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TESTING THE PERFORMANCE OF SPHERICAL FRUIT GRADER FOR APPLE AND POMEGRANATE

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Abstract: For maximum response of grading efficiency the input factors viz., feed rate and down slope of grader were optimized to 35.84 kg/min and 30.21% respectively for Apple and 31.91 kg/min and 22.57% for Pomegranate. By using these optimized input factors, the grading efficiency and capacity was found to be 76.35% and 12.14 tonnes/day of 8 hours (at 80% efficiency) for Apple. For Pomegranate, the grading efficiency and capacity was found to be 86.63% and 12.25 tonnes/day (at 80% efficiency) of 8 hours by using optimized input parameters.
Keywords: Fruit grader, grading, grading efficiency.

Introduction

The production of apple (*Malus domestica)* in India was 1470 thousand tonnes (Annonymous, 2004). Pomegranate (Punica granatum) is grown in tropical and subtropical regions of the world. The total area under cultivation of pomegranate in India is 116.4 thousand ha and production is around 849.1 thousands tons (Annonumous, 2006).

The term quality implies the degree of excellence of a product or its suitability for a particular use. Quality is a human construct comprising many properties or characteristics. Quality of produce encompasses sensory properties (appearance, texture, taste and aroma), nutritive values, chemical constituents, mechanical properties, functional properties and defects. Quality is often defined from either a product orientation or a consumer orientation (Abbott, 1999). In India due to lack of proper post harvest handling system and appropriate processing technology, not only does a huge quantity of fruits go waste, but also the country dose not get proper distribution of fresh fruits and good market for processed products for both internal trade and export.

Systematic grading is a prerequisite for efficient marketing systems, as a well design programme on grading and standardization brings about an overall improvement not only in the marketing system but also in raising quality consciousness.

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The fruits have to be graded and sorted before being packed and sent to the market for pricing. If done manually the process is slow and grading is done by visual inspection that could be error prone. Grading is done on the basis of various criteria like weight, shape, color, size etc.

In the present scenario manual grading is more popular. Grading is done manually in orchard, mandies or packing stations and only skilled persons are doing this job. Huge amount of human energy is invested in this operation and the produce is handled for number of times in this operation which results in increase in respiration rate thereby causing weight loss. The growers, wholesalers, pre-harvest contractors and packing stations are in urgent need of low cost mechanical graders.

The objective of this study was to evaluate the performance of grader for different fruits such as Apple and Pomogranate.

Material and Methods

The orange grader (Fig. 1) consisted of a 1830 x 1300 mm frame made up of m.s. angles 35 x 35 x 5 mm was fabricated. Four pairs of PVC pipes of 75 mm diameter and 1300 mm length were provided keeping spacing of 50 mm at the feed end and 90 mm at the opposite end between two pipes of each pair for grading Apple and pomegranate. These pipes were mounted over 25 mm diameter shaft by fixing four spacers of m.s. plate along the length for fitting these pipes over shafts. These shafts were fitted with the help of pillow block bearing (No. 204) in grooves at both ends of the frame. A chain and sprocket arrangement is provided at the feed end for power transmission from pipe to pipe. The chain is linked alternately on the pipes at each pair so that both the pipes of each pair will rotate in opposite direction outwardly by 80 rpm. One idler in the groove is also provided to give tension while adjusting spacing between the pipes.

A universal joint was provided at the feed end of each shaft, so that while adjusting the spacing between the pipes of each pair the alignment of the chain and sprocket will not be disturbed. Thus, the spacing between the two pipes of each pair can be varied. This facilitates the grading of spherical fruits of various sizes, by adjusting the spacing as per the grades desired. The m.s. sheet with sufficient cushioning in ‘V’ shape was welded on the feed trough so as to divert the fruits in the diverging gap between two pipes of each pair of pipes available for grading fruits. The frame was mounted on two stands made of m.s. angle 35 mm x 35 mm x 5 mm in such a way that, pipe makes a slope of about 32.5%. The tallest end was chosen as feed end with a rectangular holder of size 1250 x 760 mm made of m.s. sheet (20 gauge) with proper frame support. For outlet of fruits trapezoidal shaped frames of m.s. flats fitted with m.s. sheet partitions was provided as shown in Fig. 1. The placement of the partitions can be adjusted in the groves as per the requirement of particular grade. Steel pipes of 8 mm diameter were provided over the pvc pipes, so as to guide the fruits between two pipes of each pair, to avoid divergence of fruit. One horsepower single phase electric motor was used as a prime mover.

