Investigation and analysis of the linkage mechanism and whole process cost of livestock manure organic fertilizer

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Abstract: In recent years, the utilization of manure resources for livestock and poultry farming has attracted a widespread attention, and manure resources utilization models suitable for different regional characteristics have formed gradually. Among them, the production of organic fertilizer from animal manure is a vital utilization method. However, there are still some problems such as high production costs, difficult sales, and the unwillingness of farmers to use organic fertilizers which have affected the breeding cycle and the sustainability of manure treatment in livestock and poultry breeding. This article selected 371 organic fertilizer plants, related farms and farmers in China, focusing on the main links of the entire process of livestock manure-organic fertilizer-farm application, and studied the mode of animal manure collection by organic fertilizer plants. The costs of organic fertilizer production and farmland application were discussed. Moreover, suggestions were made for the promotion and implementation of large-scale organic fertilizers to make good utilization of manure resources in livestock and poultry farming.

Keywords: livestock manure, organic fertilizer, compost, production cost, application cost
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1 Introduction

As an essential means of production, fertilizer has an irreplaceable role in promoting the development of the agricultural output, however, there are some problems such as excessive supplementation of chemical fertilizers, blind replacement, undue emphasis on the substitution of synthetic fertilizers for crops, and the impact on soil quality. Contradictions such as the reduction of excess fertilizer, food safety, depletion of resources, and environmental pollution have become increasingly prominent. Organic fertilizers have received widespread attention due to their characteristics of improving soil fertility and environmental friendliness[1-4].

At present, the raw materials for organic fertilizer production mainly include agricultural production and processing waste, urban domestic waste, and municipal sludge[5]. According to statistics, about 3.80×10^{10} t of various types of livestock and poultry manure and 1.00×10^{9} t of crop stalks are produced each year, which can provide about 8.00×10^{8} t of organic matter and 7.30×10^{8} t of nitrogen. However, the actual utilization is less than 40%[6,7]. Among the existing organic fertilizers, the organic manure produced by livestock and poultry manures provided with higher organic matter and nitrogen, phosphorus, potassium, and various trace element substances, which can provide nutrients for crop growth and improve fertility as the market favors[8,9]. According to the literature review, the scale of fouling produced by large-scale livestock and poultry manure in China was 3.83×10^{9} t, of which fresh manure was 6.36×10^{8} t, urine was 5.65×10^{8} t, and sewage was 2.63×10^{9} t by 2015. From the perspective of accumulation,

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the nitrogen and phosphorus production in livestock and poultry manures were 1.23×10^7 t and 2.05×10^6 t, respectively, with Henan Province having the highest output, with the thresholds being Shandong, Hebei, Sichuan, and Hunan[9]. It estimated that the amount of manure produced by livestock and poultry would surely reach 4.24×10^9 t by 2020[10]. There is a vast development space using livestock and poultry manure as a raw material for organic fertilizer production.

Meanwhile, fertilization is also the most critical way to regenerate livestock manure. However, compared to the amount of livestock manure produced, the scale of domestic livestock manure organic fertilizer production enterprises is still small, and the operating rate is insufficient[11]. By 2013, according to the national soil and fertilizer professional statistics of the National Agricultural Technology Center, the total number of inorganic and organic fertilizer production enterprises has grown from less than 1000 in 2005 to 4103. The overall design capacity of organic fertilizer has increased from 8.00×10^6 t in 2005 to 4.70×10^8 t. The actual total production capacity is 2.30×10^8 t, of which 803 with an annual output of more than 2.00×10^5 t for 19.57% of the scale of enterprises, and 1279 with 0.5×10^5-2×10^5 for 31.17% of the range of enterprises. Refined organic fertilizer enterprises accounted for 72.6% of the scale of organic fertilizer production enterprises, organic-inorganic compound fertilizers accounted for 19.8% of volume, and biological organic fertilizers accounted for 7.6% of the total. At the same time, the regional distribution of internal organic fertilizer production enterprises has reduced and concentrated. Firstly, it distributed in economically developed regions, including Guangdong, Jiangsu, and Fujian. It characterized by good environmental awareness and relatively mature technical support; regions, including Shandong, Hebei, and other regions. The survey results show that organic fertilizer production enterprises in Shandong, Guangdong, Hebei, Jiangsu, and Liaoning account for more than 50% of the national organic fertilizer production enterprises [12]. Following the development of the organic fertilizer industry, due to factors such as high production costs, slow fertilizer efficiency, and high labor intensity, the promotion and application of organic fertilizers have progressed slowly. Farmers are not enthusiastic about using organic fertilizers. Other problems often occur, such as some organic fertilizer companies have overstocked product inventory, low market share, and sales obstacles[13-16].

