Researches on Relationship between Circular Agriculture and Industrial Diversity

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Abstract First, this paper establishes the conceptual model of circular agriculture, conducts systematic analysis on the circular agriculture on the basis of conceptual model, and discusses the characteristics of closeness and openness of circular agriculture and relationship between closeness and openness of circular agriculture. Second, this paper introduces the industrial diversity related to circular agriculture, defines the concept of industry and the concept of industries related to agriculture, and illustrates the related industries that are conducive to circular agriculture and the related industries that are not conducive to circular agriculture. Finally, this paper analyzes the mutual relationship between circular agriculture and industrial diversity as follows: in the system of circular agriculture, the industrial diversity can transform the wastes in upstream industries into resources in downstream industries; the industrial diversity creates possibility for recycling of agricultural byproducts; the industrial diversity is conducive to the diversification of industries related to circular agriculture.

Key words Circular agriculture, Circular material, Industrial diversity, Closeness, Openness, China

As a series of problems increasingly loom large, such as resources depletion, environmental pollution, ecological damage and so on, circular agriculture has become the inevitable choice of sustainable development of agriculture. The reasons determining whether all factors in agriculture can form cycle are manifold, wherein the diversity of relevant industries is an important determinant factor. Generally speaking, the higher degree the diversity of relevant industries, the greater the possibility all the factors form cycle, the more beneficial to realization of circular agriculture. We conduct the preliminary discussion on the circular agriculture and industrial diversity in this paper.

1 Systematic analysis of circular agriculture

1.1 Concept of circular agriculture On the basis of protecting agricultural ecological environment and making full use of high technology, circular agriculture is to adjust and optimize internal structure of agro-ecosystem and industrial structure, improve multi-level recycling of material and energy in agricultural systems, transform agricultural by-products or wastes into resources, and alleviate environmental pollution to the extreme, so that the economic activity of agricultural production is actually incorporated into agro-ecosystems, and the sustainable agricultural development and virtuous ecological circle are realized. By using principles of recycling and regeneration of materials and the technology of multi-level use of materials, circular agriculture is the agricultural production mode of producing less wastes and promoting resource utilization efficiency. Practice has proved that circular agriculture, as a kind of environment-friendly farming mode, has good social benefit, economic benefit and ecological benefits[1].

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Circular agriculture, a complex system combining economic system and ecological system, aims to promote safety, stability and coordination of the agricultural economic activities and natural ecosystem, Circular agriculture not only seeks economic benefit but also maintains the coordination of eco-system. In many cases, the economic function of agriculture is always in conflict with ecological function of agriculture. Therefore, we need to design agricultural industrial system in accordance with the principles of coordination of ecology and economy, so that the agricultural production activities not only obtain reasonable economic benefits, but also can be established based on the capacity of resources and environment, to form what Gao Wangsheng and the like described as "economy-efficient, technology-feasible, ecology-safe, environment-friendly, and society-acceptable" agricultural mode characterized by sustainable development[2]. Therefore, based on this, Gao Shengwang and the like, proposes that developing circular agriculture should adhere to principle of 4R[2] as follows: the first is Reduce, that is, to reduce the materials that enter the process of production and consumption as far as possible, save resources and reduce pollutant emissions; the second is Reuse, that is, to promote the use efficiency of products and services, and reduce the pollution of disposable goods; the third is Recycle, that is, after the goods complete the function of utilization, they can be turned into renewable resources; the fourth is Regulating, that is, through rational design and optimization of the layout, to form circular chain, use the materials and energy that enter the system of production and consumption to the extreme, improve quality and benefit of economic operation, and achieve the strategic objective of coordination of economic development, resources conservation, and environmental protection, in line with sustainable development. The principle of 4R can help us to scientifically establish technology system of circular agriculture, and better develop circular agriculture.

