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Study on the Technology of Deep Processing and Comprehensive Utilization of Vegetables

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Abstract: With the development of modern agriculture and the enhancement of consumers' health awareness, deep processing and comprehensive utilisation technology for vegetables has become an important way to enhance the added value of vegetables. This technology promotes the upgrading of the agricultural industry and meets the diversified needs of the market. This study compares a variety of deep-processing technology tools to maximise the comprehensive use of vegetables. The final study showed that the initial utilisation rate of each category of vegetables was 93.78%. Further comprehensive utilisation has reached a full utilisation rate of 99.51%. It proves that the comprehensive utilisation scheme in this article is an effective way to improve the comprehensive efficiency of the vegetable industry and a way to sustainable development.

1. Introduction

Vegetable deep processing and comprehensive utilisation technology is increasingly receiving widespread attention, with the rapid development of modern agriculture, consumer demand for healthy food continues to grow. Traditional vegetable processing methods are often limited to simple primary processing processing in limiting the added value of vegetables, market competitiveness, which also causes a waste of resources and pressure on the environment. Therefore, in improving the comprehensive benefits of the vegetable industry and promoting the sustainable development of agriculture, it is of great significance to explore the deep processing and comprehensive utilisation technology of vegetables. Vegetable deep processing and comprehensive utilisation technology covers a number of links from raw material selection, processing technology, to product development, marketing and other aspects. The innovation and application of these technologies can not only enrich the variety and quality of vegetable products to meet the diversified needs of the market, but also improve the efficiency of resource utilisation and reduce the pollution of the environment. Meanwhile, through deep processing, the added value of vegetables can be significantly increased, providing strong support for the sustainable development of the vegetable industry. In short, deep processing and comprehensive utilization technology of vegetables is one of the important directions for the development of modern agriculture. It can not only improve the added value and competitiveness of vegetables, but also meet the needs of consumers for diversified and high-quality food. With the continuous development and innovation of technology, it is believed that vegetable deep processing and comprehensive utilization technology can play a more important role in the future. At the same time, China's processing technology is becoming increasingly mature. Usually, according to different processing techniques and techniques, vegetable processed products can be divided into categories such as fresh vegetables, pickled vegetables, dehydrated vegetables, frozen vegetables, vegetable juice, canned vegetables, etc. In the process of vegetable processing, low-temperature freeze-drying technology, microwave technology, biotechnology, food irradiation processing technology, food ultra-high pressure processing technology, bacterial detection technology, microcapsule technology, membrane separation technology, low-temperature continuous sterilization technology, continuous de encapsulation technology, etc. are commonly used technologies. Microwave drying and far-infrared drying technologies have been widely applied in some enterprises. However, with people's continuous pursuit of food nutrition and health, China's deep processing technologies such as freeze-drying technology, rapid freezing and preservation technology, oxygen-containing carotenoid extraction, separation and purification technology, and high-temperature instantaneous killing technology are also constantly being developed and promoted.

This article can explore the deep processing and comprehensive utilization technology of vegetables. Firstly, it can introduce the current situation and challenges of the vegetable processing industry, and then analyze in detail the principles, characteristics, and application effects of various vegetable deep processing technologies. Next, the study can explore the implementation methods and effectiveness evaluation methods of vegetable comprehensive utilization technology. Finally, this study can combine specific cases to analyze the practical application and market prospects of vegetable deep processing and comprehensive utilization technology, hoping to provide theoretical support and practical guidance for the transformation and upgrading of the vegetable processing industry, and promote the sustainable development of the vegetable industry. At the same time, the research also hopes to attract more scholars and entrepreneurs to pay attention to and study the deep processing and comprehensive utilization technology of vegetables, and jointly promote the prosperity and development of the vegetable industry. The organizational structure of the article is as follows: Firstly, relevant research on vegetable deep processing can be introduced, and then the principles, characteristics, and application effects of various vegetable deep processing technologies can be analyzed. Then, it can explore the implementation methods of vegetable comprehensive utilization technology, and finally summarize the research results, propose prospects and suggestions.

