Economic efficiency of introduction of additive technologies in the meat processing industry

Y B Mindlin¹, A O Gorbunova², T M Tarasova³, E V Korobeynikova⁴ and O V Filimoshina⁵,⁶

¹ Moscow State Academy of Veterinary Medicine and Biotechnology named after K.I. Skryabin, Moscow, 109472, Russian Federation
² Samara University of Public Administration «International Market Institute», Samara, 443030, Russian Federation
³ Samara State University of Economics, Samara, 443090, Russian Federation
⁴ Samara State Technical University, Samara, 443100, Russian Federation
⁵ K G Razumovsky Moscow State University of technologies and management (the First Cossack University), Moscow, 109004, Russian Federation
⁶ E-mail: o.v.filimoshina@mgutm.ru

Abstract. This research work presents an assessment of efficiency of introduction of additive technologies in a meat-processing enterprise. The agricultural industrial complex and the food industry are no exception though. Introduction of additive technologies will allow solving a range of primary tasks, for example – the capability to manufacture certain individual parts of equipment directly in the production site. That will reduce downtime and reduce production costs. Using a piece of equipment as an example, it is proposed to manufacture on 3D printer some parts which are most sensitive to tear and wear. Along with introduction of additive technologies in production, the net profit will increase by 1,957,795 rubles. The estimated payback period of the project is 1 month. The obtained data confirms that introduction of additive technologies increase the financial stability of the enterprise.

1. Introduction

Today 3D modeling and 3D printing is a dynamically developing area. The products obtained on 3D printers are used both on an ongoing basis in existing production and for various experiments in new areas. The use of additive technologies is systematically included in the life of modern person; this type of technology is already widely used in design, visualization, manufacture of specific products, and production of experimental samples.

Using of additive technologies in manufacturing, marketing, design, visualization for customers and company management keeps expanding every year.

The world expert community claims the following:

• The most of companies with high innovative potential already use additive technologies;
• Within the next 20-30 years up to 90% of large manufacturers will use additive technologies in their production, as a result most complex products will be manufactured with additive components;
• Due to development of additive technologies their availability for common manufacturer and consumer will only increase, and in some areas the additive technologies will replace existing classical technologies.

Nowadays the degree of integration of additive technologies into production varies significantly; the leading positions in additive technologies application are occupied by the space industry, aircraft and automobile manufacturing, medicine and dentistry. The additive technologies are most widely spread in these industries in manufacture of prototypes, production of spare parts, creation of sophisticated products.

The reason for the rapid growth of the market for additive technologies is believed to be the following:

• simplicity and convenience of modeling new products of any complexity level;
• reducing of production costs, especially for conceptual development;
• capability to solve non-standard tasks.

The development of market for additive technologies also demonstrates the development of new technologies in this industry, the emergence of new consumables and techniques for their use. For example - in recent years steel, gold, silver, titanium ceramics, resin have been used as a material for 3D printing. So thermoplastic is not the only material for printing, but one of many. The agricultural and industrial complex and the food industry are no exception. Introduction of additive technologies will allow solving a range of primary tasks, for example, capability to manufacture certain individual parts of equipment directly in production site. That will reduce downtime and reduce production costs.

Meat processing industry at the present stage of development occupies one of the leading places in the food industry and actively introduces new technologies [1-13]. Therefore, consideration of possibility to introduce additive technologies in meat processing and to assess their economic feasibility are of scientific interest [14,15].

2. Materials and methods
For the experiment # 1 the following parts were manufactured: the bushings for sausages twisting machines NL 17, made of polyamide 12, and the gear for the packaging machine Ulma TFS 500 was made of polyetheretherketone. The parts were made on a printer VSHAPER Pro.

This experiment failed. The reasons of failure were the bushings themselves. The inner part of the bushings had small roughness and the edges had a sharp end. These factors caused the sausages casing to break when stuffing the meat product.

For experiment # 2 new bushings for sausages twisting machines NL 17 were printed on the printer VSHAPER PRO. In order to remove roughness and sharp ends, these bushings were placed in a special chemical solution. This solution was assigned to make the part a little softer, to remove internal roughness and thereby try to avoid deformation of the sausage casing.

