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DEVELOPMENT OF A COMMERCIAL SCALE FRUIT GRADER FOR SPHERICAL COMMODITIES

S. Mangaraj, *Principal Scientist, ICAR-CIAE, Bhopal (MP)*
R K Pajnoo, *Chief Technical Officer, ICAR-CIAE, Bhopal (MP)*

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Abstract: *The normal practice in India is to grade fruit manually on size basis. One person grades 200 kg of fruits in a day. Human operations may be inconsistent, less efficient and time consuming. In order to increase the output of fruit grading and save time and labour, a commercial scale step wise expanding pitch fruit grader was developed for grading of different spherical fruits having equivalent diameter of 30 mm to 145 mm. The principle involved is sizing through one-dimensional separation of fruits by carrying the fruits on an expanding pitch flap conveyor. The main components of the fruit grader are grading unit, horizontal belt conveyor and elevator feeding unit. Testing of the fruit grader showed overall grading efficiency of 93-96 % for apple, sweet lemon and orange fruits. The capacity of the grader was 5 t/h at grading conveyor speed of 7 m/minute and there was no damage to the fruits while grading. The cost of the grader is Rs. 1 lakh and only 1 hp motor has been used to operate the grader. The advantages of this fruit grader are high level of versatility, high capacity, low energy consumption, low cost, minimal handling and tumbling of the fruits. The cost of operation and energy consumption of grader is Rs. 0.30/kg and 0.25 Kw/t, respectively. This grader has been designed to meet the requirements of large industries, installation at mandi and orchards because of high capacity (5t/h) and high efficiency (97%). The grading operation adds value of the fruits by making it uniform size lot and fetch high price in the market giving profit to the produces/processors.This is useful for orchard man growing various fruits in the same field at different seasons. Hence, the fruit grader would be used through round the year for grading of multiple commodities.*

Key words: *Fruit grader, apple, sweet lemon, orange, grading efficiency, commercial.*

Introduction

India accounts for 12% of the total world production of fruit crops and ranks second with the production of 89 million tons (IHD, 2015). A group of unit operations like washing, drying, grading, waxing, packaging and pre-cooling are performed after harvesting the fruits before they reach the ultimate users (Ingle, 1997; Mangaraj and Singh, 2006). In this group of unit operations grading is one of the most important operations, which involves overall balance assessment of all these properties of the fruits, which affects its acceptance as food and as working substance for the processor (O'Brien, 1968; Mangaraj *et al.*, 2009). It adds value of the product and gives better economic gains to the producer. Grading of fruits and vegetables on the basis of size and shape is important for marketing uniform high quality produce (Mangaraj et al., 2005; Mangarajand Varshney, 2006). At present fruits are graded manually which is labour intensive and time consuming. Besides, manual grading has a wide variation in the sizes of the graded fruit (Varshney et al., 2002). In view of above considerations commercial scale mechanical fruit grader is a useful option. Mechanical grading of the fruits and vegetables is done based on weight, size and shape, while principle of optics is involved in colour sorting (Von Beckmann and Bulley, 1978).

Various researchers have developed machines for sorting fruits and vegetables into different grades. Omre (1999) developed grader which grades the fruits and vegetables based on their unit weight. Mango grader developed by Mandhar and Senthil Kumaran (1999) sorts the fruits on the basis of rolling of mango around the axis of minimum mass inertia. Ingle (1997) developed a simple electric divergent roller grader suitable for lemon, sapota, onion, potato, pomegranate and a like

fruits and vegetables. Asraf et al. (2007) designed and developed a spool type mobile grader machine, using locally available indigenous materials. The main components of the grader are take-in conveyor, grading unit and take-away conveyor, all mounted on a main frame. The average grading charges were about Rs.4 /100 kg of produce. Ukey and Unde (2010) developed a sapota fruit grader based on divergent roller type principle with grading efficiency of 89.5%. The capacity of machine was 1440 kg/hr and costed Rs.11, 450/- (without electric motor). Keeping these factors in view, a commercial scale stepwise expanding pitch fruit grader based on the principle of changing the flap spacing along the length of movement of fruits is a viable option to cater the need of growers cultivating fruits and Mandi's at which various horticultural commodities are marketed.