2. Related Works

In the field of vegetable processing and comprehensive utilization, there has been research in the academic community for a long time. Ganesh K S et al. focused on the traditional and emerging opportunities for value-added products generated from fruit and vegetable waste. The reuse technology of vegetable waste includes crushing, converting waste into energy, enzyme degradation, and adsorption, in order to extract raw materials from vegetable waste and produce nutritional supplements, packaging, seasoning agents, and nanoparticles. This study aims to evaluate the most economical and effective path for fruit and vegetable value-added technology [1]. Liu X et al. comprehensively explore the challenges, future trends, and solutions of post harvest and processing vegetables to address vegetable losses and waste, and promote vegetable consumption and sustainable development [2]. Arias A et al. introduced an example of green technology for extracting antioxidants from waste fractions [3]. In terms of technology integration in food sustainable utilization systems, Yadav V S et al. analyzed the application of the reviewed technology in food sustainable utilization systems across five research dimensions. The integration of reviewed technologies can provide low-cost solutions and enhance the sustainability of food sustainable utilization systems [4]. Meanwhile, Raffo A et al. comprehensively explored the impact of fresh cut vegetable processing on food safety and the environment, discussed the advantages and disadvantages of mainstream disinfectants, as well as alternative methods for cleaning disinfectants that can be widely applied in commerce [5]. Kumar A et al. believe that sustainable food supply chain is a research field with global significance. An increasing number of research articles in sustainable food supply chains have proven this [6]. In terms of industrial applications, Hassoun A et al. provided an overview of green and Industry 4.0 technologies from the perspective of food. He can identify and explain the connection between green food technologies (such as green preservation, processing, extraction, and analysis) and Industry 4.0 drivers (such as artificial intelligence, big data, intelligent sensors, robots, blockchain, and the Internet of Things) with sustainable development goals [7]. Paini J et al. focused on the current status of value-added routes for selected agricultural food processing waste and by-products in the concept of integrated biorefinery. Firstly, he described the most advanced extraction techniques for increasing the value of food waste, with a focus on apples, tomatoes, grapes, and defatted olive oil pomace as representative matrices [8]. Meanwhile, Aderibigbe O R et al. aim to discuss the current understanding of the intrinsic potential of grain amaranth and its current applications in the food industry, and propose action and partnership frameworks needed to expand and improve the amaranth value chain [9].

Although there have been numerous studies focusing on the value-added utilization of fruit and vegetable waste and sustainable development strategies in the food industry, there are still some shortcomings in existing research. For example, the economic and feasibility assessment of certain emerging technologies is not comprehensive enough. The study aims to further explore innovative technological pathways for converting fruit and vegetable wastes into value-added products, and to address these shortcomings by thoroughly investigating the application and integration of these technologies in a sustainable food utilisation system. Through comprehensive analyses and empirical studies, this article promotes the innovation and development of related technologies to provide new ideas and solutions for the sustainable development of the food industry.

3. Methods

3.1 Vegetable Deep Processing Technology

Vegetable deep processing technology is an important means to deeply develop and utilise common vegetables. Through a series of advanced processing methods, it not only greatly improves the economic and nutritional value of vegetables, but also greatly enriches the diversity of the food market [10]. Such processing methods not only make effective use of agricultural resources and reduce waste, but are also important for promoting sustainable agricultural development, ensuring food security and improving consumer health. Modern vegetable processing techniques are diverse and include several stages ranging from simple washing and cutting to complex fermentation and extraction.

Firstly, vegetables need to undergo strict cleaning and disinfection before processing to remove surface dirt and microorganisms, ensuring the hygiene and safety of the product. Subsequently, vegetables can be cut into different shapes and sizes according to different processing requirements for subsequent processing. In the deep processing process, vegetables can be processed into various products, such as vegetable powder, vegetable juice, vegetable crisps, dehydrated vegetables, etc.

[11]. This article provides an in-depth understanding of five common vegetable deep processing techniques, which can be listed below:

① Curing technology: traditional pickling technology includes pickles, pickled Chinese cabbage, etc., which can extend the shelf life of vegetables and increase the flavor through salt, seasoning, etc. [12]. Modern pickling technology places more emphasis on quality control and standardized production, using automated production lines to ensure product consistency and safety. According to different pickling principles, the pickling materials and techniques used, pickling techniques can be subdivided into various types. Table 1 below shows some common classifications of pickling techniques.

