Research on waste management technologies in meat clusters

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Abstract. Meat clusters existing in Russia have low investment attractiveness. The authors substantiated the need to include universities in the cluster of research divisions for conducting research and development. The study concerning the efficiency of the meat clusters operation and waste control technologies was carried out. The best available technology for liquid waste processing has been substantiated. The meat clusters include meat processing plants. The authors consider their waste as secondary resources for energy, fertilizers for farmlands and other production. “Athos”, a liquid-phase oxidation technology is proposed to reduce the technogenic pressure on the environment and energy-efficient waste processing. It is not applied in Russia, despite its obvious advantages. The article provides a flow chart of a liquid-phase oxidation unit and elements of the best available technologies obtained while its implementation. The technology of liquid-phase oxidation ensures the autothermal process and is it is recommended for the waste from the food industry processing and processing enterprises of the agro-industrial complex.

1. Introduction

The agro-industrial cluster represents an important space for high-technological knowledge, expanding the innovative capabilities of firms that they represent in the region. The nature analysis of the close science-intensive communication shows a particularly strong links among research organizations and industrial enterprises. These interactions are a multifaceted phenomenon reflecting the different methods importance concerning the knowledge transferring to solve environmental problems. The existing university and industry partnerships play a key role in this field.

Industrial clusters are widely spread in developed and developing countries, including countries in Asia, Latin America and sub-Saharan Africa. The modernization of traditional industrial clusters in rural areas has made a more significant contribution to economic development than the development of new modern industries in Japan. The development of industrial clusters is a main factor for successful industrial development in developing countries [1]. Therefore, it is extremely important to study how industrial clusters are created, develop, stagnate or decline, as well as to identify the factors that influence the success and failure of cluster-based industrial development. Although both modern and historical studies of the cluster development are based on the theory of agglomeration economics, the industrial cluster provides strong advantages for enterprises compared to non-cluster regions [2-7].
It is noted in [8] that with the help of clusters, “... end-to-end technological corridors” from research to manufacturing and introduction of the competitive production, forming “innovative clusters”; large-scale manufacturing of knowledge-intensive competitive production should be created in the home and foreign markets on the basis of partnerships between science and industry, the state and private sectors.

It can be concluded that one of the most important characteristics of any cluster is its focus on innovation, including the accelerated introduction of innovations at the enterprises included in the cluster, without a barrier of technological transfer within the cluster. Conducting research and development takes up an ever greater weight in investment costs, exceeding the costs of acquiring equipment and construction in high-technological industries.

2. Statement of the problem
The scientific potential of universities will provide a continuous process of technological development, and, consequently, the opportunity to win in the competition. That is what we exactly observe in economically developed countries, where innovation is the main weapon in modern competition; this is a new element of the business environment in clusters.

Scientific papers [9] devoted to the discussion of the cluster organizations connected with the waste control and professional cluster management in obtaining a competitive advantage are of interest. Academic, small and medium-sized enterprises in Germany, such as Insilico Biotech, SilicoLife and Senszyme, provide the necessary services, know-how and intellectual property, thereby transforming the advanced scientific developments into industrial processes and production. The paper formulates one of the most important problems of the cluster, i.e., accelerating the transferring the science into the production practice.

Rural areas rich in biomass can rely on a promising position in the creation of large agro-industrial clusters and are optimal places for this. According to [10], small regions that provide universities and stakeholders make up a base of efficient clusters. Regarding to the opinion of [10] a cluster is “the geographical concentration of interconnected companies, specialized suppliers and service providers, firms in related industries and related institutions (e.g. universities, standardization agencies and trade associations) in specific areas that compete and cooperate”.

3. Overview of existing solutions
Studies [11] showed that clusters can be formed on their own; they can appear due to the concentration of scientific knowledge (for example, thanks to advanced research institutes), urgent local demand (for example, environmental pollution) or a critical mass of interconnected companies in the certain area (e.g. suppliers and interrelated companies). When a cluster is formed, it creates a self-reinforcing process that stimulates the formation of a new business, economic growth, as well as competition among cluster companies. However, this competition particularly stimulates productivity growth, as it increases the pressure on innovation.

Within one cluster, a border of cluster elements is transparent. It allows innovations to spread easily [12]. Clusters contribute to a faster search for the right solutions in the field of resource conservation and waste disposal [13-15].

If a region attracts the attention of home research institutions to bioeconomic technologies, attracts third-party technologies and business developers, as well as investor, then a future-oriented cluster is formed. For this to become a trend, it is necessary to have a critical mass of all these stakeholders and a social climate that supports the introduction of new technologies and the adoption of business risks. Cluster management means the coordination of all its elements with their innovations. Universities and research institutes conduct research on the topics of clusters, and industrial enterprises apply the obtained developments in the field of research and development (R&D). No cluster strategy can be implemented without active participants [9].

