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Development and Evaluation of a Grader for Round Fruits and Vegetables

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ABSTRACT

Grading of agricultural produce especially the fruits and vegetables has become a perquisite of trading across borders. In India mostly fruit growers grade the fruits manually. Human operations may be inconsistent, less efficient and time consuming and costly during shortage of labour in peak seasons. Hence, a low cost grader suitable for round fruits and vegetables based on the principle of centrifugal force and gravitational force was developed. The grader was evaluated for lemon, sweet orange and onion. Average sphericity of lemon, sweet orange and onion were 0.99, 0.97 and 0.86 respectively. The developed grader was tested and evaluated at different feed rates. The grader was also evaluated at different speeds of the rotary disc like 10, 30, 50 and 70 rpm. Efficiency and capacity of the grader was optimized with respect to feed rate and disc speed. Optimum speed of the rotary disc during highest separation efficiencies was 30 rpm for all fruits and vegetables tested. Overall efficiency of grader for lemon, sweet orange and onion were 86%, 75% and 70% respectively. Maximum grading efficiency was obtained for lemon because of its more sphericity.

Key words*: Feed rate,Geometric mean diameter, Grading efficiency, Rotary disc, Sphericity, Separation efficiency.*

Grading refers to classification of cleaned products into various quality fractions depending upon the various commercial values and other usage. Grading of agricultural produce especially the fruits and vegetables has become a perquisite of trading across borders. In India mostly fruit growers grade the fruits manually. Manual grading is generally carried out by trained operators who consider a number of grading factors and fruits are separated according to their physical quality. Manual grading is costly and grading operation is affected due to shortage of labour in peak seasons. Human operations may be inconsistent, less efficient and time consuming. Farmers are looking forward to have an appropriate agricultural produce-grading machine in order to alleviate the labour shortage, save time and improve graded product's quality. Grading of fruits is a very important operation as it fetches high price to the grower and improves packaging, handling and brings an overall improvement in marketing system. The fruits are generally graded on basis of size and graded fruits are more welcome in export market. Grading could reduce handling losses during transportation.

Mostly manual grading is followed in many parts of the country and such grading results in low capacity operation, more time consuming, besides higher cost, less efficiency and contamination of quality. Especially, manual grading is laborious process. These problems and drawbacks could be overcome by the use of mechanical graders. Besides it would help to have uniform grade and quality. Therefore there is need to introduce commercial fruit and vegetable grading equipment at the farmer level itself, so as to facilitate a farmer to process the food himself.

Pawar*et al.* (2015) fabricated grading machine for onions and potatoes. During the performance test, only peel loss was observed in onion grading while in case of potato grading more damage occurred and hence the machine was only suitable for onion grading. Borkar*et al.* (2013) optimized the grading efficiency of a grader by the input factors viz., feed rate and down slope of grader to 35.84 kg/min and 30.21% respectively for apple and 31.91 kg/min and 22.57% for pomegranate.

Different mechanical and electronic sorting systems have been developed and are used. Despite some advantages of electronic and computer graders, there are many disadvantages in these approaches including high initial and operating costs. Not much work has been carried out to design simpler mechanical graders for fruits and vegetables. The available mechanical graders are specific in handling the products and usually will not work for other products. Using the knowledge generated in the area of mechanical grading, an attempt has been made in the present study to develop a grader capable of handling various round fruits and vegetables based on size and shape.

MATERIAL AND METHODS

Fruits namely lemon and sweet orange were selected for this study. Onion was chosen under vegetable category. For design of the grader, basic principal dimensions of commodity to be graded namely length, width and thickness were considered. The dimension along the axis of the fruit or vegetable was considered as the length. The other dimensions such as width and thickness were measured on mutually perpendicular planes to the length in such a way that the larger dimension was considered as width and the smaller one as thickness.

Size and shape

For one hundred lemons, a (major), b (intermediate) and c (minor) diameters were measured using a vernier caliper having a resolution of 0.01mm. The geometric mean diameter (GMD) was calculated as follows.

$$GMD = (abc)^{1/3}$$

The sphericity (Ô) was calculated using the following formula and the average values were reported.

$$\varnothing = \{(abc)^{1/3}\}/a$$

Similar procedure was adopted for sweet oranges and onions.

Development of the grader

Design of the grader is based on combined centrifugal and gravitational force (Fig.1). The gauge belt is arranged above the periphery of the rotary disc. The clearance between the gauge belt and rotary disc is gradually increased. When the round fruits or vegetables are fed on to the rotary disc through the feed hopper, the rotary disc imparts centrifugal force to them. The rotary disc takes power from an electric motor. When the fruit or vegetable attains centrifugal force, it moves towards the periphery of the disc. The fruit or vegetable rolls along the gauge belt due to the tangential force and according to their dimensions would be graded and allowed to pass through gaps to the collecting trays.

Main components of the grader were; frame, rotary disc, gauge belt, shaft, bearings, pulleys, Electric motor, feed hopper and receiving trays. Material used for different components, its specification and quantity are given in Table 1.

Evaluation of grader

The developed grader was tested and evaluated at different feed rates. The grader was also evaluated at different speeds of the rotary disc. Efficiency and capacity of the grader was optimized with respect to feed rate and disc speed. The maximum power requirement for grading onions was 0.2 hp and this power requirement calculated for grading onion was considered to be the maximum compared to lemon and sweet orange. As a matter of safety, a 0.5 hp motor was selected.