Table 1: Classification of pickling techniques

Classification	Kind	Operation
Marinade	Salt pickling	Wipe the raw materials with table salt or soak them in salt water
	Sauce pickling	Soak the raw materials in soy sauce, yellow sauce, etc
	Sugar pickling	Utilizing the high osmotic pressure of sugar for dehydration
	Wine pickling	Wine lees or alcoholic beverages are the main pickles
Technique	Internal pickling method	Inject the marinade directly into the interior of the ingredients through a syringe
	External pickling method	Apply marinade to the surface of ingredients or soak to allow marinade to penetrate into the interior of the ingredients
Pickling method	Dry pickling method	Spread table salt or mixed salt directly on the surface of food ingredients
	Wet pickling method	Immerse food ingredients in containers containing a certain concentration of salt solution
	Mixed pickling method	Combined dry and wet curing methods
Pickling time	Pickled and cured salted goods	After prolonged pickling and air drying
	Rapid production	Can be completed in a short time, such as "Pickling" and "Raw pickling"

② Dehydration technology: Dehydrated vegetables remove moisture from vegetables and produce dry products for easy storage and transportation. Dehydration technology is an important process widely used in food, chemical, pharmaceutical and other fields to remove moisture from substances, in order to achieve storage, transportation, and use purposes. In the food industry, dehydration technology is particularly important because it can effectively extend the shelf life of food and reduce transportation costs [13]. The detailed classification of dehydration technology mainly includes thermal dehydration, vacuum dehydration, freeze dehydration, mechanical dehydration, electrical dehydration, chemical dehydration, and gas-phase dehydration. In the food industry, commonly used dehydration technologies include thermal dehydration, vacuum dehydration, and mechanical dehydration. These technologies each have their own advantages and disadvantages, and are suitable for different substances and process requirements.

③ Freezing technology: Frozen vegetables are quickly frozen at low temperatures and then stored in a frozen state. This technology can maintain the original color, taste, and nutritional value of vegetables, but requires storage and transportation under cold chain conditions. When freezing vegetables, in order to avoid damaging their nutrition and facilitate storage and transportation, the basic processing flow is to perform primary cleaning, sorting, high-temperature sterilization of the harvested vegetables, then drain, bag, seal, freeze and store them. The key steps are high-temperature sterilization and rapid freezing. High temperature sterilization involves soaking vegetables in hot water at 85-95 ℃ for 1.5-3.0 minutes to inactivate polyphenol oxidase, peroxidase, and ascorbate enzyme in vegetable tissues, while achieving bacterial elimination and reducing vitamin loss. Quick freezing refers to reducing the temperature to a certain level at a certain speed, and different types of vegetables can choose to use different freezing temperatures based on their tissue structure. Common freezing techniques include vacuum freezing, ultrasonic freezing, high-pressure freezing, ice nucleation active bacterial freezing, and biological freezing protein technology.

④ Canning technology: Canned vegetables are processed by washing, cutting, and scalding vegetables, then placed in sealed cans and subjected to high-temperature sterilization treatment to achieve long-term preservation [14]. Canned storage technology is suitable for various vegetable varieties, but the processing cost is relatively high. The processing process of canned vegetables generally involves raw material grading, peeling, etc., and the amount of vegetable waste generated during the process exceeds 30%. Afterwards, softening treatment is carried out according to the types of vegetables, and enzymatic hydrolysis treatment is carried out on the fruit pulp.