To better promote organic fertilizer and clarify the issues in the current application, this preliminary study would focus on organic fertilizer production and discuss the entire process from livestock manure-organic fertilizers to farmland applications (Figure 1). Furthermore, this study would also summarize the fertilizer utilization model of livestock and poultry manure, analyze the production and application cost of organic manure sewage and organic fertilizer, and put forward some suggestions for the popularization and application of organic manure in China.

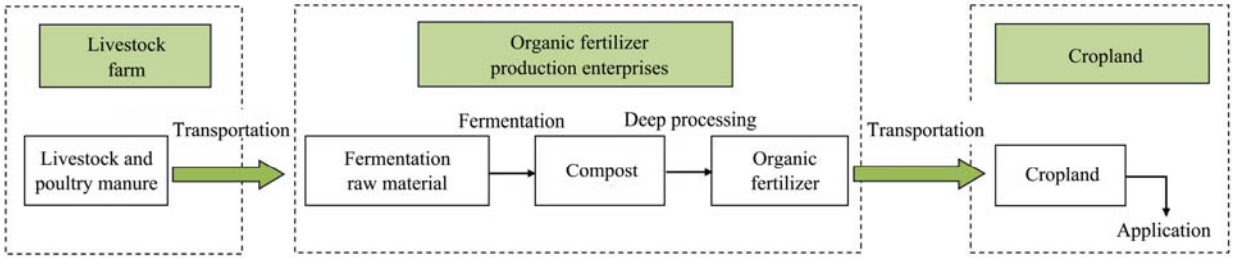

Figure 1 Main link among livestock and poultry manure, organic fertilizer, and field application

2 Methods

This study mainly adopts a discussion with enterprises and farmers and questionnaires. The survey period was from March 2017 to May 2018, and the targets were organic fertilizer plants using livestock and poultry manure as raw materials and related farms and organic fertilizers user. The survey contents mainly include the livestock and poultry manure collection and transportation mode, the main costs of each step of the organic fertilizer production process, the alternative methods, and the costs of organic fertilizer.

The exploration scope covers 23 provinces (cities, autonomous regions) and 344 counties, of which covering 96 major livestock counties, including 49 in North China, 22 in East China, 8 in South China, 8 in Central China, 4 in Northwest China, and 5 in Southwest China (Figure 2). The survey questionnaires distributed 374 copies, of which the active recovery of 343. Of the 343 questionnaires collected from organic fertilizer production enterprises, 80 organic fertilizer plants and breeding farms are the same operating entity, and 263 organic fertilizer plants are third-party agencies that do not rely on breeding farms. We mainly target third party institutional research on the mechanism and cost of integration of manure collection and transportation and organic fertilizer production.

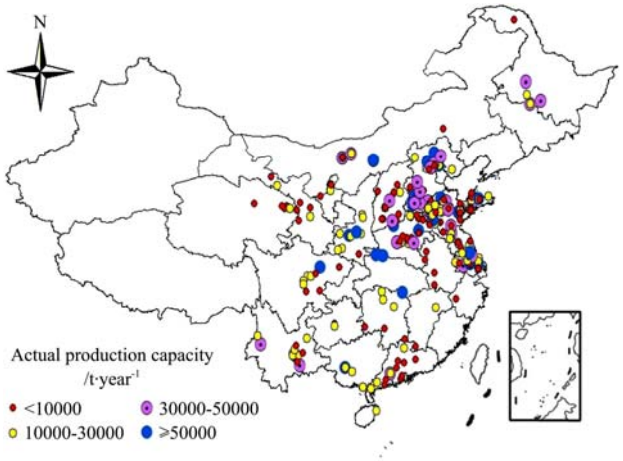

Figure 2 Distribution map of investigated organic fertilizer enterprises nationwide

3 Results and discussion

3.1 Fertilization utilization modes of livestock and poultry manure

There are three main types of livestock and poultry manure utilization was judging from the investigation currently.

