ABSTRACT
Grading is a vital as well as pre requisite step in marketing and processing of fruits. The normal practice in India is to grade manually on size basis. One person grades 200 kg of fruits in a day. In order to increase the output of fruit grading and save time and labour, a sapota fruit grader based of divergent roller type principle was designed and developed. The best combination of roller speed, its inclination and roller gap was found to be 223 rpm, 4.5° and 38 to 64 mm, respectively for highest efficiency of 89.5%. The capacity of machine was 1440 kg/hr and costed Rs.11,450/- (without electric motor).

Key words: Sapota fruits, Grader, Performance, Efficiency, Design and development, Fruit grader
Fig. 1: Grading machine

Fig. 2: Grading rollers

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maximum size of fruits. The rollers were coated by powder coating for getting the smoothness and avoid damage to the fruits, while travelling between the rollers. The guiding channels were made up of 20 gauge G. I. sheet. The overall dimensions of guiding channels were 1160 mm X 90 mm, respectively. The guiding channels were placed between the outer sides of the rollers on each pair to avoid mixing of fruits feed to the rollers and to avoid dropping outside. The provision was made to adjust the slope of guiding channels.

**Feeding unit:**

The feeding hopper was fabricated in trapezoidal shape (Fig. 3). The feeding unit/hopper was made using 20 gauge G. I. sheet. The overall dimensions of the feeding unit were 960 mm X 1020 mm X 260 mm. A felt cloth (hotlone) was fixed over the hopper as cushioning material to avoid damage and bouncing of fruits.

**Collection unit:**

The increasing spacing between the rollers from feed end to the rear end on both sides allowed the fruits to grade into three different sizes. These size graded fruits dropped on collection platform. The collection platform was partitioned into three compartments on each side, at the distance of 350 mm, 510 mm and 350 mm, respectively from feed end to the rear end. The overall dimension of the collection platform was 1220 mm X 1000 mm. X 200 mm. The collection unit was made to get three different grades of fruits by using wall / divider. These dividers make the channels for the separation of fruits when the fruits dropped on the collection platform. A felt cloth (hotlone) was fixed over the receiving ramp as cushioning material and avoid damage to fruits due to impact during collection.

**Power transmission unit:**

A power transmission (unit) frame was fabricated by using M.S. angle and fitted at the bottom of the main frame (Fig. 4). The power transmission unit was divided into two parts, i.e. sprockets-chain arrangement and speed reduction unit. The grading rollers were driven by 1-hp single-phase electric motor through sprocket chain arrangement. Speed reduction required was achieved by using two stage reduction in rpm using different diameter pulleys. The grading of sapota was done at five different speeds viz., 111, 133, 166, 223 and 334 rpm. The sapota grading machine consisting the above four units is shown in Fig. 4.
Testing:
The machine was tested for sapota fruits (var. Kalipatti). Five different speeds of rollers (111, 133, 166, 223 and 334 rpm) were combined with three different gaps of rollers (35 – 61, 38 – 64 and 41 – 67 mm) and five different angle of inclination of the rollers (0°, 1.5°, 3.0°, 4.5° and 6.0°) were taken for the study. The grading machine was operated by keeping two parameters constant at a time and changing third one. Thus giving seventy five combinations of machine parameters. The time required for grading and weight at each combination was recorded and the capacity was calculated. By comparing mean diameter of the fruit collected in any grade to that grade gap range, size of fruits under or over the gap range was decided. The test was replicated three times and average grading efficiency was calculated. The grading efficiency was calculated by using relationship given by (Singh, 1980)

\[
ES = \frac{Wt - (Wu + Wo)}{Wt} \times 100 \quad \ldots \ldots (i)
\]

where,
- \(ES\) = Grading efficiency, %
- \(Wt\) = Total weight of sample (g)
- \(Wu\) = Weight of under size fruits (g) and
- \(Wo\) = Weight of over size fruits (g).

**RESULTS AND DISCUSSION**
The results of the experiments in terms of mean values of capacity and grading efficiency at different speeds, inclinations and gaps between the rollers have been discussed. The relationship between inclination and speed of rollers on capacity at different gaps shown in Fig 5. It shows that the capacity increased with increase in inclination of the machine and speed of rollers for all gaps between the rollers. Capacity also increased with increase in the gap between the rollers. The maximum
capacity was found at gap $G_1$ (41 mm to 67 mm) whereas, the minimum capacity was found at gap $G_2$ (35 mm to 61 mm). The maximum capacity of 1728 kg/hr was found in case of combinations $S_1 I_5 G_3$ ($S_5 = 334$ rpm, $I_5 = 6.0^\circ$ and $G_3 = 41$ to 67 mm) and the minimum capacity of 508 kg/hr was found combinations $S_1 I_1 G_3$ ($S_1 = 111$ rpm, $I_1 = 0^\circ$ and $G_1 = 35$ to 61 mm). The results of capacity are in agreement with Nevkar (1990) and Patil and Patil (2002).

The relationship between inclination of the machine and speed of the roller on efficiency at different roller gaps is shown in Fig.6. The grading efficiency of the machine varied between 51.5 to 89.5 %. The best combination of roller speed, inclination of rollers and roller gap of the machine for grading sapota fruits at high efficiency was found to be $S_3 I_1 G_2$ ($S_4 = 223$ rpm, $I_1 = 4.5^\circ$ and $G_2 = 38$ to 64 mm) which gave 89.5 % grading efficiency with a machine capacity of 1440 kg/hr.

**Conclusion:**

The divergent roller type fruit grader was found to have a maximum capacity of 1728 kg/hr. The efficiency of the machine varied between 51.48 to 89.5 %. The maximum efficiency was found at gap $G_1$ (38 to 64 mm) whereas the minimum efficiency was found at roller gap $G_1$ (41 to 67 mm). The optimum capacity for maximum grading efficiency (89.5 %) of the machine was 1440 kg/hr. The results of efficiency were also found in agreement with Nevkar (1990) and Patil and Patil (2002).

**Fig. 6 : Effect of inclination and speed of rollers on efficiency at various gaps**

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