1.2 Conceptual model of circular agriculture The conceptual model of circular agriculture can be shown by Fig. 1.

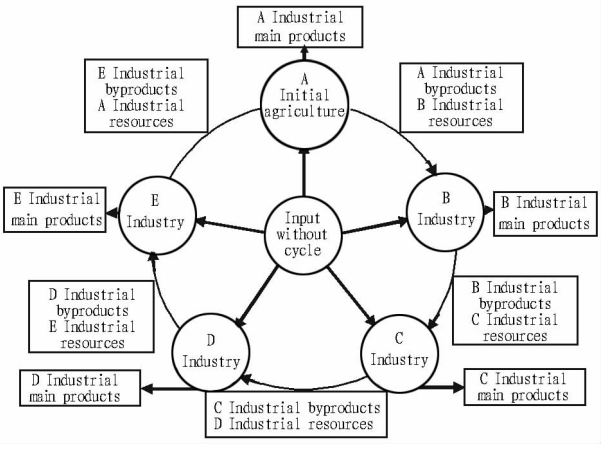

Fig. 1 Schema of conceptual model of circular agriculture

Now we conduct systematic analysis on circular agriculture, after referring to the conceptual model of circular agriculture as follows.

1.2.1 Closeness and completeness of circular agriculture. Circular agriculture, a system with various functions, tries to comprehensively coordinate agricultural production, population, resources, ecological environment and many other factors, and promote these factors to develop in tandem. It aims to establish "close-cycle" production system or "no-wastes" production system of resources utilization. Through the mutual combination of many kinds of industries, it is to make the level of industrial structure deepen and industrial chain extend as far as possible, so as to improve the utilization rate and conversion rate of resources, make all components in system link up in the most optimal way, and form close economic, efficient and environment-friendly industrial process of circular agriculture[3].

We hold that the idea of circular agriculture is to gradually transform the agricultural mode of "resources-main products of industry-discharging of byproducts as wastes" into the mode of "resources-main products of Industry A-byproducts as resources of Industry B-main products of Industry B-byproducts of Industry B as resources of Industry C". The rest may be deduced by analogy. The main products or byproducts at the end of industrial chain, in turn, become the resources of producing main products of Industry A.

As shown in Fig. 1, Industry A is the main industry in circular agriculture; Industry A gains the main products and byproducts of Industry A; byproducts are used as the production resources of Industry B; Industry B yields the main products and byproducts of Industry B; byproducts of Industry B provides means of production for Industry C. By analogy, it does not complete the whole cycle until the products or byproducts of a certain industry become the means of production of Industry A again in the circular chain. When main products of the initial industry, especially the byproducts, are eventually transformed into resources inputs of the initial industry again, it assumes the relative closeness and completeness of cycle. Be that as it may, the missing or severance of any link of production will be responsible for the fracture of whole circular chain, thus the relative closeness and completeness of cycle will be broken.

Thus, the circular agriculture should primarily be a relatively complete and close circular system. The higher the degree of completeness and closeness of circular system, the more it is conducive to the development of circular agriculture.

1.2.2 Openness and incompleteness of circular agriculture. However, agriculture is an open system, bound to have the characteristic of incomplete closeness, which is determined by its structure and function. Therefore, the closeness and completeness of circular agriculture are relative, and inevitably it has openness and incompleteness of cycle.

1.2.2.1 No matter how artful the cycle is designed and implemented, some products will inevitably deviate from cycle. For example, in light of the grain planting industry, as the initial agricultural industry, under the operation of self-sufficient peasant economy mode, after grain, as the main product, is consumed, part of substance, as fertilizer, can enter the cycle of planting industry in the form of resources. Nonetheless, under the operation mode of modern agriculture, the main product of grain is sold to many places via market, and consumed by urban residents. The substance which can be as fertilizer is discharged as wastes, and it cannot enter the cycle of planting industry as resources.

Taking the straw of agricultural crops as another example, if the straw is used as raw material for biogas production, then the straw is still in the whole circular chain, but if part of the straw is used as construction material or raw material for paper production, then part of the straw is separated from whole circular chain.

1.2.2.2 Some factors without cycle must be incorporated into cycle, in order to maintain and promote continuity of cycle. We can not wholly understand the circular agriculture as the agriculture which is not dependent on external-source material inputs. Reasonable input is one important way to increase agricultural output, and promote quality of agricultural products and agricultural productivity. For example, the inputs in the planting industry of grain crops, such as fertilizers, pesticides and so on, are the factors incorporated without the circular chain of circular agriculture. The idea that only by relying upon cycle can we realize the balance of agricultural system, is inconsistent with the actual production.

