A pneumatic assisted electronically controlled continuous aonla seed removing machine

V. Eyarkai Nambi[1*], K. Thangavel[2], D. Manohar Jesudas[2]

(1. *Central Institute of Post-Harvest Engineering and Technology, Punjab, India;*

2. *Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India*)

Abstract: A continuous flow aonla (*Emblica officinalis*) seed removing equipment which consists of a fruit platform, a punching plunger, a plunger driving mechanism, a conveying system, and an electronic control unit has been developed for the removal of seed from aonla fruit. The machine was evaluated with three different plungers viz. sharp edge, hollow cutting edge, and star cutting edge in different orientation of fruit with three varieties of aonla with variable sized fruits. The study indicated that the effectiveness of the machine and the percentage fruit pulp wastage varied with the size of fruit. The highest effectiveness of the machine was observed as 93.94±0.42% with the combination of the apex end punching with hollow edge plunger in set A for NA-7a whereas Kanchan, Chakiya and NA-7b recorded higher effectiveness of 94.47±1.22%, 95.15±0.33% and 94.14±0.49% respectively in set B. The percentage pulp wastage was 4.05±0.96%, 3.22±0.20%, 3.59±0.43% and 3.93±0.12% for Kanchan, Chakiya, NA-7a and NA-7b, respectively. The percentage juice wastage for Kanchan, Chakiya, NA-7a and NA-7b was 1.48±0.25%, 1.63±0.15%, 2.47±0.32%, and 1.92±0.61%, respectively. The evaluation study concluded that apex end punching with 12 mm hollow cutting edge plunger with 15 mm bore platform would be suitable for the deseeding of aonla fruits having less than 35 mm size, while for the fruits having more than 35 mm size, plunger of 15 mm diameter with 18 mm bore platform would be suitable. The capacity of the developed machine was 90 kg/h or 3000 fruits/h. The cost of operation including the labor cost and depreciation was calculated to be Rs.0.14 per kg of fruits.

Keywords: aonla, aonla seed removing machine, deseeding, punching plunger, continuous seed removing, Indian gooseberry deseeding

Citation: Nambi, V. E., K. Thangavel, D. M. Jesudas. 2012. A pneumatic assisted electronically controlled continuous aonla seed removing machine. Agric Eng Int: CIGR Journal, 14 (2): Manuscript No. 1985.

1 Introduction

Indian gooseberry (Emblica officinalis), popularly known as aonla, is one of the oldest Indian fruits and considered as "*Wonder fruit for health*" for its unique qualities and medicinal properties (Khanna and Bansal, 1975; Patnayak, 1987). It is the richest source of vitamin C and it also contains tannin, pectin, gallic acid and fibre. Hundred gram of aonla pulp contains about 600 - 900 mg of vitamins (Pokharkar, 2005). This indigenous fruit is one of the three constituents of the famous ayurvedic preparation, *triphala* (Parmar and Kaushal, 1982; Jain and Khurdiya, 2002), prescribed for digestive disorders. Like most of the fruits, aonla is also perishable in nature and available only for a short period (Tandan and Sood, 2003). The high acidic and astringent taste limits its consumption as fresh fruit, and since it is highly perishable, there is a need for processing. Recently, a number of processed products of aonla

Received date: 2011-10-30 Accepted date: 2012-04-21

[*] **Corresponding author: V. Eyarkai Nambi,** Scientist, Central Institute of Post-Harvest Engineering and Technology, Malout - Hanumangarh Byepass Road, Abohar 152116, Punjab, India. Phone:+91 94789 08884; E-mail: eyarkainambi@gmail.com

such as aonla pulp, RTS, nectar, squash, candy pickle, sauce and dehydrated shreds are available with longer shelf life. Besides, aonla is also used in more than 50 products in ayurvedic formulations (Patnayak, 1987). Traditional methods of processing provide poor quality products with low nutrient content and limit the utilization internationally (Verma and Gupta, 2004). Hence it is necessary to develop suitable equipments for the mechanization of aonla processing and its value addition.

In the mechanization of the aonla processing and product diversification, the challenging task is to remove the intact seed from the fruit. There are few methods and equipments such as blanching the fruit for easy separation or by shredding the fruit in the shredder (Kapadi, Bhalodia and Joshi, 2001) to remove the seed. Blanching leads to loss of valuable nutrients (Sethi and Anand, 1982; Agarwal and Chopra, 2004), while shredder crushes the fruit between rollers which leads to heavy loss of juice as well as pulp and chances of seed breakage are higher. Moreover, the shredded fruit pulp cannot be used for ayurvedic product preparation (Kapadi, Bhalodia and Joshi, 2001).