As the grader was versatile in nature for grading all types of spherical fruits, the grader was tested by using apple and pomogranate. For grading apple fruits, the partitions of outlets were provided where the spacing between two pipes of each pair was 40 mm, 50 mm, 65 mm, 80mm and 90 mm thereby receiving the fruits of less than 50 mm diameter,50 to 65 mm diameter, 65 to 80 mm diameter and greater than 80mm diameter. For grading pomogranate, the partition of outlets were provided where the spacing between two pipes of each pair was 50 mm, 65 mm, 80 mm, and 90 mm thereby receiving the fruits of < 65 mm diameter, 65 to 80 mm diameter and greater than 80 mm diameter .

The grading efficiency is sensitive to feed rate and slope of the pipes (feed end to opposite end). Hence these two factors were considered for optimization for better grading efficiency by using response surface methodology.

The experimental plan selected was for two variables and five levels in response surface methodology (Cochran and Cox, 1975) for optimization of factors for maximum grading efficiency. The two independent variables, feed rate, kg/min (x_1) and slope, percent, (x_2) and their levels, coded and uncoded are shown in Table 1 for apple and pomogranate. The centre point values were chosen as 30 kg/min feed rate and 32.5 per cent slope for both apple and pomogranate grading, from previous results at this centre. The two higher and two lower levels were added using equation.

$$\text{Central level} \pm (\sqrt{2} \times \text{interval}) \qquad \ldots\ldots\ldots(1)$$

Fig.1 PKV Fruit Grader developed at Akola Center

The second order polynomial equation of the following form can be assured to appropriate the true functions.

$$Y = b_0 + b_1x_1 + b_2x_2 + b_{11}x_1^2 + b_{22}x_2^2 + b_{12}x_1x_2 \qquad (2)$$

Where b_0, b_1, b_2, b_{11}, b_{22} and b_{12} are the constant co-efficients and x_1 and x_2 are the coded independent variales. These coded variables (x_i) in any particular application are linearly related to X_i by the following equation (Khuri and Cornell, 1987).

$$x_i = \frac{2X_i - (X_{iH} + X_{iL})}{X_{iH} - X_{iL}} \qquad (3)$$

Where,

X_i = Decoded variable

x_i = Coded variable

X_{iH} = High level (+1) of X_i

X_{iL} = Low level (-1) of X_i

The apple fruits and pomogranate were procured from the market of Akola city and transported to testing unit with sufficient cushioning material in order to minimize bruising. The sample size of 15 kg was used for each test. Various feed rates were achieved by feeding the same fruit lot during different durations and five levels of slopes were achieved by keeping required thickness of m.s. plates at the bottom of the feed end or opposite end. The major diameters of fruits before grading were measured by Vernier calliper. These fruits were divided in requisite grades, the coding was given and weights were taken before grading (Table 2 and 3)

Table 1: Experimental design for two variables five levels in response surface analysis for apple and pomegranate

Expt. No.	**Levels of input variable**			
	x_1	**Feed rate, kg/min**	x_2	**Slope, percent**
1	-1	24	-1	25
2	1	36	-1	25
3	-1	24	1	40
4	1	36	1	40
5	-1.414	21.36	0	32.5
6	1.414	38.64	0	32.5
7	0	30	-1.414	21.7
8	0	30	1.414	43.3
9	0	30	0	32.5
10	0	30	0	32.5
11	0	30	0	32.5
12	0	30	0	32.5
13	0	30	0	32.5

Table 2: Details of apple fruits taken for testing

Code	A	B	C	D	Total
Diameter, mm	>80	65-80	50-65	<50	
No. of fruits	11	30	63	32	136
Weight, kg	2.762	4.762	5.862	1.618	15.01
Average weight, kg	0.251	0.158	0.092	0.051	

Table 3: Details of pomogranate taken for testing

Code	A	B	C	Total
Diameter, mm	>80	60-85	<65	
No. of fruits	16	40	16	72
Weight, kg	5.062	7.796	2.142	15.00
Average weight, kg	0.316	0.195	0.134	

