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A novel progressively delivered fruit bagging apparatus

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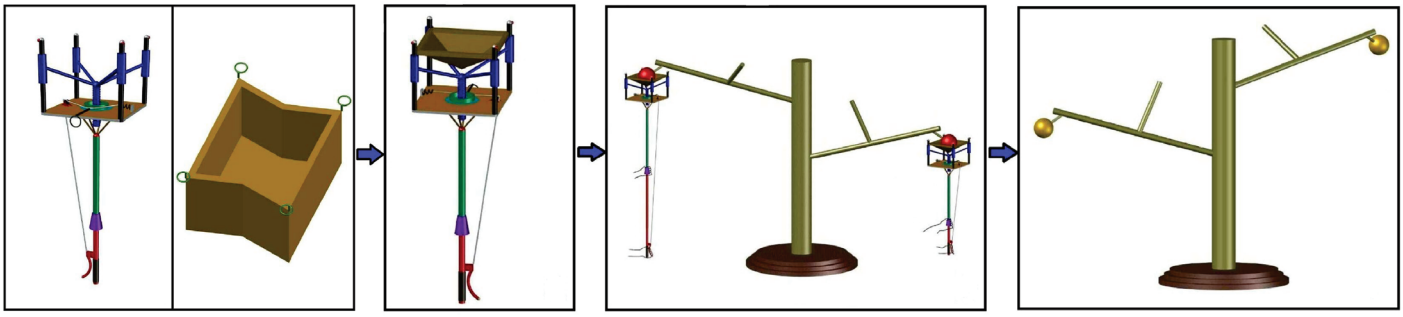
Abstract

Bagging fruit on the trees in the orchard is a challenge to the fruit industry in China and many other countries due to the heavy labor requirement and low efficiency of the current fruit bagging methods. In this study, we developed a novel semi-automatic apparatus for bagging fruits to overcome these disadvantages. This apparatus adopts a mechanism similar to 'overrunning clutch' using the self-locking principle between nut and bolt to achieve the paper bags being progressively delivered by a screwed pipe and slid out individually. Such apparatus is of simplicity in design and efficiency in operation with a low cost. It does not require a battery or any of other sources of power to complete the process. This article describes the design and operation procedure of this apparatus in details. To our knowledge, this is the first apparatus to complete the fruit bagging process using the paper bags with rubber bands and plastic rings based on the new mechanism of operation.

Graphical abstract



Key words: Fruit bagging, overrunning clutch, self-locking, paper bag with rubber bands and plastic rings

Introduction

Fruit bagging has been widely used as a physical protection technique to produce high quality fruits of apple and pear in orchards in Asian countries, especially in China. Fruit bagging can protect fruit from the damages caused by birds, insects, pathogens as well as mechanical injuries, thus leading to an improved fruit appearance for marketing and consumers. Fruit bagging can also alter the microenvironmental conditions that are beneficial to the growth and development of fruits, leading to an improved internal fruit quality (Wang *et al.*, 2007; Son and Lee, 2008; Li *et al.*, 2008; Teixeira *et al.*, 2011). It has been reported that fruit bagging could reduce levels of the light-absorptive compound anthocyanin (Li *et al.*, 2008), resulting in a higher sensitivity of bagged fruit to sunlight irradiation which improved fruit appearance by promoting anthocyanin synthesis and improving fruit coloration after the bags were removed and the fruit were re-exposed to sunlight (Arakawa, 1988; Ju, 1998; Wang *et al.*, 2000; Jia *et al.*, 2005; Bakhshi and Arakawa, 2006). In addition, fruit bagging also prevents pesticides from their direct deposit on the fruit, which might significantly reduce the potential risks to human health. Therefore, it is common practice in the orchards to enwrap fruits with paper bags (Fig. 1) during the cropping seasons throughout the world. There are a variety of fruit bagging methods available currently. However, a majority of these fruit bagging methods utilize a simple apparatus that is manual in operation. Fruit growers have to open a bag manually and then install this bag to a bagging apparatus to complete one bagging process. Such methods are unable to let bags be opened sequentially and complete the process of bagging multiple fruit at the same time. Handheld heating apparatus is another method to bag fruit. However, this apparatus requires a battery or source of power to complete the bagging process. It is also limited to the use of plastic film bags only and to bag the fruit located at a limited range of height on a tree. These fruit bagging methods also pose a safety risk to the operators when bagging the fruit located at a very high position or top of a tree. The current fruit bagging methods require heavy workload and are of low efficiency in handling in general. Fruit growers in China and many other countries of the world are in need of the fruit bagging techniques that require less labor and are more efficient. In this study, an innovative semi-automatic fruit bagging apparatus was developed. This apparatus was designed to use manual operation based on the mechanism of self-locking between bolt and screw nut. Such design could enable operators to easily reach and bag the fruit located at any positions of a tree. This apparatus is simple in design and is of

