Review

Production, Use and Recycling of Fruit Cultivating Bags in China

Hongguang Yang, Fengwei Gu, Feng Wu, Bokai Wang, Lili Shi and Zhichao Hu *

Nanjing Institute of Agricultural Mechanization, Ministry of Agriculture and Rural Affairs, Nanjing 210014, China
* Correspondence: huzhichao@caas.cn

Abstract: Preharvest bagging is a key agricultural technology in the process of the growth and development of young fruits. It can effectively improve the appearance quality of fruits, reduce pesticide residues on the surface of fruits and prevent pests and birds from harming fruits. China is one of the world’s major fruit producers. It is also the country that uses the most fruit cultivating bags. At present, the fruit cultivating bags used in Chinese orchards are mostly paper. Ways to recycle and reuse the waste fruit cultivating bags should be paid attention to. Therefore, this paper comprehensively uses the methods of data analysis and literature research to summarize and analyze. The data mainly comes from the China Rural Statistical Yearbook, a national public service platform for standard information, China’s national knowledge internet and the web of science. The topics discussed include the current situation of fruit production in China, the overview of fruit bagging technology, the production and use of fruit cultivating bags and the recycling strategy of waste fruit cultivating bags. It is hoped that this study can provide some references to the development of fruit bagging technology and the resource reuse and recycling of waste fruit cultivating bags in China and the world in the future.

Keywords: fruit bagging technology; fruit cultivating bags; agricultural non-point source pollution; resource reuse and recycling

1. Introduction

Fruit is one of the important sources of basic human food and nutrition. In recent years, people have paid more and more attention to fruit quality while meeting basic needs. The concept of diet is quietly changing from eating food that simply makes people full to eating food that is delicious and healthy. As we all know, fruit is vulnerable to invasion by insect pests, bird attacks, various pathogens and mechanical damage (mainly referring to the friction damage between fruit and branches caused by wind and the impact damage of hail on the surface of fruit) during its growth and development stages. The occurrence of these phenomena will lead to a large amount of fruit abscission and skin damage to fruits, which not only seriously reduces the commercial value of fruits but also causes significant yield and economic losses [1,2].

For the invasion of pathogens and insect pests, the most effective method is to apply fungicides and pesticides. However, this method will have adverse effects on consumer health and the ecosystem [3,4]. In order to prevent bird attacks, fruit farmers laid woven nets around and on the top of the orchard in the early years, but this method is labor-intensive and costly. With the development and improvement to orchard management, fruit bagging technology came into being.

Many studies have proven that preharvest fruit bagging can effectively prevent various pathogens, insect pests and birds from damaging fruits [5–8]. Moreover, preharvest bagging can also reduce the use of pesticides and avoid direct sunlight, and the peel color after fruit ripening is more uniform [9–12]. At present, with the promotion of fruit bagging technology, a large number of fruit bags are applied in orchards in China. As solid waste,
the waste fruit cultivating bags are discarded everywhere and fall into the roadside or drainage ditches with the wind. This has become one of the main pollution sources of agricultural non-point source pollution, seriously affecting the soil quality of orchards and the surrounding ecological environment. Determining how to reasonably recycle and reuse these waste fruit cultivating bags has become an urgent problem in China’s fruit industry.

At present, fruit bagging technology has been widely used in China, Japan, the United States, India, South Korea and Bangladesh [9,13,14], but there are few literature reports on the recovery and reuse of waste fruit cultivating bags. China is a large fruit-producing country [15,16] and is also the country that uses the most fruit cultivating bags [17,18]. More attention should be paid to the recycling and resource reuse of fruit cultivating bags.

Therefore, this paper aims to comprehensively understand the production, application and recycling of fruit cultivating bags in China from four aspects: the current situation of fruit production in China, an overview of fruit bagging technology, the production and use of fruit cultivating bags and recycling and resource reuse strategy of waste fruit cultivating bags.

2. Current Situation of Fruits Production in China

2.1. Overall Production Status

Since the reform and opening up in 1978, China’s fruit industry has developed rapidly. It has become the third largest industry after grain and vegetables in the planting industry [15]. According to the statistics of the Food and Agriculture Organization of the United Nations (FAO), the total yield of Chinese fruits and the single yield of apples, peaches and pears rank first in the world [15,19]. Figures 1 and 2 show the changes in the area of orchards, the total yield of fruits, fruits yield per unit area and consumption per capita of fruits in China during the 40 years from 1981 to 2020.

![Figure 1](image1.png)

**Figure 1.** Current situation of Chinese fruit production of 1981 to 2020. Note: the data are obtained from China Rural Statistical Yearbook [20].