Materials and Methods

Development of fruit grader

The principle involved is sizing through one-dimensional separation of fruits by carrying the fruits on an expanding pitch flap conveyor. The conveyor consists of two tracks of 19 mm pitch hollow pin conveyor chain connected by steel flap and lifting wheel tracks. The main components of the fruit grader are feeding unit, horizontal belt conveyor, grading unit and fruit collection trays.

Feeding unit: The feeding system is provided for loading of fresh commodity to be graded as well as for removal of unwanted products before they are fed to the horizontal conveyor. It is a rectangular trough of 1100 mm × 660 mm with sidewalls of 110 mm high was made with 1 mm thick stainless steel sheet. Trough dimensions were decided to hold maximum of 200 kg of fruits at a time. The feeding system was designed to allow adjustable inclination of the rectangular trough of the feeding unit in order to ensure natural movement or rolling of fruits towards the horizontal belt conveyor by gravity and also to sort out the damaged and unwanted fruits during grading. A stainless steel trapezoidal section which acts as a bridge between feed table and feed conveyor was hinged to a rectangular trough. At the end of rectangular trough, the base, side walls and outlet of feed table leading to horizontal conveyor was cushioned with 5 mm thick polyfoam and 1 mm thick rubber sheet.

Horizontal belt conveyor: The fruit grader is provided with a horizontal belt conveyor for constant and uniform feeding of fruits in to the grading unit. The length of the conveyor belt was 640 mm and width 500 mm. Fruits fed from feed table to the feed conveyor are carried and dropped on to the fruit grading bed. The speed of the conveyor belt has been synchronized with the grading unit so that there is smooth movement of fruits from conveyor to grading unit. The system of feeding prevents any overriding of fruits during the process of grading.

Grading unit: The grading unit consists of two parallel Hollow pin chains and matching sprockets, Steel flaps and rollers, Wheel track, Collection tray, Power source, reduction gear unit, Power transmission system and Fruit collection tray etc. In the grading unit the width of the main frame was 680 mm and effective width of the grading bed was chosen as 500 mm keeping in view the maximum width of the conveyor belt available for feed conveyor. Two tracks of hollow pin roller chains of 19 mm pitch were mounted on eight sprockets supported on each end thus making a continuous conveyor. The 19 mm pitch of the hollow pin conveyor chain was selected for optimization of material and also considering the full load of the fruits on grading. Steel flaps were welded with 10 mm diameter steel rods on both ends. Upper end of the flap steel rod was fixed into the chain's hollow pins on both sides. At lower end of the flap resting wheels of high-density polyethylene (HDPE) were mounted on both ends of steel rod with the help of circlips. The effective length of grading unit was calculated as 2500 mm by providing five exposures of spacing between two flaps for a particular fruit to fall in a particular grade. The grader has the provision to separate fruits into five grades by adjusting flap spacing between 30 to 145 mm. This also

overcome/reduced the momentum of the fruits at the feeding point of the grading system.

Fruit Collection Tray: Fruit collection tray of 2500 mm × 700 mm made of 1 mm thick stainless steel sheet was partitioned into five chutes with a 250 mm high wall to collect different grade fruits into separate containers. Collection tray was cushioned with 5 mm thick polyfoam which was glued on base as well as on stainless steel sidewalls to prevent the fruit from bruising and subsequent spoilage. The collection tray was supported with angle iron and welded at a slope of 7° with horizontal, which facilitated the flow of materials.

Power Transmission System: A geared motor reduction unit of 0.7 kW with output speed of 20 rev/min was mounted on separate frame and used to drive the grading unit and feed conveyor. Power was supplied to the grading unit and feed conveyor with the help of V-belts and pulleys.

The plan view of the fruit grader and the complete developed machine has been shown in Fig.1 and 2, respectively.