A hand-operated seed remover for aonla was developed by Ganachari (2005). However, this machine can handle only one fruit at a time, which limits the capacity and makes it unsuitable for medium and large scale industries. Therefore, there is a need for suitable continuously operating machine for the removal of seed with minimum fruit damage and loss. With this aim, the present study was conducted to develop a continuous flow type machine to remove the seed from aonla and to evaluate its effectiveness with different varieties of aonla fruits.

2 Materials and methods

2.1 Selection of fruits

Three varieties of aonla viz. *Kanchan*, *Chakiya* and NA-7 were procured from the nearby village orchards of Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India. Matured fruits without skin cracks and surface injuries were chosen for this study. The selected fruits were washed with potable water to remove any extraneous matter adhering to the fruits. Among the selected varieties, geometric mean diameter of *Kanchan*, *Chakiya* fruits varied from 35 mm to 47 mm while NA-7 varied from 28 mm to 40 mm. Hence NA-7 was manually graded and the fruits of less than 35mm diameter were named as NA-7a and fruits of more than 35 mm were named as NA-7b.

2.2 Machine descriptions

The continuous aonla seed removing machine (Figure 1) consisted of a fruit platform, a fruit punching plunger, a plunger driving mechanism, a conveying system, and an electronic control unit assembled in a master frame. A moving conveyor belt with holes at the center at equal distances was designed to convey the fruit to the deseeding position where the fruit platform was fixed below the belt which also has a center hole. Above the fruit platform, a fruit punching plunger with a pneumatic actuator was fixed concentrically. The seed removing operation was carried out by a pneumatic actuator which moves the punching plunger up and down with the help of compressed air. At every punching, the seed was removed and collected in the seed collecting tray. Then the deseeded fruit was conveyed by the conveyor to the discharge end. The feeding was manual at the feeding end and the stoppage of the conveyor was optimized for easy feeding.

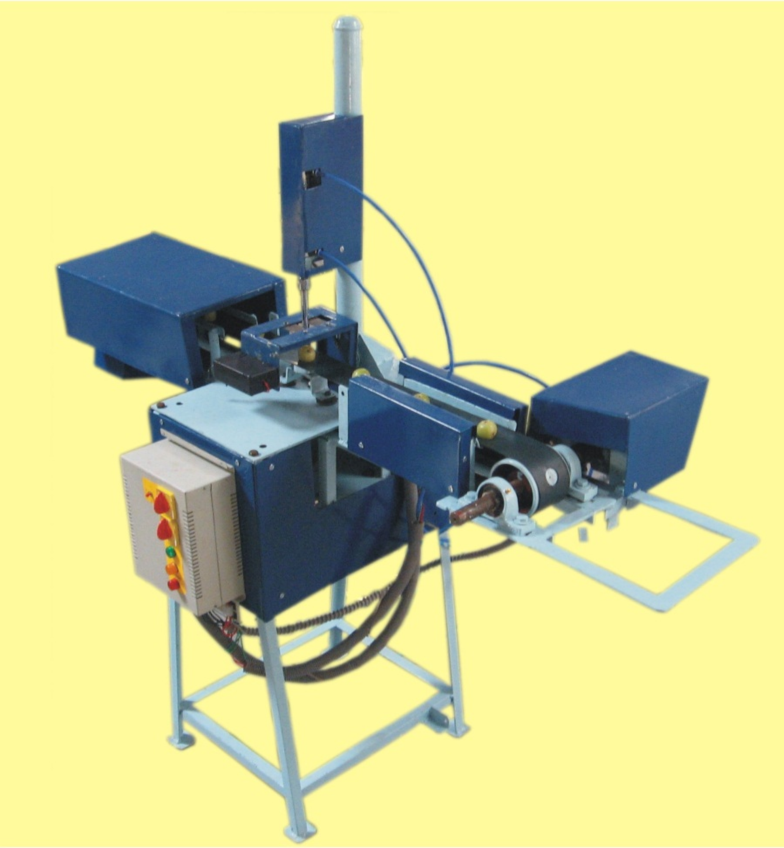

Figure 1 Continuous seed removing machine

2.3 Design and construction

2.3.1 Fruit platforms and punching plungers

The fruit platform (Figure 2) is the machine component on which the fruit rests for punching to remove the seed. It was fabricated with stainless steel solid cylinder material with centre bore having diameter equal to the size of the seed with a clearance. The top surface of the platform was filleted inwardly towards the center hole thus helps the fruit to rest comfortably without any displacement during punching. Internal cutting edge was provided along the center hole of the fruit platform which facilitates the initial tearing of the bottom surface of the fruit to reduce the deseeding load. Two sets of fruit platforms (Figure 3) were designed based on the seed size of different aonla varieties.

