Analysis of approaches to waste management of pig farms

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Abstract. This paper aims to analyze effective approaches to waste management in agro-industrial cluster. It considers the studies confirming the relevance and importance of the development of technologies for processing and recycling of waste from the agro-industrial cluster, and, in particular, waste from pig farms. The methods of system analysis, information synthesis, statistical data analysis were used to identify the existing problems. The period from 2000 to 2020 was considered. The most popular directions and production branches have been identified. Quantitative analysis of scientific works on recycling and disposal of waste of agro-industrial cluster was carried out. Based on the data obtained, graphs were built, comparisons were made, conclusions were drawn about the demand for the development of resource-saving technologies, and waste recycling. Based on the analysis of the existing approaches, the authors proposed a cluster form of organization and waste management.

1 Introduction

In recent years, extensive research on recycling and waste management in the agro-industrial cluster has been conducted increasingly. The studies include the introduction of existing technologies, but are not limited only to this; barriers and problems of transition to circular resource consumption are identified. Waste and additional means are considered. Bibliometric analysis helped researchers analyze numerous publications on waste management and resource-saving. However, the activities of researchers that correspond to the principles of waste recycling in practice are still unclear, and there are unsolved problems. Consequently, there is no complete map of research topics and trends corresponding to the prospects in the literature.

This work gives a careful examination of literature, providing the volume of knowledge on the disposal and recycling of waste of the agro-industrial cluster, its major topics, trends, characteristics, evolution, and directions for future research. To achieve the purpose of this study, a mixed methodical approach is used, which includes bibliometric analysis, text mining and content analysis. The following research questions are posed: how the field of research has developed; what are the main research topics and trends; what are possible directions for future research [1]. In [2], considered is the possibility of using biomass

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generated as agricultural waste, contributing to the reduction of fossil fuel use and greenhouse gas emissions, and promoting the development of new markets and jobs by facilitating the conversion of plant waste into value-added products. Aspects of the study are relevant for farmers and other interested organizations in agricultural systems as they are passing to a new economic model.

Agricultural waste and by-products can be converted into valuable resources using intensified conversion processes, so the new value-added products appear, such as bioenergy, biofertilizers, biomaterials and biomolecules, depending on the biomass volume. However, the profitable exploitation of waste is a very comprehensive and interdisciplinary problem that requires knowledge of materials, technologies, the market and social-economic issues related to the valorization of lateral flow. Research on the processing of agricultural waste has been carried out for more than 60 years, mainly in the USA, India and China, but also in Latin America (Brazil and Mexico, as well as Chile, Colombia, Peru, Trinidad and Tobago and other countries), and in Europe with a special focus on the collection and processing of nutrients in production at the fields. The number of publications has increased significantly over the past 13 years; this correlates with the introduction of a new regulatory framework for sustainable development and new policies and strategies for the circular economy and bioeconomics. Spatial clustering of various enterprises is considered as one of the adequate ways to make the valorization of biomass possible [3]. The clusterization in waste processing and disposal, various algorithms for analyzing their management were studied in [4].

There is a growing demand for the use of insects as high-quality protein ingredients in animal feed. The efficiency of decomposition of this organic waste by larvae ranges from 55 to 80%. The potential for commercialization of larvae and fertilizers is relatively new, but has received a flurry of interest in the last couple of years. The creation of fertilizer as a second value-added product from cultivation would increase the profits of farmers who deal with insects, as well as directly contribute to increasing soil fertility and crop yields [5].

Data from the literature published between 2013 and 2017 on nutrient and carbon reuse and recovery technologies and practices used in wastewater and agricultural wastes were described and compared. 177 studies describing 25 technologies for the recovery and recycling of waste were found. As for wastewater, 476 studies carried out worldwide have described 28 technologies for recycling and recovery [6]. The ecological industrial chain of rural biomass energy can not only remove environmental pollution caused by forest and field waste but also contribute to the employment of rural workers and increase farmers' incomes [7]. Organic waste is expected to play a key role as a valuable feedstock when turned into cost-effective renewable energy.

While the concept of converting what is normally disposed as waste into usable energy, chemicals and fuels is not new, its applicability has greatly expanded in recent years, even in waste treatment. Operating in parallel, a new model called the circular bioeconomy considers the potential of bioresources to obtain renewable biological resources and transform them into value-added bioproducts. Within the framework of this bio-based model, biomass waste can be an opportunity to extract valuable nutrients for enriching and improving soil quality or for extracting bioenergy and products [8]. There are various valorization opportunities in alternative sectors leading to new products and practical applications with lower or higher cost [9]. Problematic oriented research was focused on the sustainable nutrient supply of crop and livestock production [10]. The combined use of mineral and organic fertilizers can potentially lead to lower or higher yields if compared with its separate use.

