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Procedia Food Science 6 (2016) 103 – 107

Procedia Food Science

International Conference of Sabaragamuwa University of Sri Lanka 2015 (ICSUSL 2015)

Design, development and evaluation of a size grading machine for onion

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Abstract

Improvement of quality and value addition of agricultural produces has gained higher concern in recent times in Sri Lanka due to creation of new opportunities for sale of agricultural commodities in open market at competitive prices. Grading according to the sizes is an important value adding technique for most agricultural products. And also the price of the many agricultural products varies significantly according to their uniformity in size. Uniformity in size not only makes the produce more attractive to consumers but also improve its processing qualities. At present, size grading of most agricultural crops including big onion are carried out manually by crop collectors, whole sellers and retail sellers, most of farmers market their products without any grading. In Sri Lanka, persons engaging in post-harvest crop handling such as collectors, whole sellers, retail sellers, and farmers have less chance to use high technical and costly grading technique. And also local market survey reported, retail market price of the big onion bulbs are significantly varied according to its size. Hence, this research study attempted to design and development of a low cost size grading machine for size grading of big onion bulbs. Size grading machine was fabricated by cast iron and PVC tube and It was designed for grading of onion bulbs into three sizes i.e. small ($\varphi < 4$ cm), medium ($4 < \varphi < 6$cm) and large ($\varphi > 6$cm). Grading machine was also fabricated to operate either by manual or electric motor. The machine was tested for grading efficiency/quality accordingly, machine performance was optimized. Optimized machine adjustments for its maximum performance were 3ºinclined angle of the grading cylinder against horizontal axis and 15 rpm rotating speed of the grading cylinder. Maximum grading qualities/efficiencies under optimized machine adjustments for small, medium and large sizes were reported 84.47%, 93.46% and 90.14 respectively. The capacity of the grading machine was 630 kg/hour under the optimized operational conditions.

Peer-review under responsibility of International Conference of Sabaragamuwa University of Sri Lanka 2015 (ICSUSL 2015).

*Keywords:*Size grading; onion; design; machine; evaluation; optimization

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Peer-review under responsibility of International Conference of Sabaragamuwa University of Sri Lanka 2015 (ICSUSL 2015).
doi:10.1016/j.profoo.2016.02.022

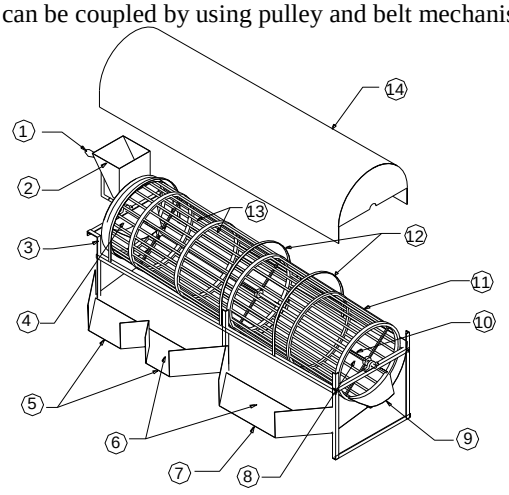
1. Introduction

Apart from quantitative losses, quality deterioration and hence a reduction in the market value due to use of improper post harvest techniques are common in agricultural commodities in Sri Lanka. Improvement of quality and value addition of agricultural produce has gained importance in Sri Lanka in recent times due to creation of new opportunities for sale of agricultural commodities in the open market at competitive prices. This situation has resulted in a growing awareness and increased demand for better market quality among consumers. Improvement of product quality by grading according to the size will become even more important in the future for Sri Lanka, as well as most of the other countries, entering into international as well as regional trade agreements and thereby opening its market to the outside world. The price of many agricultural produce varies significantly according to their uniformity in size. Uniformity in size not only makes the product more attractive to consumers but also improve its processing qualities. Therefore, size grading of agricultural commodities to achieve uniformity in size is an important value adding technique to increase their market value.

Big onion (*Allium cepa*) is one of the major spice/vegetable cash crops, grown in Sri Lanka. The level of big onion production and prices shows an immense potential for increasing incomes of local farmers. Profit from big onion is greater than other major cash crops such as chilli and potato[1]. Generally, it can be observed, that there is an appreciable difference in the market price of big onion according to the size of bulbs. Graded big onion bulbs according to their size fetches a higher price than the un-graded onions[2]. Local farmers sell their produce to the market without grading. Hence, farmers are getting lower value for their produce. However, manual size grading of most crops are practiced by collectors, whole sellers and retailers and thereby, they make higher profit than farmers. In Sri Lanka, persons engaged in post harvest handling of crops have less chance to use high cost size separation techniques. Hence, this research study attempted to design, development and performance optimization low cost machine for size grading of big onion bulbs