One is that organic farms produce organic fertilizer on their own (Figure 3). This model accounted for 24.02% of the total

survey. This method reduces the procurement of manure, the cost of organic fertilizer production, and avoids pollution caused by manure transportation. However, there is a problem of substantial investment in the construction of the farm. For example, the production materials of Beijing Century Dade Environmental Protection Technology Co. Ltd. are all purchased from the breeding farm at the cost of 300 RMB/t for the production of organic fertilizer and biological organic fertilizer. Among the organic fertilizer enterprises surveyed, this model accounted for more than 90%.

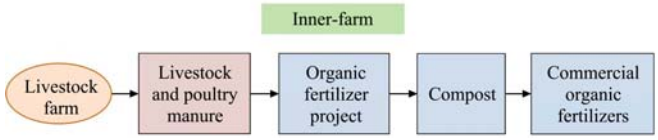

Figure 3 Mode 1: Organic farms produce organic fertilizer on their own

The second is the harmless in-situ treatment of farms and deep third-party processing to produce organic fertilizer (Figure 4). This model accounts for 5.11% of the total survey. The specific method is that the farm composts livestock and poultry manure in situ to form the first product, and the third-party company purchases the original product and further processes it to produce organic fertilizer. The composting process not only did a harmless treatment but also reduced the water content in the feces[17]. This mode can also avoid pollution caused by fecal transportation and minimize transportation costs. For instance, Xincai County China Power Construction Group in Henan Province implemented a fee system for manure treatment. If the manure concentration is 3%-8%, it will be treated for free. When the manure concentration is higher than 8%, the price is 30-40 RMB/t. A certain processing fee also will be charged if the manure concentration is lower than 3%. Similar to this, Anping County in Hebei Province relies on Yufeng Jingan Company to implement centralized treatment of pig manure, and the manure concentration at 3%-8% is for free. If the concentration is higher than 8%, the price is 40-80 RMB/t. When the concentration is less than 3%, a processing fee will be charged for 20 RMB/t.

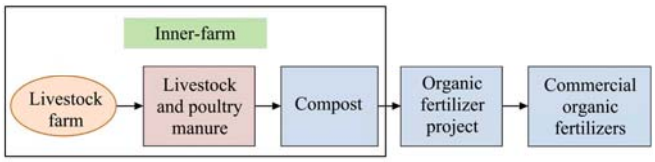

Figure 4 Mode 2: Harmless in-situ treatment of farms and deep third-party processing to produce organic fertilizer

The third one is using third parties to collect animal manure to produce organic fertilizer (Figure 5). This model accounts for 70.87% of the total survey. The specific method is that third-party companies purchase animal manure and focus on the production of organic fertilizer. This model mechanism is flexible, but fecal transportation is easy to cause pollution, which also increases raw material purchase and transportation costs. Shuangcheng Dimeng Biotechnology Co. Ltd. in Heilongjiang Province provided integrated processing equipment for farms and promoted the operation mode of organic fertilizer exchange for primary fertilizer. Every 5 t of primary fertilizer collected in the farm is exchanged for 1 t of commercial organic fertilizer. Waterway Ecological Technology Co., Ltd. in Chongqing Province invested in the establishment of waste treatment facilities in large-scale farms to solve the waste pollution of the farms, and obtained raw materials for free.

