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Analysis of Tail Vegetable Recycling Mode under The Background of Clean Vegetable Listing

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Abstract

In order to solve the difficulty of tail vegetables in China, analyze the current situation of resource utilization of tail vegetables, and consider the supply chain structure composed of single environmental protection enterprises and single vegetable library. Organic fertilizer is required for the production of vegetables in the vegetable library. At the same time, tail vegetables are used as raw materials of organic fertilizer, and commercial organic fertilizer is recycled and produced by environmental protection enterprises. The mathematical models about the sales price of organic fertilizer and the proportion of tail vegetables between environmental protection enterprises and vegetable banks in the vegetable bank environmental protection enterprise cooperative recycling mode and environmental protection enterprise recycling mode are constructed respectively, and the above decision variables and their influencing factors are analyzed. The results show that the resource utilization of tail vegetables can be fully implemented only by reducing the transportation cost of tail vegetables, It provides guidance and research significance for the implementation of the listing of clean vegetables and the recycling of tail vegetables.

Keywords

Resource utilization of tail vegetables, Listing of clean vegetables,Recycling decision.

1. Introduction

China is a large agricultural country. With the rapid development of vegetable industry, there are a large number of defective vegetables and tail vegetables such as leaves, roots, stems and fruits produced during vegetable processing. Existing data show that in 2018, tail vegetables accounted for about 51% of the total vegetable output. The water content of tail vegetables is generally 75% - 95% [1]. Tail vegetables have the characteristics of high water content and easy deterioration, so it is difficult to treat them. Vegetable planting enterprises bury these tail vegetables centrally, and the treatment cost is as high as 140 Yuan per mu [2]. In addition, a large number of tail vegetables are also produced in the process of packaging, transportation, kitchen processing and unsalable, that is, the ratio of vegetable output to waste is approximately 1:1 [3]. In order to reduce the tail vegetable waste and residents' domestic waste generated in the process of vegetable circulation and sales, the work scheme of "clean vegetable listing" has been implemented throughout the country. Clean vegetables are produced in a stable standardized production base. After cleaning, sorting, testing, refrigeration, transportation and other links, they are safe, fresh, nutritious, neat and convenient commercial vegetables with a certain shelf life. According to statistics, 20 tons of waste will be generated every 100 tons of boiled vegetables transported into the city[4]. The "listing of clean vegetables" can effectively reduce kitchen waste and minimize the generation of waste.

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About 30% of vegetables in China are rotted and damaged during transit transportation and storage every year, while the loss rate of fruits and vegetables in developed countries is less than 5%. In order to maximize resource conservation, Japan promulgated laws such as the law on food recycling, the basic law on promoting the establishment of a recycling society and the law on promoting the effective utilization of resources around 2000.Guo Tingjie(2001) studied Japan's food waste recycling law and proposed that China should introduce "comprehensive utilization" and "Regulations on the implementation of solid waste law" as soon as possible to carry out food waste composting instead of chemical fertilizer [5].Tail vegetables contain nitrogen, phosphorus, potassium and other nutritional elements. If they can be recycled, the utilization rate of tail vegetables will be greatly improved. The fertilizer treatment methods of tail vegetables mainly include direct return to the field, anaerobic composting and high-temperature aerobic composting. Zhang jiaguo et al.(2010) proposed that the tail vegetable can be mixed with livestock manure to become organic fertilizer and produce liquid organic fertilizer[6], while Xie Jiping(2019) and others sought an effective method to treat the tail vegetable into organic fertilizer by biotechnology for the residual pesticides, heavy metals and other harmful substances in the tail vegetable[7]. Bian Xiaodong(2021) and others also proposed that the harmless treatment of tail vegetables can turn waste into treasure, and studied the construction of simple fermentation tank and large-scale[8]. They put forward different resource utilization technologies for different kinds of vegetable tail vegetables, so that the tail vegetables can be processed into organic fertilizer and vegetable leaf fertilizer (liquid) for vegetable production, realizing the resource recycling of tail vegetables. On this basis, this paper expects to analyze the recovery mode of tail vegetables and how to formulate the recovery strategy?