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low costs since there is no need of battery or any of other sources of power to operate.

Materials and methods

The fruit bagging apparatus: A portable fruit bagging apparatus was developed based on the self-locking mechanism between nut and bolt to achieve the paper bags being progressively delivered by a screwed pipe slid out individually (Fig. 2 and 3; Table 1). Four plastic rings (19) of a paper bag (21) were respectively fitted on the four smooth pipes (5) by an operator. The height of the operation handle could be adjusted to a desirable level by moving the inside pipe (16) within the outside pipe (13) and fixed by the fixed device (14). An operator could use his left hand to hold the operation handle and place his right hand on both the movable handle (17) and the end of the handle with rubber sleeve (fixed handle,18). An operator could move the apparatus to ensure the opening of the paper bag being toward the fruit and then completely cover it. While using his left hand palm to clench the movable handle to pull the wire rope (15), the vertical force was then turned into the horizontal force through fixed pulley (7). This horizontal force drived the unidirectional active wheel (9-A) being rotated and the spring II (8) being stretched simultaneously, and then the unidirectional active wheel could drive the driven wheel with internal thread (10-B) being rotated, forcing the screw with external thread (12) being moved upward

Fig. 1. The demonstration of fruit bagging on apple and pear fruit trees in the field using the portable fruit bagging apparatus developed from this study: (a) Apple 'Red Fuji' (*Malus×domestica* Borkh.); (b) Pear 'Dangshansuli' (*Pyrus bretschneideri* Rehd.)