1.2.2.3 Relationship between closeness and openness of circular agriculture. Circular agriculture either has closeness or openness. The closeness of circular agriculture mainly refers to the characteristic of interlocking and close circular chain in terms of industrial correlation. If any part has problem, the cycle will not form. The openness of circular agriculture means that in the process of cycle, sometimes it needs some external resources to construct cycle, and sometimes some products or outcomes will be also separated from circular chain. Therefore, the closeness and openness of circular agriculture are complementary, both intended to make circular agriculture operate better.

1.3 Circular matter in circular agriculture What on earth cycling in circular agriculture? In circular agriculture, it mainlydi-

rectly or indirectly takes the products in the previous production part as the resources for the next production part to be used again, thus forming the agricultural mode with virtuous cycle. These products are mainly byproducts, and some main products are products after being used. If these products are not used, they will become wastes, while if these products are used properly, they will become important resources, bringing good economic benefits, social benefits and ecological benefits. For example, the modern rabbit garden of Xuping Rabbit Industry Corporation in Xieyuan Town, Dayi Couny, Sichuan Province, establishes 110 cubic meters of marsh gas pool, annually handling the excrement of 150 000 rabbits, which reduces the pollution arising from excrement of rabbits, and daily produces methane provided to 80 people for life use. Biogas residues, as byproducts, can serve as manure for grass and nutrient for fish. Thus it can save 20 000 to 30 000 yuan expense of lighting electricity, coal briquettes, fertilizer and so on in one year[4]. By referring to Fig. 1, we can make the following analysis: rabbit industry is Industry A of Xieyuan Town. The main products of Industry A are rabbits, the byproduct is the excrement of rabbit, and the excrement becomes raw material for Industry B (marsh gas). The marsh gas residues, as byproducts of Industry B, become raw materials for Industry C (grass planting and fish farming). The products of grass planting industry in Industry C become rabbit feed again, thus it comes to Industry A, completing the whole circular process.

2 Industries related to agriculture

2.1 Industries and industries related to agriculture

2.1.1 Definition of industry. Industry is the aggregation of production of material products, including agriculture, industry, commerce, catering, transport and other sectors. The best saying of alternative industry may be "Business Ecosystem". A business ecosystem may involve several industries. As shown in Fig. 1, the circular chain of circular agriculture and food chain in ecological system have similarities. In Fig. 1, Industry A, Industry B, Industry C, Industry D, and Industry E, are the components of whole circular agriculture, that is, each industry is closely linked up with the system of circular agriculture. As long as one part has problem, the whole circular chain will be broken. The operation of the system is closely related with all components within the system or various subsystems.

2.1.2 Industries related to agriculture. Agriculture is important primary industry, and it is the foundation of other industries. There are multifarious industries related with agriculture, including traditional grain farming, livestock breeding, fishery, processing industry of agricultural products and byproducts, planting industry of ornamental flowers and trees, agricultural tourism, mushroom cultivation, dairy cow breeding and so on. Now, some agricultural products are as raw materials for energy production and additives for industrial production. Traditional agriculture and new agriculture-related industries jointly constitute the business ecosystem in agriculture. Each agricultural industry is an important part of the business ecosystem, closely related to the entire agricultural production system. Now, many industries closely related with agriculture continue to emerge. Agriculture is increasingly linked up with industry, tertiary industry as well as the information industry.

2.2 The related industries conducive to circular agriculture Some agriculture-related industries are the industries responsible for the formation of circular chain in circular agriculture. For example, taking methane as a link, the model of ecological circular agriculture is to establish a composite ecological chain, to realize recycling and overall use of agricultural wastes. This model is mainly to transform the excrement of human, livestock and poultry, straw and other agricultural wastes by virtue of fermentation of methane pool, into "three agricultural treasures"-biogas, biogas liquid, biogas residue[5]. For example, fungus grower Wang Yide in Qingjiang Town, Jintang County of Sichuan Province, uses waste straw as raw material for production of edible mushrooms. As for the yielded residues of edible fungus, he adopts four models to process them, one of which is to adopt biological enzyme, transform protein in residues of edible fungus into biological feed, thus the feces arising from breeding livestock enter biogas pool, to be converted into clean energy[4]. In this model of production, the livestock breeding industry, growing industry, biogas pool construction industry and so on, are all the industries conducive to the formation of circular chain of circular agriculture. Thus, the circular chain of circular agriculture can realize less external resources inputs. For instance, we can directly use biogas liquid as fertilizer for plant, which saves the cost of fertilizer and energy. Besides, the biogas can be used for electricity production and combustion, which solves the problem of fuel and electricity for living and production.

