Technology of Poultry Manure Utilization as a Renewable Energy Source

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Abstract. the aim of the research is to improve the efficiency of technologies for recycling poultry manure. The achievement of this goal involves the development of technological regulations for the processing of manure, research and development work on the creation of technological lines for the production of fuel briquettes and organic fertilizer, development of the technological process of processing of manure and its introduction into production. The technological scheme of the manure processing complex has been developed and substantiated, which includes: a receiving and storage station for receiving manure coming from poultry houses, and its dosed supply for further processing; a container for collecting liquid formed during the drying of manure; a technological line for the production of fuel briquettes and a line for the production of organic-mineral fertilizer. The capacity of the complex with a litter moisture content of 65–70% coming for processing is about 5 t/h. It is proved that the annual processing of manure at the round-the-clock operation of the complex will be about 43.0 thousand tons. At the same time, the production of organic-mineral fertilizers with a nutrient content of up to 32% will be about 1.5 thousand tons, and the fuel briquettes with a calorific value of up to 18.0 MJ/kg will be about 8.0 thousand tons. The estimated annual economic effect from the processing of litter on this complex is about 20.0 million rubles, the payback period of the complex is up to 1.5 years. This technology of poultry manure utilization allows to process all poultry manure removed from poultry houses in the stream, as a result of which there is no need for a litter storage. The production of organic fertilizer can solve the problem of increasing soil fertility. When the price of one ton of this fertilizer is 5 thousand rubles and the contents until 320 kg of active ingredient, its use in the cultivation of crops would be economically profitable. As a result of the utilization of manure through this technology, the company receives energy, agro-chemical, economic, environmental and social effects.

Introduction
By the beginning of the twenty-first century, the world has intensified the research to find new, alternative energy sources. In particular, there was found the possibility of using solar radiation, wind energy, water energy of small rivers and reservoirs, geothermal energy, biomass energy, etc. Nowadays, the annual economic potential of alternative energy sources exceeds the production volume of all types of fossil fuels and is within 200 billion tons of conventional fuel. According to the forecasts of analysts, by 2030 the share of alternative energy sources in the total energy consumption will be up to 21% and will be equal to the share of the natural gas. At the same time, the great attention is paid to the use of biomass, primarily waste wood, pulp and paper industry, utilities and agriculture.

Any production is accompanied by the release of manure. At the same time, the higher the production culture, the more attention is paid to the recycling processes. Recycling should be understood as the processing of waste into a new and popular product. Agriculture is one of the main producers of organic waste, which include crop residues, animal manure, poultry manure, etc. Chelyabinsk region is one of the three leaders in Russia in the production of eggs and poultry. As a result of the modernization of existing poultry farms and the introduction of new ones, there is an annual increase in the number of...
poultry. However, along with this, the yield of poultry manure is increasing, the annual volume of which is close to 1.5 million tons. At the cellular content of poultry, the moisture content of the litter is in the range of 65-70% and belongs to the third class of hazardous substances, so it requires a special approach to its disposal [1–2]. Currently, the culture of the egg production and meat in poultry farms is very high, however, in most cases, the technology of litter disposal does not meet modern environmental and economic requirements. Very often, hundreds of thousands of tons of hazardous substances accumulate in the storage facilities, causing harm to the environment. When using such a litter as a fertilizer, which has a low amount of nutrients, while transporting over long distances, the cost of application is not paid off by increasing the yield of crops. The crop production needs an effective fertilizer. It is necessary that this fertilizer has a low cost, high nutrient content, a long period of action and it can be used by the existing system of machines [3–4].

An urgent problem in agriculture is energy supply. It is known that in the cost of agricultural production a large share of energy costs, which is mainly due to the high cost of energy. The constant increase in the cost of electricity, petroleum products, natural gas, solid fuel, leads to an increase in the cost of production, resulting in reduced profitability of all agricultural production. Agriculture, receiving a large amount of organic waste, for its own needs can produce solid and gaseous fuels, thermal and electrical energy.

