Experimental investigation of abrasive peeling of pumpkin

Bagher Emadi*[1], Vladis Kosse[2], Prasad Yarlagadda[3]

[1, 2, 3] School of MMME, Queensland University of Technology (QUT)
2, George Street, P.O.Box 2434, Brisbane, QLD 4001, Australia

Fax: +617 3864 1469

Bagher_Emadi@yahoo.com
V.Kosse@qut.edu.au
P.Yarlagadda@qut.edu.au

Abstracts

Peeling stage is to be considered as one of the important processing stages of pumpkin. Low efficiency of semi-manual current peeling causes high losses. Uneven surface of pumpkin requires removal of thick layer of flesh to peel off grooves in concave areas and leads to high losses. In this paper the results of experimental investigation of an improved abrasive peeling method of pumpkin are discussed. The performance of peeling process was evaluated by using Taguchi method for design of experiments and analysis of variance (ANOVA). Angular velocities of vegetable and peeler head, contact angle, and overlapped distance between a peeler unit and a pumpkin were considered as independent variables. Peeling losses and peeling efficiency in concave and convex areas were evaluated as dependent variables. The results showed close values of efficiency of peeling in concave and convex areas. Higher level of overlaps and lower levels of other independent variables resulted in high peeling efficiency and low amount of peel losses.

Introduction

One of the important stages of fruit and vegetable processing is peeling. Low efficiency peeling leads to high losses, and poor quality of final processed products. Many peeling methods are labour consuming and difficult to automate. Although a number of methods of peeling had been developed for some kinds of fruits and vegetables, but there is no any adopted peeling method which can satisfy all producer and consumer needs. Mechanical, chemical, and thermal methods are currently in use. These methods are using mechanical devices, caustic solutions, and heat respectively to peel off products. Every method has different advantages and limitations on the basis of technique used. Although mechanical method has high losses and low flexibility, it is still preferred among current methods because it maintains freshness of edible portions of product and does not damage tissue.

The use of knife, blade, lathe, and abrasive tools can be classified as part of mechanical peeling methods. Abrasive method can be implemented in a very simple way by using gloves with abrasive outside layer. Vegetables are rubbed by these gloves to remove the skin. That is common method for peeling of potatoes in small amounts. Somsen, et al. (2004) have proved that manually peeling of potatoes with using sandpaper that result in the lowest possible peel losses. They proved that these losses are normally expected losses (wanted losses).

Batch and continuos type of abrasive peelers are well known peelers for potato. They are mostly found in the shape of cylinder or rollers. The inner wall of cylinder or outer layer of rollers is covered by abrasive carborundum. The contact between potato surface and coated layers accompanied by movement of one of them, leads to peeling action. Radhakrishnaiah setty et al. (1993) admitted the sensitivity of this peeler to the load as most important limitation. Incorrect load applied causes high losses and low efficiency. Also inability of these machines to follow the irregular shape of product is definitely another important limitation.

Jasper et al. (2001) patented a peeler equipped with a rough exterior surface. Peeler abrades the outside surface of fruits and vegetables when it comes into contact with the outside surface of the fruits and vegetables. The surface roughness of peeler can be adjusted depending on the skin of vegetable to be peeled. One of the obvious disadvantages of this device is that it can only be used in a kitchen environment.

Authors could not find any documented work for mechanical peeling of pumpkin. Thermal blast peeling of pumpkin was tried by Smith and Harris (1986). They reported 11 % peeling losses. They already patented this method in 1985 and mentioned to 89.4 % peeling yield by weight after thermal blast peeling at 650°F for 45 seconds. They used Alagold variety of pumpkin. Peeling of pumpkin currently is carried out semi-manually at food processing companies. Rotating graters are used in most cases. This dangerous process causes high peeling losses and low productivity because of uneven shape of surface of pumpkin (Fig.1). As the grater can not access inside the grooves, complete peeling of the grooves (concave areas) leads to high removal of flesh from other areas (convex areas) and finally high peeling losses (see Fig.1). The worst situation will happen in the case of uncircular shape of whole pumpkin. This research was focused on a new abrasive method. The main objective was to find mechanical peeling method that efficiently peels both concave and convex area and reduce losses.