⑤ Refrigeration and preservation technology: The main mechanism of vegetable refrigeration and preservation is to adjust the temperature to the optimal state and reduce the respiration of fresh vegetables. The commonly used refrigeration and preservation methods include differential pressure ventilation refrigeration, CA controlled atmosphere storage, and MA modified atmosphere storage [15]. When refrigerated, vegetables that can be washed and harvested are graded according to length, cut into equal sizes, weighed, bundled, boxed, and refrigerated. The differential pressure ventilation refrigeration method is to divide two small cold storage rooms in a large cold storage room, and form a pressure difference between the cold storage rooms through refrigeration machines, blowers, etc., to maintain cold air around the vegetables. CA refrigeration method is to regulate the content of CO^2 and O^2 in the storage environment to slow down the respiration of fresh-keeping materials, slow down the loss of nutrients and other substances, delay metabolism, and delay aging and spoilage. The MA controlled atmosphere refrigeration method stores fresh-keeping materials in specific packaging bags to extend their storage period. The selection of packaging bags should be based on the characteristics of the fresh-keeping materials.

3.2 Comprehensive Utilization Technology of Vegetables

The comprehensive utilization technology of vegetables plays a crucial role in agricultural production. It is a key link in realising a circular economy in agriculture, which is not only conducive to promoting the improvement of resource utilisation efficiency in the vegetable industry to reduce waste. Originally neglected waste and by-products can also be turned into valuable resources through the application of scientific technology in the process of vegetable cultivation, processing and waste treatment. Vegetable leaves, roots and other by-products produced in the process of vegetable processing are often regarded as waste materials that are not used. However, these by-products can be revitalised through the comprehensive use of vegetable technology. Using fermentation technology, these by-products can be converted into nutritious organic fertilisers that provide sufficient soil nutrients and improve soil fertility and productivity. At the same time, these by-products can also be processed into animal feed so that the recycling of resources for the livestock industry to provide high-quality feed resources.

At the same time, the wastewater, waste residue and other waste generated during vegetable processing, if discharged directly into the environment without treatment, can cause serious pollution to water bodies, soil, and air. The comprehensive utilization technology of vegetables converts these wastes into valuable resources through biodegradation, resource utilization, and other means. For example, wastewater can be treated with biological technology to remove harmful substances and convert them into clean irrigation or industrial water; Waste residue can be utilized through resource utilization technology to extract useful components and produce bioactive substances or other high value-added products. By extracting pigments, pectin, dietary fiber, seed oil, organic acids and other components from vegetables, more new foods, health products, and cosmetics can be developed. These products not only enrich the market supply and improve the quality of life for consumers, but also bring higher added value and economic benefits to the vegetable industry. For example, dietary fiber and seed oil extracted from vegetables can be used as ingredients in healthy foods to meet people's pursuit of a healthy lifestyle. The pigments and organic acids extracted from vegetables can be used in the manufacturing of cosmetics, providing female consumers with more natural and safe skincare options.

The application of soilless cultivation technology and integrated water and fertilizer technology has significantly improved the yield and quality of vegetables. At the same time, the application of advanced processing technology and equipment has made the vegetable processing process more efficient and environmentally friendly, and the added value and competitiveness of products have also been improved. This coordinated development model not only promotes the sustainable development of the vegetable industry, but also brings more economic benefits and employment opportunities to farmers.

3.3 Comprehensive Processing and Utilization Mode of Vegetables

A new comprehensive vegetable processing and utilization model has been developed based on existing vegetable deep processing technologies, aiming to maximize the utilization of vegetable resources, reduce waste, and enhance the added value of the vegetable industry. The specific process of this mode is shown in Figure 1.