The so-called regional innovation network “a model region for innovative and sustainable material flows” is of great interest [1]. It includes farmers, processors, and universities implementing an
interdisciplinary approach that combines agricultural sciences, biology, biotechnology, chemistry, technology, logistics, economics and social sciences. The complexity of interaction of various cluster’s elements can lead to new approaches and synergies and it can pose new scientific questions. The article [3] presents an analysis of ways for increasing the competitiveness and stability of a cluster based on a synergistic effect. The synergistic effect is realized on the basis of the production potential growth of the integrated structure.

The resource potential of the model region is crucial in shaping the development strategy and cluster’s scale. The active cluster management helps to determine the coordinated development of technologies and market trends and faster implementation of regional potential in the field of waste management [16].

In recent years, in an effort to adopt best practices, cluster methods have also begun to be applied in Russia. It resulted in creation of a large-scale all-Russian integration project “PARK: Industrial-Agricultural Regional Clusters” under the auspices of the “Center for Innovation” of Non-Profit Partnership. The main objective of the project is to create a modern innovative and technological structure for a full cycle of redistribution of raw materials, with maximum use of energy-saving bio- and nanotechnologies.

The agro-industrial cluster will include a plant for the deep processing of grain crops and biomass, a feed mill, a pig and poultry complex, a meat factory, as well as a number of enterprises producing enzymes, acids and amino acids.

Clusters will ensure the development of the new business in the field of production, distribution, transportation and disposal of waste. The cluster approach can be efficiently applied for the distribution of by-products of the meat industry. In [17], a high-level analytical model is presented for developing optimal networks for the sale of by-products of meat processing.

Nowadays, large meat processing plants play the leading role in the meat industry operating. They account for more than 800 thousand tons of meat products in terms of meat, which is 18% of all meat received for industrial processing in Russia and 10% of total meat resources in terms of meat.

Each enterprise generates waste polluting the environment. A lot of them can be considered as secondary resources, as technogenic raw materials for obtaining useful products. As a part of the cluster, waste management can be effectively organized with the maximum extraction of valuable components and minimal environmental pollution [18].

For their own needs, meat processing enterprises annually use about 60 million m³ of water; the volume of liquid waste is about 46 million m³. The proportion of liquid waste contaminated with substances of chemical and microbiological composition to the total volume of effluents is about 77%, which indicates the low efficiency of the existing treatment facilities.

Liquid waste contains residues of feed, salt, detergents, disinfectants, nitrites, phosphates, alkalis, acids; the presence of pathogenic microflora is also possible.

The meat processing plant makes a significant contribution to environmental pollution. Using large amounts of water for the needs of the enterprise, the proportion of pollution is high, and approximately 50% of the total volume is purified. A part of the waste generated at the enterprise is simply dumped into the sewer, which leads to a deterioration in the operation of the processing plant. As a result, the intended degree of purification will not be achieved.

4. Proposed solution
It is possible to reduce the cost of waste processing and reduce the negative impact of meat processing plants on the environment applying methods to extract protein substances and fats from waste with the subsequent sale of the resulting products simultaneously. Unfortunately, significant capital costs for the implementation of such methods, the complexity of the hardware development, structures operation and some other circumstances cannot apply these methods in home meat processing plants.

The significant environmental pollution from the meat processing plants, a large amount of aggressive waste, insufficient efficiency of the technologies used for their disposal make it possible to consider the research topic actual.
The aim of the work is to conduct the research on the operation efficiency of meat clusters and waste management technology, justification of the best available technologies for waste processing.

The practice of applying the best available technologies in Russia shows that it is necessary to adapt and use the positive experience of economically developed countries in this area, taking into account the specifics of our country in order to improve the environmental situation.

The objects of study are meat clusters and waste management technologies.

The analysis of scientific and technical information on the performance of local processing plants allows us to draw the following conclusions with the help of the theoretical research methods,

1. The existing equipment for pre-processing of liquid waste of meat processing plants in most cases are not able to provide the required degree of pollution removal in any of the standardized indicators.

2. The reconstruction and expansion of existing processing plants based on fundamentally new technologies are necessary to ensure the required degree of removal of contaminants from the liquid wastes of the meat processing plant.

3. The aerobic technology for preliminary processing of liquid waste from a meat factory is the most appropriate in most meat processing plants as it has several advantages before anaerobic cleaning:

   - aerobic processing plant is much simpler than the anaerobic processing plant;
   - need for aerobic purification of liquid waste after anaerobic purification to further reduce biochemical oxygen demand (BOD), ammonium nitrogen concentrations and their saturation with oxygen;
   - long duration (1.5-2 months) of putting into operation plants for anaerobic waste processing;
   - necessity in some cases to heat these wastes and maintain a certain temperature environment.

4. The pre-processing technology provides for the sequential removal of big wastes, suspended solids, fat, colloidal and partially dissolved impurities from them in grates, in sand traps, in combined facilities - sedimentation tanks-flotators and in aero tanks-sedimentation tanks designed for incomplete biological processing.

