Design and manufacturing of test rig for investigation of improved mechanical peeling methods of tough skin vegetables

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Abstract

One of the important preparatory stages of fruit and vegetable processing is peeling. Low efficiency of peeling leads to high losses, and poor quality of final processed products. Although several methods of peeling had been developed for some kinds of fruits and vegetables, but there is no any adopted peeling method which can respond to all producer and consumer needs. Mechanical, chemical, and thermal methods are currently in use. Mechanical peeling methods are generally preferred because of keeping freshness and low harmful effects on edible portions of products. Low level of flexibility and efficiency for different size and shape of products are main limitations. This paper presents work done to design and manufacture of a test rig for investigation of improved mechanical peeling methods. High level of flexibility and manoeuvrability of test rig for different size and shape of products and peeling tools were considered in this design.

Key words:

Design, Peeling, Vegetable, Test rig

1. INTRODUCTION

Peeling is one of the important preliminary stages of fruits and vegetables processing. The quality and quantity of final processed products are influenced by this stage. Low quality of peeling leads to high loss and low quality of final product.

Mechanical, thermal, and chemical methods are most common peeling methods of fruits and vegetables [1]. Mechanical peeling is preferred method among current peeling methods. Keeping freshness and making minimum impact on the remaining flesh of products are main advantages of mechanical methods while the high loss is considered as important limitation.

There are different kinds of mechanical peeling methods that are used for different kinds of fruits and vegetables. Using abrasive devices [2-5], knives and tools with blades [6-13] are main commercial application of this method. Application of those devices is accompanied with high losses especially when the product is of irregular shape.

In this paper a new test rig is described for investigation of different mechanical peeling methods of tough skin vegetables such as different varieties of pumpkin and melon.

Facilitate to investigate of using different peeling tools for different size and shape of products are considered as benefits of the design.

2. PEELING METHODS OF VEGETABLES

For some kinds of vegetables only manual peeling is currently used. That stage is accompanied with high losses, labour cost, and is time consuming. Current methods of peeling can be classified into three main groups: mechanical, thermal and chemical peeling. In mechanical peeling, machines use mechanical tools to peel off the skin of fruits and vegetables. For example, machines equipped with abrasive, knife and sieve drum tools are commonly used in this group. Generally, the quantity of losses in this kind of peeling is high, but the quality of final peeled vegetables such as freshness is good.

To reduce the losses during mechanical peeling, chemical peeling is considered. In this method, skins can be softened from the underlying tissues by submerging vegetables in hot alkali solution. The quantity of solution and the exposure time are different for different kinds and varieties of vegetables. Generally, lye may be used at a concentration of about 0.5-3%, at about 93ºC (2000ºF) for a short period of time (0.5-3 min) [14]. The loosened skins are washed away by high velocity jets of water or compressed air. This method of peeling reduces the losses but it has harmful effects on the flesh of vegetables and also is not environmentally friendly.

Thermal peeling as well as chemical peeling is used for thick-skinned vegetables. This method can be performed by wet heat (steam) or dry heat (flame). The steam pressure that is used in wet heat is about 10 atm and it leads to the softening of skins and underlying tissues. When the pressure is suddenly released, steam under the skin expands and causes the skin to puff and crack. Then the skin is washed away with jets of water at high pressure (up to 12 atm) [15]. Floros and Chinnan (1988) reports that the widespread application of steam peeling is due to its high level of automation, precise control of time, temperature and pressure by electronic devices to minimize peeling losses and reduced environmental pollution compared to chemical peeling [16]. In another kind of thermal peeling, some vegetables such as peppers can be peeled by dry heat (flame). In this method, vegetables are exposed to direct flame (for about 1 min at 1000ºC) or hot gases in rotary tube flame peelers. Here too, heat causes steam to develop under skins and puff them so that they can be washed away with water. Each heat treatment should be immediately followed by cooling in water. This method of peeling causes a cauterizing of the surface, wound areas, and small pieces of charred skin, which if not removed, give bad appearance to the canned product especially [15].

The capability of every peeling method as mentioned above is different. None of them can be considered as the ideal peeling method for all products. Generally mechanical methods are preferred because of keeping the freshness and low harmful effects on remaining flesh.