The test lot of apples was consisting of 136 fruits, weighing 15.01 kg (Table 2). Out of which there were 11 fruits weighing 2.762 kg of major diameters more than 80 mm (A), 30 fruits weighing 4.762 kg of major diameter ranging between 65 to 80 mm (B), 63 fruits weighing 5.862 kg of major diameter ranging between 50 to 65 mm (C) and 32 fruits weighing 1.618 kg of major diameter less than 50 mm (D). The average weight of each fruits of grade A, B,C and D was 0.251, 0.158, 0.092 and 0.051 kg respectively as given in Table 2. The test lot of pomogranates was consisting of 72 fruits weighing 15 kg (Table 3). Out of which there were 16 fruits weighing 5.062 kg of major diameter greater than 80 mm (A), 40 fruits, weighing 7.796 kg of major diameter ranging between 60 to 85 mm (B), 16 fruits weighing 2.142 kg of of major diameter less than 65 mm (C). The average weight of each fruit of grade A, B and C was 0.316, 0.195 and 0.134 kg respectively as given in Table 3.

After testing the grader by using apple and pomegranate as per treatment combinations given in Table 1 replicated thrice, the grading efficiency was calculated by dividing the weight of correctly graded fruits by total weight of fruits taken for grading. After optimizing the input parameters (feed rate and slope) for maximum grading efficiency by using response surface methodology, the grader was tested by using the optimized input parameters. The percent overall effectiveness of separation was also calculated as described in Annexure A by using optimized input parameters.

Man months involvement of component project workers for the specified years.	Scientific - 3 Technical - 4 Supporting – 1.2

Results and discussion

The experimental average results of three replications for grading efficiency are depicted in Table 4 for apple and pomogrante . The observed data was fitted in second order polynomial model equation. The partial regression coefficients obtained after multiple regression analysis are presented in Table 5. The regression analysis resulted the following second order polynomial equations for grading efficiency.

For apple

$$Y = 76.73 + 1.24\ x_1 + 4.02\ x_2 - 0.81\ x_1^2 - 4.68\ x_2^2 - 2.17\ x_1x_2 \quad (R^2 = 0.92) \quad \ldots(4)$$

For pomegranate

$$Y = 87.16 + 1.67x_1 - 0.68\ x_2 - 0.38\ x_1^2 - 0.13\ x_2^2 + 1.15\ x_1x_2\ (R^2 = 0.87) \quad \ldots\ldots(5)$$

The analysis of variance (Tale 6) for the effect of factors on response indicated that the regression was significant (at 10% level) and lack of fit was non significant and hence the mathematical model can be considered as quite adequate for the both apple and pomogrante grading.

Table 4: Observed and predicted response for grading efficiency (percent) under various treatment conditions

Expt. No.	Grading efficiency for apple		Grading efficiency for pomegrante	
	Observed	Predicted	Observed	Predicted
	Y	Y	Y	Y
1	64.57	63.80	86.63	86.81
2	73.66	70.63	88.30	87.84
3	75.94	76.20	81.84	83.15
4	76.35	74.34	88.12	88.79
5	73.59	73.37	84.92	84.03
6	73.89	76.87	88.74	88.75
7	59.57	61.67	87.50	87.86
8	72.40	73.06	87.18	85.95

9	76.74	76.73	87.11	87.16
10	76.60	76.73	87.23	87.16
11	76.88	76.73	87.12	87.16
12	76.52	76.73	87.22	87.16
13	76.96	76.73	87.12	87.16

Table 5: Values of partial regression co-efficient of second order polynomial equations for grading efficiency

Response	Partial regression coefficient					
	b_0	b_1	b_2	b_{11}	b_{22}	b_{12}
Apple	76.73	1.24	4.02	-0.81	-4.69	-2.17
Pomegranate	87.16	1.67	-0.68	-0.38	-0.13	1.15

Table 6: Analysis of variance for the effect of input variables on grading efficiency (Y)

Source	Apple		Pomegranate	
	df	Sum of square	df	Sum of square
Model (Reg.)	5	313.77*	5	32.32*
Residual	4	27.85	4	4.86
Lack of fit	3	27.72	3	4.85
Pure error	1	0.136	1	0.014
F ratio (LDF)	-	67.95	-	113.75
R^2	-	0.92	-	0.87

