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A Low Cost Divergent Type Apple Grader for Kashmiri Apples

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A B S T R A C T

The state of Jammu and Kashmir has the distinction of producing best quality apples with highest proportion among all member states of Indian state. These apples are usually graded by manual labours of all age groups. The heavy reliance on manual labours and their non-availability at peak season has increased the overall cost of apple production. The existing mechanical graders are bulky, costly, imported and non-portable. A low cost motorized portable apple grader was fabricated with feeding hopper, conveying rollers, flow reduction device, main frame, power transmission system and collecting trays. The apples were graded into four grades viz., Grade I- less than 50 mm, Grade II - 50-60 mm, Grade III - 60-70 and Grade IV above 70 mm. The apple grader has overall dimensions of 1460 mm x 842 mm with a cost of Rs. 12,000. The optimum conditions for the efficient working of apple grader occurred at roller spacing of 56-82 mm and hopper inclination of 30 degree resulting in a grading efficiency of 84.2 % at 100 rpm. The machine has a throughput capacity of 530 Kg per hour. The grader resulted in cost saving of Rs. 1782/- per tonne and 17 fold reduction in grading time in comparison to manual method of grading. The cost analysis of grader revealed that break-even point occurred at 424 hours per annum with an annual utility of 225 tonnes and the corresponding pay-back period of apple grader was one year.

Introduction

Apple is the pomaceous fruit in the rose family (Rosaceae) under *Malus domestica* species. India is second largest producer of fruits (64 MT) accounting for 10 % of world fruit production (Pawar and Khodke, 2016). The apple production in India is about 2896.6 ('000) MT, constituting about 2.9 % of world apple production. The state of Jammu and Kashmir (J&K) has the distinction of producing high quality apples to the tune of 2003.07 metric tonnes, sharing about 69.15 % of total production (Horticulture Statistics Division, 2016). Apple is considered as common entity, consumed on regular basis by people from different cultures and nations (Strapatsa *et al.*, 2006). In post-harvest operations, grading of apples is one of the most critical operation that defines the quality market price trading and commercial purpose utilisation. This also ensures fairness to both buyers and sellers. The apple fruit varies in size to a larger extent, even from the same plant and same variety. This variation necessitates the grading of apples after harvesting. Grading is sorting of apples into different grades according to the size, shape, colour and volume to fetch high price in the market. The most common method of grading employed for apples is manual method by using labour of different age groups. The manual method is manifested with low efficiency, costly, slow, time consuming, labour intensive, uneven, requirement of skilled labour and errors in judgement for same apple fruit at different intervals (Narvankar and Jha, 2005). On an average, one skilled labour grades about 200-300 Kg per day. The existing mechanical apple graders have failed to fill the vacuum and ameliorate the problems caused by manual method of apple grading. These graders usually employ complex grading arithmetic's like fuzzy logic (Kavdir and Guyer, 2003), image processing (Rosli *et al.*, 2012), artificial neural network (Jhuria *et al.*, 2013), computer vision (Ohali, 2011), multi-class kernel support vector (Zhang and Wu, 2012) and colour mapping (Dah-Jye-Lee *et al.*, 2011). They are very costly, imported, bulky, requires large areas, non- portable and need technical skills for their operation and maintenance. A divergent roller mechanism was developed to test evaluate the fruit grading based on size for sapota (Patil and Patil, 2002), onion (Anonymous, 2003) and lemon (Nevkar, 1990). The divergent roller grading method is fast, accurate and causes little damage with appropriate insulation material in comparison to other methods of grading of fruits (Ukey and Unde, 2010).

Therefore, a study was carried out to design and develop a low cost motorized divergent roller type apple grader to find the solution of the problems due to manual apple grading in order to reduce the grading cost responsible for increasing the cost of production of apples.