This study focuses on the recycling methods and treatment decisions of agricultural waste. In product waste recycling, Pazoki m et al.(2019) found through design that self recycling by manufacturers can improve the recovery rate of goods, increase the number of remanufactured goods and improve environmental quality[9]. Pang Yan and Yan Xiaolan(2010) established a straw recycling logistics system by using straw as fertilizer and feed in combination with the yield and characteristics of straw in Hunan Province[10]. Duan Rui and Cheng Zhiping(2020) took sugarcane processing waste as an example and preliminarily constructed the reverse logistics recovery mode and system of sugarcane industry waste[11]. Wei Fengyu(2014) analyzed the current situation of urban agricultural product waste treatment in Chongqing and put forward the development ideas of urban agricultural product waste logistics in China, so as to reduce production and circulation costs, increase farmers' income and improve the overall benefits of agriculture[12]. Fei Wei(2016) built a mathematical recycling model of waste agricultural products, studied the income of processors and recycling enterprises, and introduced government subsidies to provide countermeasures for the effective recycling, treatment and utilization of waste agricultural products in China[13]. Tail vegetable can produce high-efficiency organic fertilizer for farmland production and realize recycling. This study aims to solve the problem of tail vegetable recycling benefits not involved in the above research. Through theoretical research on the sales price of organic fertilizer and the proportion of tail vegetable under the cooperative treatment mode of vegetable warehouse and environmental protection enterprises and the recycling mode of environmental protection enterprises, this paper constructs the profit function model of vegetable warehouse and environmental protection enterprises, It provides an analytical reference for the income of each participant in the implementation of tail vegetable recycling.

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2. Problem Description and Model Establishment

2.1. Problem Description

Consider a two-level supply chain composed of a single vegetable warehouse and a single environmental protection enterprise. The production of vegetables in the vegetable bank provides daily demand. There is a significant positive correlation between vegetable yield and the input of organic fertilizer nitrogen and potassium[14]. Every D unit of organic fertilizer can produce Q units of vegetables. Therefore, the demand for organic fertilizer is $D = \alpha - \beta p$, and α represents the maximum demand for organic fertilizer, β is the sales price sensitivity coefficient of organic fertilizer. The yield of vegetables is $Q = Q_0 + \mu D$. Where Q_0 represents the minimum production of vegetables without organic fertilizer, μ is the demand sensitivity coefficient of organic fertilizer and meets the condition $Q \gg D$. In order to effectively implement the resource utilization of clean vegetables into the city and tail vegetables, after the vegetables are mature, the vegetable warehouse is responsible for processing the vegetables, and the ratio of clean vegetables to tail vegetables produced in the processing process is $(1 - \lambda)$： λ. And wholesale the clean vegetables to the clean vegetable sales market at the unit sales price of $P_v = a - b(1 - \lambda)Q$. a represents the maximum selling price in the clean vegetable market, and b represents the sensitivity coefficient of clean vegetable supply. Obviously, α,β,Q_0,μ,a and b are fixed coefficients and both are greater than 0. In order to save production costs and meet the needs of environmental protection, the tail vegetables will be transported to environmental protection enterprises with a unit transportation cost of T. after professional treatment, the treatment cost per unit of tail vegetables will be P, which will be processed into commercial organic fertilizers such as dry matter organic fertilizer and vegetable leaf fertilizer (liquid). The sales price per unit of commercial organic fertilizer is p, and the tail vegetables will be recycled, The process of processing and producing organic fertilizer is shown in Figure 1.