This study is aimed at improving the efficiency of recycling processes of poultry manure. To achieve this goal, the following tasks were set and solved:

1. The experimental design work has been carried out and the technological line for the production of fuel briquettes and organic fertilizer has been created.
2. The technological process of manure processing has been developed for widespread introduction into production.

**Materials and methods**

The current level of agriculture development, both in Russia and abroad, requires new directions for the creation of waste-free production with a high sanitary and veterinary level. For later use of crop residues, animal manure and poultry manure, with the aim of preserving in it the essential nutrients, improve the physical and chemical properties, are used available for the enterprise methods of processing [5]. All known methods of processing can be divided into four separate methods: biological, physical, chemical and mixed. These methods contain 15 methods. Each of the methods can be carried out by 2-3 different technologies. Thus, currently there are more than thirty different technologies for processing livestock and poultry manure (Figure 1).

The largest amount of organic waste processing technologies are based on the biological method. The deeper understanding of the factors affecting the processes in industrial methods of biological processing, allow us to take into account the technological features of the choice and compliance with the optimal modes and parameters of the equipment [6].

The biological method of processing is based on aerobic, anaerobic, oxidative and biothermal methods, as well as the method using Californian worms. The implementation of the same method can be performed by different technologies, indoors or directly in the open air. If we take into account that biological processes are based on the laws of microbiologists, its application in the technology of manure and litter utilization allows to use more fully and with greater effect the laws of biological processes of biofermentation of various components in which the main ingredient is organic matter.

Without knowledge of the basics and features of composting technology, with a biothermal method of processing organic mixtures, the fermentation process can lead to unknown and even negative results. Instead of valuable organic fertilizers can be obtained, at best, ballast material, at worst - significant amounts of additional environmentally hazardous waste with a large number of seeds of various weeds and seedlings of pathogenic microflora.

One of the rational methods of processing organic waste is physical, which is based on changes in physical and mechanical properties, in particular and the removal of moisture. For this purpose, a variety of drying methods are used. The high-temperature drying deserves the greatest attention. The drying is carried out in cylinder-type dryers at a temperature of 800–900°C. During the heat treatment of manure or droppings, it is dehydrated to a moisture content of 12–14%, disinfection from pathogenic bacteria, viruses, helminth eggs, liberation from germinating seeds of weeds, down hair and feathers. The result is a dry substance containing essential nutrients (NPK) that can be used as an organic fertilizer.
However, due to the fact that such a fertilizer contains a small amount of nutrients (3 – 4%), in order to provide plants with the necessary amount, it is required to make doses in a larger volume, which leads to an increase in transport costs. The cost of using this fertilizer is not paid off by increasing the yield of the cultivated crops [8].

To solve the problems of poultry manure utilization and providing producers of the crop products with effective fertilizers in the South Ural State Agricultural University, the technology of processing of poultry manure with the production of complex organo-mineral fertilizer and fuel briquettes has been developed [9–10]. The scheme of the technological line of the complex for processing of the unshielded poultry manure with a capacity of 5.0 t/h is shown in Figure 2.

Figure 1 – Organic waste treatment methods

Figure 2 – Diagram of the technological line of the complex for poultry manure utilization
1 – receiving-storage station; 2 – scraper conveyor (TSN); 3 – reactor for drying manure; 4, 6, 9, 15, 17, 20, 22, 24, 28 – conveyor; 5, 16 – cooling column; 7, 10, 18 – storage tank; 8, 19 – shredder centrifugal rotary; 11 – piston press; 12 – briquette packing table; 13 – warehouse 14 – reactor for manure gasification; 21 – dispenser; 23 – mixer; 25 – granulator; 26 – conveyor belt; 27 – pellet packing table; 29 – water tank; 30 – gas tank
The complex consists of the receiving-funded station, intended for reception of manure coming from the poultry houses, and batched it for further processing, containers for collection of liquids generated during drying of the manure, technological lines on manufacture of fuel briquettes, line for production of the organo-mineral fertilizers. All technological equipment is linked to a single process.

