Study on Mechanical Grading of Sweet Oranges

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Abstract

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 for overall effectiveness of separation.

The mathematical model was evaluated for its adequacy by testing the grader for three samples with factors constant at above level (49 kg/min feedrate and 34.6% slope). The overall effectiveness of separation of grader was found to be 61.02 per cent with ± 0.69 standard deviation. The corresponding average grading efficiency i.e. weight of fruits correctly graded out of total weight of fruits taken for grading was 88.20 per cent. This lower overall effectiveness of seeration and lower average grading efficiency can be attributed to the difference between the major and minor diameter of fruit (fruit being not perfectly spherical) ranging from zero to 5 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 maxing of various grades of fruits.

Keywords: Diameter; federate; Grading efficiency

Introduction

India ranks seventh in the production of citrus in the world. Oranges occupies first place among the citrus fruits produced in the country. The world production of orange is 58.13 million tonnes in which India ranks sixth with its production level as 2.10 million tonnes. Presently in Vidarbha region orange crop covers about 70,000 ha. area annually producing 0.4 million tonnes which is comprising about 80% of area and production of Maharashtra (Commissionerate of Agriculture 1995-96). Post harvest management of oranges is of prime importance in order to sustain higher production, proper distribution with minimum losses and increasing export. 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 does not get proper distribution of fresh fruits and good market for processed products for both internal trade and export. In order to know the research gaps the existing post harvest management practices need to be studied and research gaps to be identified. Similarly at present some operations needs to be mechanized.

Material and Methods:

The orange grader 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 53 mm at the feed end and 83 mm at the opposite end between two pipes of each pair. These pipes are mounted over 25 mm diameter shaft with fixing four spacers of m.s. plate along the length for fitting these pipes over shaft. These shafts are fitteed with the help of pillow block bearing (No. 204) in grooves at both ends of the frame. A chain and sproket arrangemet 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 idlers in the groove is also provided to give tesion 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 chaim 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 onthe feeding 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 rectangular holders of size 1250 x 760 mm made of m.s. sheet (20 guage) with proper frame support. Fr outlet of fruits trapexoidal shaped frames of m.s. flats fitted with m.s. sheet partitions and canvas cloth at the bottom was provided. The placement of the partitions can be adjusted in the grooves as per the requirement of particular grade. At present the partitions are provided where the spacings between the pipes of each pair is 53 to 60 mm, 60 mm, 67 mm, 75 mm and 83 mm thereby receiving the fruits of 53 to 83 mm diameters. The discharge ends were kept horizontally on alternate sides across the length for easy collection of graded fruits. Pannels of acrylic sheet with proper frame support was provided over the pipes, so as to guide the fruits between two pipes of each pair, to avoid divergence of fruit. One horsepowers single phase electric motor was used as a prime mover.

As the grader was versatile in nature for grading all types of shperical fruits and since the sweet lime (mosambi) where available just after completion of grader, the grader was tested by using sweet lime (Mosambi).

The overall effectiveness of grader is sensitive to feederate and slope of the pipes (feed end to opposite end). Hence these two factors were considered for optimization for better overall effiectiveness of separation.

The experimental plan selected was for two vairables and five levels in response surface methodology (Cochran and Cox, 1975) for optimization of factors for maximum percent overall effectiveness of seperation. The two independent variables, feed rate of sweet lime, kg/min (x_1) and slope per cent (x_2), and their levels, coded and uncoded are shown in Table 1. The percent point values were choosen as 50 kg/min feed rate and 32.5 per cent slope from previous results at this centre. The two higher and two lower levels were added using equation.

Central level ± (2 x interval) ....(1)

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

Y = b0 + b1x1 + b2x2 + b11x12 + b22 x22 + b12x1x2.. (2)

Where b0, b1,b2,b11 and b12 are the constant co-efficients and x1 and x2 are the coded independent variables. These coded variables (x_i) in any particular application are linearly related to X_i by the following equation (Khuri and Cornell, 1987).

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

Where,

x_i = Coded variable

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

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

The sweet lime (mosambi) were procured from the garden nearby Akola city and transported to testing unit with sufficient cushioning material in order to minimize bruising. The sample size of 30 kg of fruits was used for each test. Various feedrates were achieved by feeding the same fruit lot during different durations, and five levels o 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 are divided in four grades, the coding is given and weights were taken before grading (Table 2). After grading the percent overall effectiveness of separation was calculated as described in Annexure II. Similarly the garding efficiency was calculated by dividing the weight of correctly graded fruits by totl weight of fruits taken for grading.

The Nagpur oranges of Ambia bahar were used for testing the grader. The test lot fruits was consisting of 89 oranges, weighting 15 kg. Out of which there were 21 fruits weighting 4.360 kg of major diameters ranging between 53 to 60 mm (A), 46 fruits weighing 2.350 kg of major diameter ranging between 67 to 75 mm (C) and 5 fruits weighing 0.570 kg of major diameter ranging between 75 to 83 mm (D). The average weight of each fruits of grade A,B,C and D was 0.21, 0.17, 0.14 and 0.11 kg respectively as given in Table 2. The grading fat fruit was replicated four times. The effectiveness of separation and grading efficiency for each grade and overall effectiveness of separation was completed.