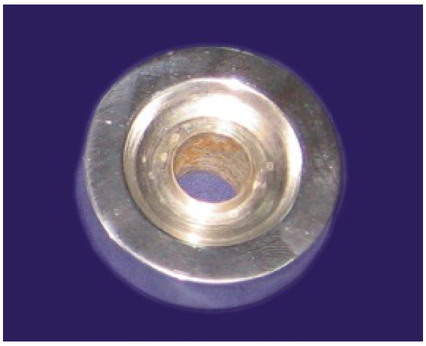

Figure 2 Pictorial representation of a fruit platform

The plunger (Figure 3) penetrates into the fruit and removes the core material of the fruit along with the seed when actuated pneumatically. The plungers were made with food grade SS with three types of bottom cutting edge viz. sharp edge with 30 degree slope, hollow cutting edge with 15 mm internal convex fillet, and star cutting edge with 60 mm carving cuts at the bottom based on empirical knowledge. The length of the plunger was 120 mm. The top head of the plunger was made with internal threads thus enabling the plunger to be attached to the pneumatic actuator. Amrish (2005) reported the maximum diameter of aonla fruit among the three selected aonla varieties was 17 mm and the highest frequency rate was between 13 - 15 mm. Based on this study, two sets of fruit platforms with punching plungers were designed. The dimensions of the platform and plunger sets are given in Table 1.

Table 1 Dimension details of platform and plunger sets

Parameter	Set A	Set B
Diameter of the center bore in fruit platform	15 mm	18 mm
radius of the fillet in fruit platform	30 mm	40 mm
Size of the fillet in fruit platform	25 mm	30 mm
Diameter of the plungers	12 mm	15 mm

The platform was provided at appropriate height, so that the core material with seed will be pushed down and could be collected in the collection tray provided below the base plate for removing the seed.

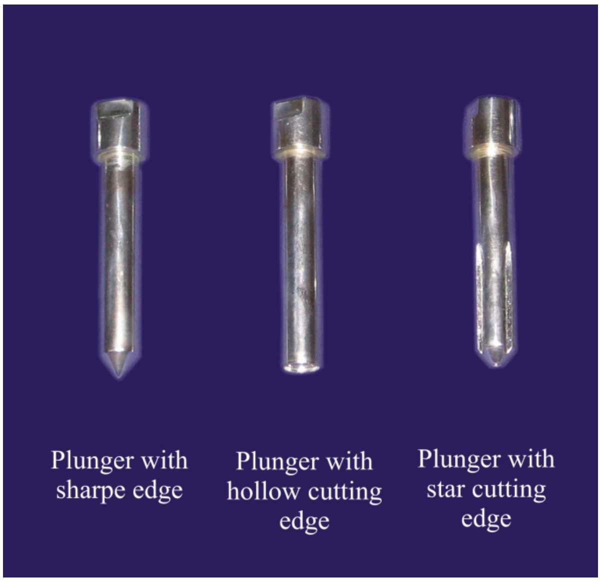

Figure 3 Pictorial representation of three types of plungers.

2.3.2 Conveying system

The conveying belt mechanism helps the machine to operate continuously. It consisted of a conveyor belt, pulleys, shaft with bearings and a power source for driving. A food grade polypropylene flat belt of width 75 mm was used to continuously convey the fruits which were directly fed or placed in the holes made on the center of the belt. There were 30 mm holes made continuously at the center of the belt at an equal distance of 150 mm to hold and convey the fruits to the plunger. Conveyor belt was guided on both sides with plates. The flat pulleys with central shaft were mounted on both sides with self-aligning roller ball bearings.

When the aonla fruits are conveyed on the conveyor belt, the fruits have to be stopped over the fruit platform instantly and positioned at the centre hole of the platform so as to enable the plunger to penetrate the fruit and to remove the seed efficiently. Hence an instant start and stop single phase AC synchronized motor of 20 kg -cm torque (0.25 hp) was used as prime mover of the conveyor. The speed of the conveyor was optimized at 40 r/min for the ease of manual feeding.

2.3.3 Plunger driving mechanism

The unit consisted of a pneumatic actuator, a solenoid valve and an air compressor. The punching plunger was directly attached with the pneumatic actuator which penetrates into the fruit when actuated. Solenoid valve controlled the displacement of the actuator. A maximum cutting force of 18 kg_f is needed to plunge the selected varieties of aonla fruits (Ganachari, 2005). As per the calculation, FESTO pneumatic actuator (DSEU32-100PA, FESTO, Germany) with 2.5 cm diameter, displacement of 100 mm and working pressure of 10 kg/cm^2 was used. A two way control valve with 6 mm orifice (IMFH-5-1/4, FESTO, Germany) was used with the working pressure of 10 kg/cm^2. The valve was controlled by 24 V DC power.