Testing of the fruit grader

Testing of fruit grader was done with sweet lemon, orange and apple fruits (Fig. 3). In the case of sweet lemon and orange, care was taken to present all the sizes of fruits. The harvested fruit is loaded in the feeding unit thereafter the horizontal belt conveyor takes the produce and ensures constant and uniform feeding of fruits into the grading unit. About 100 kg each fruits were used for grader testing. The grading unit facilitates the sorting of commodity in five different size lots uniformly by changing the flap spacing along the length of movement of fruits. The graded fruits are finally collected in trays from different chutes.

The flap spacing's for Grade I, Grade II, Grade III, Grade IV and Grade V were adjusted as 60, 70, 80, 90 and 100 mm, respectively with the help of track height adjustment mechanism. The above flap spacing's were decided on the basis of physical dimensions of fruits. Graded fruits were collected in trays from different chutes. The random samples of 50 fruits were drawn from each grade. The physical dimensions of the individual fruit like major 'a', intermediate 'b' and minor 'c' were measured with vernier and weight of the individual fruit was measured with electronic balance. The average geometrical mean diameter (GMD) was calculated.

Determination of grading Efficiency

From the GMD values all those commodities which are not included (undesirable in that particular grade) in a particular size category, whether oversize or undersize, were considered as misclassified produce. The number of the misclassified produce were calculated from the geometrical mean diameter data. The above procedure was replicated, three times and average separation efficiency of a particular grade was calculated using the following formula:

$$E_s = \frac{N_t - N_u - N_o}{N_t} X\ 100$$

Where,

E_s= Separation efficiency of a particular grade, %

N_t= Total number of sample of a particular grade

N_u = Total number of undersize in that sample

N_o = Total number of the oversize in that sample

The overall Grading efficiency of the grader was calculated by the following formula[16]:

$$E_s = \frac{N_{to} - N_{tu}}{N_{to}} X\ 100$$

Where,

E_s = overall separation efficiency of the grader, %

N_{to} = Total number of the sample of all grade commodity

N_{tm} = Total number of the misclassified commodity in all the samples

Results and Discussions

The average geometrical mean diameter of fruits samples collected in four grades are presented in Table-1. The average geometrical mean diameter of sweet lemon, orange and apple discharged from the collecting chutes of Grade I, Grade II, Grade III and Grade IV were 56.36, 68.19, 77.95, 88.17, and 97.42; 57.30, 67.82, 75.90, 86.53, and 95.81; 55.62, 66.79, 78.12, 85.70, and 94.93 respectively. It may be seen that average geometrical mean diameter of fruits discharged to a particular grade chute was less than

the adjusted flap spacing for sweet lemon, orange and apple.

The number of misclassified fruits, separation efficiency for different grades and overall separation efficiency of the machine is presented in Table-2. In the case of sweet lemon, the maximum number of misclassified fruits was 10 (7 undersize and 3 oversize) in the entire grade. The separation efficiency of particular grade ranged from 94.00% (Grade II) to 98.00% (Grade V) for sweet lemon. The overall separation efficiency of sweet lemon was 96.00%. In the case of orange, the maximum number of misclassified fruits was 15 in with 9 undersize and 6 oversize. The separation efficiency of particular grade ranged from 92.00% (Grade II and grade III) to 96.00% (Grade V) for orange. The overall separation efficiency of orange was 94.00%. The overall grading efficiency of apple was found to be 93%. The overall separation efficiency of apple and orange was less than that of sweet lemon due to the lesser sphericity of orange and apple. The capacity of the grader was 5.00 t/h at grading conveyor speed of 7 m/minutes and there was no skin, cutting and bruising damage to the fruits while grading. The cost of operation of grader was found to be Rs. 300 per ton.

Conclusions

The commercial scale fruit grader has been designed to meet the requirements of large industries, installation at mandi and orchards because of high capacity (5t/h) and high efficiency (93-96%). The grader has the provision to separate round or nearly round fruits namely, sweet lemon, orange, apple etc with equivalent diameter of 30 to 145 mm into five grades by adjusting flap spacing. This is useful for orchard man growing various fruits in the same filed at different seasons.