**Significant at 10% level*

The stationary point where the slope of the curve on the first derivative is zero was located as described by Khuri and Cornell (1987). Results in Table 7 show that the stationary point for the response was laying inside the experimental region as defined by $x_1 = \pm$ 1.414 and $x_2 = \pm 1.414$. The model was tested whether the function has maximum or minimum prediction values. It was observed that, the function possesses maximum value for apple and neither maximum not minimum value for pomegranate grading. The co-ordinates (x_1 = 0.973 & x_2 = 0.035) correspond to the uncoded values as 35.84 kg/min feed rate and 30.21 per cent slope of pipes for apple grading and coordinates (x_1 = 0.318 and x_2 = -1.238) correspond to the uncoded value as 31.91 kg/min feed rate and 22.57 per cent slope for pomegranate grading. Using these input factors the grading efficiency was calculated to be 77.24 per cent for apple and 87.85 per cent for pomegranate respectively.

Table 7 Predicted levels of factors yielding optimum response

Factors	**Grading efficiency (Y) for Apple**		**Grading efficiency (Y) for Pomegrante**	
	Coded	**Uncoded**	**Coded**	**Uncoded**
Feed rate, kg/min	0.973	34.84	0.318	31.91
Slope, percent	0.035	30.21	-1.24	22.57
Response, per cent	77.24		87.84	

The response surface and contour plot was generated on computer screen in order to study the pictorial form of behavior of response variables using the prediction model equation as shown in Fig. 2 and Fig. 3 for grading efficiency for apple and pomegranate respectively.