Materials and Methods

Measurement of physical parameters

The design of the machine necessitates the determination of physical dimensions of apples. A sample of Golden Delicious apple variety was selected and their length and diameter were measured with the help of Vernier Calliper with 0.001 mm accuracy. The mean length, width and sphericity were found to be 61.0 mm, 67.08 mm and 1.06, respectively (Table 1).

$$\text{Sphericity} = \frac{(l * b * t)^{\frac{1}{3}}}{l}$$

Fabrication of components of machine

A divergent roller type apple grader was designed and developed in the workshop of college of agricultural engineering, SKUAST-K, Shalimar in 2017-18. The basic structure comprised of feeding hopper, conveying rollers, main frame, power transmission system and collecting trays (Fig. 1).

Feeding hopper

The feeding hopper was designed and developed in trapezoidal shape to provide feasible conditions for easy movement of apples towards grading/conveying rollers. The hopper was made from 20 gauge G.I. sheet. The dimensions of the feeding unit were 682 mm x 470 mm x 2 mm (Table 2). The inclination of the feeding hopper was made adjustable to accommodate different varieties of apples. An insulating material with soft cloth was fixed over the hopper to avoid bouncing and damage to the surface of apple.

Grading/conveying unit

The grading unit consisted of main frame, conveying/grading rollers and flow reduction device (stopper). The main frame was designed in rectangular shape (1460 mm x 842 mm x 50 mm) to provide a support to grading/conveying rollers. The grading/conveying rollers have a diameter of 50 mm and length of 1250 mm.

The rollers were coated with smooth insulating material to prevent the damage to the surface of apples. The two pairs of grading rollers were placed side by side on the main frame exactly below the end of feeding hopper. The grading/conveying rollers were rotated by belt and pulley arrangement provided at the rear end while feed end was attached on revolving bearings of 30 mm diameter. The gap between the rollers was made adjustable to accommodate apples of different varieties.

Power transmission unit

A power transmission unit was placed below the main frame and consists of belt-pulley mechanism and speed reduction unit. The rollers of grading were driven by 1 HP electric motor through belt and pulley mechanism. The reduction in the speed was necessary to ensure the easy movement of apples over the grading rollers. The reduction was achieved by using different diameter pulleys.

Collecting trays

The diverging action of grading/conveying rollers from feed end to rear end allowed the fruits to grade into four different sizes. The graded fruits fell downwards towards the collection platform. The platform was partitioned into four rectangular compartments, each having a dimension of 535 mm x 340 mm x 2 mm from feed end. The dividers were provided in between to grade the apples into different sizes. The collection trays were cushioned to prevent the damage to apples due to impact during collection.

Test procedure

The developed prototype (Fig. 2) was tested for apple (Golden Delicious) at three roller spacing (54-78 mm, 56-82 mm and 58-86 mm) and feeding hopper inclination (25^O, 30^O and 35^O). The response parameters were measured in terms of grading efficiency (%) and time of grading (s) (Table 3). The preliminary experiments revealed that roller speed of 100 rpm ensured smooth flow of apples from feed end to rear end. Therefore, the speed was kept constant at 100 rpm. The time required for grading and weight at each combination was recorded to calculate the capacity of the developed prototype of apple grader.

The mean diameter of the apples collected in a particular grade was compared to grade gap range in order to decide whether the apples are under or over the gap range. The test was replicated three times and average grading efficiency was calculated. The grading efficiency was calculated by using relationship given (Singh, 1980).

$$\text{Grading efficiency (\%)} = \frac{G_t - G_m}{G_t} \times 100$$

Where,

G_t = Total number of apples; G_m =Total number of misclassified apples

Results and Discussion

The results of the experiments in terms of response parameters (Table 3) at different spacing of rollers and inclination angle of hopper have been discussed.