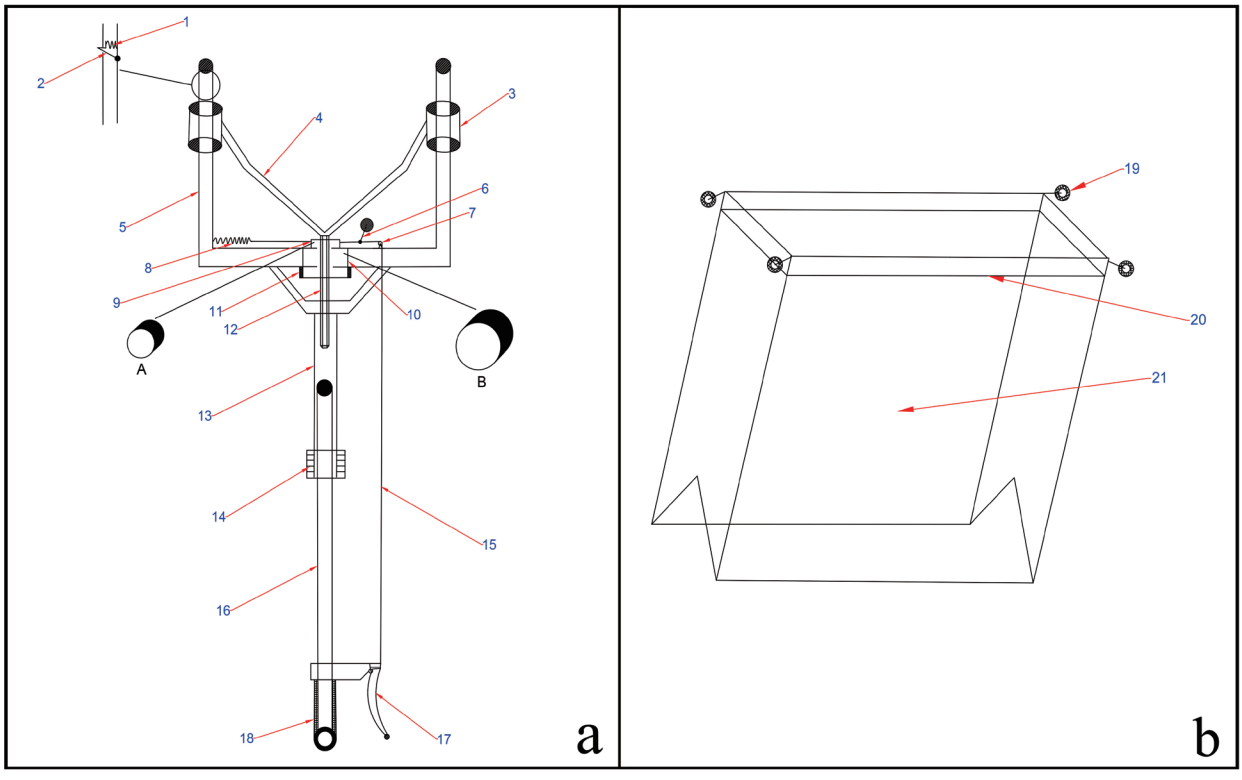

Fig. 2. The 2D design of the fruit bagging apparatus: (a) fruit bagging apparatus; (b) paper bag

Table 1. Labeling of different parts of the apparatus in Fig. 2 and Fig. 3

No.	Part	Function
1	Spring I	Make the plecturm (2) retained projection state
2	Rotatable plectrum that one end is fixed	Ensure the plastic ring (19) of paper bag slid out individually
3	Sliding tube	Slide and release paper bag (21)
4	Support holder	Connect sliding tube (3) and screw with external thread (12), make the force of screw with external thread (12) transferred to four sliding tubes (3)
5	Smooth pipe	Connect to plastic ring (19) of paper bag
6	Reset rope	Connect with wire rope (15), let the wire rope not to act on unidirectional active wheel (9) at the same moment by pulling reset rope (6)
7	Fixed pulley	Turn vertical force into horizontal force of wire rope (15)
8	Spring II	Make wire rope (15) restored to the original state
9-A	Unidirectional active wheel	Drive driven wheel with internal thread (10) to do a one-way rotation
10-B	Driven wheel with internal thread	Rotate and make screw with external thread (12) extended a certain distance upward
11	Reset spiral	Rotate and make screw with external thread (12) extended a certain distance downward
12	Screw with external thread	Drive sliding tube (3) slid upward and release plastic ring (19) of paper bag
13	Big diameter operation pipe	Work together with small operation diameter pipe (16) to achieve the adjustment of operational distance when bagging
14	Fixed device	Make big diameter pipe (13) closely connected with small diameter pipe (16), then fix the working distance of operation pipes (13 and 16)
15	Wire rope	Transfer handle force to unidirectional active wheel (9)
16	Small diameter operation pipe	Insert into big diameter operation pipe (13) and work together with big diameter operation pipe (13) to adjust the height of reach when bagging
17	Movable handle	Make grip strength switched to rope tension based on principle of leverage
18	Fixed handle with rubber sleeve	Comfortable for holding and operation
19	Plastic ring	Connect to paper bag (21) and set on the smooth pipe (5)
20	Rubber band	Embedded in paper bag (21) and has the effect of sealing
21	Paper bag	Bag fruit

by using the self-locking mechanism between nut and bolt. At the same time, this force drived the support holder (4) and the sliding tubes (3) to be moved upward, driving the plastic rings that were connected on smooth pipes. When the plastic rings glided the rotatable plectrum of which one end was fixed (2), the rings would press the plectrum downward. With this force, the spring I (1) was compressed by the plectrum. When the rings detached from the plectrum, the plectrum was bounced instantly due to the action of the spring I. Four plastic rings of paper bag would be detached from the smooth pipes entirely. Paper bag was shrunk and sealed due to the action of the rubber band (20) located in the bag opening. When spring II shrinks, it produced a force that was able to pull the wire rope to make the unidirectional active wheel done the rotation in the opposite direction. The horizontal force made from the wire rope would be turned into vertical force through fixed pulley, pulling the movable handle and making it resumed to the original location. At this point, the process to bag the first fruit was completed. Then, the apparatus could be moved down to carry out the second fruit bagging process until all paper bags were run out. To prepare for the next round of bagging work, the operator needed to pull the reset rope (6), rotate the reset spiral (11), and make the screw with external thread, support holder and sliding tubes to be moved down to restore them to the initial states.