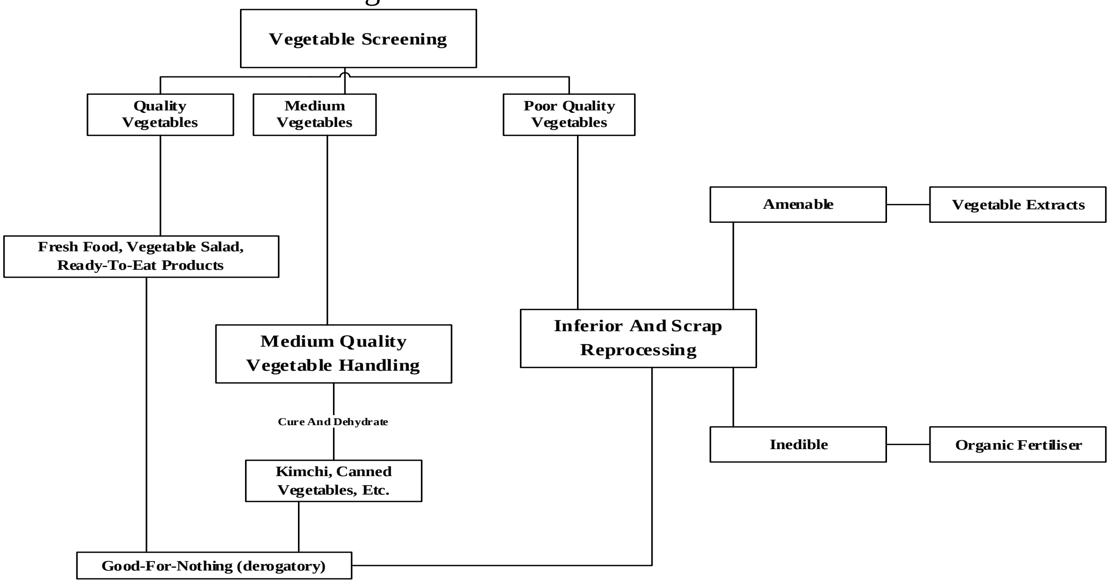

Figure 1: Process flow of vegetable comprehensive processing and utilization processing mode

The first step of vegetable screening: At this stage, vegetables are classified into different levels based on factors such as quality, size, and maturity. Fresh and high-quality vegetables can directly enter the next step of agricultural and sideline product processing to preserve their original nutrition and taste. These vegetables are usually used to make fresh food, vegetable salads, ready to eat products, etc., to meet the market's demand for high-quality vegetables.

Step 2: Medium quality vegetable processing: Medium quality vegetables, which are not perfect but still have edible value, can be used for processing methods such as pickling and canning. These vegetables may have slight flaws in appearance or quality, but after being pickled or canned, their shelf life can be extended while giving them a unique flavor and taste. Pickled vegetables such as kimchi and sour beans, as well as canned vegetables such as canned vegetables and corn, are popular products in the market.

The third step is to reprocess inferior and waste materials: In the screening process, inferior and waste materials are often considered useless parts, but in the comprehensive processing and utilization mode of vegetables, they also have enormous value. These vegetable parts can be transformed into valuable resources through extraction, fermentation, and other methods. The nutrients in inferior and waste materials can be extracted through extraction techniques and used to make vegetable extracts, concentrated juices, etc. These extracts can be used to make seasonings, food additives, etc., providing abundant raw materials for the food industry. Waste can also be fermented and transformed into organic fertilizers or bioactive substances. Through the action of microorganisms, the organic matter in waste is decomposed and converted into organic fertilizer, which can be used for agricultural production and improve soil fertility. Meanwhile, some special microorganisms produce bioactive substances during the fermentation process, such as enzymes, antibiotics, etc. These substances have broad application prospects in fields such as medicine and agriculture.

4. Results and Discussion

4.1 Tracking of Vegetable Deep Processing

The study selected a specific vegetable producing area as the research object. According to statistics, the annual vegetable production of this vegetable production area is quite considerable, specifically 20 tonnes of tomatoes, 15 tonnes of cabbage, 3 tonnes of carrots, 5 tonnes of cucumbers, and 3 tonnes of pumpkins. In order to gain an in-depth understanding of the comprehensive utilisation of this vegetable production area, the research team has followed the whole process of vegetable raw materials, including the sale of fresh vegetables and the processing of agricultural by-products. Through this tracking study, this paper can more accurately understand the comprehensive utilization effect of vegetables, but also more accurately understand the comprehensive utilization rate of vegetable yield. By counting the kilograms of waste material, it is possible to measure the comprehensive utilisation rate of vegetable output and thus assess the efficiency of resource utilisation and thus the comprehensive utilisation of this vegetable production area. The specific data is shown in Figure 2.