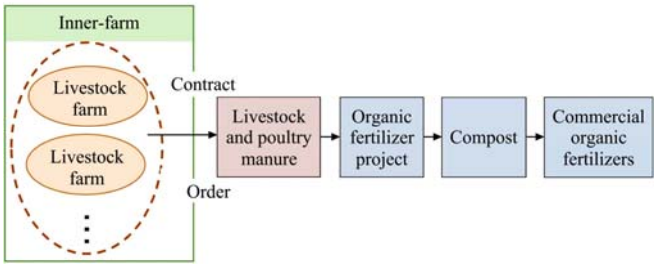

Figure 5 Mode 3: Third parties collect animal manure to produce organic fertilizer

Of the above three collection modes, the first one accounts for the vast majority, and the mechanism is simple and easy to operate. The second collection mode judges whether to collect fees or pay according to the concentration of fecal sewage, which can better reflect the environmental protection contribution of organic fertilizer plants and help increase the enthusiasm of natural fertilizer plants. The third collection mode places integrated processing equipment on the farm. Processing primary fertilizer products before transportation help reduce long-distance transport of livestock and poultry manure and reduce environmental pollution. Besides, the manure charging model and the provision of integrated equipment models are more suitable for small and medium-scale farms. It is recommended to promote the use of manure resources in the entire county to help solve the problem of low and medium-scale manure pollution.

3.2 Analysis of organic fertilizer production cost

Organic fertilizer is one of the leading products of natural fertilizer plants. It is mainly commercial organic fertilizer formed by composting products through further processing and granulation[18]. The survey found that 65.01% of organic fertilizer plants mainly produce commercial organic fertilizer.

Based on the three modes, we analyzed the cost of organic fertilizer production, respectively (Figure 6). Like the first one, the farm produces organic fertilizer on its own, the total price is 500.3 RMB/t, of which the purchase cost of auxiliary materials (mainly including straw, wood chips) is 228.6 RMB/t, accounting for 45.69%; the transportation cost of supplemental materials is 56.8 RMB/t, accounting for 11.36%; the cost of fuel power is 124.6/t, accounting for 24.9%; selling expenses of 90.3 RMB/t, accounting for 18.05%. Other than that, there is the harmless in-situ treatment of farms and deep third-party processing to produce organic fertilizer. The total cost is 645.0 RMB/t, of which the primary product purchase cost is 331.7 RMB/t, accounting for 51.42%; the primary product transportation cost is 46.7 RMB/t, accounting for 7.24%; the fuel power cost is 163.3 RMB/t, accounting for the ratio is 25.32%; the selling expense is 103.3 RMB/t, accounting for 16.02%. Besides, there is another way to use third parties to collect animal manure to produce organic fertilizer. The total cost is 696.9 RMB/t, of which the purchase cost of raw materials and auxiliary materials is 338.3 RMB/t, accounting for 48.54%; the transportation cost of raw materials and supplemental materials is 100.7 RMB/t, accounting for 14.45%; the cost of fuel power is 141.7 RMB/t, considering for it is 20.33%; the selling expense is 116.2 RMB/t, accounting for 16.68%. From the results, it showed that the third mode has the highest, followed by the second mode and the first mode has the lowest production cost.

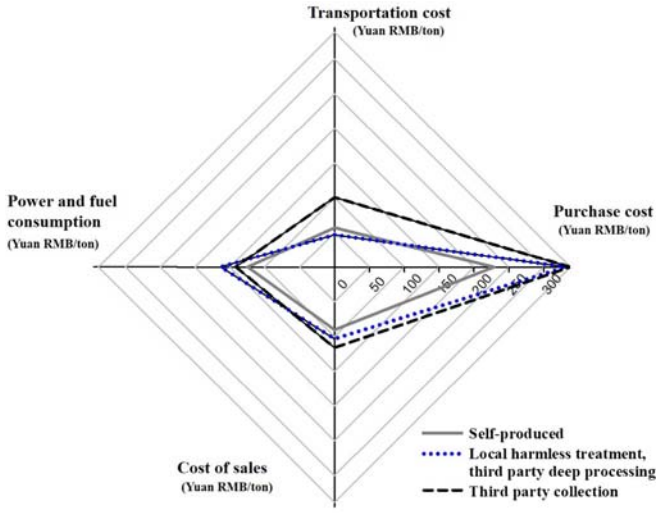

Figure 6 Cost analysis of producing organic fertilizer

3.3 Analysis of compost production cost

Compost is another one of the leading products of organic fertilizer plants. It is mainly a powdered fertilizer product formed by aerobic fermentation of raw materials such as livestock manure[19]. 34.99% of natural fertilizer plants mainly produce compost products.