Working principle: 1. The work of the wire rope (15) is dependent upon the operation of the movable handle (17) and fixed handle with rubber sleeve (18). 2. The vertical force of the wire rope (15) is turned into the horizontal force through the fixed pulley (7). 3. Drive the unidirectional active wheel (9-A) to do a one-way rotation by wire rope (15). 4. Drive the driven wheel with internal thread (10-B) to whirl by the unidirectional active wheel (9-A). 5. The screw with external thread (12) is pushed forward by force action between the threads. 6. Drive the support holder (4) and sliding tubes (3) to be moved up. 7. Drive the plastic rings (19) of paper bag to be slid out. 8. Rubber band (20) has the effect on sealing paper bags when shrunk. 9. The installation of plectrum (2) is to ensure the paper bags being slid out individually.

Innovative characteristics of this apparatus: 1. The apparatus enables the plastic rings (19) of paper bag being slid out individually by using progressively deliver method based on the self-locking principle between nut and bolt [the driven wheel with internal thread (10-B) and the screw with external thread (12)]. 2. The apparatus enables the paper bag (21) being slid out individually by ingenious combination of spring I (1) and rotatable plectrum (2). 3. The scalable movable operation pipes [a combination structure of large operation pipe (13), fixed device (14) and small operation pipe (16)] make it possible to bag the fruit located at any positions of a tree, resulting in a reduction in workload. 4. The paper bags with plastic rings (19) and rubber bands (20) can effectively improve the efficiency of bagging. 5. This apparatus uses a lever-type handle design [working together with movable handle(17), fixed handle with rubber sleeve (18), and wire rope (15)], making the grip strength transferred to active wheel. 6. The apparatus does not require battery or any of other