2.3.4 Electronic control unit

The belt conveyor system and the plunger driving mechanism have to be controlled precisely for the synchronization of the fruit conveying and plunging operation. The detailed circuit diagram is shown in Figure 4.

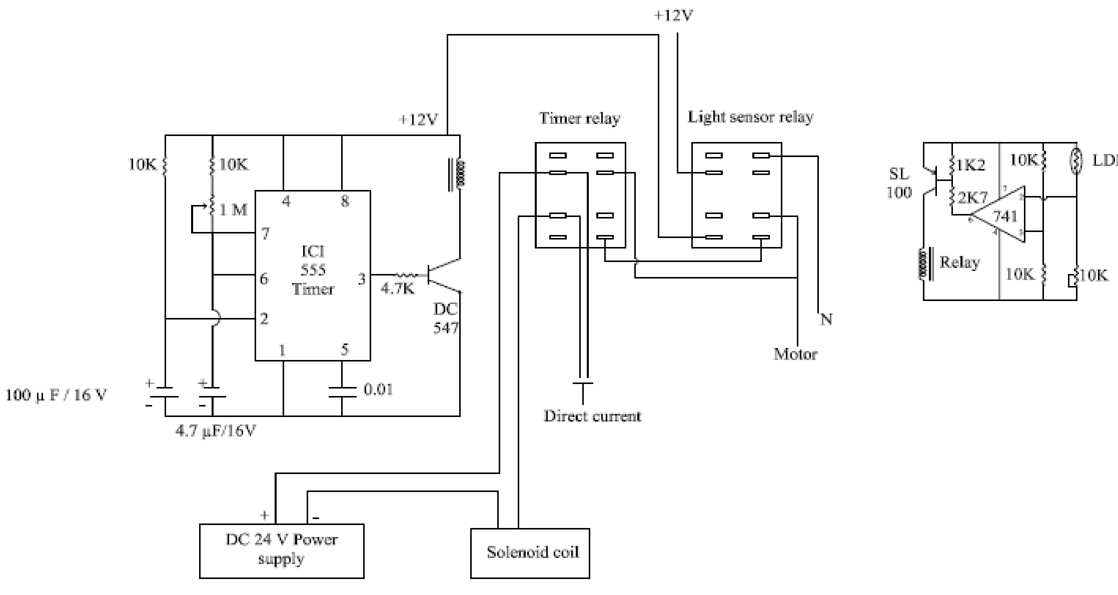

Figure 4 Circuit diagram of electronic control unit

The aonla fruit has to be sensed when it comes to the deseeding area during the conveying process and the belt has to be stopped instantly. Thus a Light Dependent Resistor (LDR) was used with a pointed light source towards the moving belt to sense the fruit. When the fruit moving on the belt obstructs the light, it leads to an instant stoppage of the motor and the belt. A timer relay circuit was introduced between the sensing unit and the power supply of the motor which will restart the motor at a particular time interval. Beside this process, the pneumatic actuator will be activated by the solenoid valve and deseeding operation will be carried out.

2.3.6 Master frame

The whole conveyor system was assembled with a fixed structure in a fixed stand arrangement. The height of the topside of the belt conveyor from the ground level was fixed at three feet for easy feeding while standing. The pneumatic actuator was fixed in a vertical column with height adjustment. After deseeding, during the return stroke of the punching plunger to remove the adhering fruit along with the plunger, a stripping plate was provided below the piston with height adjustment.

2.3.7 Experimental design

A general full factorial design was developed by using Minitab 15.0 with three varieties of aonla fruits, three types of plungers in different orientations viz. stem end, apex end, and transverse to the axis of the fruit in both sets, and with three replications. Each run was tested with 50 fresh fruits. The initial whole fruit weight, the final deseeded fruit weight and the weight of the pulp removed along with seeds were recorded. The difference in initial weight of whole fruits and the weight of deseeded fruits with seeds was taken as juice wastage. The following formulae (Ganachari, 2005) were used to find out the performance of the machine. The speed of the conveyor and the feeding rate was kept constant for all experimental trails. The complete deseeding was observed in all types of plungers. So the effectiveness of the machine was calculated based on pulp recovery with the help of the following formulae.