Results and Discussion

The experimental average results of three replications for percent overall effectiveness are depicted in Table 3. The observed data was fitted in second order polynomial modal equation using SPAR 1 programme (Doshi and Gupta, 1981). The partial regression coefficients obtained after multiple regression analysis are presented in Table 4. The regression analysis resulted the following second order polynomial equation for overall effectiveness of separation.

$$Y = 60.354 - 5.761 x_1 + 13.742 x_2 - 11.188X_1^2 - 15.322x_2^2 + 7.539x_1x_2$$

$(R^2 = 0.952)$ 3

The analysis of variance (Table 5) for the effect of factors on response indicated that the regression was highly significant ($P < 0.01$) and lack of fit was non significant and hence the mathematical model can be considered as quite adequate.

The stationary point where the slope of the curve on the first derivative is zero was located as described by Khuri and Cornell (1987). The stationary point for the response was laying inside the experimental region defined by x1 = $\pm$ 1.414 and x2 = $\pm$ 1.414. The mould was tested whether the function has maximum or minimum prediction values. It was observed that, the function possesses maximum value. The co-ordinates (x1 = 0.115 & x_2 = 0.42) correspond to the uncoded values as 49 kg/min feed rate and 34.6 percent slope of pipe. Using these input factors the overall effectiveness of separation was calculated to be 63.87 per cent.

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 for overall effectiveness of separation.

The mathematical model was evaluated for its adequacy by testing the grader for three samples with factors constant at above level (49 kg/min feedrate and 34.6% slope). The overall effectiveness of separation of grader was found to be 61.02 per cent with $\pm$ 0.69 standard deviation. The corresponding average grading efficiency i.e. weight of fruits correctly graded out of total weight of fruits taken for grading was 88.20 per cent. This lower overall effectiveness of seeration and lower average grading efficiency can be attributed to the difference between the major and minor diameter of fruit (fruit being not perfectly spherical) ranging from zero to 5 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 maxing of various grades of fruits.

With this optimized feedrate the capacity of grader for grading sweet oranges (mosambi) comes out to be 23.520 tonnes per day of eight hours, with 71 per cent efficiency, the capacity of the grader is 17.64 tonnes per day of eight hours for sweet lime.

It was observed that the effectiveness of seperation of grade A, B, C and D were observed 0.3584, 0.3436, 0.8202 and 0.8560 respectively. Thus the overall effectiveness of separation is 0.0872 i.e. 8.72 per cent. The corresponding grading efficiency (average weight of fruits correctly graded out of total weight of fruits) was observed to be 44.10 per cent which was lower. This can be attributed to the large variation in the minor and major diameters ranging from 1 to 16 mm and hence during conveying through the diverging gap between pipes of each pair the fruits having minor diameters equal to that of major fruits got mixed since the orientation could not be controlled in this unit.

The average time required for grading 15 kg Nagpur oranges was 25 seconds. Thus, theoretical capacity of grader for grading Nagpur orange is 16.8 tonnes per day of eight hours. Considering 75 per cent efficiency, the efficiency is 12.6 tonnes per day of eight hours.

Conclusions :

1. An orange grader is fabricated for fruit grading on size basis.
2. For sweet limes (mosambi) for maximum response of overall effectiveness of separation and grading efficiency, the input factors, feedrate and slope of grader were optimized to 49 kg/min and 34.6 per cent respectively.
3. Using optimized input factors, the overall effectiveness of separation, grading efficiency and capacity was found to be 61.02 per cent, 88.20 per cent and 17.64 tonnes per day (at 75% efficiency) of eight hours for sweet limes (Mosambi)
4. The capacity for grading Nagpur oranges was found to be 12.6 tonnes per day of eight hours but overall effectiveness of separation and grading efficiency was 8.72 per cent and 44.10 per cent which is low and need further modification.

Table 1. Experimental design for two variables five levels in response surface analysis.

Experiment	**Levels of input variables**			
No.	x_1	Feed rate kg/min	x_2	Slope per cent
1.	-1	42	-1	27.50
2.	1	58	-1	27.50
3.	-1	42	1	37.50
4.	1	58	1	37.50
5.	-1.414	38.69	0	32.50
6.	1.414	61.31	0	32.50
7.	0	50	-1.414	25.43
8.	0	50	1.414	39.57
9.	0	50	0	35.50
10.	0	50	0	35.50
11.	0	50	0	35.50
12.	0	50	0	35.50

13.	0	50	0	35.50

Table 2. Details of sweet limes (mosambi) taken for testing

Code	**A**	**B**	**C**	**D**
Diameter, mm	53-56	60-67	67-75	75-83
No. of fruits	4	147	15	5
Weight, kg	0.550	24.400	5.550	1.500
Average weight, kg	0.138	0.166	0.237	0.300

Table 3. Observed and predicted response for overall effectiveness of separation (per cent) under various treatment conditions

Experiment	**Overall effectiveness of separation**	
No.	Observed	Predicted
	Y	Y
1.	40.3	33.46
2.	6.14	6.72
3.	45.58	45.78
4.	41.79	64.74
5.	41.38	46.25
6.	35.63	41.47
7.	5.89	10.50
8.	54.68	79.75
9.	60.13	60.35
10.	60.99	60.35
11.	59.96	60.35
12.	60.37	60.35
13.	60.31	60.35

Table 4. Values of partial regression coefficient of second order polynomial equations for average effectiveness of seperation

Response	Partial regression coefficient					
	b_0	b_1	b_2	b_{11}	b_{22}	b_{12}
Overall effectiveness of separation	60.354	-5.761	13.742	-11.188	-15.322	7.593

Table 5. Analysis of variance for the effect of input variables on overall effectiveness of separation (Y)

Source	df	Sum of square Y
Model (Reg.)	5	4223.752*
Residual	4	211.504
Lack of fit	3	210.892
Pure error	1	0.612
F ratio (LDF)	-	114.86

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