While removing manure from poultry houses load it in a dump vehicle, deliver to the facility for processing and overload in the emergency-funded station. From the receiving and storage station 3.0 t/h litter is fed to the drying and 2.0 t/h for gasification. When drying the litter, about 1200 kg/h of dry litter with a moisture content of up to 15 %. The dried manure is cooled, ground and fed into the storage tank. The part of the dry crushed manure is fed to the preparation of organo-mineral fertilizer, and the rest is used to the preparation of the fuel briquettes. The received fuel briquettes are packed and sent to the warehouse. As a result of the pyrolysis of manure, a combustible gas is formed, the part of which is used to maintain its own pyrolysis process, and the rest is fed to the reactor for the dried manure. As a result of pyrolysis, about 160 kg/h of ash is formed, which is cooled, crushed and fed to mix with dry manure. The resulting organic-mineral mixture contains 25 % of dried manure and 75 % of ash. The mixture is formed into granules, which are packaged and sent to the warehouse.

Results and discussion
The proposed technology of processing manure in the first stage involves the removal of moisture from it by drying. This occurs as a result of a combination of thermal and mass transfer processes occurring both at the surface and inside the wet manure, contributing to its dehydration from 70–75% to 14–15%. As a result, there are structural-mechanical, chemical, biochemical and rheological changes in the manure. The rate of these changes and the degree of the completion depends on many factors, the main factors are the method of supplying heat to the dried material and the drying mode. Since the manure contains a high percentage of organic matter, its drying prevents the occurrence of undesirable phenomena in it, such as self-heating, decomposition with the formation and release of ammonia, oily compounds, etc.

The poultry manure refers to a pasty dispersed material, so it is advisable to dry it by convective or contact methods. The most common method is convection drying, where the heating of the dried material is carried out by a gaseous drying agent (heated air, flue gases or a mixture thereof), in direct contact with the surface of the manure. The same agent is used to remove moisture vapor outside the dryer. The speed of the drying process of the litter with a gaseous agent depends on the intensity of the external and internal heat and mass transfer, since the amount of moisture supplied to the evaporation surface depends on it. With this method, the part of the thermal energy is not used for its intended purpose, but is lost along with the vapors. While drying the manure, a large amount of evaporating moisture is formed, which requires condensation. To do this, the dryer must be equipped with a reliable condensing unit. At the same time, the steam removed from the dryer has a sufficiently high temperature, so it can be used to preheat the manure in the receiving and storage station. This helps to reduce the energy consumption for its drying and reduce the time of the process.

The amount of moisture that is required to evaporate from the manure is defined as:

$$Q_{WED} = Q_{MDAY} \cdot \left( W_I - W_D \right) / 100 - W_D$$

(1)

where $Q_{WED}$ - the amount of moisture evaporated per day, tons. $Q_{MDAY}$ - the amount of manure processed by the dryer per day, tons. $W_I$ - the initial moisture content of the manure, %. $W_D$ - the humidity of the dried manure, %.

For the purpose of expediency the dryer should work round-the-clock. With an hour of its capacity of 3.0 t/h, 72 tons of wet manure will be processed per day, while about 51.0 tons of water will evaporate. The daily amount of dried manure coming out of the dryer will be 21 tons.

The process of drying the litter is very energy-intensive and involves heating the material and evaporation of moisture. The heat consumption for evaporation of 1 kg of moisture is determined based on the heat and moisture content of the air:
\[ q_{EVA} = \frac{I_{AE} - I_{AB}}{d_{ME} - d_{MB}}, \text{kcal/kg} \]  

where \( q_{EVA} \) - the amount of the heat to evaporate moisture, kcal/kg;

\( I_{AE} \) - the heat content of air at the exit from the dryer, kcal/kg (\( I_{AE} = 230 \text{ kcal/kg} \));

\( I_{AB} \) - the heat content of air before heating in the dryer, kcal/kg (\( I_{AB} = 10.25 \text{ kcal/kg} \));

\( d_{MB} \) - the moisture content of air before heating in the dryer, kg/kg (\( d_{MB} = 0.01 \text{ kg/kg} \));

\( d_{ME} \) - the moisture content of air at the outlet of the dryer, kg/kg (\( d_{ME} = 0.308 \text{ kg/kg} \)).