As result of this experiment, it was found that the sausage casing was torn again with these bushings, but not immediately. In the very first experiment the bushings tore the sausage casings right after the machines started their operation.

For experiment # 3, the bushings for sausages twisting machines were printed on a printer VSHAPER Pro. In order to stop the bushings tearing the sausage casing a video was shot that clearly showed the operation of the machine. And also, the following characteristics were found: the average turnover of the bushings is 1500-2500. The bushings are often changed because they grind off very quickly, and due to that the weight of the meat product varies a lot, but it must be adjusted in order to be accurate. In view of this data a new batch of bushings was printed. The article below provides calculations of economic parameters according to the following formulas:

Let’s calculate the cost of a unit of production using the formula:
Prime cost of the unit of production = \( \frac{M+I+D+S+\text{Other expenses}}{\text{Annual volume}} \), \( (1) \)

where 
- \( M \) – materials; 
- \( I \) – insurance payments; 
- \( D \) – depreciation; 
- \( S \) – salaries.

\[
\text{Goods production} = \text{Wholesale prices} \times \text{Annual production output} \quad (2)
\]
\[
\text{Revenue} = \text{Wholesale prices} \times \text{Annual production output} \quad (3)
\]
\[
\text{Profit per unit of production} = \text{Release prices} - \text{Prime cost} \quad (4)
\]
\[
\text{Total profit} = \text{Profit per unit of production} \times \text{Annual volume} \quad (5)
\]
\[
\text{Net profit} = \text{Sales profit} - \text{Income tax} \quad (6)
\]

Let’s calculate the payback period of financial investment to the project:

\[
T_o = \frac{C_i}{CR}, \quad (7)
\]

where 
- \( C_i \) – capital investments, 
- \( CR \) – cash receipts (Net profit).

3. Results and discussion

Below in the table 1 the costs for original parts consumption and the costs of additive technologies were considered.

| Assortment of the goods                  | Consumption per month, pieces | Cost of purchase from the manufacturer, rubles. | Average term of supply/delivery, month. | Costs per year, rubles | Price of the new material, rubles | Costs per year, rubles |
|-----------------------------------------|------------------------------|-----------------------------------------------|----------------------------------------|-----------------------|----------------------------------|-----------------------|
| Bushing of sausages twisting machine D=21 9702420 NL-17 | 581.25                      | 820                                           | 1.00                                   | 5719 500.0            | 252                              | 1757.7                |
| Bushing of sausages twisting machine D=22 9702438 NL-17 | 229.17                      | 820                                           | 1.00                                   | 2255 032.8            | 252                              | 693.01                |

According to the results of the data given above in the table, the cost of purchasing the original parts per year will amount to 7,974,532.8 rubles. The cost of new parts manufacture with the help of additive technologies will amount to 2,450,710 rubles per year. The estimated savings achieved by introduction of additive technologies for production is 5,523,823 rubles per year.

To compare two technologies let’s consider the efficiency of experiment using the meat production as an example. The volume of products output, in monetary terms, on the production line where this twisting machine is installed accounts for 172,800,000 rubles. Further it’s necessary to determine the costs for salaries. There were 8 employees. The monthly salary fund amounted to 410,000 rubles. Contributions to extra-budgetary funds for the year were 1,499,640 rubles.
The total amount of annual costs for salaries was 6,419,640 rubles. The next step is to calculate the cost of equipment and depreciation charges. Depreciation is calculated in a linear way. Along with the cost of sausages twisting machine NL as 17, 1,600,000 rubles and its service life of 7 years, the annual amount of depreciation deductions was 228,600 rubles. Electric power consumption of the sausages twisting machine NL 17 was equal to 7.5 kW/h.

For sausages twisting machine NL 17 the cost of 1 kW/h of electric power is 0.9 rubles. The electric power consumption for 1 sausage twisting machine is 7.5 rubles kW/h. The cost of electric power per batch - 6.75 rubles. The cost of electric power per day is 162 rubles, per month – 4,860 rubles, per year – 58,320 rubles. The cost for fire safety declaration is 15,000 thousand rubles, purchase of fire extinguishing equipment is 900 rubles per one fire extinguisher, fire insurance for the building – 200,000 rubles, maintenance of fire alarm system is 30,000 rubles per month and 360,000 rubles per year. These costs include checking all fire-fighting equipment: panels, devices and related fire extinguishing systems, fire alarm systems and management of evacuation of people, smoke protection, elevators. The total cost of fire safety is 784,000 rubles.