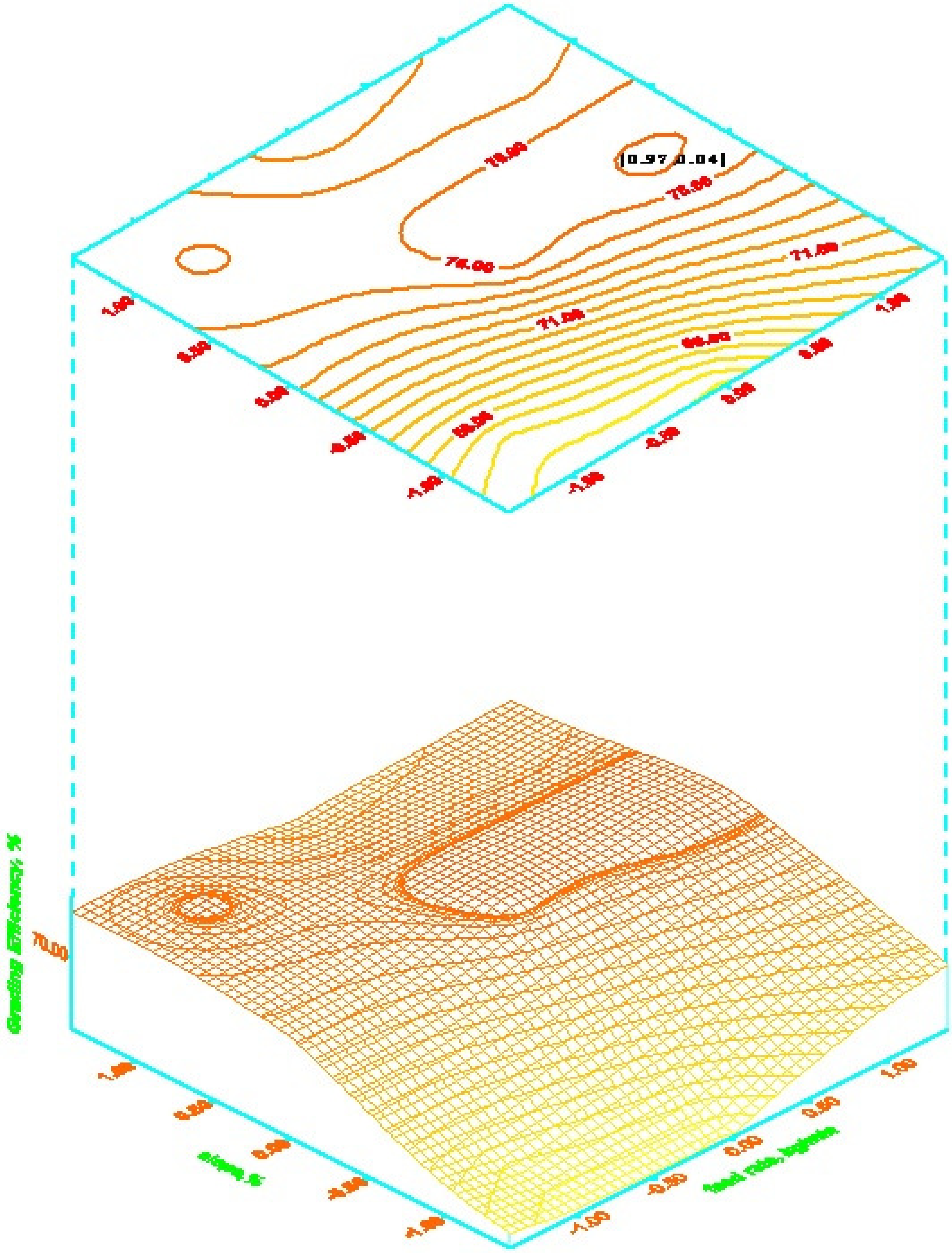

Fig. 2 Contour plot and response surface showing effect of feed rate and slope on grading efficiency of apple