Grading efficiency

A Vernier caliper with a resolution of 0.01mm was used to measure the linear onion dimensions of well-classified plus misclassified bulbs for each outlet. The grading efficiency of the outlet was calculated according to the following formula (Singh, 1980).

$$E_s = \frac{Wt - Wu - Wo}{Wt} x100$$

Where,

E_s = Separation efficiency of particular grade, %

W_t = Total weight of the sample of a particular grade, (kg)

W_u = Weight of the undersize in that sample, (kg)

W_o = Weight of the oversize in that sample, (kg)

The overall efficiency of the fruit grader was calculated by the following formula.

$$E_o = \frac{Wto - Wtm}{Wto} x100$$

Where,

E_o = Overall efficiency of the fruit grader, %

W_{to}= Total weight of the sample of all grade fruits, (kg)

W_{tm} = Total weight of the misclassified fruits in all the samples, (kg)

RESULTS AND DISCUSSION

The efficiency of the grader for lemon increased with feed rate from within a speed range of 10-30 rpm of rotary disc (Fig.2) and decreased

Table 1. Specifications of the developed grader.

Sl. No.	Material	Specification	Quantity
1	MS Sheet	20 gauge (0.86 mm)	2.25 m^2
2	MS Sheet	3 mm	0.36 m^2
3	Nuts & Bolts	3/8 inch (200 mm)	8 No.
4	Nut & Bolts	¼ inch (50 mm)	9 No.
5	Roller bearings	3 cm diameter	2 No
6	MS Angular	1.5 inch (38.1 mm)	6 No.
7	MS Shaft	3.00 cm	2 No.
8	MS Flat	2.54 cm	4 No.
9	Pulleys	7.50 cm and 10.00 cm diameter	1 No. 1 No.
10	V belt	B21	1 No.
11	Surface material	Cotton cloth	0.36 m^2
12	Surface material	Plastic sheet	0.36 m^2
13	Red oxide	500 ml	1 No.
14	Paint	500ml	1 No.

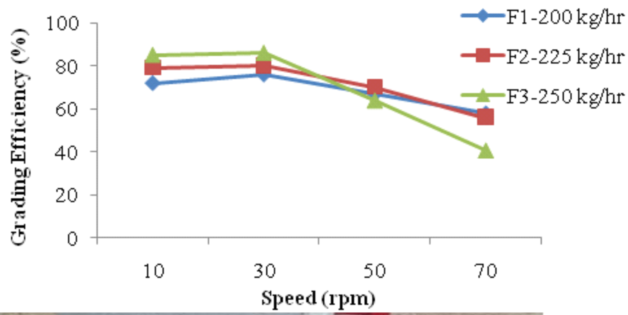

Figure 1. Grader for round fruits and vegetables

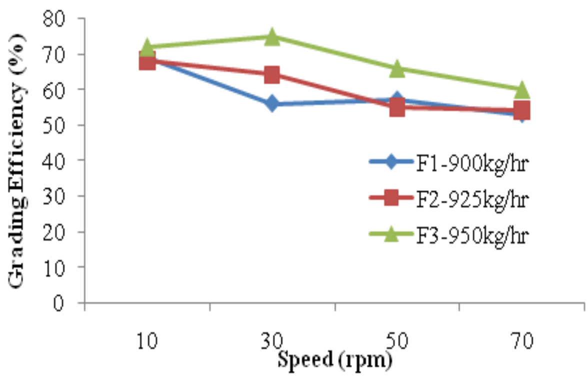

Fig. 2. Effect of rotary disc speed on grading efficiency of lemon.

Fig. 3. Effect of rotary disc speed on grading efficiency of sweet orange.

with further increase in disc speed. The maximum efficiency of the grader for lemon recorded was 86 % at a speed of 30 rpm. As the speed is increased beyond 30 rpm, the efficiency decreased at all feed rates dramatically and the lowest efficiency noted was 41 %.The efficiency of the grader decreased at higher speeds which indicated that the fruits move very fast and had no time to move along the gauge belt. Hence 30 rpm was found to be optimum speed for lemon on mild steel surface.

For sweet orange, the maximum efficiency recorded among the different feed rates was 75 % at a feed rate of 950 kg/h and a speed of 30 rpm (Fig.3). The efficiency at a feed rate of 950 kg/h increased up to 30 rpm and decreased up to 70 rpm which indicated that 30 rpm was the optimum speed. The decrease in efficiency indicates the increase in mismatch of fruits. The mismatch of fruits into different categories may be due to small centrifugal forces and gravitational forces that cause fruits to roll around itself and move to the next outlet rather than to the accurate outlet. The lowest efficiency observed was 53 % at a feed rate of 900 kg/hr. The cutting damage noted for sweet oranges was within permissible limits.

The maximum efficiency recorded among the different feed rates of onion (Fig. 4) was 70% at a feed rate of 700 kg/hr and a speed of 10 rpm. The lowest efficiency observed was 49 % at a feed rate of 650 kg/hr and a speed of 70 rpm.The damage of the produce which includes removal of outer peel occurred at speeds beyond 30 rpm.The damage might be due rupture of outer cells caused due to friction caused during rolling and at the time of passing the clearance of gauge belt. The losses occurred to the fruits were less than 1% at 10 rpm without any bruising or abrasion (Pawar*et al.* 2015).

CONCLUSIONS

The optimum efficiency recorded for lemon on mild steel sheet was 86% at a feed rate of 250 kg/hr and a speed of 30 rpm.The optimum efficiency recorded for sweet orange on mild steel sheet was 75%at a feed rate of 950 kg/hr and a speed of 30 rpm.The optimum efficiency recorded for onion on mild steel sheet was 70% at a feed rate of 700 kg/hrand a speed of 10 rpm.Overall efficiency of grader for lemon, sweet orange and onion were 86%, 75% and 70% respectively. Maximum grading efficiency was obtained for lemon because of its more sphericity.

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