After analyzing the data above, we considered in table 2 all annual costs of production when using original parts.

| Parameter                      | Amount, thousand rubles. |
|-------------------------------|--------------------------|
| Salaries                      | 4,920.000                |
| Deductions to extrabudgetary funds | 1,499.640               |
| Depreciation of equipment     | 228.600                  |
| Fire safety                   | 784.000                  |
| Costs for electric power      | 58.320                   |
| Purchase of parts             | 7,974.532.8              |
| Total                         | 15,465.092.8             |

Tax base = 172,800.000 – 15,465.092.8 = 157,334.907 thousand rubles.

Net profit = 172,800.000 – 15,465.092.8 – 31,466,981.4 = 125,867,926 thousand rubles.

Further let’s consider the costs with additive technologies.

The volume of products output, in monetary terms, on the production line where these sausages twisting machine is installed, is equal to 172,800,000 rubles per year.

The price of the printer (including delivery, adjustment and fine-tuning) is 2,150,000 rubles.

In table 3 we consider the salaries of the employees along with the new positions recently added. Taking into account the introduction of new equipment, the staff were increased by 2 people. The following positions were introduced – 2 locksmiths (for new parts maintenance). So the total number of employees is 10 people.

The monthly salary fund amounted to 435 thousand rubles. Annual amount is 5,220 thousand rubles.

Annual deductions to off-budget funds are 1,581.72 thousand rubles. The total amount of annual costs for salaries amounted to 6,801.72 thousand rubles.

The next step is to calculate the cost of equipment and depreciation charges. For the sausages twisting machine NL 17 the data and figures remain unchanged.

Calculation of the cost of equipment (printer) and its depreciation.

The annual amount of depreciation charges for the 3D printer VSHAPER PRO is 537,400 thousand rubles. Based on the data above the cost is 2,150,000 rubles, the service life is 4 years. The calculation is made in a linear way.

After that we’ll calculate the cost of electric power for the new equipment. The power consumption per item is 3.6 kW. As the cost of electric power of 0.9 rubles per kW/h, the cost of electric power consumption is 3.24 rubles. It is planned to print 6 parts per day. The cost of electric power per day is 19.44 rubles, per month is 583.2 rubles, per year is 6,998.4 rubles. After analysis of data provided in the tables above, we represent in the table 3 all annual costs of production when using the additive parts.
IOP Conf. Series: Earth and Environmental Science 839 (2021) 022062  doi:10.1088/1755-1315/839/2/022062

Table 3. Annual costs with additive parts used.

| Item                                         | Amount, thousand rubles |
|----------------------------------------------|-------------------------|
| Salaries                                     | 5.220.000               |
| Deductions to extrabudgetary funds           | 1.581.720               |
| Depreciation of equipment                    | 228.600                 |
| Depreciation of the new equipment (3D printer) | 537.500               |
| Purchase of printer                          | 2.150.000               |
| Fire safety                                  | 784.000                 |
| Costs for electric power                     | 58.320                  |
| Costs for electric power for the new equipment (3D printer) | 6.998.4               |
| Purchase of parts                            | 2.450.710               |
| Total                                        | 13.017.848.4            |

Tax base – 172.800.000 – 13.017.848.4 = 159.782.152.0 rubles.  
Tax – 159.782.152* 20% = 31.956.430.3 rubles.  
Net profit – 172.800.000 – 13.017.848.4 - 31.956.430.3 = 127.825.721 rubles.  
Payback period of the project – 13.017.848.4/127.825.721 = 0.1 = 1 month

4. Conclusion

The table 4 below shows a comparison of using of original and additive parts on the example of the meat production enterprise.