$$\text{Effectiveness of machine} = \frac{\text{Amount of pulp present in the deseeded fruit}}{\text{Total amount of pulp present in fruit}} \times 100 \qquad (1)$$

$$\text{Per cent fruit pulp wastage} = \frac{\text{Amount of pulp along with seed}}{\text{Total amount of pulp present in fruit}} \times 100 \qquad (2)$$

$$\text{Per cent fruit juice wastage (Weight basis)} = \frac{\text{Whole fruit weight - (Total fruit pulp + seed weight)}}{\text{Total amount of pulp present in fruit}} \times 100 \qquad (3)$$

3 Results and discussion

The deseeded fruits and the core of the pulp with seeds are shown in Figure 5. The deseeding operation for a single fruit was completed within fraction of a second. From the feeding end to the discharge end, the machine took more than a second for a single fruit. The machine was run for 30 min and the capacity was calculated as 3000 fruits/h. The developed machine was evaluated based on the Equations (1), (2), and (3). The parameters were calculated and tabulated in the full factorial design using Minitab 15.0 statistical software. All the possible combinations were tested for their significance at 1%.

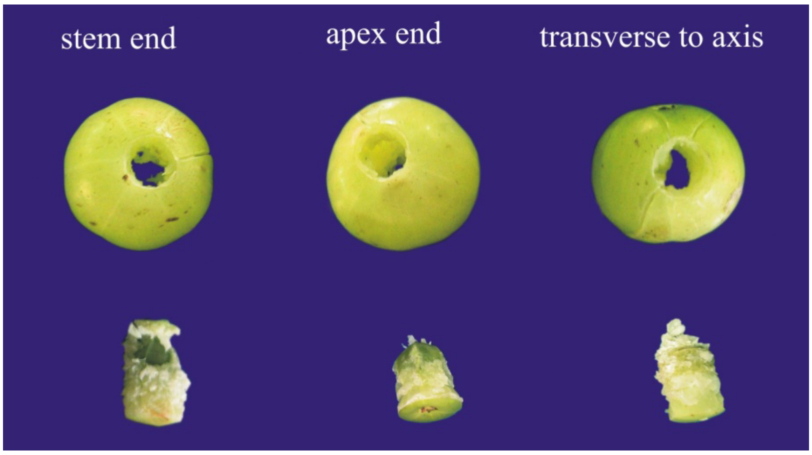

Figure 5 Deseeded fruits with different orientation using hollow edge plunger

3.1 Effectiveness of machine

The effectiveness of machine was calculated by Equation (1) in all possible combination generated in full factorial design. It was found that all the parameters and their interactions were highly significant at 1% ($P<0.01$) and the R-square value and the adjusted R-square value was 98.73% and 98.60%, respectively. The interaction plot drawn using data means is given in Figure 6. The left column of the Figure 6 shows the interaction between plunger type and the variety of fruits. The effectiveness of the machine was higher for hollow cutting edge type plunger, followed by star type and sharp edge type plunger.

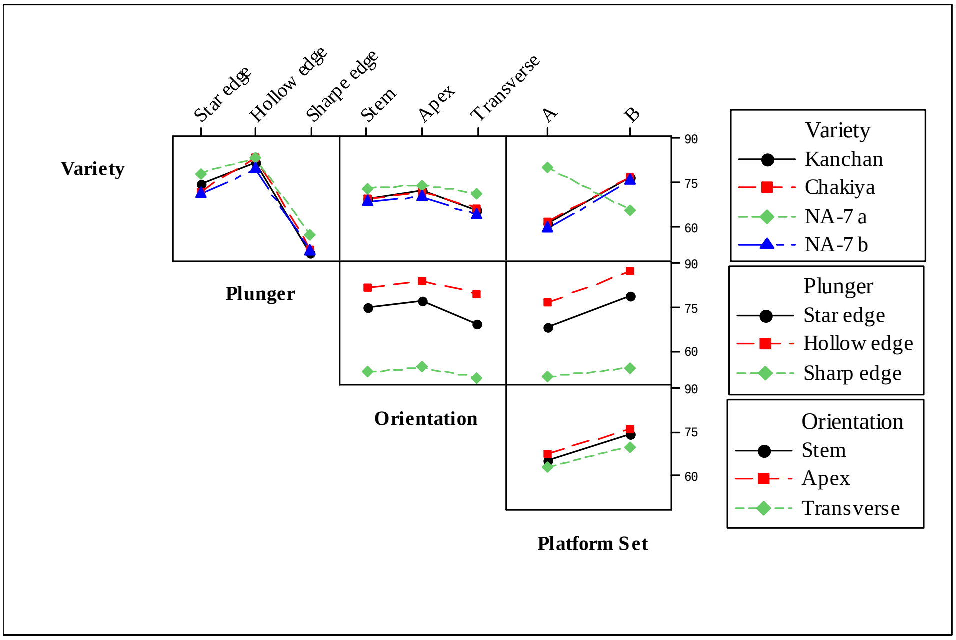

Figure 6 Interaction plot (data means) for effectiveness of machine
Note: fruits of less than 35mm diameter were named as NA-7a and fruits of more than 35mm named as NA-7b