Similarly, we analyzed the cost of compost production in three modes (Figure 7). The first mode that the farm produces organic fertilizer on its own, the total price is 415.195 RMB/t, of which the purchase cost of auxiliary materials (mainly including straw, wood chips) is 198.6 RMB/t, accounting for 47.83%; the transportation cost of supplemental materials is 46.92 RMB/t, accounting for 11.30%; the cost of fuel power is 80.99/t, accounting for 19.51%; selling expenses of 88.7 RMB/t, accounting for 21.36%. Secondly, there is the harmless in-situ treatment of farms and deep third-party processing to produce organic fertilizer. The total cost is 539.25 RMB/t, of which the primary product purchase cost is 315.6 RMB/t, accounting for 58.53%; the primary product transportation cost is 40.4 RMB/t, accounting for 7.48%; the fuel power cost is 106.2 RMB/t, accounting for the ratio is 19.68%; the selling expense is 97.2 RMB/t, accounting for 18.01%. Another way is using third parties to collect animal manure to produce organic fertilizer. The total cost is 623.0 RMB/t, of which the purchase cost of raw materials and auxiliary materials is 319.9 RMB/t, accounting for 51.35%; the transportation cost of raw materials and supplemental materials is 95.5 RMB/t, accounting for 15.32%; the cost of fuel power is 92.1 RMB/t, considering for it is 14.78%; the selling expense is 115.53 RMB/t, accounting for 18.54%. Like organic production cost, for compost production, the third mode has the highest production cost, followed by the second mode and the third one with the lowest. Compared with the production cost of organic fertilizer, the production cost of compost is relatively small, which is because that the organic fertilizer requires higher physical and chemical characteristics such as livestock manure and the accumulation rate of raw materials of straw, and the oil and electricity consumed during processing is more elevated.

3.4 Application cost analysis between organic fertilizer and chemical fertilizer

In addition to production costs, we also analyzed the application costs when using organic and chemical fertilizers on different crops (corn, vegetables, apples) based on three models (Figure 8). At present, there is little analysis and research on the cost of using organic fertilizers. The fertilizer application data source in the calculation process is from the 'National Agricultural Product Cost-Effective Data Collection 2017'[20]. The application cost mainly refers to the expenditure of farmers in applying organic fertilizer in the field, including organic fertilizer transportation and field application costs.