According to Figure 2, the distribution of 5 types of vegetables in different destinations can be clearly observed. Most vegetables are sold directly, while the remaining vegetables have different proportions in the categories of kimchi, canned food, and fruit juice based on their types. For example, cabbage is suitable for pickling kimchi, so out of the 15 tons of production, nearly 6 tons were made of kimchi, accounting for 38.4% of the total production, except for direct sales. Cabbage is not suitable for juice production, so no cabbage was used for juice processing. But tomatoes and cucumbers are very suitable for juice processing, so nearly 4 tons of tomatoes have undergone juice processing, accounting for 19.4% of the total production. And cucumbers have over 1 ton for juice processing, accounting for 21% of the cucumber production.

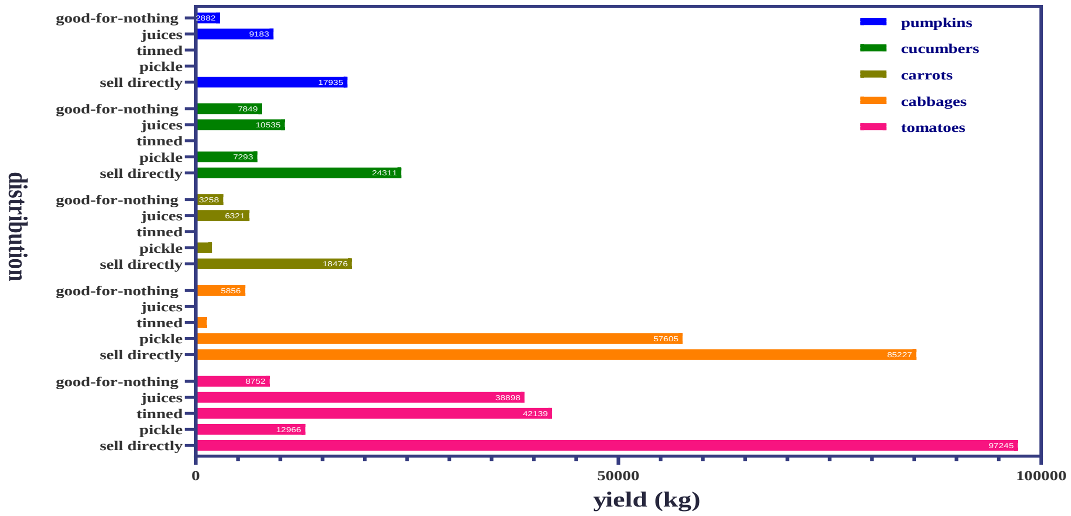

Figure 2: The destination of vegetables in vegetable production areas

At the same time, a study was conducted to calculate the proportion of waste from various vegetables. Based on the amount of waste and the original yield of various vegetables, the complete utilization rate of each vegetable was calculated. By comparing the original yield with the amount of waste, the following results were obtained: the complete utilization rate of tomatoes is 95.62%; The complete utilization rate of cabbage is 96.09%. The complete utilization rate of carrots is 89.14%, although slightly lower than the first two, it is still at a relatively high level; The complete utilization rate of cucumber is 84.3%. The complete utilization rate of pumpkin is 90.39%, which also reflects a high resource utilization effect. According to the above data, the utilization rate of all categories of vegetables can be further calculated to be 93.78%.

4.2 Vegetable Waste Utilization

In order to further improve the complete utilization rate of vegetables, research is conducted on further processing of inferior vegetables and waste after screening, classifying these waste materials, partially fermenting them, and reusing them. Finally, the weight of the residue was counted to calculate the complete utilization rate of this batch of vegetables, as shown in Table 2.

Table 2: Treatment methods for vegetable waste

Treatment	Quantity (kg)	Volume sharec
Composting	11456	40.06%
Feed for agriculture and livestock	9421	32.94%
Chemical extract ingredients	5452	19.06%
Discard of residue	2268	7.93%

According to Table 2, it can be seen that after using methods such as composting fermentation, animal husbandry, and chemical extraction to treat the waste, there is still 2268kg of residue remaining, but it only accounts for 7.93% of all waste. The total yield of vegetables in this area is 460000kg, and it can be calculated that the complete utilization rate of this batch of vegetables after reuse reaches 99.51%.