Several publications [11-14] substantiated the rationality of the method of reagent treatment of pig waste to obtain organic mineral fertilizers. The effectiveness of their practical application in increasing the yield of agricultural crops is considered. The features

of fertilizer drying have been studied, optimal process parameters have been established, and a technological scheme for dewatering the finished fertilizer has been proposed. The paper [15] shows that, because of the significant environmental impact, the livestock industry is increasingly subjected to rigorous legal scrutiny in an attempt to reduce this impact These ambitious reduction goals cannot be achieved by one measure alone, they require a judicious combination of several mitigation technologies, such as precision animal feeding and handling concepts, improved manure storage, treatment, handling and application of technologies to optimize animal feed in the food chain. The integrated bioeconomical model presented in [16] includes agricultural production and waste disposal systems to simulate the impact of technological improvements in pig manure processing on economic and environmental benefits for the case of a pilot farm in Beijing, China. Modeling results show that the economic and environmental benefits of a livestock farm can be improved by reducing the application of manure to arable land and increasing composting production using modern technology. At the same time, technical efficiency, waste recycling capacity and economic benefits can be further improved through the introduction of new technologies. The analyses carried out on wastewater of pig farm showed a high efficiency in water recycling and nutrient extraction [17]. The authors [18] concluded that the use of municipal food waste for animal nutrition purposes would result in better environmental and health impacts than recycling by composting or anaerobic digestion. They summarized legislation on the use of food products in feed, considered nutritional properties, waste treatment, resource and environmental impacts. Animal manure, effectively exported during certain seasons of the year to nearby or remote crop fields, can eventually become a valuable resource. To consider this possibility, it is necessary to take into account the financial and environmental costs of transporting large amounts of manure as limiting factors for transferring nutrients from livestock farms to agricultural fields. The optimal centralized method of solving the problem of transporting manure from livestock farms to agricultural fields for utilization as organic fertilizer is proposed on the example of Catalonia (Spain) in [19]. Some types of processing of liquid waste from pig farms (for example, acidification, ammonia denitrification, separation into solid and liquid components) can increase their value. Solid-liquid separation is a technology that produces a solid fraction with a higher dry matter content and a richer nutrient content (especially P and N) which allows them to be transported over long distances. The new approach proposed in [20] will make it possible to obtain new organic fertilizers with a known N:P ratio approximately close to the value usually used by farmers.

2 Materials and methods

This study presents an analysis of the existing technologies for the disposal and processing of waste from agro-industrial clusters and pig farms. The performed bibliographic review revealed a variety of modern technologies and the tasks they solve. The search for scientific publications was carried out in the ScienceDirect database. The two main search directions were agro-industrial clusters and pig farms. The search domain included the following keywords: waste of agro-industrial clusters, waste processing of agro-industrial clusters, fertilizers from waste of agro-industrial clusters, waste of pig farms, recycling of pig farm waste, fertilizers from waste of pig farms. The search depth for generating statistics and identifying demand growth was 20 years (the period from 2000 to 2020). For the analysis, graphs of the dependence of the number of publications on the year were plotted. The dynamics of publications by author affiliation to different countries was determined.

3 Results

At the first stage, twenty sources with different technologies for disposal and recycling of waste from agro-industrial clusters were analyzed. The most acute is the problem of recycling waste from pig farms. We identified three main areas for analysis and determined the most relevant of them. It was established that obtaining fertilizers from wastes of pig farms is particularly in demand. The results of the analysis of the dynamics of publications for the "pig farms" topic are presented in Figure 1.