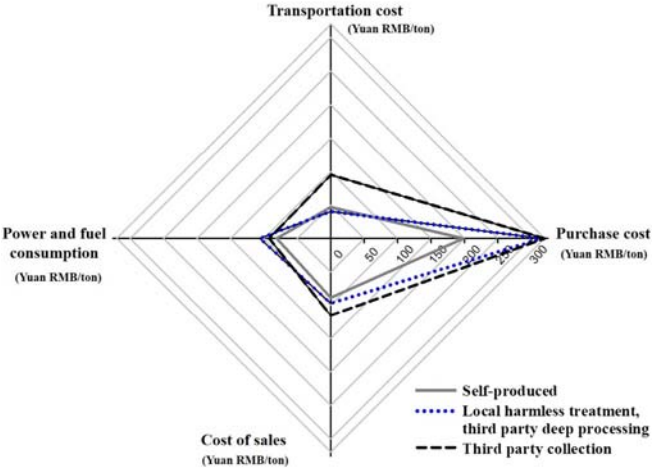

Figure 7 Cost analysis of producing compost fertilizer

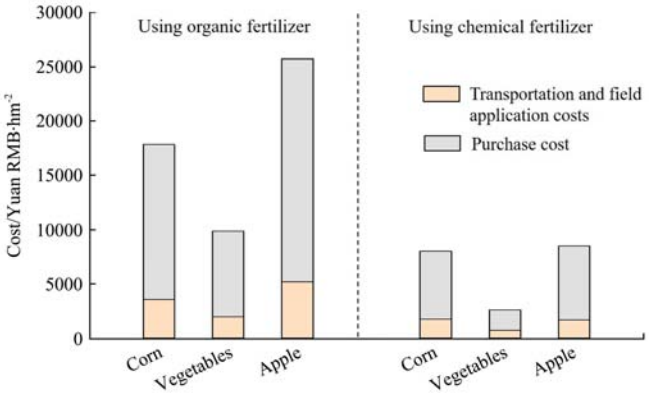

Figure 8 Application cost of organic fertilizer and chemical fertilizer

It can be seen from the results that the average price of organic fertilizer applied to corn, vegetables and apple crops are 9.91×10^3 RMB/hm^2, 1.78×10^4 RMB/hm^2 and 2.56×10^4 RMB/hm^2, respectively. By contrast, the average cost of chemical fertilizers are 8.07×10^3 RMB/hm^2, 2.64×10^3 RMB/hm^2, and 8.54×10^3 RMB/hm^2, respectively. The results showed that the application cost per unit area of organic fertilizer was significantly higher than that of chemical fertilizer, among the application cost, which was consistent with results obtained by Liu et al.[21] Especially the raw material cost occupies a higher proportion of the application cost, whether using organic or chemical fertilizers. At the same time, it can be found that, for all three crops, the costs of transportation and field applications occupy a higher expense of using organic fertilizers when compared with using chemical fertilizers per unit area. The reasons for the high price of organic fertilizers are mainly because the artificial organic fertilizers are currently employed, and there is no dedicated fertilizer application equipment, as the cost of labor continues to increase, the cost of organic fertilizers also increases[22]. Besides, compared with chemical fertilizers, organic fertilizers made from livestock and poultry manure generally have lower nitrogen and phosphorus contents than chemical fertilizers. Still, their bulk density is relatively small, while their quantity and quality are relatively

large[23,24]. It results in higher transportation costs for organic fertilizer fields.

4 Conclusions

4.1 Promoting suitable fertilizer manure utilization models for livestock and poultry

Among the three fertilizer and utilization modes of livestock and poultry manure, the way of self-producing organic fertilizer by the farm, which can treat livestock and poultry manure in situ, can effectively avoid pollution caused by transportation and reduce production costs. It is recommended that large and medium-sized farms be promoted. While, for small-scale farms, the mode of harmless in-situ treatment and deep third-party processing of organic fertilizers can be adopted. It can also avoid pollution caused by transportation, and benefit the scale benefits brought by the concentrated production of organic fertilizers. Promoting according to the actual situation will be suggested.

4.2 Organic fertilizer subsidy policy

To encourage the production and application of organic fertilizer, it is recommended that the central government establish a special subsidy fund for organic fertilizer. From the production side, it is recommended to focus on subsidizing farms that produce organic fertilizer on their own. Each ton of organic fertilizer can be supported at 50% to 60% of the total production cost, which is a subsidy of about 300 RMB/t, which can effectively reduce breeding and the burden of organic fertilizer production in the field. From the demand side, allowances can be subsidized according to the principle that the application costs after subsidies are the same as the cost of chemical fertilizers, which is about 500 RMB/hm^2. To motivate farmers using organic fertilizers, it is recommended to subsidize farmers directly. Green fertilizer subsidies can be piloted in counties where livestock manure resources are utilized.

4.3 Increasing scientific and technological research and development of fertilizers for livestock manure

At present, livestock and poultry manure fertilizer utilization technology innovation and engineering integration in China are still unable to meet the actual needs. Livestock and poultry manure in-situ rapid composting technology and equipment are still lacking. The organic combination of organic fertilizer application machinery and agronomic technology is not close enough. Mechanism and technical research are also obviously insufficient. It is recommended to set up a unique R&D plan for the utilization of livestock manure waste resources, organize relevant scientific research institutions in the industry to strengthen scientific and technological research for the usage of livestock manure.

Acknowledgements

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