3. OBJECTIVE OF THE DESIGN

3.1. Adaptability for investigation of different mechanical peeling methods

Several mechanical peeling tools are currently applied. Using blades, knifes, and abrasive tools are important techniques. The possibility of investigation of these and other mechanical tools on the test rig was considered. Miller cutter, wire brush, abrasive ropes are some examples of interested peeling tools to investigate in the test rig.

3.2. Possibility of accommodation of different product size

As the variation in product size is considerable, it was attempted to design the test rig in which it would be possible to use different sizes of products. The range of product size variation was taken into account in designing the peeler head to cover the whole product in different sizes.

3.3. Possibility of peeler head position adjustment in three directions

To cover the whole surface of products of different sizes, it was necessary to enable the peeler head to adjust its position. It was desirable to adjust its position in three main directions: axial, lateral and vertical.

3.4. Possibility of installation of peeler tool in the vertical and horizontal planes

To enable investigation of different angles of acting forces on product by peeler tools, it was necessary to make possible positioning of peeler head in both the vertical and horizontal planes.

3.5. Facility of rotation of peeler tool at different angular velocities

In some methods, the rotation of peeler tool at different angular velocities is needed. Rotary blades and some abrasive tools require rotational movement to accomplish the task.

3.6. Facility of rotation of vegetable holder at different angular velocities

As the different angular velocities of product during peeling leads to different results, so the table with a product holder should be spun to achieve large range of speed variation.

3.7. Simplicity and low cost of manufacturing

Low cost of manufacturing is one of the objectives of every design. Attempts were made to reduce the number of components of the test rig. Corrosion resistance requires the use of stainless steel. Simple spring and screw mechanisms were used to provide necessary adjustments.

4. ENFORCEMENT OF THE OBJECTIVES

4.1. Chassis and Chamber

The chassis was designed as portable body equipped with one chamber at the top and expandable to two separate chambers. The spacious chamber was designed to accommodate large size products and the peeler head. The product holder was mounted at the base of the chamber and the peeler head was installed at the front side of chamber (Fig.1). There are two possible positions of the product holder, on the centre line of the peeler head and offset in the lateral direction (fig.2). Such solution was selected for two reasons: firstly to enable handling of different product size, and secondly to enable peeling by both of just one side of the peeler head.

Fig.1. Test rig

4.2. Vegetable holder

Product holder was designed as a rotating table that can carry the product (Fig.2). The product can be fixed on the disc by a three sharp blades that form a pyramid to provide access to sides and the top (fig.3).

Fig.2. Product holder and two available positions

The drive is a 24V DC motor that produces up to 270 rpm depending on supplied voltage. The DC motor is installed outside under the base of the chamber. This assembly can be easily repositioned.

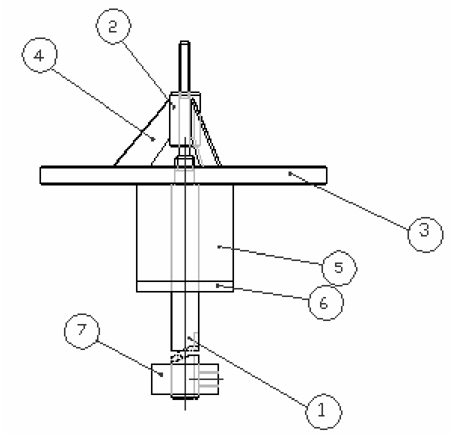

Fig.3. Product holder

1. Shaft, 2. Tube, 3. Plate, 4. Blade, 5, 7.Bush, 6.Teflon

4.3. Peeler head

The mechanism of the peeler head was designed to produce adjustment in three different directions. Two vertical rods enable movement in the vertical direction (Z axis) in front wall of chamber (fig.1). Position adjustment in the longitudinal direction (X axis) is provided by a screw and spring mechanism. Resilient ability of the holder of peeling tools was needed to able tools follow the irregular shape of different products. Spring mechanism was preferred to use in these cases. Peeler tools can be installed on two different kinds of rotary plates. The first plate (Fig.4) contains six flaps with adjustable angular position with the plane of rotation parallel to the product and second one with the plane of rotation perpendicular to the product.