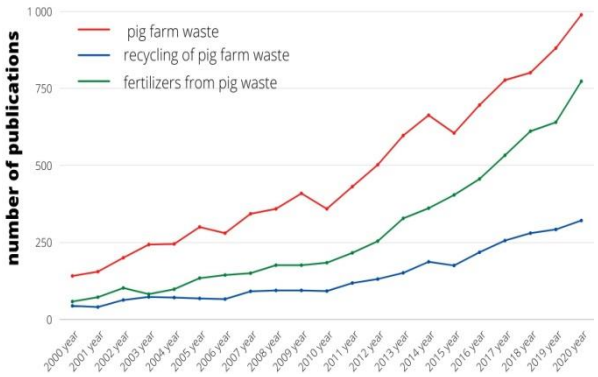

Fig. 1. The dynamics of scientific publications by queries for the topic "pig farms"

A tendency to increase the number of publications in the selected time period was revealed for all search queries. This can be explained by the increased interest in waste as a potential valuable resource. At the same time, there is a lag in the number of studies related to the processing of waste and the production of fertilizers from them. There has been a significant increase in the number of publications since 2012. At the same time, there was a jump in the number of works (almost 2 times) in the period from 2010 to 2014. The number of studies devoted to obtaining fertilizers from waste is growing in proportion to the number of publications related to the study of pig waste.

The relevance of scientific research in the countries was analyzed. The countries making the greatest contribution to scientific research on waste of pig farms were identified. The graphs showing the number of publications by years and depending on the author's country affiliation were constructed and analyzed, Figure 2.

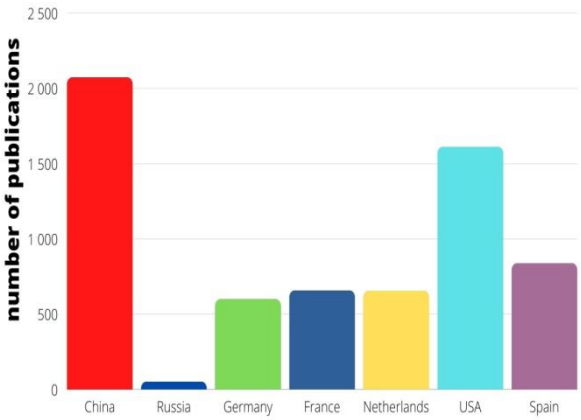

Fig. 2. Analysis of the number of publications depending on the authors' affiliation.

The number of publications in 2021 for the topic "waste of agro-industrial cluster" was 562, and for the topic "waste of pig farms" this number was 1258. This shows the existence of several urgent problems in this area that require detailed study.
Based on the study of the existing approaches to waste management of agro-industrial clusters, a scheme was developed which includes processing of the maximum number of wastes (Figure 3).

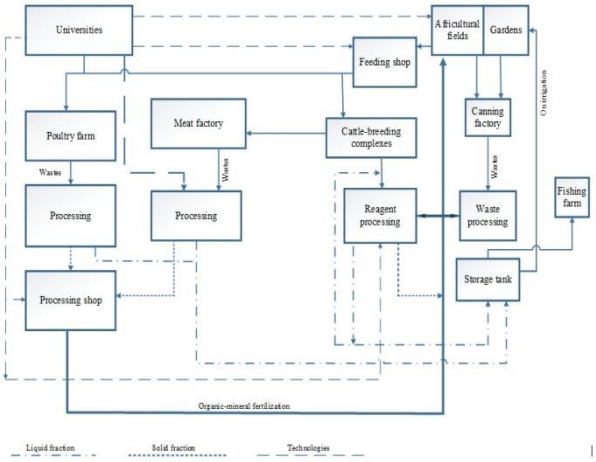

Fig. 3. Waste management scheme for the agro-industrial cluster.

The scheme is relevant for all countries, the priority of recycling can change depending on the degree of development of the industries included in the agro-industrial cluster.

4 Discussion

China and the USA hold leading positions in waste management. It should be noted that in other countries under consideration, the problem of waste is also being actively studied. However, the number of studies is significantly lower compared to that of the leading agro-industrial countries. There is no complete waste management system in Russia, so the proposed scheme can serve as a basis for the development of effective approaches to waste disposal in the agro-industrial cluster. The developed scheme is based on the close interaction between the components of the agro-industrial cluster: industrial production of different directions, agricultural holdings, research complexes, farms. The scheme will make it possible to develop an effective approach to integrated waste management, which will contribute to ensuring food independence. An important component is the use of local raw materials.

5 Conclusion

The performed research established the relevance of studying the problems associated with waste from agro-industrial clusters, in particular, pig farms and their processing into fertilizers. There has been a multiple increase in the number of publications in the studied areas. The studies on pig farm waste gained an increased interest as compared to the waste of the agro-industrial cluster. A steady difference in the number of scientific papers devoted to the topics of obtaining fertilizers from pig waste and the issues of their processing is

noted for the study period. The cluster form of waste management proposed by the authors is characterized by a prompt transition from research results to their implementation.

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