However, at the same time, the comprehensive utilization cost of vegetable waste is relatively high. For example, vegetable waste is used to produce organic fertilizers. In order to produce high-quality fertilizers rich in multiple elements, a certain amount of fermentation agents, cow (sheep) manure and other auxiliary materials need to be added during the stacking process, and there are also certain labor and electricity costs. The price for directly purchasing subsidized organic fertilizer in the market is about 150 yuan per ton. Taking the example of stacking a fertilizer pile with a length of 30m, width of 5m, and thickness of 1m, the cost of organic fertilizer from vegetable waste stacking is shown in Table 3.

The fermentation agent cost, cow manure cost, electricity cost, and labor cost are 1350, 6660, 215, and 3000 yuan respectively, with a total cost of 11225 yuan. The organic fertilizer yield of this fertilizer pile is about 75 tons, while the cost of directly purchasing subsidized commercial organic fertilizer is only about 8700 yuan. It can be seen that the cost of using vegetable waste to produce organic fertilizer is higher than the cost of directly purchasing commercial organic fertilizer. Therefore, further improvement of fertilizer treatment technology is needed. However, due to the fact that composting a large amount of waste can save the cost of original waste treatment and help protect the environment, it is still advisable to use vegetable waste to produce organic fertilizer for vegetable waste treatment.

Table 3: Cost statistics of organic fertilizer production from vegetable waste

Kind	Dosage	Sum of money
Fermentation agent	15 barrels	1350
Cattle manure and sheep manure	37 tonnes	6660
Electrical	250 degrees	215
Manually	15 people	3000
Total		11225

4.3 Optimizing Compost Fermentation Technology

The processing flow of vegetable residues in technology: In the process of plant residue treatment in vegetable bases, specific operational procedures should be followed: vegetable plant crushing - adding fermentation agents - building piles for fermentation - lasting for more than 10 days - returning for reuse. The temperature and time relationship during the fermentation of vegetable plant residue compost is shown in Figure 3.

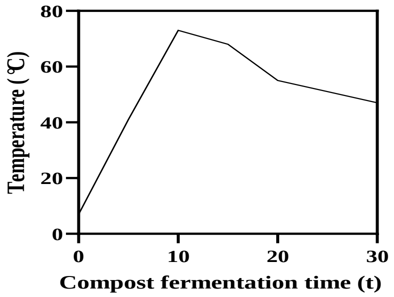

Figure 3: Relationship between composting fermentation time and temperature

Figure 3 shows the temperature and time relationship during the fermentation of vegetable plant residue compost. By referring to this figure, the key parameters during the fermentation process can be more accurately grasped to ensure the maximization of the treatment effect. Through experimental testing, it was found that during vegetable processing, temperature changes correspondingly with fermentation time. After 5 to 10 days of stacking vegetable residues, the speed of stacking material increases. When stacked for about 10-15 days, the temperature of the stacked vegetables becomes high and begins to decrease, indicating that the vegetable residues have completed their decomposition.

5. Conclusions

Through in-depth exploration of vegetable deep processing and comprehensive utilization technology, this article finds that this field not only has enormous development potential, but also faces many challenges. The deep processing technology of vegetables effectively extends the shelf life of vegetables, increases their added value, and provides consumers with more diverse product choices. In addition, the comprehensive utilization technology of vegetables, such as extracting pigments, pectin, dietary fiber, etc., not only improves the economic value of vegetables, but also provides raw materials for other industries. The widespread application of vegetable deep processing technology has enabled the vegetable industry to break through traditional seasonal and regional limitations, achieving annual production and global sales. The use of this technology not only improves the utilization rate of vegetables and reduces waste, but also provides consumers with more healthy, nutritious, and convenient food choices. Although vegetable deep processing and comprehensive utilization technology has many advantages, its limitations must also be acknowledged. Due to limitations in technology and equipment conditions, the level of deep processing of vegetables in some regions is still relatively low. Therefore, it is necessary to further strengthen technological research and innovation, and improve the level and competitiveness of vegetable deep processing and comprehensive utilization technology.

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