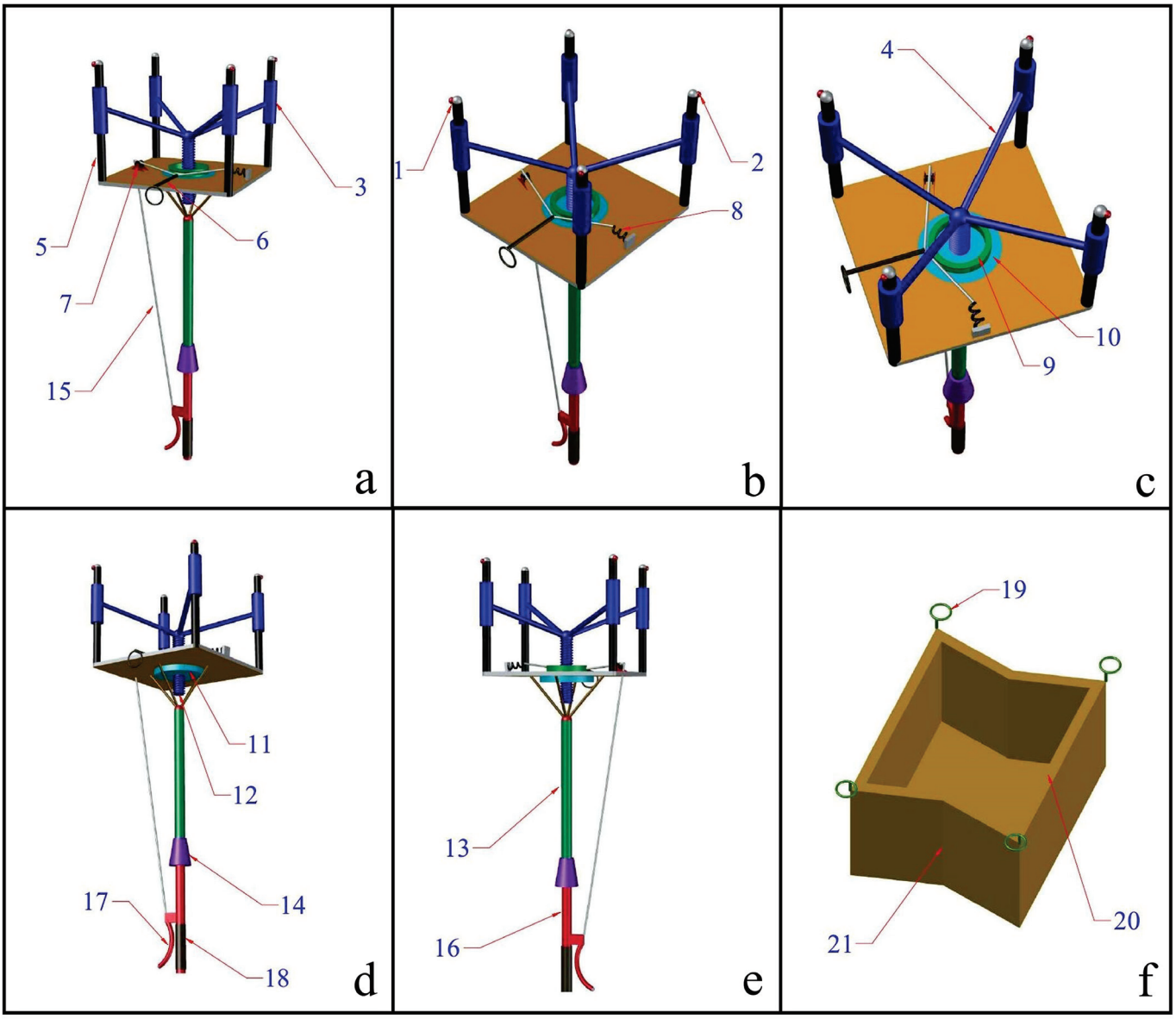

Fig. 3. The 3D design of the fruit bagging apparatus: (a-e) demonstration of apparatus in different parts; (f) demonstration of paper bag

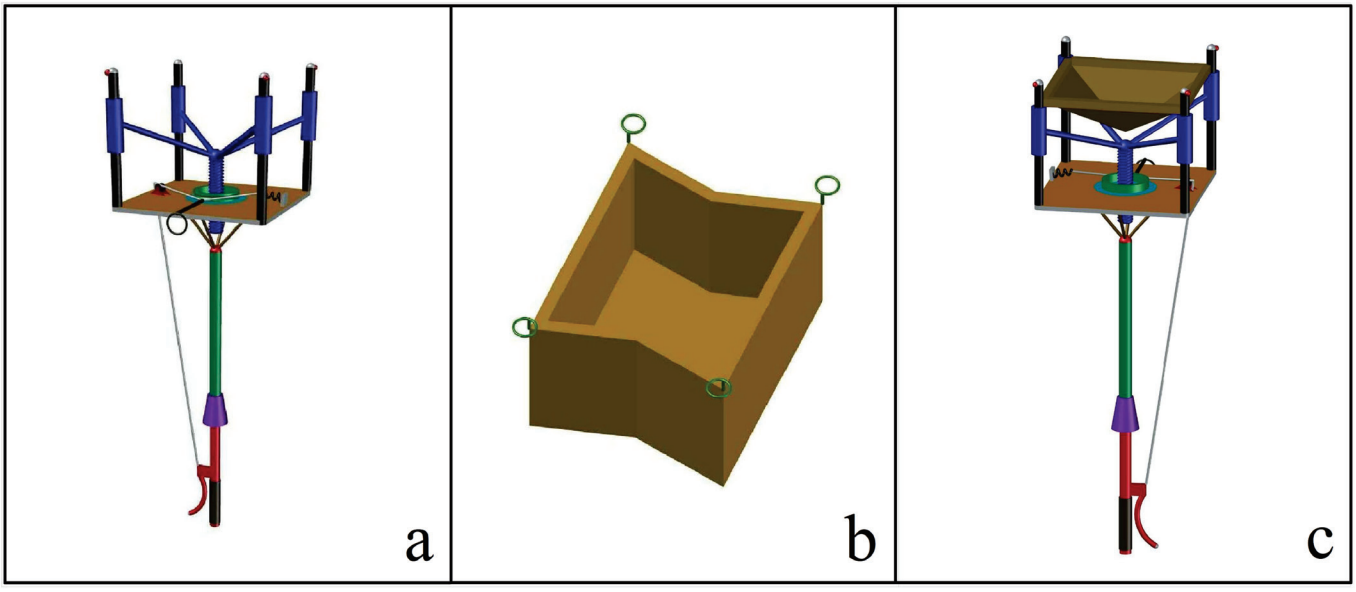

Fig. 4. The 3D design of the fruit bagging apparatus: (a) fruit bagging apparatus; (b) paper bag; (c) fruit bagging apparatus with paper bag

