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Abrasive peeling of pumpkin

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Abstract

This paper presents new abrasive peeling methods for the pumpkin. The design of two innovative peeling devices, called abrasive pads and abrasive disks, are aimed at evenly peeling the varieties of pumpkin with uneven surfaces (i.e. Jarrahdale and Jap). The performance of the peeling process was evaluated for each method by using the Taguchi method and compared. High and equal peeling effect in convex and concave areas, and low peel losses, were the criteria of experiments.

Optimization of the results of abrasive pads indicated the possibility of the peeling effect in concave and convex areas as 4.5 and 3.83 %/min respectively with peel losses of 0.14 %/min. These results were obtained in optimum conditions of independent variables involving 0° flap angle, overlap of 26.5 mm, 140 rpm of peeler head speed, and 10 rpm of vegetable speed.

Higher peeling productivity compared to abrasive pads was achieved by using abrasive disks. Optimized results showed the peeling effect can approach 71.85 and 79.01 %/min in concave and convex areas, respectively with 1.02 %/min peel losses. The results were obtained in optimum conditions of independent variables of abrasive disks including abrasion grade of 24, vegetable speed of 5 rpm, peeler head speed of 1000 rpm, pushing force of 1.65 N, and with the specially shaped foams (shape A).

Keywords: Peeling; Mechanical peeling; Abrasive peeling; Pumpkin; Abrasive pads; Abrasive disks

1. Introduction

The quality of processed fruits and vegetables is highly dependant on the peeling stage. Poor peeling management leads to expensive finished products due to high peeling losses and low quality of finished produce. The ideal peeling method aims to remove the peel with high efficiency and low peeling losses as normally desirable (expected losses). Except for manual abrasive peeling which results in close to the ideal peeling (Somsen, Capelle, & Tramper, 2004), other current peeling methods cause high waste of flesh (unexpected losses). Mechanical, chemical, and thermal (steam and freeze) are conventional peeling methods of fruits and vegetables (Luh & Woodroof, 1988; Toker & Bayindirli, 2003). These methods use mechanical devices, caustic solutions, and heat to peel produce respectively. Each method has its benefits and limitations depending on the technique used. Mechanical methods can be preferred because of some certain advantages such as low damage to the flesh and enhanced freshness of peeled produce, low environmental pollution, and possibility of utilization of removed peel. Although there are some limitations such as low flexibility and relatively high peeling losses, the high demand of the industry encourages researchers to step up efforts to find new mechanical methods. Manual abrasive peeling can provide high flexibility for access to uneven surfaces and the lowest peeling losses (Somsen et al., 2004). Abrasive devices can provide more flexibility compared to the other mechanical peeling devices such as the knife or blade. Batch and continuous types of abrasive peelers are well-known peelers for potato, carrot, and apple (Radhakrishnaiah Setty, Vijayalakshmi, & Usha devi, 1993; Singh & Shukla, 1995). They are mostly found in the shape of a cylinder or rollers. The inner wall of the cylinder or outer layer of rollers is covered by abrasive

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carborundum. The contact between the pumpkin and the coated layers of moving parts produces the peeling action. Radhakrishnaiah Setty et al. (1993) identified the sensitivity of this type of peeler to the load as the most important limitation. Application of incorrect load causes high peeling losses (unexpected losses) and low efficiency. In addition, the incapability of these machines to follow the irregular shape of produce is another important limitation causing high peeling losses. The latter limitation is also the main cause of high peeling losses in the common abrasive peeling of pumpkin. Accessing the inner surface of grooves is accompanied with the high removal of the flesh in current peeling methods used for the peeling of pumpkin. Eliminating those limitations will increase the potential benefits of abrasive peeling tools for industrial application.