![Figure 2](image2.png)

**Figure 2.** Consumption per capita of fruits of China from 1981 to 2020. Note: the data are obtained from China Rural Statistical Yearbook [20].
It can be seen from Figures 1 and 2 that the area of orchards, fruit yield and consumption per capita of fruits in China are increasing year by year. In 2020, the area of orchards was 12.7 million hectares, an increase of 6.0 times compared to 1981. The total yield of fruits increased from 7.8 million tons in 1981 to 286.9 million tons in 2020, an increase of 35.8 times and an average annual growth rate of 9.7%. The average yield of fruits increased from 4.3 tons/hectares in 1981 to 22.7 tons/hectares in 2020. The consumption per capita of fruits also increased from 7.8 kg in 1981 to 203.2 kg in 2020, an increase of 25.1 times. Among them, it should be noted that the fruit yield increased sharply from 2002 to 2003. The main reason is that the data regarding the output of fruits included melons since 2003. In general, China’s fruit output has increased steadily, mainly due to the comprehensive impact of using good orchard management and advanced production technology.

2.2. Spatial Pattern of Fruit Industry and Production Status of Main Fruits

China has a vast territory, and various fruits are widely planted and distributed [21,22]. Figure 3 shows the area of orchards and fruit yield data from various regions in China in 2020. Among them, 8 regions meet the requirements of an orchard area of more than 0.5 million hectares and a fruit yield of more than 10.0 million tons. They are Hebei, Shandong, Hunan, Guangdong, Guangxi, Sichuan, Shaanxi and Xinjiang.

![Figure 3](image.png)

*Figure 3. Current situation of fruits in various regions of China in 2020. Note: the data are from China Rural Statistical Yearbook [20] and post-processing calculation. The data excludes the Hong Kong Special Administrative Region, Macao Special Administrative Region and Taiwan Province of China.*

Apples, citruses, pears, grapes and bananas are the main fruit species in China [15] and are also the main application objects of bagging. The total yield and planting area of the above-mentioned fruits was 138.9 million tons and 6.8 million hectares, accounting for 48.4% and 54.0% of the country, respectively. Figure 4 shows the total yield and orchard area of these fruits in 2020. It can be seen from Figure 4 that citruses have the largest planting area and yield among these fruits, followed by apples, pears, grapes and bananas.

![Figure 4](image.png)
3. Overview of Fruit Bagging Technology

Preharvest bagging is the key operation in the process of fruit cultivation. Fruit bagging technology originated in Japan \[23,24\] and has a history of more than one hundred years \[25\]. Limited by the development of pesticide and spraying technology, the main purpose of early fruit bagging is to prevent various pathogens and insect pests from harming the fruits.

At present, fruit bagging has become a common practice in the major fruit producing countries. In Japan, this technology has long been applied to the production of pears \[23\], apples \[24\] and peaches \[25\]. In India, this technology has been applied to the production of apples \[26,27\], pomegranates \[28,29\], guavas \[30\], grapes \[31\] and litchis \[32\]. In the United States, this technology is widely used in the production of apples \[33\] and peaches \[34,35\]. In Bangladesh, this technology has been successfully applied to the production of dragon fruits \[36,37\], mangos \[38\] and guavas \[39\]. In addition, bagging technology is applied to the production of pomegranates \[40\] in Türkiye, pomegranates \[41\] in Spain, mangos \[42\] in the Philippines, mangos \[43\] in Pakistan, mangos \[3\] in Myanmar, pears \[44\] in South Korea, organic grapes \[45\] in Jordan, red dragon fruits \[46\] in Vietnam and golden fruits \[47\] and pomegranates \[48\] in Brazil.

Fruit bagging technology was applied to pear, peach and grape cultivation and production by the Chinese in the 1950s and 1960s \[18\]. The bagging materials used at that time were mostly waste newspapers. From the 1980s to the 1990s, through the introduction and improvement of Japanese fruit cultivating bags, production machinery and related bagging technology, China’s fruit bagging technology developed rapidly. In particular, it was widely promoted and applied to the main apple-producing areas of Shandong and Shaanxi. At that time, fruit bagging was once an important measure to produce high-quality apples \[18\].

With the wide use of fruit bagging, its advantages have been fully reflected. At present, fruit bagging technology has been applied for the production of Chinese apples \[49\], pears \[50\], peaches \[10\], grapes \[11\], pomegranates \[51\], loquats \[52\], mangos \[53\], lemons \[54\], citruses \[55\], cherries \[56\], longans \[57\], kiwifruits \[58\], bananas \[59\], dragon fruits \[60\] and litchis \[61\]. Figure 5 shows the main advantages of bagging operation.