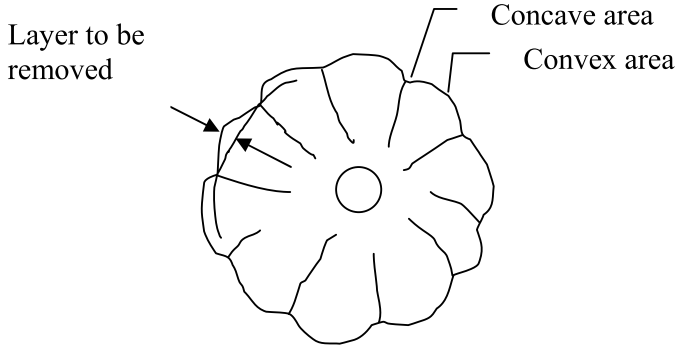


Fig.1.The top view of pumpkin

Materials and methods

The Jap variety of pumpkin (*Cucurbitaceous family*) from different local farms around Brisbane (Queensland, Australia) was used for the experiments. The products were randomly selected from ripe and defect free pumpkins. They were kept under controlled temperature and humidity for at least 24 hour before test. The environment temperature was maintained between 20-25 ˚C as well as 50-55% humidity.

The tests were conducted on a test rig that was designed and fabricated at the school of Mechanical, Manufacturing, and Medical engineering, QUT. Test rig has chamber equipped with two D.C. motors, driving mechanisms, peeler head and vegetable holder (Fig.2a). Peeler head contained six adjustable flaps which can carry the abrasive tools. Vegetable holder was designed as a rotating disc with three blades that can rotate the product at different angular velocities (Fig.2b). The test rig can accommodate products of different size and enables peeler head position adjustments in three directions.

Abrasive pads were made from foam coated with abrasive and attached to the flaps of peeler head. Cubic abrasive pads were prepared from market. They were cut in two different shapes: triangular and rectangular (Fig.2c). Those shapes were prepared in short and long lengths. Pads were glued to steel holders. To facilitate peeling, each pad was positioned at angle of 10˚ to the vertical plane. As triangular shape units were supposed to penetrate and work in grooves, so they should stay higher on the flaps of peeler head. So two different thicknesses of foam pads were considered: thicker one (35mm) and thinner one (25mm) for triangular and rectangular units respectively. On each flap, two different shapes of abrasive units were installed. Actually all pads were installed on peeler head in two different diametrical circles (Fig.2d). Units were installed on flaps on elastic suspension to enable following the shape of product. Peeler head was installed in test with an offset relative to the centre of pumpkin. Just one side of the peeler head was in contact with pumpkin during peeling to increase efficiency.

Experiments were planned on the basis of Taguchi method. L9 array was used. The experimental design of different levels of independent variables is given in Table 1. The design enabled to do experiment for four factors in three levels each. Factors were the angular velocity of peeler head (p. speed), angular velocity of vegetable holder (v. speed), angle of flaps (angle) and overlap between abrasive units and pumpkin (overlap). Experiments were carried out in four time intervals (t_1 to t_4) five

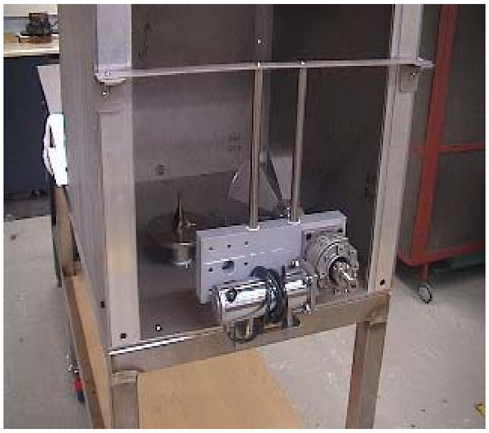


Fig.2a.The chamber of test rig (the drive motor of vegetable holder located at the beneath of chamber)

Fig.2b. The vegetable holder

Fig.2c. Abrasive units in different shapes

Fig.2d. Assembled peeler head

Table1. Taguchi experimental design for independent variables and levels

Exp.no.*	Independent variable levels			
	Angle (degree)	P.speed (rpm)	V.speed (rpm)	Overlap (mm)
1	0	140	10	21.5
2	0	200	20	26.5
3	0	160	5	16.5
4	5	140	20	16.5
5	5	200	5	21.5
6	5	160	10	26.5
7	10	140	5	26.5
8	10	200	10	16.5
9	10	160	20	21.5

*Experiments were randomly performed.