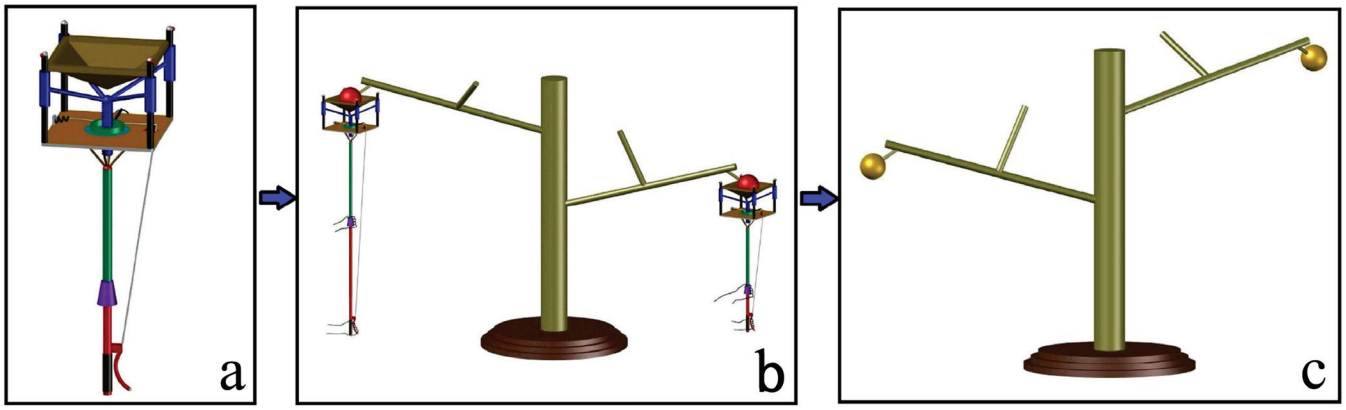

Fig. 5. The demonstrated fruit bagging processing using the fruit bagging apparatus: (a) the fruit bagging apparatus with paper bags; (b) bagging the fruit at two different positions of a tree; (c) two bagged fruit in the tree

sources of power to operate. 7. Such apparatus is portable and is of simplicity in design and efficiency in operation with a low cost.

Results and discussion

A novel portable progressively delivered fruit bagging apparatus has been developed in our study. This apparatus adopted a design similar to 'overrunning clutch' and using the self-locking mechanism between nut and bolt to achieve the paper bags being progressively delivered by a screwed pipe and slid out individually. Such apparatus is of simplicity in design and efficiency in operation. This apparatus performed very well on bagging fruit of apple and pear crops as demonstrated in Fig. 1. It was able to bag the fruit at any positions of trees. To our knowledge, this is the first semi-automatic apparatus to complete the fruit bagging process using the paper bags with rubber bands and plastic rings based on the new mechanism of operation (Fig. 4 and 5). However, one of the disadvantages of this apparatus was that an operator had to take cautious steps to ensure the paper bags with rubber bands to be opened and set on the smooth pipe correctly. Failure to do so might cause failures or errors in operation to bag fruit. There are still several improvements needed to be made to the apparatus. For example, the apparatus could be improved to handle the fruit bagging process using different bag materials such as plastic and fiber, rather than paper, and to bag the fruit in different sizes. The current apparatus was limited only to handle certain sizes of fruit. It would also be desirable that this apparatus can be modified to have the ability of harvesting fruit. Additional work on the cost-benefit analysis is needed to understand the economic benefits of using this new fruit bagging method at a commercial level.

Intellectual property

The progressively delivered fruit bagging apparatus has been authorized by the Chinese New Practical Patent (Patent No. ZL 201520795475.4).

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