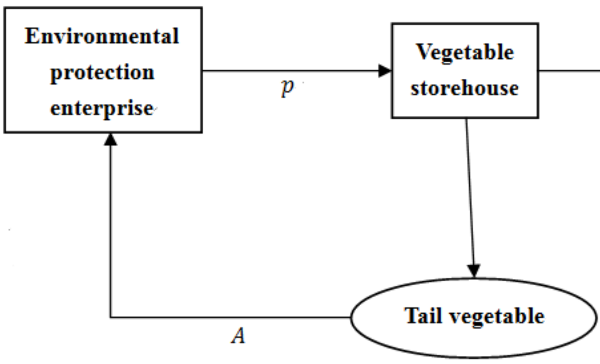

Figure 1:Logistics structure of tail vegetable recycling

In the recycling decisions of vegetable banks and environmental protection enterprises, the decisions of both parties meet the Steinberg game. Among them, environmental protection enterprises are leaders and vegetable banks are followers. It is determined by the comparison of the business entities and scale advantages of both parties. Generally, the production of vegetable banks requires the application of organic fertilizer, while environmental protection enterprises have various choices of raw materials for the production of organic fertilizer, large production scale and leadership advantages. Therefore, in the recovery mode of tail vegetables, the reverse induction method is used to solve the problem. The vegetable bank first maximizes the production of fresh vegetables according to its own interests and determines the ratio of tail vegetables. At the same time, the recovery strategy of tail vegetables is selected. The environmental protection enterprise decides to use raw materials or tail vegetables to produce commercial organic fertilizer and price it according to the decision of the vegetable bank.

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2.2. Model Establishment

2.2.1. Mode 1: cooperative treatment mode between environmental protection enterprises and vegetable banks

Under this mode, the vegetable warehouse needs to complete the processing of vegetables, the clean vegetables flow into the fresh agricultural product market, and the tail vegetables flow into environmental protection enterprises. At this time, the vegetable storehouse has reached a cooperative relationship with the environmental protection enterprise. The vegetable storehouse collects and transports the tail vegetables and pays the transportation expenses of the tail vegetables. The environmental protection enterprise processes the tail vegetables to produce commercial organic fertilizer and promises to return the organic fertilizer it needs. Therefore, the profit of environmental protection enterprises is the sales income of organic fertilizer - tail vegetable treatment cost, and its profit can be expressed as:

$$\pi_m^1 = p(\lambda Q - D) - \lambda QP$$

The vegetable storehouse obtains the sales revenue of clean vegetables and is responsible for the transportation of tail vegetables. Under this recovery mode, the profit of the vegetable storehouse is the sales revenue of clean vegetables - transportation cost of tail vegetables. The profit model is as follows:

$$\pi_v^1 = P_v(1-\lambda)Q - \lambda QT$$

Through the first-order optimal conditions, it can be solved that the optimal sales price of organic fertilizer and the optimal ratio of tail vegetables are:

$$p_1^* = \frac{\alpha}{2\beta} - \frac{Q_0+\mu\beta P}{2\beta(1-\mu)} + \frac{a+T}{4b\beta(1-\mu)}$$

$$\lambda_1^* = 1 - \frac{2(1-\mu)(a+T)}{2b\mu(\mu\beta P-\alpha(1-\mu)-Q_0)-\mu(a+T)+4b(Q_0+\mu\alpha)}$$

By substituting the optimal sales price of organic fertilizer and the optimal ratio of tail vegetables into the profit function of environmental protection enterprises and vegetable banks, the maximum profits of environmental protection enterprises and vegetable banks can be obtained as follows:

$$\pi_m^* = \frac{(1-8b\beta(1-\mu))(a+T-2b(Q_0+\mu\beta P-(1-\mu)\alpha))^2}{16b^2\beta(1-\mu)} - P\left(Q_0+\mu\alpha-\frac{a+T}{2b}\right)$$

$$\pi_v^* = \frac{a+T}{4b}\left(\frac{\mu T}{(1-\mu)}+a-T\right) + \frac{\mu\alpha T}{2} - \frac{\mu T(Q_0+\mu\beta P)}{2(1-\mu)} - T\left(Q_0+\mu\alpha+\frac{a+T}{2b}\right)$$