Table 4. Comparative characteristics of original and additive parts.

| Parameter                                   | Original parts   | Additive parts   |
|---------------------------------------------|------------------|------------------|
| Revenue, rubles                             | 172.800.000      | 172.800.000      |
| Costs, rubles, including:                   |                  |                  |
| -Salaries                                   |                  |                  |
| -Deductions to extrabudgetary funds         | 15.465.092.8     | 13.017.848.4     |
| -Depreciation of equipment                  |                  |                  |
| -Costs for electric power                   |                  |                  |
| -Purchase of parts                          |                  |                  |
| Income tax, rubles                          | 31.466.981.4     | 31.956.430.3     |
| Net profit, rubles                          | 125.867.926      | 127.825.721      |
| Payback period, months                      |                  | 1                |

Therefore, the introduction of additive technologies in production will increase the net profit by 1.957.795 rubles. The estimated payback period of the project is 1 month. Based on the obtained data it can be concluded that the use of additive technologies in the meat processing industry is highly promising. This approach will reduce production costs, as well as will let avoid downtime of production process.

References

[1] Akhmetova S, Suleimenova M and Rebezov M 2019 Mechanism of an improvement of business processes management system for food production: case of meat products enterprise Entrepreneurship and sustainability issues 7(2) 1015-35 doi: 10.9770/jesi.2019.7.2(16)

[2] Artamonova M, Khayrullin M, Zamkova P, Kostikova O and Popov P Study of changes in active acidity (ph) in sausages IOP Conference Series: Earth and Environmental Science Sci 677 022055 doi:10.1088/1755-1315/677/3/032011

[3] Assenova B et al. 2020 Effect of germinated wheat (triticum aestivum) on chemical, amino acid and organoleptic properties of meat pate Potravinarstvo 14 503-9 doi: 10.5219/1273

[4] Kabulov B et al. 2020 Developing the formulation and method of production of meat frankfurters with protein supplement from meat by-products EurAsian Journal of BioSciences 14(1) 213-
8 http://dx.doi.org/10.31838/jcr.07.02.30

[5] Kabulov B et al. 2019 Effect of mechanical processing of minced meat on the change of yield stress International Journal of Mechanical and Production Engineering Research and Development 9(5) 333-42 IJMPERDOCT201928

[6] Khayrullin M, Buhteeva M, Kotova P, Glebova S and Karasev V 2021 The influence of complex spices on the change in the quality indicators of chopped semi-finished products during storage IOP Conference Series: Earth and Environmental Science Sci 677 022055 doi:10.1088/1755-1315/677/2/022111

[7] Khayrullin M, Curcan A, Nesterenko A, Zhuravlev M and Rystakov V 2021 Results of studies of samples of boiled-smoked loin with different injection levels IOP Conference Series: Earth and Environmental Science Sci 677 022055 doi:10.1088/1755-1315/677/3/032014

[8] Okuskhanova E et al. 2018 Rheological properties of low-calorie red deer meat pate Journal of Pharmaceutical Research International 23(1) 1-9 doi: 10.9734/IPRI/2018/42317

[9] Rebezov M et al. 2020 Role of beetroot as a dietary supplement in food products Plant Cell Biotechnology and Molecular Biology 21(57&58) 8-16

[10] Zinina O et al. 2019 Enrichment of meat products with dietary fibers Agronomy Research 17(4) 1808-22 doi: 10.15159/AR.19.163

[11] Zinina O et al. 2020 Effects of microbial transglutaminase on technological, rheological, and microstructural indicators of minced meat with the addition of plant raw materials International Journal of Food Science 8869401

[12] Zinina O, Rebezov M, Khayrullin M, Neverova O and Bychkova T 2020 Functional and technological indicators of fermented minced meat IOP Conf. Ser.: Earth Environ. Sci. 548 082010 doi:10.1088/1755-1315/548/8/082010

[13] Zinina O, Rebezov M, Khayrullin M, Neverova O and Bychkova T 2020 Sensory, physical and chemical characteristics of fermented minced meat IOP Conf. Ser.: Earth Environ. Sci. 548 082012 doi:10.1088/1755-1315/548/8/082012

[14] Anichkina O et al. 2019 Development strategy of agricultural enterprises in the production of high-tech products IOP Conference Series Earth and Environmental Science 403 012133

[15] Anichkina O, Terekhova A, Avtsinova A, Akulina E and Dotsenko E 2021 Evaluation of the effectiveness of an investment project for the processing of whey IOP Conference Series: Earth and Environmental Science Sci 677 022055