minutes each. The dependent variables were measured after every five minutes and the mean was used for assessment.
The percentage of peel losses was calculated by using the following formula (Willard, 1971):

$$\breve{y}_1 = \frac{W_1 - W_2}{W_1} \times 100$$

Where $\breve{Y}_1$ is peel losses in percent and W_1 and W_2 are weight of raw and peeled pumpkin respectively. Pumpkins were weighted before and immediately after peeling by analogue scale with 1 gram accuracy. Weight losses (W_1-W_2) were related to a circular band around pumpkin because test rig was not designed as a peeler machine to cover the whole pumpkin.
For measuring peeling efficiency, three places (120° including angle) at affected area on pumpkin for each convex and concave area were considered. The peeling efficiency after each time interval of peeling was measured at the same place and mean value in percentage was recorded. A washer with internal diameter of 15 mm was used for the measurement of efficiency. The optical judgement was made by authors. Following formula was applied for calculation of peeling efficiency (Singh and Shukla, 1995):

$$\breve{y}_2 = \frac{A_1 - A_2}{A_1} \times 100$$

$$\breve{y}_3 = \frac{A_1 - A_2}{A_1} \times 100$$

where $\breve{Y}_2$ and $\breve{Y}_3$ are percentage of peeling efficiency in concave and convex areas respectively. A_1 and A_2 are area of internal diameter of washer and remaining peel in internal diameter of washer respectively.
Taguchi ANOVA was used to calculate the contribution and prepare regression analysis.

Results and discussion

The contribution of four independent variables involving overlaps, v. speed, p. speed, and angle to three dependent variables with ignoring the interactions and on the basis of Taguchi ANOVA is shown in Fig.2. Experimental results for three dependent variables involving peel losses (%), peeling efficiency (%) in concave area, and convex areas were measured and the main effects of independent variables on them are illustrated in Fig.3 by using fitted regression models to the experimental data. Small difference for removal rate of peeling in convex areas compare to the concave can be seen as important point. As the difference is not significant, equal peeling in different areas can easily be achieved by improved design. The significant difference among independent variables was noted in concave efficiency ($\breve{Y}_2$). While overlap had considerable contribution 77 %, v. speed and angle with 1 and 3 % were not effective contributors to concave efficiency. Significantly higher contribution of overlap to the concave efficiency compared with the two other independent variables ($\breve{Y}_1$ and $\breve{Y}_3$) revealed different overlap levels can significantly change the depth of penetration of abrasive pads through the grooves in concave areas. Fig.3a shows the increasing of overlap can considerably increase the concave efficiency. The concave efficiency also is decreasing in reaction of higher angular velocities of pumpkin (Fig.3d) although its contribution was lowest. The reason was reducing the engagement time of abrasive pads with grooves for higher velocities of vegetable. The sinusoidal function of efficiency for different angles of peeler flaps specified 2.5 degree as the best angle to reach to the highest access to the inside of grooves. P. speed as the second important contributor to the concave efficiency causes reduction of the efficiency of peeling in grooves for higher velocities.

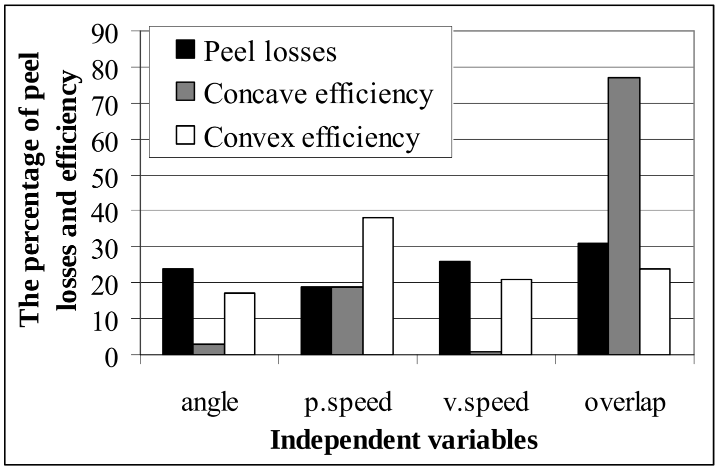
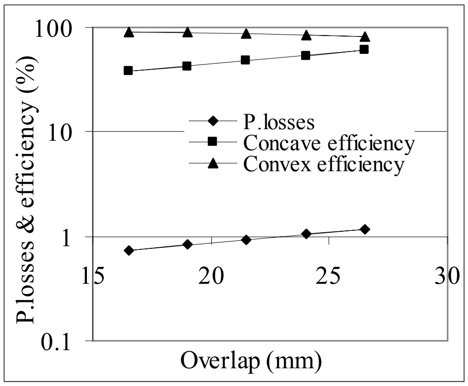


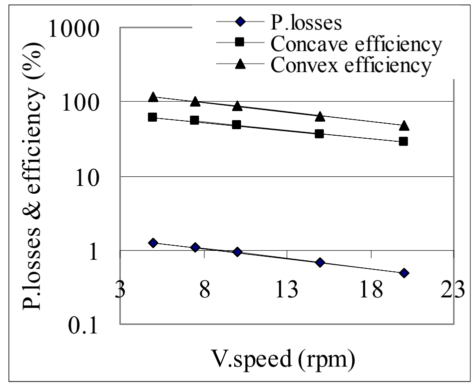
Fig2. The contribution (%) of independent variables to the experimental data