2.2.2. Mode 2: recycling mode of environmental protection enterprises

Under this mode, the vegetable warehouse processes vegetables and flows the clean vegetables into the fresh agricultural products market to obtain income. The tail vegetables are recycled and transported by environmental protection enterprises, and the unit recycling price of tail vegetables is A. Environmental protection enterprises use professional technology and large-scale facilities and equipment to make resource use of tail vegetables to produce commercial organic fertilizer. At the same time, the vegetable warehouse purchases organic fertilizer from environmental protection enterprises for production needs. At this time, the environmental protection enterprise recovers the tail vegetables, gives the tail vegetables recovery price to the vegetable warehouse, and bears the transportation expenses and tail vegetables treatment expenses. Therefore, the profit of the environmental protection enterprise is organic fertilizer sales income - tail vegetables recovery price - tail vegetables transportation cost - tail vegetables treatment cost, and its profit can be expressed as:

$$\pi_m^2 = (p - A - T - P)\lambda Q$$

Under this recycling mode, the profit of the vegetable warehouse is net vegetable sales revenue + tail vegetable sales revenue - organic fertilizer purchase cost. The profit model is as follows:

$$\pi_v^2 = P_v(1-\lambda)Q + A\lambda Q - pD$$

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The optimal sales price of organic fertilizer and the optimal ratio of tail vegetables can be obtained:

$$p_2^* = \frac{Q_0+\mu\alpha}{2\mu\beta} + \frac{A-a}{4b\mu\beta} + \frac{A+T+P}{2}$$

$$\lambda_2^* = 1 + \frac{2(A-a)}{a-A+2b(Q_0+\mu\alpha-\mu\beta(T+P+A))}$$

By substituting the optimal sales price of organic fertilizer and the optimal ratio of tail vegetables into the profit function of environmental protection enterprises and vegetable banks, the maximum profits of environmental protection enterprises and vegetable banks can be obtained as follows:

$$\pi_m^{**} = \left(\frac{2b(Q_0+\mu\alpha)+A-a}{4b\mu\beta} - \frac{A+T+P}{2}\right)\left(\frac{Q_0+\mu\alpha}{2} + \frac{A-a}{4b} - \frac{\mu\beta(A+T+P)}{2}\right)$$

$$\pi_v^{**} = \frac{a(a-A)}{4b} - \frac{(\mu\beta A+\alpha)(A+P+T)-(Q_0+\mu\alpha)A}{2} - \frac{\alpha(2b(Q_0+\mu\alpha)+A-a)}{4b\mu\beta} + \beta\left(\frac{2b(Q_0+\mu\alpha)+A-a}{4b\mu\beta} + \frac{A+T+P}{2}\right)^2$$

3. Analysis of influencing factors

3.1. Factors affecting the price of organic fertilizer

According to the optimal sales price of organic fertilizer in mode 1, the partial derivative of each parameter can be obtained:

$\frac{\partial p_1^*}{\partial a} = \frac{1}{4b\beta(1-\mu)} > 0$, $\frac{\partial p_1^*}{\partial b} = -\frac{a+T}{4b^2\beta(1-\mu)} < 0$, $\frac{\partial p_1^*}{\partial \alpha} = \frac{1}{2\beta} > 0$, $\frac{\partial p_1^*}{\partial \beta} = \frac{Q_0+\mu\beta P}{2\beta^2(1-\mu)} - \frac{a+T}{4b\beta^2(1-\mu)} - \frac{\alpha}{2\beta^2} < 0$, $\frac{\partial p_1^*}{\partial Q_0} = -\frac{1}{2\beta(1-\mu)} < 0$, $\frac{\partial p_1^*}{\partial P} = -\frac{\mu}{2(1-\mu)} < 0$, $\frac{\partial p_1^*}{\partial T} = \frac{1}{4b\beta(1-\mu)} > 0$

According to the optimal sales price of organic fertilizer in mode 2, the partial derivative of each parameter can be obtained:

$\frac{\partial p_2^*}{\partial a} = -\frac{1}{4b\mu\beta} < 0$, $\frac{\partial p_2^*}{\partial b} = \frac{a-A}{4b^2\mu\beta} > 0$, $\frac{\partial p_2^*}{\partial \alpha} = \frac{1}{2\beta} > 0$, $\frac{\partial p_2^*}{\partial \beta} = \frac{a-A}{4b\mu\beta^2} - \frac{Q_0+\mu\alpha}{2\mu\beta^2} < 0$, $\frac{\partial p_2^*}{\partial Q_0} = \frac{1}{2\mu\beta} > 0$, $\frac{\partial p_2^*}{\partial A} = \frac{1}{4b\mu\beta} + \frac{1}{2} > 0$, $\frac{\partial p_2^*}{\partial P} = \frac{1}{2} > 0$, $\frac{\partial p_2^*}{\partial T} = \frac{1}{2} > 0$