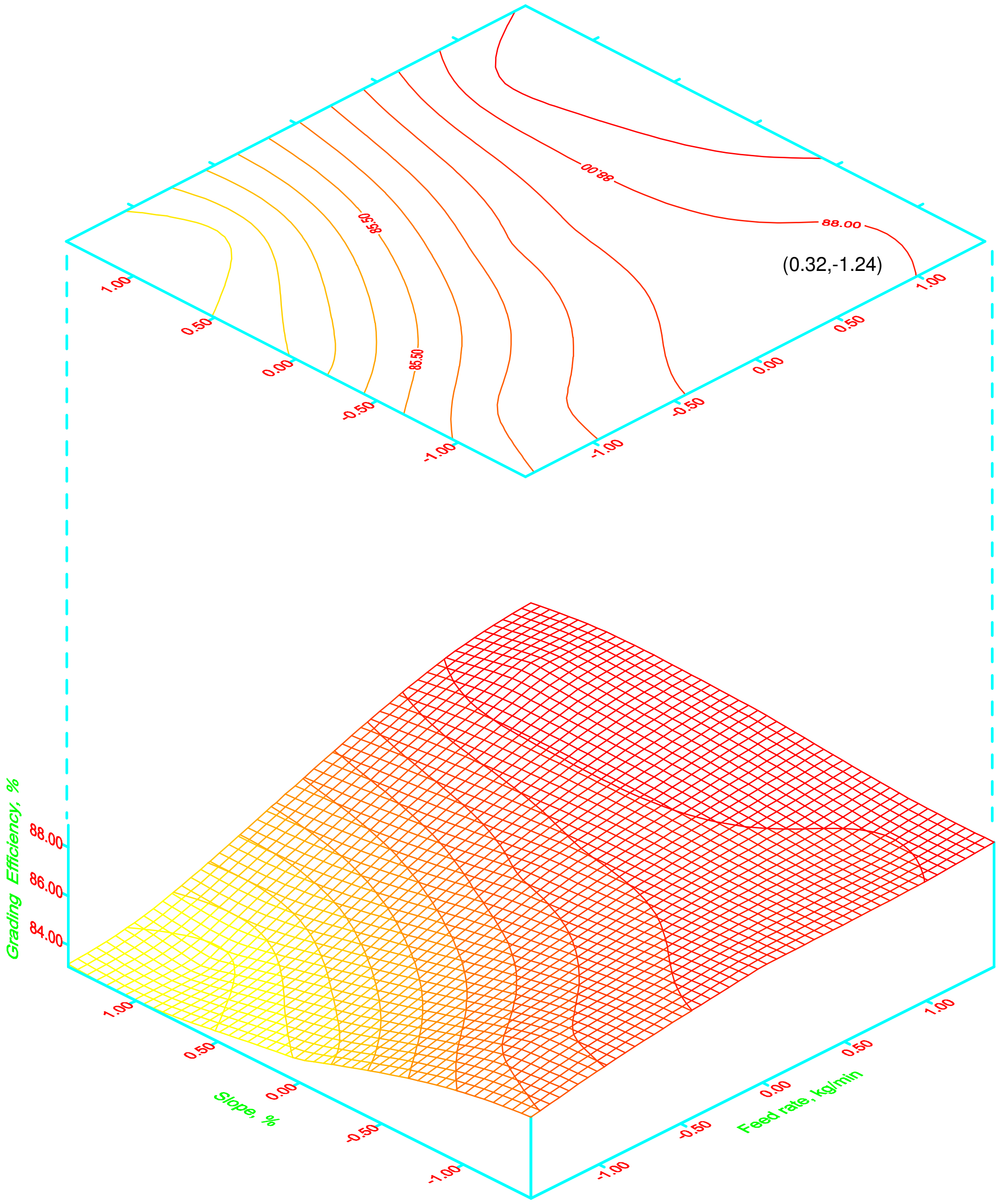

Fig. 3: Contour plot and response surface showing effect of feed rate and slope on grading efficiency of pomegranate

Table 8 presents the statistical analysis of joint test on the two parameters involving one particular factor. For example, test x_1 tests the hypothesis that parameters of model equation viz. x_1, $x_1^2$and x_1x_2 are all zero. Similar is the case for x_2, Table 8 revealed that, x_1 (feed rate) is highly significant than x_2 (slope) for apple and x_2 (slope) is highly significant at 10% level than x_1 (feed rate). This shows that, the effect of feedrate is much effective than the slope for the response in case of apple and vice versa in case of pomogranate may be due to the textural difference .

Table 8: Analysis of variance for the overall effect of individual factor

Factor	df	S.S.	Mean square	F ratio
For Apple				
x_1	3	277.06*	92.35	8.71
x_2	3	34.52	11.50	0.99
For Pomegranate				
x_1	3	7.88	2.63	1.6139
x_2	3	24.86*	8.29	5.0825

** Significant at 10% level*

The mathematical model was evaluated for its adequacy by testing the grader by using apple for three samples (sample size 20 kg) with factors constant at above level (35.84 kg/min feed rate and 30.21% slope). The grading efficiency of grader was found to be 76.35 per cent with $\pm$ 0.65 standard deviation. The corresponding average overall effectiveness of separation was 27.78 per cent with $\pm$ 0.13 standard deviation. Similarly the mathematical model was evaluated for its adequacy by testing the grader by using pomegranate for three samples (Sample size 20 kg) with factors constant at above level (31.91 kg/min feed rate and 22.57% slope). The grading efficiency was found to be 86.63 per cent with $\pm$ 0.75 standard deviation. The corresponding average overall effectiveness of separation was 60.35 per cent with $\pm$ 0.26 standard deviation. This lower overall effectiveness of separation can be attributed to the difference between the major and minor diameter of fruit (fruit being not perfectly spherical) ranging from zero to 10 mm and the orientation of fruit (either major diameter/ minor diameter perpendicular to slope) while conveying within the diverging gap between two pipes of each pair, which caused the mixing of various grades of fruits. Moreover the overall effectiveness of separation is the multiplication of effectiveness of separation of each grade /outlet.

With this optimized feed rate the capacity of grader for grading apple comes out to be 17.20 tonnes per day of eight hours and with 80 per cent efficiency, the capacity of the grader is 13.76 tonnes of per day of eight hours for apple.

Similarly with the optimized feed rate, the capacity of the grader for grading pomegranate comes out to be 15.32 tonnes per day of eight hours and with 80 per cent efficiency, the capacity of the grader is 12.25 tonnes per day of eight hours.

Conclusion

For maximum response, of grading efficiency, the input factors, feed rate and slope of grader were optimized to 35.84 kg/min and 30.21 per cent respectively for apple and 31.91kg/min and 22.57per cent for pomegranate. Using optimized input factors, the grading efficiency and capacity was found to be 76.35 per cent and 13.76 tonnes per day (at 80% efficiency) of eight hours for apple. For pomegranate, the grading efficiency and capacity was found to be 86.63 per cent and 12.25 tonnes per day (at 80% efficiency) of eight hours by using optimized input parameters.

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