The following measures should be taken to improve environmental protection management and interaction between enterprises and special authorized organizations in the field of environmental protection:

   - enterprise is obliged to submit a list of raw materials and chemicals, including qualitative and ecotoxicological characteristics of substances (list of harmful substances), to the relevant authorized organizations for environmental protection;
   - results of the enterprise self-control and its reporting should be presented to the relevant authorized organizations for environmental protection;
   - special authorized organizations should take into account the experience gained and facilitate the implementation of pilot projects to transfer environmental protection experience to other enterprises;
   - it is necessary to develop the exchange of information between enterprises with similar production, research institutions.

A meat cluster is characterized by a large number of different types of waste. The position of the authors in this matter is to consider the waste generated in the meat cluster as secondary resources for obtaining: leather production from animal skins; fertilizers for farmlands and products from fat-containing waste.

It is necessary to consider energy-efficient waste management to obtain feed, as an alternative if there are no livestock farms and agricultural fields in the meat cluster. For large-scale meat processing
plants located in the city, the priority is environmental friendliness, i.e., the waste treatment technology should be as efficient as possible according to this criterion. The analysis of the best technologies applied in the world for wastes from meat processing plants let us recommend Athos liquid-phase oxidation technology for Russia. The high efficiency and low energy consumption allow the authors to recommend liquid phase oxidation for local sewage sludge equipment of large meat processing plants (figure 1).

![Technological scheme of the liquid-phase oxidation plant Athos](image)

**Figure 1.** The technological scheme of the liquid-phase oxidation plant Athos
1-oxidation reactor; 2-pump high pressure; 3-circuit heat recovery; 4-circulation pump; 5-heat exchanger-heater sediment; 6-heat exchanger-cooler; 7-sump; 8-separator and condensation column.

Energy-efficient sewage sludge precipitation processing is an important technological problem; its solution is possible applying the experience and technologies of the industrialized countries. The sustainable management by biological sludge from sewage sludge processing plants and industrial enterprises is a complex problem. Consider the thermal technology of liquid-phase oxidation of sewage sludge, which is not well known in the Russian Federation, although there are a lot of working full-scale plants in the world [19]. Unlike the combustion, where oxidation occurs in the gas phase, the thermal process of liquid-phase oxidation of organic substances is carried out in the liquid phase at temperatures of 125-320 °C and a pressure of 5-200 bar. The increased solubility of oxygen at these temperature and pressure provides a high process speed. Within 15-20 minutes, depending on the temperature, the chemical oxygen consumption is reduced by 75-90%. Liquid phase oxidation is carried out in accordance with the Athos process developed at the Veolia Center for Environmental Research and Innovation. The technology has been implemented and applied since 2005 in sewage processing plants with a capacity of 150 thousand to 1.2 million in Belgium, Italy and France. Deep mineralization and a decrease in sewage sludge are achieved within one hour. It is important to note that the Athos autothermal process of liquid-phase oxidation does not require the application of any fuel in the operating mode, with the exception of the plant start-up periods, which lasts 3-4 hours.

The elements of the best available technologies for liquid-phase oxidation are short process duration (up to 1 hour); positive experience in industrial implementation; autothermal conductivity and low costs; low sediment volume; high level of process automation; reduction of air pollution and hydrosphere.
An important fact is the need for research and development as well as the technological regulations development in developing effective technologies for each enterprise, confirmed by the results of research.

It should be noted that a current reference document containing information on the best available technologies in the food production is BREFFoods, Drink and Milk Industries 08.2006 (Production of food, drinks and milk).

Despite all the diversity of the food industry, some of its branches have common problems, and the same best available technologies are applicable to reduce resource consumption, prevent and reduce emissions and discharges. Moreover, some of the best available technologies can be applied for solving some environmental problems at the same time, for example, modern maintenance of the refrigeration equipment can prevent ammonia leakage, reduce water and energy consumption.

The generalization of the approach also means minimization of the resources consumption, levels of emissions and discharges of pollutants by increasing the overall production culture.

5. Conclusion
The following conclusions can be drawn based on the results of the research:

1. The meat clusters existing in the Russian Federation cannot be classified as efficient in terms of environmental performance and, especially, in terms of investment attractiveness. It is necessary to conduct research and development for the effective, innovative meat clusters formation that is possible in cooperation with universities.

2. The priority problem is the development of waste management technologies with the least environmental impact for meat processing plants. The implementation of such technologies will increase the investment attractiveness of not only the enterprise, but of the whole cluster.

3. For large meat processing plants, the best indicators of environmental friendliness and energy conservation is the Athos liquid-phase oxidation technology with a heat recovery circuit that ensures the thermally automatic process. This technology could be categorized as the best environmental friendliness and profitability available by the criterion.

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