2.3 The related industries unfavorable to circular agriculture Some agriculture-related industries are not the industries in circular chain of circular agriculture. The products of these industries cannot be recycled and used, or the products of these industries are out of circular agriculture. The excrement of rabbit can be put into biogas pool to produce methane, while the residues of biogas can become the feed for fish. But once the rabbits are sold, they are out of circular chain. In these production parts, the food processing industry, sales industry and so on, are all the industries out of circular agriculture, thus it is not conducive to the development of circular agriculture.

3 The mutual relationship between circular agriculture and industrial diversity

3.1 The industrial diversity can transform the wastes in upstream industries into resources in downstream industries The circular agriculture is in pursuit of the advanced model of economic production with more economic benefits, less resource consumption, less environmental pollution and more employment. If the byproducts produced by the upstream industries are without the support of downstream industries, they are always regarded as wastes to deal with, just like burning straw and disposing of waste material in a landfill, easily can be seen in rural areas. It is because that the agricultural industry is excessively simple, so that the wastes from the up-

stream industries cannot be used well. But if we raise the level of industrial diversity, the wastes from the upstream industries are likely to become resources for the downstream industries, to be rationally used. Likewise, the higher the degree of industrial diversity, the more choices we have for the wastes, the more beneficial to reuse of wastes. However, the development of market economy requires farmers' production to have exclusiveness. How to solve the contradictions between industrial diversity required by circular agriculture and simplicity of agricultural production required by the market economy ? We can implement cooperation of the surrounding villages, cooperation of counties and towns, and cooperation of cities and villages, so that the wastes are used effectively and the resources are saved to the extreme, further promoting the development of circular agriculture.

3.2 The industrial diversity creates possibility for recycling of agricultural byproducts According to the study, it shows that straw resources of various types of agricultural crops produced in China annually are up to 700 million tons, and the excrement of livestock and poultry generated in China annually is up to 4 billion tons. The amount of chemical fertilizer consumed by agriculture annually accounts for 25 % of that of the world, and agricultural consumption accounts for 30% of the world. If the concept of carbon economy is used for measuring, the current agriculture in China can be said as a kind of " high-carbon farming" [6]. This will do serious harm to the environment and cause the waste of considerable resources, which does not meet the requirements of modern agriculture. From the holistic perspective, the circular agriculture is to construct the material circular industrial system of agriculture and the related industries, which makes the agricultural system intertwine with ecosystem, to form large industrial system. In this way, in traditional agriculture, the byproducts regarded as the wastes can be used, becoming one circular chain of circular agriculture. The higher the level of industrial diversity, the more the types of agricultural byproducts produced by various industries, the higher the utilization rate of byproducts, the more likely it is involved in the whole cycle. Taking Xiedao sightseeing park of circular agriculture in Beijing City as an example, this park avoids the flaw of general agricultural sightseeing parks, takes circular agriculture as idea, adopts the feedback process of " resources-products-renewable resources" in terms of industrial layout, and establishes three-dimensional composite system of close cycle of material, multi-level energy use, and recycling of water resources[7]. Diverse industries create the possibility for the recycling of agricultural byproducts in local areas, thus realizing win-win of economic development in this sightseeing park and environmental protection.

Thus, we can find that the higher the diversity degree of industry operated by farmers, the more conducive to the development of circular agriculture, and *vice versa*. On the one hand, in the process of the development of circular agriculture, the farmers increase the industries they operate, focus on leading industries, and meanwhile take the related industries as support or services. Through the division of labour and cooperation among industries to promote mutual benefit, and bear mutual risk, we can effectively promote the economic benefits of circular agriculture and meanwhile create more jobs. On the other hand, promoting the degree of industrial diversity by farmers can create more types of byproducts. We should selectively add these byproducts to the circular chain, thereby reducing unnecessary extra material and human power inputs. Furthermore, the higher the degree of industrial diversity, the better we dispose of and use the wastes generated after production, so that effectively reducing environmental pollution becomes possible.