Take ‘fruit bagging’ as the keyword, and search for the national public service platform for standard information \[62\]. As shown in Table 1, 16 current standards of fruit bagging were obtained through search and screening. Among them, three agricultural industry standards related to apples, table grapes and lemons were promulgated and implemented by the Ministry of Agriculture and Rural Affairs of the People’s Republic of China in 2007, 2011 and 2013, respectively. There are 9 local standards, which are mainly formulated according to the local fruit planting characteristics. Among them, Jiangsu Province formulated the technical standards for bagging grapes, pears, apples and peaches earlier and comprehensively. In addition, there are 2 group standards and 2 enterprise standards.
Figure 5. Advantages and functions of fruit bagging.

Table 1. Technical standards for fruit bagging.

<table>
<thead>
<tr>
<th>Type</th>
<th>Standard Number</th>
<th>Standard Name</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NY/T 1998-2011</td>
<td>Rules of bagging for fruit producing-Table grape</td>
<td>2011</td>
</tr>
<tr>
<td></td>
<td>NY/T 2314-2013</td>
<td>Rules of bagging for fruit producing-Lemon</td>
<td>2013</td>
</tr>
<tr>
<td>Local standard</td>
<td>DB32/T 930-2006</td>
<td>Rules of cultivated technology of bagged grapes in whole orchard</td>
<td>2007</td>
</tr>
<tr>
<td></td>
<td>DB32/T 1102-2007</td>
<td>Rules of cultivated technology of bagged apples in whole orchard</td>
<td>2007</td>
</tr>
<tr>
<td></td>
<td>DB32/T 1335-2009</td>
<td>Rules of cultivated technology of bagged juicy peach in whole orchard</td>
<td>2009</td>
</tr>
<tr>
<td></td>
<td>DB32/T 1412-2009</td>
<td>Rules of bagging technique for ‘Cuiguan’ pear</td>
<td>2009</td>
</tr>
<tr>
<td></td>
<td>DB45/T 722-2011</td>
<td>Technical standard for mango fruit bagging</td>
<td>2011</td>
</tr>
<tr>
<td></td>
<td>DB42/T 930-2013</td>
<td>Regulations of bagging technology for sand pear (Pyrus pyrifolia Nakai)</td>
<td>2013</td>
</tr>
<tr>
<td></td>
<td>DB41/T 1775-2019</td>
<td>Technical standard for peach fruit bagging</td>
<td>2019</td>
</tr>
<tr>
<td></td>
<td>DB/T 360-2021</td>
<td>Technical standard for grape fruit bagging</td>
<td>2021</td>
</tr>
<tr>
<td>Group standard</td>
<td>T/SDAS 150-2020</td>
<td>Technical standard for apple fruit bagging</td>
<td>2020</td>
</tr>
<tr>
<td></td>
<td>T/SDAS 77-2019</td>
<td>Technical standard for pear fruit bagging</td>
<td>2019</td>
</tr>
<tr>
<td>Enterprise standard</td>
<td>Q/AHTZ.N 04-2022</td>
<td>Technical specifications for pomegranate fruit bagging</td>
<td>2022</td>
</tr>
<tr>
<td></td>
<td>Q/YD 10005-2021</td>
<td>Rules for intensive cultivation of Yue Duo apple dwarf rootstock</td>
<td>2021</td>
</tr>
</tbody>
</table>

Fruit bagging involves many processes and is an expensive, laborious and time-consuming process. These factors have restricted the development and application of fruit bagging technology to a certain extent [13,18,58]. In general, fruit bagging technology mainly involves the management before bagging, bagging, removal of bags and management after bag removal. As shown in Figure 6, taking apple bagging as an example, the key links and processes of bagging are briefly described.
4. Production and Use of Fruit Cultivating Bags

4.1. Classification of Fruit Cultivating Bags

China has a vast territory, and the climates of the north and the south are very different. Suitable fruit cultivating bags should be selected for different fruit varieties and different regions. The fruit cultivating bags that are currently used are mainly divided into plastic film bags, paper bags, paper-film composite bags and other material bags [18]. Among them, paper bags can be divided into double-layer and single-layer [63]. Other material fruit bags are mainly nylon bags and non-woven bags [13]. As shown in Figure 7, fruit cultivating bags of different materials are available. Their characteristics and application objects are shown in Table 2.

![Figure 6. Key steps and processes of apple bagging.](image)

![Figure 7. Cont.](image)
Figure 7. Different types of fruit bags. (a) Plastic film bag [64]; (b) Nylon bags [65]; (c) Non-woven bags [66]; (d) Paper-film composite bags [67]; (e) Single-layer paper bags [68]; (f) Double-layer paper bags [69]. Note: the pictures were obtained from Taobao Marketplace. Copyright 2022, the Taobao shop or the photographer.
Table 2. Characteristics and application objects of different fruit cultivating bags.