Taking into account the data on the heat and moisture content of the air before heating in the dryer and heated, the amount of heat required to evaporate 1 kg of moisture is about 716 kcal/kg.

The required amount of the heat for heating 1 kg of evaporated moisture is defined as:

\[ q_{HE} = G_{MD} \cdot \frac{100 - W'}{W_f - W_p} (T_{MD} - T_{MW}) - G_W \cdot T_w \text{, kcal/kg} \]  

where \( G_{MD} \) - the heat capacity of poultry manure, kcal/kg deg. C (\( G_{MD} = 0.42 \text{ kcal/kg deg. C} \));

\( T_{MD} \) - the temperature of dried poultry manure, deg. C;

\( T_{MW} \) - the temperature of wet poultry manure, deg. C;

\( G_W \) - the heat capacity of water, kcal/kg deg. C (1 kcal/kg deg. C);

\( T_w \) - the water temperature, deg. C.

Since before feeding the manure for drying in the receiving and storage stations, its preheating is provided, in this regard, the temperature of the wet manure entering the drying drum will be about 300°C, and the temperature of the dry manure when leaving the dryer is 1200°C. The amount of heat to heat 1 kg of evaporated moisture is about 2.5 kcal/kg.

While drying the manure, the heat loss to the environment also occurs, the approximate amount of which can be determined by multiplying the amount of evaporated moisture by 10 kcal. In our case, the heat loss to the environment will be about 7.0 kcal/kg. Thus, the total heat consumption will be about 726 kcal/kg. With the efficiency of the dryer 95%, the total heat consumption for evaporation of 1 kg of moisture from the litter will be about 764.0 kcal/kg, the Total hourly heat consumption will be 1619680 kcal/h.

The amount of burned fuel (natural gas) to obtain this amount of the heat for drying the manure is determined by the formula:

\[ G_{GAS} = \frac{q_H}{g_{GAS}}, \text{ m}^3 \]  

where \( G_{GAS} \) - the amount of burned gas during the drying of manure, m³/h;

\( q_H \) - the hourly heat consumption, kcal/h;

\( g_{GAS} \) - the calorific value of gas, kcal/m³.

When the gas heat of combustion is about 8040 kcal/m³, its consumption will be 201.4 m³/h.

The required volume of the drying cylinder is defined as:

\[ V_{DC} = \frac{Q_{MEH}}{A}, \text{ m}^3 \]  

where \( Q_{MEH} \) - the amount of moisture evaporated per hour, kg/h;

\( A \) - the tension of the cylinder for the evaporated moisture, kg(m³/h).

With the cylinder voltage of 80 kg of evaporated moisture (m³/h), the volume of the dryer must be at least 26.5m³. Taking the cylinder diameter of 1.5 m, its length should be about 12 meters.

Taking into account these studies, a prototype of the dryer was made, which passed production tests (Figure 3).
The proposed technology of manure processing allows to process up to 5.0 t/h of wet manure, while producing about 0.7 MW/h of thermal energy, 1150 kg/h of fuel briquettes and 210 kg/h of organic-mineral fertilizer. As a result of mixing dried poultry manure, with a content of 8.4% of nutrients, with ash and a content of 41.3% of nutrients, a complex of organo-mineral fertilizer is obtained, which contains about 320 kg of the active substance. The resulting organic-mineral fertilizer in the amount of nutrients is comparable to mineral fertilizer [11].