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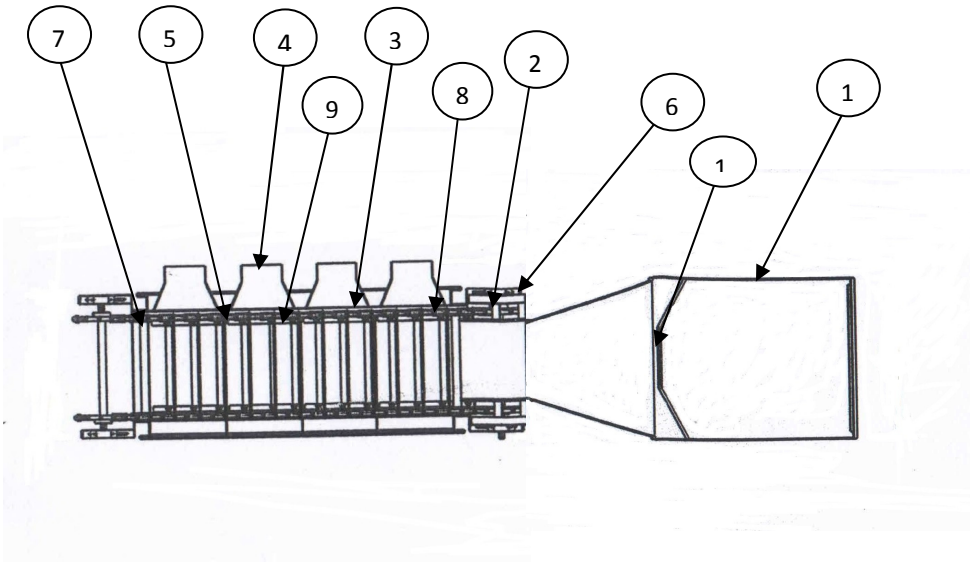

Sl. No.	Part/Assembly name
10	Adjustable gate
9	Track height adjustment mechanism
8	Hollow pin chain
7	Flap Mechanism
6	Reduction gear motor
5	Chain conveyor assembly
4	Fruit collection trays
3	Grading system
2	Belt Conveyor
1	Feeding unit

Fig. 1: Plan View of the Commercial Scale Fruit grader

Fig. 2: Developed Commercial Scale Step Wise Expanding Pitch Fruit grader

Fig. 3: Testing of Commercial Scale Fruit Grader with Orange

Lists of Tables

Table 1: Average geometrical mean diameters of graded sweet lemon, orange and apple in different grades

Fruits	Geometrical mean diameter, mm				
	Grade I (60)*	Grade II (70)	Grade III (80)	Grade IV (90)	GradeV (100)
Sweet lemon	56.36	68.19	77.95	88.17	97.42
Orange	57.30	67.82	75.90	86.53	95.81
Apple	55.62	66.79	78.12	85.70	94.93

***** Numerical value in parenthesis is spacing between the flaps in mm

Table 2: Number of misclassified fruits and separation efficiency of the fruit grader with sweet lemon, orange and apple

Size category	No. of fruits in category	No. of Misclassified fruits		Separation efficiency of particular grade, %	Overall separation efficiency, %
		Undersize	Oversize		
Sweet lemon					
Grade I	50	---	2	96.00	96.00
Grade II	50	2	1	94.00	
Grade III	50	2	---	96.16	
Grade IV	50	2	---	96.00	
Grade V	50	1	---	98.00	
Orange					
Grade I	50	---	3	94.00	94.00
Grade II	50	3	1	92.00	
Grade III	50	3	---	94.00	
Grade IV	50	2	1	92.00	
Grade V		1	1	96.00	
Apple					
Grade I	50	---	4	92.00	93.00
Grade II	50	3	2	90.00	
Grade III	50	3	1	92.00	
Grade IV	50	2	1	94.00	
Grade V		2	---	96.00	