<table>
<thead>
<tr>
<th>Type</th>
<th>Characteristic</th>
<th>Application Object</th>
</tr>
</thead>
<tbody>
<tr>
<td>plastic film bags</td>
<td>Advantage: (1) There is a wire on the top for sealing and a plurality of small holes on the bottom for ventilation. (2) Cheap, tiny and easy to use. (3) There is no need to remove bags when harvesting fruits, and they can be transported and sold with bags. Shortcoming: (1) Although there are air holes at the bottom, the moisture permeability and air permeability are still poor. (2) The fruit has a poor coloring effect and is prone to sunburn.</td>
<td>apple</td>
</tr>
<tr>
<td>single-layer paper bags</td>
<td>Advantage: (1) The paper bag material is effectively waterproof. Water does not penetrate inward but forms water droplets on the surface of the bag and then rolls down. (2) There is a vent at the bottom corner, which can ensure the air permeability of the fruit. (3) The paper bag is provided with wire, which can be used for sealing. Shortcoming: The fruit coloring effect was slightly poor.</td>
<td>grape, loquat, peach, pear and citrus</td>
</tr>
<tr>
<td>double-layer paper bags</td>
<td>Advantage: The advantages are the same as single-layer fruit bags. At the same time, because of the use of double-layer paper, the fruit coloring effect is better. Shortcoming: (1) The price of double-layer paper bags is higher. (2) Sometimes, in order to improve the fruit coloring effect, the outer bag and the inner bag need to be removed twice, which is labor-intensive and costly.</td>
<td>apple, pear, peach, mango</td>
</tr>
<tr>
<td>paper-film composite bags</td>
<td>Advantage: (1) There is a wire on the top for sealing. (2) The inner membrane surface is uniformly distributed with pores to ensure air permeability and moisture permeability. Shortcoming: The fruit coloring effect was slightly poor.</td>
<td>apple, pear and loquat</td>
</tr>
<tr>
<td>nylon bags</td>
<td>Advantage: (1) The effect of insect and bird prevention is good. (2) Good ventilation and light transmission. Shortcoming: Poor water resistance, not suitable for fruits requiring coloring.</td>
<td>dragon fruit, grape, mango</td>
</tr>
<tr>
<td>non-woven bags</td>
<td>Advantage: (1) It has good ventilation and waterproof effect. (2) The materials used are degradable and pollution-free and can be reused. Shortcoming: Poor water resistance and high price.</td>
<td>grape, litchi</td>
</tr>
</tbody>
</table>

4.2. Production and Use of Fruit Cultivating Bags

4.2.1. Plastic Film Bags

Plastic film fruit bags are common polyethylene film bags that are processed by blowing, heat sealing, cutting and other processes of the addition of appropriate additives. The material is polyethylene. This plastic film bags were widely used in apple production many years ago [18]. As shown in Figure 7a, the color of the bag is mainly white, and it can also be made yellow, red and purple as required. However, due to the poor effects of moisture permeability, air permeability, shading and coloring of fruits in use [70], they have been gradually replaced by paper bags in recent years. At present, plastic film bags are only used in some apple production processes with low-quality requirements. The main application object of plastic film bags is in post-harvest storage and maintaining the freshness of citruses and other fruits [71].

4.2.2. Paper-Film Composite Bags

The outer layer of a paper-film composite bag is a paper bag, the inner is a polyethylene film, and the inner and outer layers are bonded together. As shown in Figure 7d, it makes full use of the advantages of paper bags and film bags and avoids their disadvantages. Generally, the outer paper bag is yellow or red, and the inner is black. At present, this kind of fruit bag is mainly used in the production of apples, pears and loquats in China.

4.2.3. Paper Bags

Paper bags are the main type of fruit bagging in China. The material is wood pulp paper, which can be divided into double-layer and single-layer according to its application objects [18,52]. As shown in Figure 7e, the single-layer paper bag can be made white, yellow, pink, green, blue or yellow on the outside and black on the inside, according to the needs of different varieties of fruits. As shown in Figure 7f, in general, the inner layer of
the outer bag is black, the outer layer is light yellow and the inner bag is red or white and coated with wax [18,72].

The materials used in the early fruit paper bags in China were mainly waste newspapers. In the late 1980s, China began to introduce fruit cultivating paper bags from Japan [73]. As a special paper for agriculture, fruit cultivating bag paper is an important raw material for producing fruit bags. In the 1990s, many domestic institutions began to research domestic fruit bag paper on the basis of learning from and digesting Japanese fruit bag paper. After several years of experiments, a series of papers was developed, which completely reversed the current situation of only focusing on imitating the appearance of imported paper bags and ignoring their internal quality differences. These early studies strongly promoted the development and use of domestic fruit paper bags.