From the graph, it could be observed that the effect of the plunger on fruit variety was more in Chakiya than the rest of varieties. Comparatively, Chakiya is bigger in size than the other varieties which might be the possible reason. The second column of Figure 6 shows two interaction effects between the orientation of punching and plunger types as well as the variety of fruit on the effectiveness. In case of the orientation of punching with plunger types, there were visible differences on effectiveness. The sharp edge plunger had lower effectiveness and hollow type plunger had higher effectiveness than the other two types. In interaction between orientation and fruit variety, apex end punching had shown higher effectiveness in all varieties followed by stem end and transverse punching. The interaction effect of the platform set with the orientation plunger type and variety were in upward trend (ie. set B had higher value than set A except NA-7a). However for NA-7a, set A had higher effectiveness than set B. So it could be conceived that plunger platform sets closely relate with the size of fruits than variety since both NA-7a and NA-7 b are from the same variety with varied sizes. Based on the effectiveness of the machine, apex end punching with hollow edge plunger with set A for the fruit of size less than 35 mm and set B for the fruit of size more than 35 mm had shown higher value. The highest effectiveness of the machine was 93.94±0.42% for NA-7a in apex end punching with hollow edge plunger with set A, whereas with set B, the highest effectiveness were 94.47±1.22%, 95.15±0.33% and 94.14±0.49% for Kanchan, Chakiya and NA-7b respectively.

3.2 Percentage pulp wastage

The percentage pulp wastage was highly significant at 1% ($P<0.01$) for all the combinations, and the R-square value and the adjusted R-square value was 98.34% and 97.90% respectively. The interaction plots were drawn with data means is given in Figure 7. The interaction plot shows the interaction effect between the independent variable on the percentage of pulp wastage. In the interaction effect between variety and the plunger type, all the varieties had followed the same trend. Among three plungers, hollow type had lower pulp wastage. Hollow plunger had more clinching effect due to its cutting edges over the other two plungers which might be the reason for the low pulp wastage. In the plunger with sharp edge, at the time of penetration there was a chance of displacement of fruits due to less contact area between fruit and plunger, which could have increased the wastage of fruit pulp. From these observations, it may be concluded that the contact area of the plunger with the fruit at the time of punching varies according to the cutting edge, and it significantly affects the pulp wastage. The second column in Figure 7 showed the interaction effects between fruit orientation with plunger and variety. Apex end punching had lower pulp wastage than the other two orientations in all three types of plungers. The aonla fruit has more pulp in apex end compared to stem end. It was observed that, the pulp wastage was less in the punching side compared to the opposite side (Figure 5). The reason may be due to the bottom cutting edge provided in the fruit platform.