Table.1 Physical dimensions of apple relevant to apple grader design

Variety	Length, l (mm)	Width, b (mm)	Thickness, t (mm)	Sphericity
Golden Delicious	55	66	63.7	1.10
	58	63	64.1	1.06
	54	60	61.2	1.07
	59	58	59.1	0.99
	47	52	53.2	1.07
	58	64	64.9	1.07
	62	71	70.3	1.09
	70	75	74.2	1.04
	68	72	71.3	1.03
	63	77	76.4	1.14
	68	74	73.1	1.05
	70	75	74.2	1.04
Average	61.0	67.08	67.14	1.06

*values are average of five

Table.2 Specifications of developed prototype of apple grader

Components	Design values
Feeding hopper	682 mm x 470 mm x 2 mm
Grading/conveying rollers	Diameter = 50 mm Length = 1250 mm
Main frame	1460 mm x 842 mm x 50 mm
Power transmission unit	1 HP electric motor
Collecting trays	Number of compartments = 4 (535 mm x 340 mm x 2 mm)

Table.3 Plan of experiment

Variables	Levels	Responses
Spacing of rollers	3 (54-78 mm, 56-82 mm and 58-86 mm)	Grading efficiency (%) Time of grading (s)
Hopper inclination	3 (25^{O}, 30^{O} and 35^{O})	

Table.4 ANOVA for grading efficiency and time of grading

S. No.	Parameters	Main effect (p- values)		Interaction effect (p-values)		
		Roller spacing	Hopper inclination	(Roller spacing)^2	(Hopper inclination)^2	Roller spacing* Hopper inclination
1.	Grading Efficiency	*< 0.0001**	*0.2005*	*< 0.0001**	*0.0910*	*0.2918*
2.	Time of Grading	*0.9897*	*< 0.0001**	*0.0234*	*0.0028*	*0.6480*

Table.5 Optimum conditions for the operation of prototype of apple grader

S. No.	Roller spacing (mm)	Hopper inclination (degree)	Grading efficiency (%)	Time (s)	Desirability	Result
1	56-82	30	84.2	17.1	0.941	Selected

Table.6 Cost comparison of manual and mechanical apple grading

Method/Cost	Details		Cost, Rs.
Manual grading			
	Fixed charges	Nil	Nil
	Variable charges	1 skilled labour 250 Kg per day	500 per day
Total cost of manual grading (Rs. tonne^{-1})			2000
	Capacity of manual grading (Kg.h^{-1})		31.25
Mechanical grading	Fixed cost		
	1.Depreciation (Rs. h^{-1})	@ 10 % salvage value, life = 8 years, working hours = 500 hours	2.7
	2.Interest on investment (Rs. h^{-1})	Interest @ 16%	2.11
	Total Fixed cost (Rs. h^{-1})	Depreciation + Interest on investment	4.81
	Variable cost		
	1.Repair and maintenance 2.Labour charges 3.Electricity	@2% of initial cost 1 labour @500 per day @8 per day	0.48 62.5 47.7
	Capacity of machine (Kg.h^{-1})		530
Total cost of mechanical grading (Rs. tonne^{-1})			218

Ratio of cost of manual and mechanical grading was 2000: 218 =9:1

Table.7 Capability of material handling of apple grading

Apple grader	Attributes	Value
	Capacity (Kg.h^{-1})	530
	Annual Utility (tonnes per annum)	225
	Break-even point (hours per annum)	424
	Pay-back period (year)	1