In addition, Chen Youguang et al. [74] earlier tested the physical properties of 24 kinds of Japanese imported and domestic paper bags. The results show that the main performance indexes of imported paper bags are better than domestic paper bags, which provides a direction for the optimization and improvement of Chinese paper bags at that time. Zhang Meiyun’s team from Shaanxi University of Science and Technology paid attention to the quality of Chinese fruit bag paper [75]. They compared the quality of domestic fruit bag paper with that of imported ones and pointed out that domestic fruit bag paper should be optimized in terms of air permeability, tensile strength, water resistance and softness. They also conducted a lot of research on the sizing durability of fruit bag paper and the production of outer bags by lamination, coating and printing. The research of the above scholars has laid a solid theoretical foundation for the development of Chinese fruit bag paper [76].

In order to standardize the production and use of fruit cultivating bag paper, in 2003, the China Standardization Technical Committee of Papermaking Industry took the lead in formulating the first compulsory national standard for fruit cultivating bag paper [77]. This standard specifies the product classification, technical requirements and test methods of fruit cultivating paper bags in detail. According to its quality, the fruit cultivating bag paper was divided into three grades: excellent products, first-class products and qualified products. According to the use, it is divided into outer bag paper and inner bag paper. The standard was revised for 2015. It was changed from a mandatory standard to a recommended standard, and the relevant parameters were appropriately adjusted according to the use of fruit cultivating bag paper in recent years [78]. The formulation of this standard provides a basis for the production and use of Chinese fruit cultivating bag paper. At present, all Chinese fruit cultivating bag paper manufacturers implemented this national standard. The technical indicators of fruit cultivating bag paper specified in the standard are shown in Table 3.

Take ‘fruit cultivating’ or ‘bagging’ as the keyword, and search for the national public service platform for standard information [62]. 108 current standards related to the production of fruit bags were obtained through screening. Among them, there was 1 agricultural industry standard, 1 local standard, 1 group standard and 105 enterprise standards. As shown in Table 4, there are several main standards, which mainly specify the requirements, test methods, inspection rules, packaging, marking, transportation and storage of fruit cultivating bags. It is worth noting that Shaanxi Province has formulated the production and use standards of apple cultivating paper bags in 2001. It can be seen that the application of apple bagging technology in Shaanxi Province is early, and it is one of the main apple production areas in China. In 2007, the Ministry of Agriculture and Rural Affairs of the People’s Republic of China formulated the industry standard of apple cultivating paper bags, which provides the basis and guidelines for the production and use of apple paper bags, and has great significance for the development of China’s fruit bagging industry.
Table 3. Technical indicators of fruit cultivating bag paper. Date from reference [78]. Copyright 2015, China Standards Press.

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Unit</th>
<th>Parameter Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td><strong>Excellent</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Inner</td>
</tr>
<tr>
<td>Weight g/m²</td>
<td>%</td>
<td>26.0</td>
</tr>
<tr>
<td>Weight deviation ≤</td>
<td>%</td>
<td>4.0</td>
</tr>
<tr>
<td>Deviation of profile basis weight ≤</td>
<td>g/m²</td>
<td>1.0</td>
</tr>
<tr>
<td>Tensile index (longitudinal) ≥</td>
<td>N·m/g</td>
<td>65.0</td>
</tr>
<tr>
<td>Wet tensile index (longitudinal) ≥</td>
<td>N·m/g</td>
<td>20.0</td>
</tr>
<tr>
<td>Tearing index ≥</td>
<td>mN·m²/g</td>
<td>3.60</td>
</tr>
<tr>
<td>Air permeability ≥</td>
<td>µm/(Pa·s)</td>
<td>3.0</td>
</tr>
<tr>
<td>Water absorption (front) ≤</td>
<td>g/m²</td>
<td>20.0</td>
</tr>
<tr>
<td>Decolorization test a (water)</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Heavy metal a ≤</td>
<td>Pb mg/kg</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td>As mg/kg</td>
<td>1.0</td>
</tr>
<tr>
<td>Moisture content</td>
<td>%</td>
<td>7.0 ± 2.0</td>
</tr>
</tbody>
</table>

a The decolorization test and heavy metal index of the fruit cultivating bag paper used in a single layer shall conform to the provisions of the inner bag paper, and the other technical indexes shall conform to the provisions of the outer bag paper.

Table 4. Production standard of fruit cultivating bags.