Similar to concave efficiency, angle and v.speed also had lower contribution to the convex efficiency but had smaller difference with other variables. The increasing of pumpkin velocity lead to decreasing convex efficiency (Fig.3b) in almost similar rate compare to concave efficiency. The only reason as it was mentioned previously is reducing contact time for higher angular velocities of pumpkin. Angle did show similar effect on convex efficiency but the efficiency of peel removal from convex areas was higher than grooves. P. speed showed maximum contribution (38%) to the convex efficiency compared to the other variables. While the increasing of the velocity of abrasive peeler pads causes decreasing of concave efficiency, increasing of p. speed leads to increasing of convex efficiency in lower slope. Higher velocities of peeler pads may cause the reduction of contact time between abrasive pads and the grooves of pumpkin. The increasing of overlap as the second contributor (24%) leaded to a gradual decrease of convex efficiency. For higher amounts of overlap, the efficiency of peeling in convex and concave areas was getting close. This means that higher overlap could provide the same access to the grooves as to the other areas of pumpkin for abrasive pads. Generally the independent variables except the angle did show similar main effect on peel losses as peeling efficiency especially in concave areas. Increasing of overlap and v. speed as the first two contributors (24 and 21 % in order) did increase and decrease the peel losses respectively. This behaviour can be explained as the high sensitivity of the contact rate per unit time to those variables. The peel losses are strongly related to this parameter. Higher angular velocities of abrasive pads also reduce the peel losses as the result of mentioned reason above.

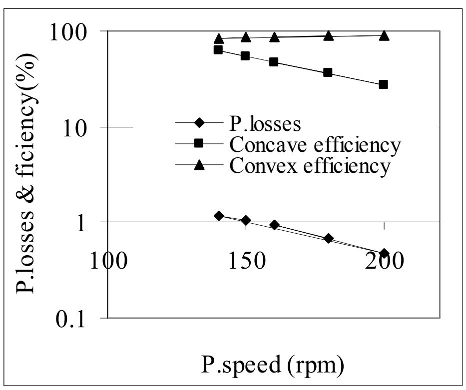
Angle also had considerable contribution to the peel losses (24%). Increasing the angle may increase the covering area of product for peeling and then increase the peel losses. However, maximum efficiency of peeling in concave and convex areas was obtained for lower angle as it seen in Fig 3d.



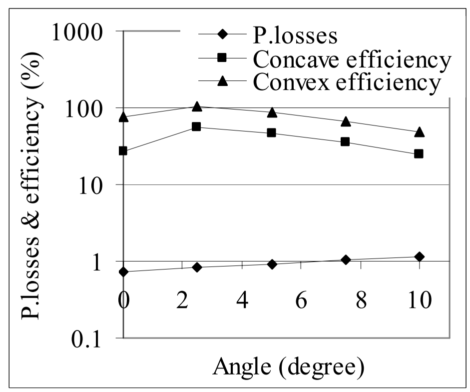
(3a)



(3b)



(3c)



(3d)

Fig.3.The main effects of independent variables on response dependent variables
3a.Overlap, 3b.V.speed, 3c.P.speed, 3d.Angle

References

Harris, H. and Smith D. A. (1985). *Methods and apparatus for thermal blast peeling, skinning, or shelling of food products*. U. S. Patent No. 4524681. U. S. Patent and Trademark Office, Washington, D. C.

Jasper, A., Hhrig, J. r., & Warren L. (2001). *Electrically – operated hand fruit and vegetable peeler*. U. S. Patent No. 6186058B1. U. S. Patent and Trademark Office, Washington, D. C.

Radhakrishnaiah Setty,G., Vijayalakshmi, M. R., and Usha devi, A. (1993). Methods for peeling fruits and vegetables: A critical evaluation. *J. Food Sci. Technol*., 30 (3), 155-162.

Singh, K. K. & Shukla, B. D. (1995). Abrasive peeling of potatoes. *Journal of Food Engineering*, 26, 431-442.

Smith, D.A.; Harris, H. (1986). Thermal blast peeler increases food processing efficiency. *Highlights of agricultural research*, 33(2), 9.

Somsen, D., Capelle, A., & Tramper, J. (2004). Manufacturing of par-fried French-fries Part 2: Modelling yield efficiency of peeling. *Journal of Food Engineering*, 61, 199-207.

Willard, M. J. (1971). A grading system of peeled potatoes. *Proc. 21st Nat. Potato Util. Conf*., July 28.