The analysis of the fertilizer price in the Chelyabinsk region and the content of the active substance shows that the average cost of one kilogram of the active substance is 41.5 rubles. Based on the cost of 1 kg of the active substance of the mineral fertilizer, the price of one ton of the organo-mineral fertilizer containing 320,000 kilograms of active substance should be about 13.0 thousand rubles. However, the calculations show that if 1 kg of the active substance of the fertilizer gives an increase in the yield of wheat grain 5.0–7.0 kg, then to cover the costs only for the purchase of fertilizer, the purchase price of grain should be about 8.0–6.0 rubles/kg. If we take into account the costs of storing this fertilizer, transportation, introduction into the soil, post-harvest processing of the increase in the crop from its application and the minimum profit, the purchase price of grain in this case should be 12-10 rubles/kg. Often, the purchase price of commercial grain is much lower than these figures, so the use of mineral fertilizers becomes economically unprofitable. Consequently, the price of mineral fertilizers in the domestic market is overstated, which hinders its use. In our calculations to determine the economic efficiency of poultry manure processing on the proposed technology, the price of 1 kg of the active substance of the resulting fertilizer was taken within 16-17 rubles. Based on this, with the content of nutrients in the organo-mineral fertilizer is 32%, its price will be about 5.0 thousand rubles/ton.

The fuel briquettes on caloric value correspond to coal. The briquettes require a minimum of storage space, it can be automated feed during combustion. It can be used as a flue material in existing boiler plants without conversion, and combustion is relatively harmless to the environment. When burning fuel briquettes remains ash, which can be used as fertilizer. A significant share of consumption of fuel briquettes falls on European countries. In recent years, the interest in the fuel briquettes has also increased in Russia. Depending on the material from which the briquettes are made, its market price is 4.0–6.0 thousand rubles/ton. For comparison, the price of coal is 3.1–3.9 thousand rubles/ton. In determining the economic efficiency of the price of the fuel briquettes, we adopted 3.0 thousand rubles/ton.

When processing 120 tons per day of manure with a moisture content of 65-70%, the annual production of the organo-mineral fertilizer will be about 1500 tons and fuel briquettes about 8000 tons. The revenue from the sale of these products will be about 31.5 million rubles. With the amount of direct costs of 11.5 million rubles, the estimated annual economic effect of the utilization of poultry manure on the proposed technology is about 20.0 million rubles. With the cost of the complex 25.5 million rubles,
the payback period is not more than 1.5 years. In the processing of poultry manure, the company gets the following effects:

1. Energy effect: the production of the fuel briquettes with qualities superior to classical energy resources (wood, coal, etc.);
2. Agrochemical effect: obtaining an effective complete organo-mineral fertilizer and restoration of natural soil fertility;
3. Economic effect: profit from the sale of fertilizers and fuel briquettes. Diversification of agricultural production. Reduction of expenses for purchase of mineral fertilizers for own needs. Reduction of costs for heating business premises due to the self-reliance of solid fuels;
4. Environmental effect: utilization of poultry manure in the stream, without the use of a repository. Reducing pollution of the environment and arable land;
5. Social effect: creation of new jobs. Increasing the attractiveness of living in rural areas and employment of rural population. The emergence of an additional source of income. Improvement of rural infrastructure, increase of literacy and communication of the population with territorial authorities.

Conclusion
1. By utilizing the hazardous substance, which is the manure, this method for the poultry farm solves the environmental problem, establishes the production of popular and competitive products. With the utilization of one production line of 120 tons per day of manure with a moisture content of 65-70 %, the annual production of thermal energy will be about 6000 MW, the fuel briquettes - 8000 tons, the organo-mineral fertilizer - 1500 tons, the implementation of which the company receives an economic effect of about 25 million rubles/year.
2. The production of the organic-mineral fertilizer can solve the problem of soil fertility increase. With the price of the organo-mineral fertilizer 5.0 thousand rubles/ton containing 320.0 kilograms of the active substance, its use in the cultivation of crops becomes economically beneficial.

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