<table>
<thead>
<tr>
<th>Type</th>
<th>Standard Number</th>
<th>Standard Name</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural industry standard</td>
<td>NY/T 1555-2007</td>
<td>Fruit cultivating paper bag for apple</td>
<td>2008</td>
</tr>
<tr>
<td>Local standard</td>
<td>DB61/T 292-2001</td>
<td>Fruit cultivating paper bag for apple</td>
<td>2001</td>
</tr>
<tr>
<td>Group standard</td>
<td>T/MYXGY 001-2018</td>
<td>Fruit cultivating paper bag for apple and peach</td>
<td>2018</td>
</tr>
</tbody>
</table>

For the queried enterprise standards, from the perspective of application scope, they are mainly divided into two categories: fruit cultivating bags and fruit cultivating bags with detailed fruit names. The proportion of different cultivating bags is shown in Figure 8. Among them, there are 52 production standards named after fruit cultivating bags, accounting for 49.52% of the total. The second is the production standard of apple and grape cultivating bags, which are 18 and 12, respectively, accounting for 17.14% and 11.43% of the total, respectively.

As shown in Figure 9, from the perspective of the location of the manufacturing enterprises, the enterprise standards are mainly distributed in 10 provinces, including Hebei, Shanxi, Fujian, Shandong, Henan, Gansu, Shaanxi, Sichuan, Yunnan and Hainan. Among them, it is mainly distributed among Hebei, Shaanxi and Sichuan, which are more than 80% of the total.

As shown in Figure 10, according to the standard types of fruit cultivating bags, paper bags are mainly used, accounting for 95.24% of the total. The reason is that single-layer paper bags or double-layer paper bags are widely used in the bagging of main fruits such as apples, peaches and pears in China. This result is consistent with the fact that more paper bags are used in actual fruit bagging production.
4.2.4. Other Types of Fruit Bags

With the development of bagging technology and the needs of different fruit bagging operations, some fruit cultivating bags of other materials have been applied, such as nylon fruit cultivating bags and non-woven fruit cultivating bags. Among them, as shown in Figure 7b, the applied nylon fruit bags are mainly white and black [79]. As shown in Figure 7c, the non-woven fruit bags are mainly white and green [31,80]. At the
same time, these two types of fruit bags have been widely used in bagging fruit such as dragon fruits [60], grapes [11], mangos [53] and litchis [61] in southern China due to their advantages in ventilation and insect prevention.

5. Discussion on the Present Situation and Strategy of Recycling Waste Fruit Cultivating Bags

5.1. Current Situation of Recycling Waste Fruit Cultivating Bags

In recent years, with the development of fruit bagging technology, a large number of fruit bags are used in orchards. Properly handling the used waste fruit bags has become an urgent problem for fruit farmers and government departments in the main fruit-producing areas. Through investigation, it is found that the following methods are commonly used by Chinese fruit farmers to treat waste fruit bags.

(1) Throwing the waste fruit bags directly into the orchard. When removing the fruit bags, throw the fruit bags on the ground. This method can effectively save labor. However, the used fruit bags that are removed from the fruit will still be directly in the orchard, which will seriously affect the quality of cultivated land in the orchard. Moreover, the fruit bags of the orchard drift into the roadside, ditches and near water sources with the wind, which seriously affects the surrounding environment of the orchard area.

(2) After the fruits are harvested, the waste fruit bags are burned in the orchard. Clean and collect the waste fruit bags manually, and burn them together with the fallen leaves and dead branches in the orchard. This way not only wastes resources but also pollutes the environment, which seriously violates China’s concept of ecological environmental protection and sustainable agricultural development. At the same time, it also hinders China’s goal of achieving peak carbon dioxide emissions by 2030 and achieving carbon neutrality by 2060.

5.2. Recycling Strategies for Waste Fruit Cultivating Bags

At present, the fruit bagging operation is dominated by paper bags [18,81]. The fruit cultivating bag paper is a kind of solid waste resource with high recyclable value. Discarded and burned fruit bags have become one of the main sources of agricultural non-point source pollution and environmental pollution. Scientifically and effectively recycling these waste fruit bags is the key to solving the problem, which is of great significance in promoting the green development of China’s fruit industry.

However, the current research on the recycling technologies of waste fruit bags in China lags behind. From the existing literature, other countries also have no relevant reports and mature experience and methods to learn from. As shown in Figure 11, according to the current situation and trend of the application of fruit bagging technology in China, some thoughts, suggestions and solutions are proposed for the recycling of waste fruit bags.

As shown in Figure 11, the ideas for recycling waste fruit bags mainly include 5 aspects: sorting and recycling of waste fruit bags, improving farmer awareness of recycling fruit
bags, improving the level of mechanized operation, establishing a comprehensive recycling system and exploring fruit non-bagging technology. The specific strategies for recycling waste fruit bags are as follows:

(1) Sorting and recycling of waste fruit bags

Different recycling methods shall be formulated for different fruit bags. Plastic film bags, paper-film bags and paper bags of high wet strength can be treated harmlessly by referring to the method of agricultural packaging (such as centralized burial, incineration and power generation). Ordinary paper bags, nylon bags and non-woven cloth bags are recycled as solid resources. Also attention must be paid to the wet strength dissociation treatment when handling paper bags, especially those in southern China, because in order to prevent rain from infecting fruits, inner paper bags of these areas generally have high wet strength [82,83].

