economics (United Kingdom), 45 (1), pp. 21-35, 2014.

[10] R.W.Seifert, J.-S.Tancrez, I. Biger. Dynamic product portfolio management with life cycle considerations. International Journal of Production Economics, 171, pp. 71-83, 2016.

[11] S. Shrestha, T. Hennessy, M. Abdalla, D.Forristal, M.B. Jones, Determining short term responses of Irish dairy farms under climate change. German Journal of Agricultural Economics, 6 (3), pp. 143-155, 2014.

[12] M. Tyapkina, E. Bina and E. Domanova Analysis of Agricultural Enterprise Investment Appeal Factors. Live Science Journal, 11 (12), pp. 873-877, 2014.

[13] Ya. M. Ivano. About some methods of modelling of production agricultural production. IGSHA bulletin, 45, pp. 129-136, 2011.

[14] B. Aouni, S. Laflamme, From mono-criterion to multi-criteria decision aid: A necessary but unfinished evolution in operational research. International Journal of Applied Decision Sciences, 7 (2), pp. 123-135, 2014.

[15] V. R. Elohin, About optimising models of planning of agricultural production. News of the Baikal state university, 3, pp. 137-141, 2009.

[16] T. N. Medvedeva, O model of production of main types of agrarian production in the agricultural organizations of the Kurgan region. KSHA bulletin, 2, pp. 55-58, 2015.