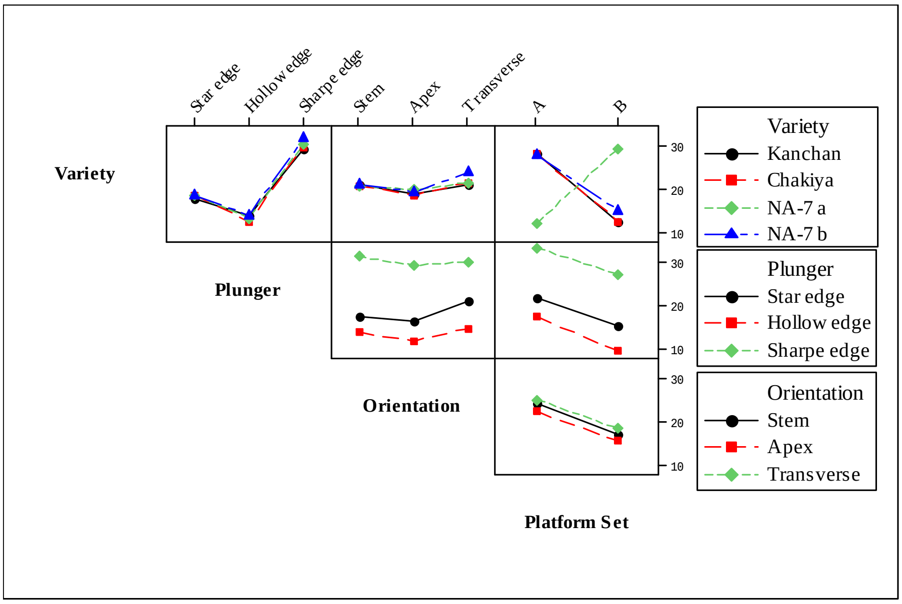

Figure 7 Interaction plot (data means) for percentage pulp wastage

Hollow cutting edge with the apex end punching had the lowest pulp wastage than other combinations. The interaction effect between orientation and variety showed that the variety of fruit had less effect on pulp wastage. The interaction effect of plunger sets with orientation and plunger type showed that set A had higher pulp wastage than set B. But in case of fruit variety except NA-7a, all the other three had low pulp wastage with set B, and for NA-7a, set A had lower pulp wastage. From these observations, it could be concluded that the size of fruit had more significant effect on the percentage pulp wastage rather than fruit variety. The lowest percentage of pulp wastage (3.59±0.43%) was observed for NA-7a in apex end punching with hollow type plunger in set A. In apex end punching with hollow type plunger in set B, the lowest percentage pulp wastage were 4.05±0.96%, 3.22±0.20%, and 3.93±0.12% for Kanchan, Chakiya and NA-7b respectively.

3.3 Percentage juice wastage

The percentage juice wastage was also highly significant at 1% ($P<0.01$) for all the combinations, and the R-square value and the adjusted R-square value was 97.53% and 96.77% respectively. The interaction plot drawn with data means is given in Figure 8. Since the percentage of juice wastage is an interlinked parameter with the other two parameters viz. effectiveness of machine and percentage pulp wastage, the interaction effect of variety, plunger type and orientation on juice wastage had shown the same trend with earlier observations on effectiveness and percentage pulp wastage. The sharp edge plunger showed higher juice wastage compared to the other two plungers in different orientation and also with different plunger sets. Due to less contact area with fruit, the sharp cutting edge needs more force to penetrate and this might have led to higher wastage of juice. In case of percentage juice wastage, NA -7a followed the same trend with the other three varieties; however, in case of effectiveness and percentage pulp wastage for NA-7a, plunger set A was effective.

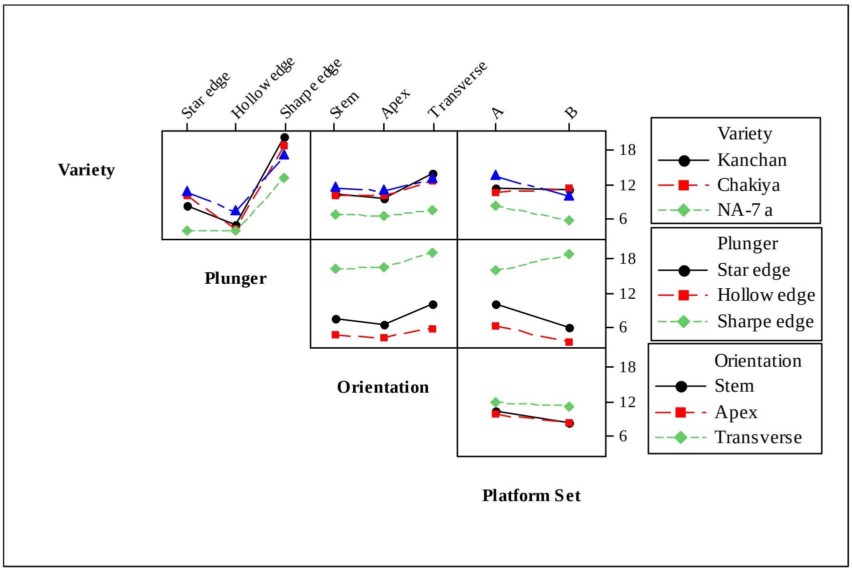

Figure 8 Interaction plot (data means) for percentage juice wastage

From these observations, it could be concluded that fruit variety had more significant effect on percentage juice wastage than fruit size. The lowest percentage juice wastage for Kanchan, Chakiya, NA-7a, NA-7b in apex end punching with hollow cutting edge in plunger set B were 1.48±0.25%, 1.63±0.15%, 2.47±0.32%, and 1.92±0.61% respectively.

3.4 Interactive effect between the evaluation parameter

The Figure 9 shows the three way relationship between the effectiveness of machine, percentage pulp wastage and percentage juice wastage.