3.3 The industrial diversity is conducive to the diversification of industries related to circular agriculture In China, the developmental level of circular agriculture is not particularly high. At current stage, we need to promote the diversification of related industries conducive to circular agriculture, expand the whole circular chain of circular agriculture, and further promote the development of circular agriculture. We should focus on the development of critical industries that make great contribution to agricultural economy, such as planting industry, breeding industry, and so on. In the mean time, we should also develop and tap those industries that play the role of supporting circular agriculture correspondingly, such as methane fermentation industry, bio-feed conversion industry, and so on. Development of these industries plays a great role in promoting the development of whole circular agriculture.

Meanwhile, sometimes we need to weigh the relationship between the related industries which are conducive to circular agriculture and the related industries which are not conducive to circular agriculture. When necessary, in pursuit of greater and better social and economic benefits, we can develop the related industries which are not conducive to circular agriculture, such as tourism, processing industry of agricultural products and byproducts and so on.

Whether we are to develop the industries conducive to circular agriculture or the industries not conducive to circular agriculture, finally, only by the coordinated development of these two types of industries and mutual complementary functions can we obtain high overall benefits and promote the quick development of the agricultural economy.

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cal function, living function and so on, which is the extension and permeation of the primary towards the tertiary industry, conducive to the extension of agriculture towards economy, science and technology, education, environmental protection, tourism, cultural heritage and other fields, better meeting the development requirements of low-carbon economy.

3.3 Ecological integration model Traditional agriculture is a kind of one-way linear structural model of "resources-products-pollutant discharge", with the prominent characteristics "two highs one low" (high consumption of resources, high emission of pollutant, low efficient use of material and energy). In the traditional strategy of agricultural development, the farmers intensively use the natural ecological resources unplanned and uncontrolled. In the mean time, they adopt the technology and workmanship with low use rate, to conduct production and processing, resulting in a large number of "pollutants of no value for use". They discharge a large number of pollutants into the natural environment, and pursue the quantitative growth of economic output at the cost of nature with reverse growth. Through the circular mechanism of "resources-products-reuse", the ecological agriculture is to achieve coordination of economic development and ecological balance. The specific form of ecological integration model includes "combination of planting and fallowing of highland", "small watershed comprehensive management and development", "forest coverage", "field inlaid with forest" and so on. It can clearly be seen that developing circular agriculture, on the basis of elevation and integration of ecological agriculture, is conducive to China's agricultural development. Due to the complex topography of the regions in China and great difference of distribution of agricultural resources, each region can choose to promote the form that is suitable for the regional development, in accordance with the actual situation.

3.4 The developmental model of reusing agricultural byproducts Through processing and disposal, the model is to transform the byproducts in the process of agricultural production into usable resources, so as to make the agricultural byproducts become resources, reduce the pollution and damage of the byproducts on the environment and ecology, and ensure the sustainable development of agriculture[5]. It can be divided into the following two forms.

3.4.1 Use excrement of fowl, straw and other byproducts to promote production technology of edible fungus. It takes the byproducts, such as excrement of fowl, straw and so on, as the material for the production of mushroom. It extends the agricultural ecological industry chain, and realizes the multi-level use and virtuous cycle of "agricultural byproducts-edible fungi-fungus chaff-fertilizer-field crop", which can not only create considerable economic benefits, and provide high-quality edible fungus products, but also improve physical and chemical properties of soil, so as to achieve good economic benefits, social benefits and ecological benefits.

3.4.2 Use the technology of producing methane by agricultural organism. Through processing and disposal, it is to use the straw of agricultural crops generated in the process of agricultural production, so as to make the straw become compost, feed, raw material, and resources, and smooth away the pollution and damage of straw on the environment and ecology, thus it is an important measure of constructing recycling-based agriculture and low-carbon agriculture, and realizing sustainable development.

4 Conclusion

We should vigorously promote the development of circular agriculture, and realize sustainable use of the limited agricultural natural resources, with less resource consumption and less environmental pollution, which is the need of China's new village construction, and the need of realizing high-efficiency sustainable use of agricultural resources and virtuous cycle of agricultural ecological environment, and gradually strengthening the agricultural sustainability. In terms of the development of circular agriculture, China has taken actions with enthusiasm and achieved good results. In the future, China should choose or create different circular agricultural model in different domains, in order to better use agricultural resources, reduce the consumption of agricultural energy inputs, reduce the emission of agricultural greenhouse gas, develop low carbon agriculture, and make great contribution for meeting the international challenges and promoting China's agricultural development.

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