According to the partial derivative, no matter which model, when other factors remain unchanged, the price of organic fertilizer will increase with the increase of the maximum demand of organic fertilizer and the transportation cost of tail vegetables. At the same time, it will also decrease with the increase of the price sensitivity coefficient of organic fertilizer. The income of environmental protection enterprises comes from the sales of organic fertilizer. In mode 2, when environmental protection enterprises need to purchase tail vegetables as raw materials to make organic fertilizer, the recovery price of tail vegetables will increase, and the sales price of organic fertilizer will gradually increase. The difference is that in mode 1, the price of organic fertilizer increases with the increase of the maximum sales price in the clean vegetable market, and decreases with the increase of the supply sensitivity coefficient of clean vegetables, the minimum production of vegetables and the treatment cost of tail vegetables, while the price of organic fertilizer in mode 2 is just the opposite.

3.2. Factors affecting the proportion of tail vegetables

The partial derivative of each parameter in the tail dish proportion of mode 1 can be obtained:

$$\frac{\partial \lambda_1^*}{\partial a} = -\frac{4b(1-\mu)(\mu^2\beta P+\mu\alpha(1+\mu)+(2-\mu)Q_0)}{\left(2b\mu(\mu\beta P-\alpha(1-\mu)-Q_0)-\mu(a+T)+4b(Q_0+\mu\alpha)\right)^2} < 0,$$

$$\frac{\partial \lambda_1^*}{\partial b} = \frac{2(1-\mu)(a+T)(2\mu^2(\beta P+\alpha)+2Q_0(2-\mu)+2\mu\alpha)}{\left(2b\mu(\mu\beta P-\alpha(1-\mu)-Q_0)-\mu(a+T)+4b(Q_0+\mu\alpha)\right)^2} > 0,$$

$$\frac{\partial_{\lambda_1^*}}{\partial_\alpha}=\frac{4b\mu(1-\mu)(a+T)(3-\mu)}{\left(2b\mu(\mu\beta P-\alpha(1-\mu)-Q_0)-\mu(a+T)+4b(Q_0+\mu\alpha)\right)^2}>0,$$
$$\frac{\partial_{\lambda_1^*}}{\partial_\beta}=\frac{4b\mu^2P(1-\mu)(a+T)}{\left(2b\mu(\mu\beta P-\alpha(1-\mu)-Q_0)-\mu(a+T)+4b(Q_0+\mu\alpha)\right)^2}>0,$$
$$\frac{\partial_{\lambda_1^*}}{\partial_{Q_0}}=\frac{4b(1-\mu)(a+T)(2-\mu)}{\left(2b\mu(\mu\beta P-\alpha(1-\mu)-Q_0)-\mu(a+T)+4b(Q_0+\mu\alpha)\right)^2}>0,$$
$$\frac{\partial_{\lambda_1^*}}{\partial_\mu}=\frac{2(a+T)\left(2b\mu(2-\mu)(\alpha+\beta P)+2b(\alpha+Q_0)-(a+T)\right)}{\left(2b\mu(\mu\beta P-\alpha(1-\mu)-Q_0)-\mu(a+T)+4b(Q_0+\mu\alpha)\right)^2}>0,$$
$$\frac{\partial_{\lambda_1^*}}{\partial_P}=\frac{4b\mu^2\beta(1-\mu)(a+T)}{\left(2b\mu(\mu\beta P-\alpha(1-\mu)-Q_0)-\mu(a+T)+4b(Q_0+\mu\alpha)\right)^2}>0,$$
$$\frac{\partial_{\lambda_1^*}}{\partial_T}=-\frac{4b(1-\mu)\left(\mu^2\beta P+\mu\alpha(1+\mu)+(2-\mu)Q_0\right)}{\left(2b\mu(\mu\beta P-\alpha(1-\mu)-Q_0)-\mu(a+T)+4b(Q_0+\mu\alpha)\right)^2}<0,$$