(2) Improving fruit farmer awareness of recycling fruit bags

Fruit farmers should strengthen the awareness of environmental protection and establish the awareness that wasted fruit bags cannot be burned. After removing the fruit bags, collect the used fruit bags in time and consciously send them to the centralized collection and treatment place. In order to solve this problem, government departments can strengthen and improve the environmental protection of fruit farmers and their awareness of recycling fruit bags by issuing leaflets, holding on-site training meetings and inviting technicians to give on-site guidance.

(3) Improving the level of mechanized operation

Accelerating the process of mechanized removal and collection of fruit bags. At present, removing fruit bags in China is all done manually, which has the problems of high labor intensity and low efficiency [84,85]. If the operator is required to collect the waste fruit bags when removing the bags manually, it will further increase the labor intensity and reduce the work efficiency. Therefore, it is necessary to accelerate the research and development of machinery that can complete the identification, removal, collection and packaging of fruit bags at one time in order to realize the replacement of labor by machines and promote the recycling of waste fruit bags of mechanical operations.

(4) Establish a comprehensive recycling system for waste fruit bags

Establishing a comprehensive recycling system of waste fruit bags by means of government support, market operation, social participation and step-by-step implementation. It is necessary to ensure that all the waste fruit bags are recovered as far as possible. The specific method is to set up exchange or sell points for waste fruit bags in areas where fruit bag usage is relatively common and arrange for special personnel to take charge of this work. Fruit bag manufacturers should take the initiative to reach a consensus with fruit farmers. Allow fruit farmers to exchange the used fruit bags for new fruit bags, and jointly agree on an appropriate exchange ratio (for example, 6 kg of waste fruit bags for 1 kg of new fruit bags). At the same time, local government departments should actively support some relevant enterprises in the recycling and processing of waste fruit bags. These enterprises should realize that they also have a responsibility to recycle and reuse local fruit bags and ensure the green and healthy development of the local fruit industry and the environment. As shown in Figure 12, they use waste fruit bags to make new fruit bags or other paper products. The former can be used by fruit farmers, and the latter can be used in other industries.

(5) Exploring and implementing fruit non-bagging production technology [86]. Although fruit bagging has many advantages, it also has negative problems such as resource consumption, environmental pollution, labor cost and economic cost increase. For example, at present, apple bags used by Chinese fruit farmers are generally paper bags, and their production materials are wood pulp paper (WPP). In general, about 5 paper bags are required for 1 kg of apples, and each paper bag is calculated as
5 g WPP. Hence, if 1 kg of apples is produced, about 25 g of WPP is required, and
25 kg of WPP is required for 1 ton of apples. In 2020, China’s apple total yield was
44.1 million tons, and 80% of apples were bagged with paper bags. It would take
1.1 million tons of WPP to bag apples, which would be a huge resource consumption.
② In addition, bagging and bag removal operations are completed manually. The
bagging farming time is short, and the problems of an aging rural population and
difficult and expensive employment are becoming more and more prominent. It is
estimated that the labor cost and paper bag cost of an apple from bagging (paper
bag) to picking is about 0.2 Renminbi (Yuan). According to this calculation, the labor
cost and paper bag cost of 1 kg of apples (5 paper bags) are 1 Renminbi (Yuan),
accounting for 40–50% of the orchard expenditure. ③ If the apple yield of 30,000 kg
per hectare is calculated, the total cost is 30,000 Renminbi (Yuan). If the removed fruit
bags are not handled in time, they will fall all over the ground and seriously pollute
the environment.

![Diagram of waste fruit bag recycling process](image.png)

**Figure 12.** Recycling process of waste fruit bags.

### 6. Conclusions

In this paper, the fruit industry, fruit bagging technology, and the types, characteristics
and production of fruit bags in China, as well as the recycling methods and strategies of
waste fruit bags are summarized in detail. From the above description and discussion,
it can be concluded that bagging is a direct and safe agricultural technology during the
growth and development of young fruits. Fruit bagging is the most effective method to
protect fruits from pests and birds and reduce pesticide use and pesticide residues on the
fruit’s surface. Fruit bagging technology has been widely used in China and other countries
around the world. However, with the extensive application of fruit bags, attention should
be paid to the recycling and resource utilization of waste fruit bags.