According to our knowledge, pumpkin is one of the most highly demanded vegetables in Asia and the Pacific region. Consumed parts are either fresh or processed and for any kind of application it needs to be peeled. The authors could not find any documented work on the mechanical peeling of pumpkins. Kunz (1978) patented a steam peeler of pumpkins. Pumpkin halves were exposed briefly to pressurized wet steam and then loosened peels were washed away. Thermal blast peeling of the Alagold variety of pumpkin has been investigated by Harris and Smith (1985). They achieved 89.4% peeling yield by weight after thermal blast peeling at 343 °C for 45 s. Mechanical peeling, as mentioned above, is still preferred and for the pumpkin it is currently carried out either semi-automatically or automatically. Rotating graters are used in semi-automated peelers. This process causes high peeling losses and low productivity because of the uneven shape of the pumpkin surface. Low safety is another problem because of the possibility of the rotated grater coming into contact with the operator's hands. Whole pumpkins can also be passed continuously through the automatic peelers. The floor of the peeling machine is equipped with many rotating disks. These disks could be carborundum or blade. As there is no access to the inner surfaces of grooves with available peelers in both methods, peeling off the entire groove (concave areas) leads to a high removal of flesh from other areas (convex areas) and finally high peeling losses (Fig. 1a). The most undesirable situation takes place in the case of an irregularly shaped of the whole pumpkin. Two new methods of abrasive peeling which aim to solve the above problem have been investigated and compared in this paper. The aim was to approach even peeling at different areas of the produce (Fig. 1b). Firstly, abrasive pads of different shapes and sizes were attached to flexible flaps (named abrasive pads) and their peeling effect was investigated. Secondly, disk-shaped tools made from foam (named abrasive disks) covered with different grades of abrasive particles were developed to improve peeling productivity compared to abrasive pads.

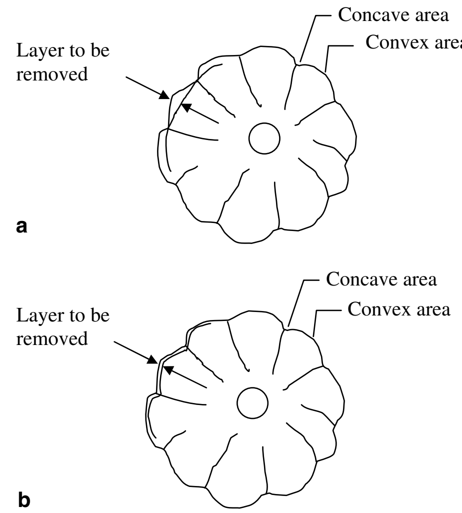

Fig. 1. The top view of pumpkin. (a) Current peeling methods and (b) proposed peeling method.

2. Experimental procedure

2.1. Materials

2.1.1. Produce

The Jap variety of pumpkin (*Cucurbitaceous family*) from different local farms around Brisbane (Queensland, Australia) was used for the experiments. The produce was randomly selected from ripe, defect-free and quite similarly sized (18–23 cm diameter) pumpkins. The peel content varied between samples and even amongst different areas of one pumpkin ranging from 0.8 to 2.1 mm. They were kept under controlled temperature and humidity at least 24 h before the test. The environment temperature was maintained in the range of 20–25 °C and 50–55% relative humidity.

2.1.2. Test rig

Experiments were conducted on a test rig that was designed and fabricated at the School of Engineering Systems, QUT (Emadi, Kosse, & Yarlagadda, 2004). The test rig was a chamber equipped with two DC motors, driving mechanisms, peeler head and vegetable holder (Fig. 2a). The vegetable holder and peeler head could be driven separately at different angular velocities. The vegetable holder was driven in an anticlockwise direction on a horizontal plane and the peeler head was driven in a clockwise direction on a vertical plane. The peeler head contained six flaps. It was applied for abrasive pad experiments. The pads were installed on flaps (Fig. 2b). The angular position of the flaps could be adjusted from 0 (perpendicular to the shaft) to 30°. Flaps were adjusted by means of a screw mechanism that contains a spring and a lock screw. This mechanism enabled adjustment of the angular position of the flaps to accommodate the irregular shape of the produce. The main shaft was driven by a DC motor that provided angular velocities up to 300 rpm. The vegetable