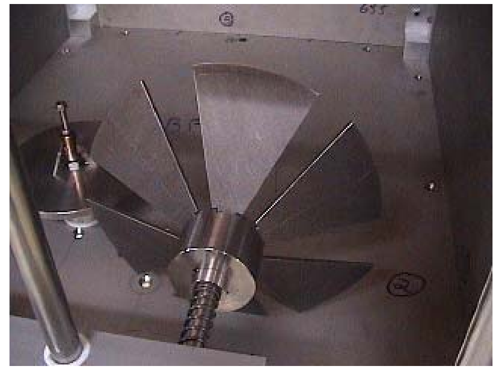

Fig.4. Peeler head (First rotary plate)

4.3.1. The first rotary plate

Each of the six flaps has ten holes placed in a spiral pattern to improve the yield of peeling production (fig.5). The angular position of flaps is adjusted from 0 to 30^{o}. Flaps are adjusted by means of a screw mechanism that contains a spring and a lock screw. The springs 7 and 12 in fig.6 enable adjustment of angular position of flaps to accommodate different shape of a product. The main shaft is driven by a DC motor that can provide angular velocities up to 300 rpm. Different peeler tools can be installed on the flaps using holes and fixtures.

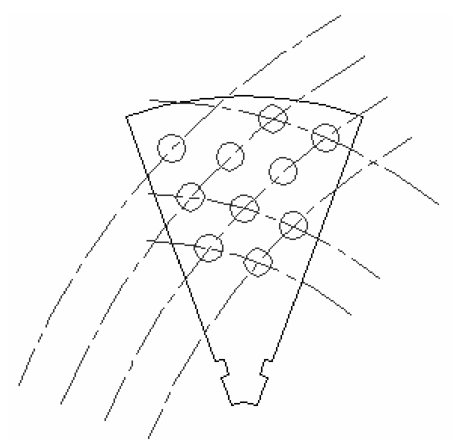

Fig.5. Flap with holes in spiral pattern

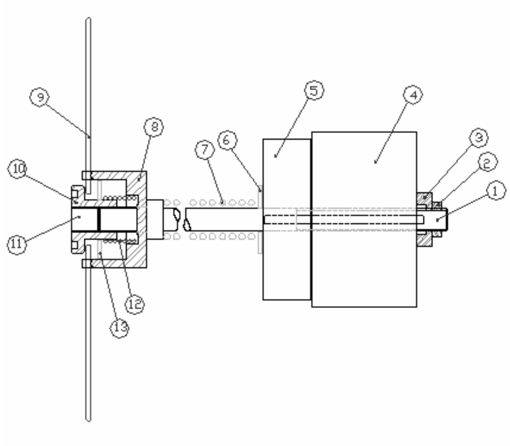

Fig.6. Details of the first rotary plate

1. Shaft, 2. Lock nut, 3. Nut, 4. Motor, 5.Block, 6,13. Washer, 7,12. Spring, 8. Bush, 9. Flap, 10. Nut Screw, 11. Grip screw

4.3.2. The second rotary plate

It is basically three solid plates that can carry peeling tools in the plane perpendicular to the product surface. It was needed to increase the penetration ability of abrasive tools for some products which have irregular groovy surface. The speed of rotation can be adjusted up to 2000 rpm. The position of motor can be also adjusted in the longitudinal and lateral directions.

5. PERFORMANCE OF THE TEST RIG

As the test environment is acidic because of product juices, stainless steel was used as the material of the test rig. In application the test rig showed good performance and versatility enabling the use of different peeling tools and handling tough skinned vegetables of different size. Flexibility of the test rig and the ease of adjustment and installation of different peeling tools including abrasive, knife and blade tools were excellent. The test rig enabled access to the whole surface of product except the area engaged with the mounting table.

The test rig has shown ability to extend the range of application for investigation of new approach mechanical peeling tools. Also some other fruits and vegetables can be investigated by using this test rig in future.

6. CONCLUSION

Mechanical peeling methods are preferred method of peeling for vegetables and fruits. Among current main peeling methods such as chemical and thermal methods, mechanical methods can keep the freshness of remaining flesh and reduce the harmful effects on flesh. High losses encourage researchers to improve current mechanical methods or to propose new methods.

The test rig for investigation of new concepts of mechanical peeling methods was designed and manufactured. Some requirements regarding to different sizes of products and different prospect peeling tools were considered in design of the test rig. High flexibility and possibility of peeler head adjustments as well as simplicity and low cost of manufacturing enabled experimental verification of a wide range of mechanical peeling devices.

The test rig proved reliable easy to use. Those capabilities enable to extend the range of test rig application for more different kinds of products in future. It is also believed that investigation of new concepts of peeling tools is easily possible on available test rig.

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