Aiming to solve the problems of high environmental pollution risk and a serious
waste of resources in the existing waste fruit bag treatment methods in China, a specific
recycling strategy for waste fruit bags was proposed. The methods mainly included
sorting and recycling waste fruit bags, improving farmer awareness of recycling fruit bags,
improving the level of mechanized operation, establishing a comprehensive recycling
system and exploring fruit non-bagging technology. Only by organically combining the use
and recycling of fruit bags can we ensure the long-term implementation of fruit bagging
technology and the green development of the global environment.

**Author Contributions:** Conceptualization, methodology and supervision, H.Y., F.G. and Z.H.; vali-
dation, data curation and investigation, F.W., H.Y., B.W. and L.S.; writing—original draft preparation
and writing—review and editing, H.Y., L.S. and F.G.; project administration and funding acquisition,
Z.H. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research was funded by the Agricultural Science and Technology Innovation Project
of Chinese Academy of Agricultural Sciences, grant number CAAS-ASTIP-31-NIAM.
Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are available on demand from the first author at (hgyang2016@163.com).

Conflicts of Interest: The authors declare no conflict of interest.

References


5. Frank, D.L. Evaluation of fruit bagging as a pest management option for direct pests of apple. Insects 2018, 9, 178. [CrossRef] [PubMed]


16. Yuan, B.; Yue, F.Z.; Cui, Y.H.; Chen, C. The role of fine management techniques in relation to agricultural pollution and farmer income: The case of the fruit industry. Environ. Res. Lett. 2022, 17, 034001. [CrossRef]


40. Mamay, M. The influence of calyx removal and fruit bagging on carob moth, *Ectomyelois ceratoniae* Zeller (Lepidoptera: Pyralidae), infestation in pomegranate. *Crop Prot.* 2021, 147, 105708. [CrossRef]


45. Karajeh, M.R. Pre-harvest bagging of grape clusters as a non-chemical physical control measure against certain pests and diseases of grapevines. *Org. Agric.* 2018, 8, 259–264. [CrossRef]


47. Nascimento, W.; Müller, C.H.; Araújo, C.D.S.; Flores, B.C. Fruit bagging of *Pouteria caimito* (Anacardiaceae) and its impact on quality of mango fruits. *Int. J. Plant Soil Sci.* 2021, 147, 105718. [CrossRef]


52. Zhi, C.; Ali, M.M.; Zhang, J.; Shi, M.; Ma, S.; Chen, F. Effect of Paper and Aluminum Bagging on Fruit Quality of Loquat (Eriobotrya japonica Lindl.). *Plants*** 2021, *10, 2704. [CrossRef]
64. Taobao Marketplace. Available online: [https://item.taobao.com/item.htm?&a=230r1.14.13.33.274f1546rFvnX8&amp;ns=1&amp;abbucket=16#detail](https://item.taobao.com/item.htm?&a=230r1.14.13.33.274f1546rFvnX8&amp;ns=1&amp;abbucket=16#detail) (accessed on 12 August 2022).
66. Taobao Marketplace. Available online: [https://item.taobao.com/item.htm?&a=230r1.14.68.1eb15836ws4KA&amp;ns=1&amp;abbucket=16#detail](https://item.taobao.com/item.htm?&a=230r1.14.68.1eb15836ws4KA&amp;ns=1&amp;abbucket=16#detail) (accessed on 12 August 2022).
67. Taobao Marketplace. Available online: [https://item.taobao.com/item.htm?&a=230r1.14.21.7a0b1c3a2H4JXk&amp;ns=1&amp;abbucket=16#detail](https://item.taobao.com/item.htm?&a=230r1.14.21.7a0b1c3a2H4JXk&amp;ns=1&amp;abbucket=16#detail) (accessed on 12 August 2022).
68. Taobao Marketplace. Available online: [https://item.taobao.com/item.htm?&a=1z10.1-c.w4004-1793242006.30.7a143f698vQFC2&amp;ns=1&amp;abbucket=16#detail](https://item.taobao.com/item.htm?&a=1z10.1-c.w4004-1793242006.30.7a143f698vQFC2&amp;ns=1&amp;abbucket=16#detail) (accessed on 12 August 2022).
69. Taobao Marketplace. Available online: [https://item.taobao.com/item.htm?&a=1z10.5-c.w4002-15905271393.10.16351f8dRUBBT&amp;ns=1&amp;abbucket=16#detail](https://item.taobao.com/item.htm?&a=1z10.5-c.w4002-15905271393.10.16351f8dRUBBT&amp;ns=1&amp;abbucket=16#detail) (accessed on 12 August 2022).
82. Song, Y.L. *Study on Recycling Technology of Waste Fruit Bag Paper*; Tianjin University of Science & Technology: Tianjin, China, 2019.
83. Liu, L. *Study on New Wet Strength Dissociating Agent and Its Mechanism of Action*; Tianjin University of Science and Technology: Tianjin, China, 2020.