Fig.1 Conceptual model of apple grader

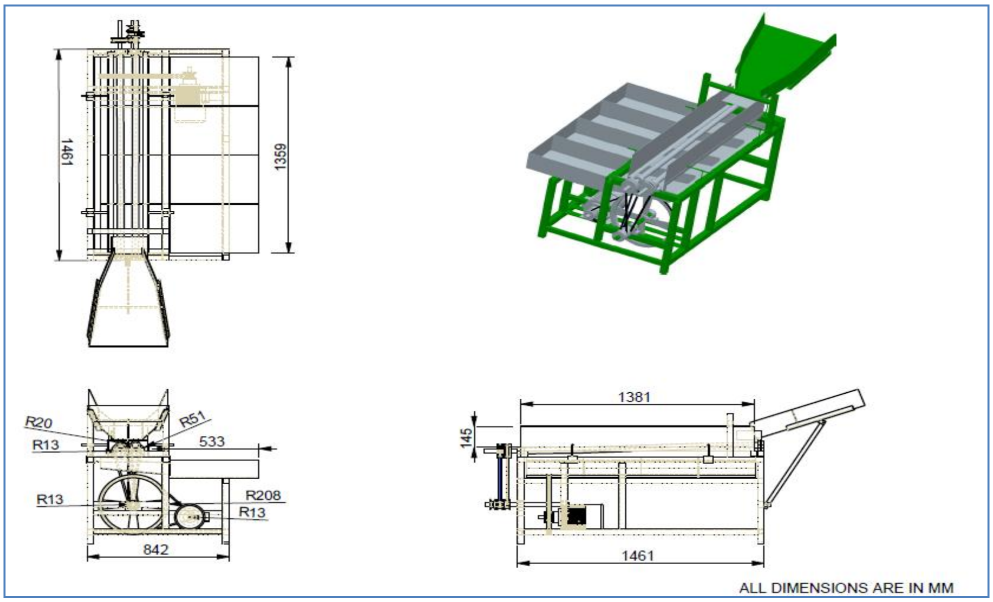


Fig.2 Prototype of divergent roller type apple grader

Fig.3 Effect of roller spacing on grading efficiency

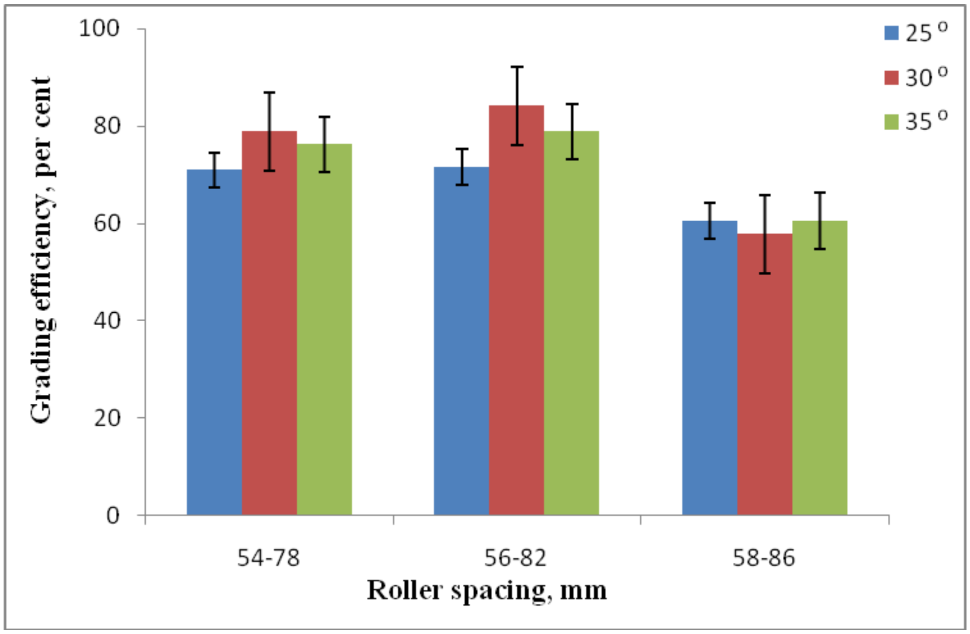
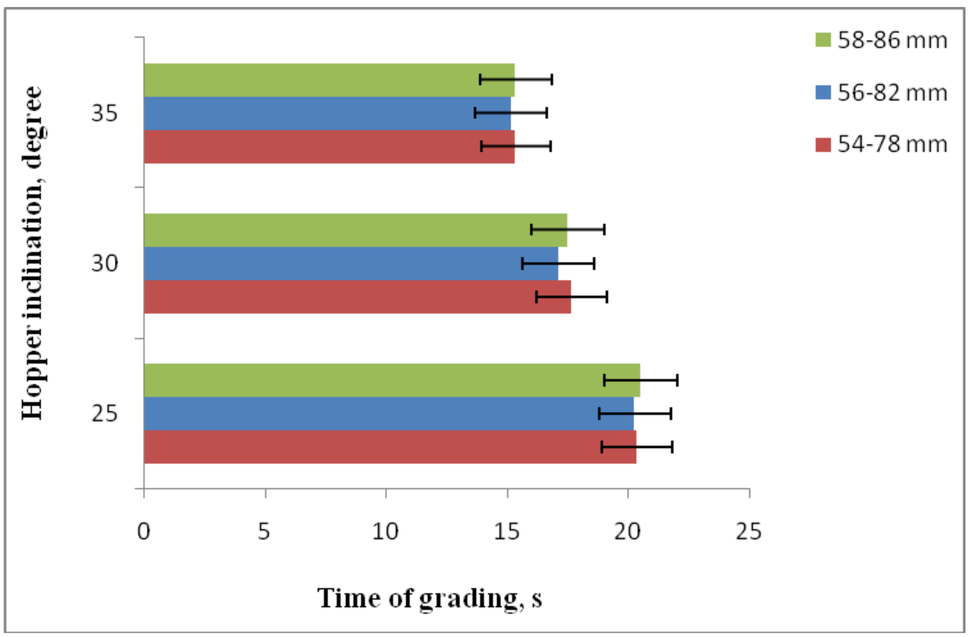