The partial derivative of each parameter in the tail dish proportion of mode 2 can be obtained:

$$\frac{\partial_{\lambda_2^*}}{\partial_a}=-\frac{4b(Q_0+\mu\alpha-\mu\beta(T+P+A))}{\left(a-A+2b(Q_0+\mu\alpha-\mu\beta(T+P+A))\right)^2}<0,\frac{\partial_{\lambda_2^*}}{\partial_b}=\frac{-4(A-a)(Q_0+\mu\alpha-\mu\beta(T+P+A))}{\left(a-A+2b(Q_0+\mu\alpha-\mu\beta(T+P+A))\right)^2}>0,$$
$$\frac{\partial_{\lambda_2^*}}{\partial_\alpha}=\frac{-4\mu b(A-a)}{\left(a-A+2b(Q_0+\mu\alpha-\mu\beta(T+P+A))\right)^2}>0,\frac{\partial_{\lambda_2^*}}{\partial_\beta}=\frac{4\mu b(A-a)(T+P+A)}{\left(a-A+2b(Q_0+\mu\alpha-\mu\beta(T+P+A))\right)^2}<0,$$
$$\frac{\partial_{\lambda_2^*}}{\partial_{Q_0}}=\frac{-4b(A-a)}{\left(a-A+2b(Q_0+\mu\alpha-\mu\beta(T+P+A))\right)^2}>0,\frac{\partial_{\lambda_2^*}}{\partial_\mu}=\frac{-4b(A-a)(\alpha-\beta(T+P+A))}{\left(a-A+2b(Q_0+\mu\alpha-\mu\beta(T+P+A))\right)^2}<0,$$
$$\frac{\partial_{\lambda_2^*}}{\partial_A}=\frac{4b(Q_0+\mu\alpha)-4b\mu\beta(a+T+P)}{\left(a-A+2b(Q_0+\mu\alpha-\mu\beta(T+P+A))\right)^2}>0,\frac{\partial_{\lambda_2^*}}{\partial_P}=\frac{4b\mu\beta(A-a)}{\left(a-A+2b(Q_0+\mu\alpha-\mu\beta(T+P+A))\right)^2}<0,$$
$$\frac{\partial_{\lambda_2^*}}{\partial_T}=\frac{4b\mu\beta(A-a)}{\left(a-A+2b(Q_0+\mu\alpha-\mu\beta(T+P+A))\right)^2}<0,$$

It can be seen that no matter which model, when other factors remain unchanged, the proportion of tail vegetables will increase with the increase of the supply sensitivity coefficient of clean vegetables, the maximum demand for organic fertilizer and the minimum production of vegetables, and also decrease with the increase of the maximum sales price of clean vegetables and the transportation cost price of tail vegetables. Similarly, when environmental protection enterprises need to purchase tail vegetables as raw materials to make organic fertilizer, the recovery price of tail vegetables will increase, and the vegetable library will choose to increase the proportion of tail vegetables. The difference is that in mode 1, the proportion of tail vegetables increases with the increase of the price sensitivity coefficient of organic fertilizer and the demand sensitivity coefficient of organic fertilizer, and decreases with the increase of the treatment cost of tail vegetables. In mode 2, the proportion of tail vegetables is opposite.

4. Conclusion

This paper studies the treatment of tail vegetables in the agricultural product market, uses the game theory analysis method to study the Countermeasures for the recovery and treatment of tail vegetables by vegetable storehouses and environmental protection enterprises, and analyzes the results. The results show that: (1) in order to make tail vegetables resource as much as possible, only the transportation cost of tail vegetables and the sales price of clean vegetables can be reduced; (2) At present, the amount of chemical fertilizer applied in the production of agricultural products in China is much higher than that of organic fertilizer. Only by reducing the transportation cost of tail vegetables and the production cost of organic fertilizer can we vigorously promote the application of organic fertilizer.

The above results will help environmental protection enterprises and vegetable depots make scientific decisions in recycling, and also provide a certain theoretical reference for promoting

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the resource utilization of tail vegetables. In addition, it still needs extensive attention from all sectors of society, effective publicity of tail vegetable recycling and government regulations, opinions and policy support, so as to stimulate the recycling of tail vegetables and form a good circular development model.

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