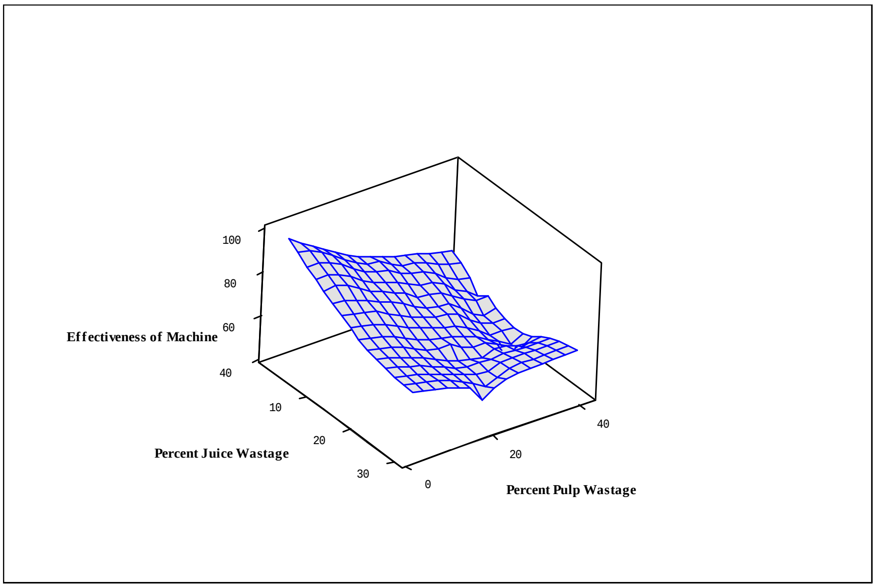

Figure 9 Surface plot between effectiveness, percentage pulp and juice wastage

It could be observed from the graph that the effectiveness of the machine was inversely proportional with fruit pulp wastage and juice wastage.

3.5 Comparison with existing methods

Presently, deseeding of aonla fruits is carried out manually by cutting the fruit into small pieces, which is a time and manpower consuming process. By considering the time of operation, depreciation of machine and labour charges, the cost of operation has been calculated Rs. 0.14/ kg of fruit for mechanical deseeding, while the cost of operation was Rs. 7/ kg of fruit for manual deseeding.

4 Conclusions

A continuous flow aonla seed removing machine has been developed and was evaluated. The effectiveness of the machine and fruit pulp wastage varied with the size of fruit. Apex end punching of aonla fruit with 12 mm hollow cutting edge plunger with 15 mm bore platform would be suitable for the fruits having less than 35 mm size, and for the fruits having more than 35 mm size, plunger of 15 mm diameter with 18 mm bore platform would be suitable for effective deseeding. The capacity of the developed machine was 3000 fruits/h. The cost of operation including the labor cost and depreciation was calculated to be Rs.0.14 per kg of fruits. Future research may be carried out on effective continuous feeding mechanism to increase the capacity of the machine.

References

Agarwal S., and C. S. Chopra. 2004. Studies on changes in ascorbic acid and total phenols in making aonla products. *Beverage and Food world,* 31(5): 32-34.

Ganachari, A. 2005. Design and development of an equipment for aonla seed removal and studies on value addition through osmotic dehydration. Unpublished M.E. (Ag) Thesis. Tamilnadu Agricultural University, Department of Food and Agricultural Process Engineering, Coimbatore, India.

Jain, S. K., and D. S. Khurdiya. 2002. Studies on juice extraction of Aonla (emblica officinalis gaertn.) cv. 'Chakaiya'. *Journal of Food Science and Technology*, 39 (5): 515-516.

Kapadi, S. S., V. B. Bhalodia, and D. C. Joshi. 2001. Motorized shredding-cum-stone extracting machine for aonla. *Beverage and Food World*, 28 (8): 43-44.

Khanna, P. and R. Bansal. 1975. Phyllantidina and phyllantine from Emblica officinalis leaves fruits and in vitro tissue culture. *Indian Journal Experimental Biology*, 13: 82.

Nambi, V. E., and K. Thangavel. 2007. A continuous seed removing equipment for Aonla fruit. Filed for the grant of patent No. 1711/CHE/2007 under IPR India.

Parmar, C., and M. K. Kaushal. 1982. *Emblica officinalis: Wild Fruits*. Kalyani Publishers, New Delhi, India: 26-30.

Patnayak, N. 1987. Medicinal importance of aonla (Emblica officinalis) varieties for processing. VI International Symposium on Medicinal and Aromatic Plants, XXII IHC.

Pokharkar, S. M. 2005. Development and performance evaluation of aonla shredding machine. *Beverage and Food world*, 32 (3): 52-53.

Sethi, V., and J. C. Anand. 1982. Physico-chemical and microbiological quality of carrot and amla preserves. *Indian Food Packer*, 36 (5): 38-43.

Tandan, D. K., and S. Sood. 2003. Postharvest handling, storage and transportation of fresh aonla. National seminar on production and utilization of anola, Salem, Tamil Nadu, India.

Verma, R. C., and A. Gupta. 2004. Effect of pre-treatments on quality of solar-dried amla. *Journal of Food Engineering*, 65(3): 397-399.