Fig.4 Variation in grading time by hopper inclination angle



Effect of roller spacing on grading efficiency

The grading efficiency increased with the increase in roller spacing from 54-78 mm to 56-82 mm and then decreased with the increase in roller spacing to 58-86 mm for all hopper inclination angles (Fig. 3). The maximum grading efficiency of 84.2 % occurs at roller spacing of 56-82 mm at hopper inclination of 30^{o}. The minimum grading efficiency of 57.9% occurs at roller spacing of 58-86 mm at same hopper inclination angle of 30^{O}. The capacity of the developed prototype of apple grader was found to be 530 Kg per hour.

The statistical analysis of the results by design expert 10.0 confirmed that roller spacing significantly influences the grading efficiency at 1 % level of significance. The effect of feeding hopper inclination was non-significant at 1% level of significance (Table 4).

Effect of hopper inclination on grading time

The variation in time of grading of apples from feeding hopper to collecting trays at different roller spacing is shown in Figure 4. The grading time of apples increased with the reduction in hopper inclination angle from 35-25 degree. It was observed that higher inclination of feeding hopper angle results in higher velocity of apples on grading/conveying rollers, thereby resulting in less time of grading. The trend was observed at all roller spacing. The time of grading varied from 15.15 to 20.5 seconds. The statistical analysis revealed that time of grading is significantly affected by hopper inclination angle at 1% level of significance (Table 4).

Optimum conditions for the operation of the prototype of apple grader

The observed data was analysed to determine the optimum conditions that will ensure the most favourable conditions for the working of the developed prototype of apple grader to attain maximum efficiency. The statistical analysis by design expert 10.0 revealed that optimum conditions occurred at roller spacing of 56-82 mm and hopper inclination of 30 degree with a desirability index of 0.941 (Table 5).

Cost economics of apple grading

Cost economics and comparison with manual method of apple grading was determined and shown in Table 6. The cost of manual grading was found to be Rs. 2000 per tonne and mechanical grading as Rs. 218 per tonne. The machine costs Rs. 12000. The machine resulted in saving of Rs. 1782.0 in comparison to manual method of apple grading. It also ensured timeliness of operation by reducing the time 17 times than manual method. The break-even point occurs at 424 hours per annum with capability to handle about 225 tonnes per annum. The pay-back period of apple grader is one year (Table 7).

In conclusion, the divergent roller type apple grader worked efficiently in sorting the apples into different categories on the basis of their size and shape. The grading efficiency varied from 57.9 – 84.2 %. The optimum conditions occurred at a roller spacing of 56-82 mm, hopper inclination of 30^{O}, roller speed of 100 rpm resulting in grading efficiency of 84.2 % and time of grading of 17.1 seconds. The throughput capacity of the machine was 530 $Kg.h^{-1}$ in continuous operation. The machine results in cost saving of Rs. 1782.0 and 17 fold reduction in grading time in comparison to manual method of apple grading. The break-even point of the machine occurred at 424 hours per annum with annual utility of 225 tonnes. The pay-back period rests within one year.

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