2. Material and Methods

Big onion bulbs size grading machine, designing and fabrication works were carried out at research workshop, R & D Centre, Institute of Post Harvest Technology, Anuradhapura. Figure 1 is shown three dimensional view with its component of the big onion bulbs size grading machine and Figure 2 is shown engineering drawing of the size grader. The grading techniques and material use for fabricating the machine were selected to minimize the mechanical damage of big onion. Machine mainly comprise of grading cylinder made by PVC (tubes diameter 20mm), iron circle, feeding hopper and supporting frame. Front portion of the feeding hopper was adjustable. Grading cylinder consist two segments and four outlets. First segment was longer and it consist two outlets used for separation of small onion bulbs diameter less than 4cm. Second segment consist one outlet was used for separation of medium size onions bulbs diameter in between 4cm to 6cm and larger onion bulbs diameter more than 6cm were collected from the outlet located end of the grading cylinder. Lengths of the segments were 150cm and 100cm respectively. Soft wire mesh was used for fabrication of outlets and also PVC tubes were wrapped by rubber for the prevention of mechanical damaged for onion bulbs. A lever /handle was fixed for manual operation and also electric motor can be coupled by using pulley and belt mechanism if required for operating mechanically.



1. Manual rotating lever
2. Hopper
3. Frame for grading cylinder.
4. Section for grading of small onion bulbs
5. Out let for small size big onion
6. Net and cushioning material
7. Out let for medium size big onion
8. Section for grading of medium onion bulbs
9. Out let for large size big onion
10. Main axel
11. Rotating cylinder
12. Supporter for outer cover
13. PVC tube
14. Outer cover

Figure 1: Three dimensional line diagram and component of the big onion size grader

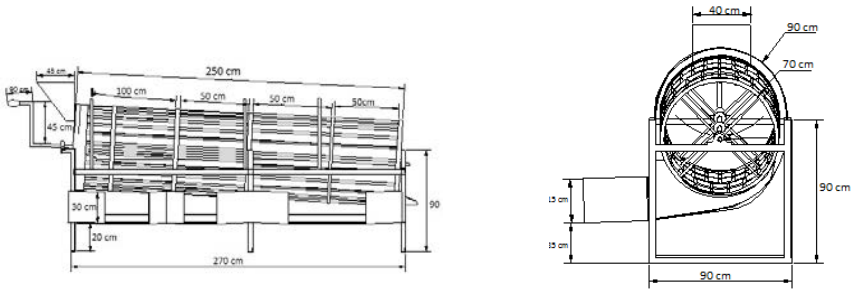


Figure 2:Engineering drawing of the big onion bulb size grading machine

2.1 Procedure for optimization and evaluation of the machine

Optimization of the machine was done by surface response methodology by Design Expert® (version 7) software. Grading machine was optimized by altering its adjustable parameters such as incline angle and rpm of grading cylinder. Incline angle and rpm of the grading cylinder were considered in the range of 2 to 4 and 10 to 20 respectively during optimization. Electric gear motor was used for optimization and evaluation of machine. Capacity of the size grader was determined under optimum operating conditions (optimum rpm and incline angle) and it was calculated by weight of the onion bulbs graded at one hour duration.

2.2 Measuring of grading efficiency/quality

Grading efficiency/quality of above mentioned graded sizes such as small size, medium size and larger sizes were calculated by following equations respectively.

$$\frac{W_1 - P_1}{W_1} * 100 \qquad \frac{W_2 - P_2}{W_2} * 100 \qquad \frac{W_3 - P_3}{W_3} * 100$$

Where:

P_1 – Weight of the bulbs other than small size grade ($\varphi < 4$ cm)
W_1 – Total weight of the onion bulbs collect in small size collector bin
P_2 – Weight of the bulbs other than medium size grade ($4 < \varphi <$ 6cm)
W_2 – Total weight of the big onion collect in medium size collector bin
P_3 – Weight of the bulbs other than larger size grade ($\varphi >$ 6cm)
W_3 – Total weight of the big onion collect in large size collector bin

3.0 Results and Discussion

3.1 Variation in grading efficiency/qualities of 3 size grads with inclined angles and rotational speed (rpm) of grading cylinder

Figure 3 shows the variation in grading efficiency/quality of 3 size grades with three different inclined angles i.e. 2º, 3ºand 4º against horizontal axis and under rotational speeds of 10, 15 and 20 rpm of grading cylinder. It was clear that the higher grading efficiencies/qualities for 3 size grades under 10, 15 and 20 rotational speed were obtained by 3º inclined angle adjustment (against horizontal axis) of grading cylinder. However, the highest grading efficiency/quality for 3 size grades were obtained under 3º inclined angle adjustment and 15 rpm rotational speed of the grading cylinder. Results clearly indicated that grading efficiency was decreased with increase in rotational speed more than 15rpm and 3º inclined angle these results was proved by following optimization methods.

3.2 Selection of optimum rotational speed and inclined angle of cylinder for best grading performance.

Graphical surface response optimization technique was adopted to determine the workable optimum operational combination in above mentioned range of rpm and inclined angle. Figure 4 shows the desirability contour plot for

overall grading efficiency/quality. The maximum grading efficiency of 3 grades were positioned close to 15rpm and 3º inclined angle of the grading cylinder adjustments. It can be predicted that (Table 1) maximum grading efficiency of three grades can be obtained under 14.45rpm and 2.99 inclined angle of grading cylinder.

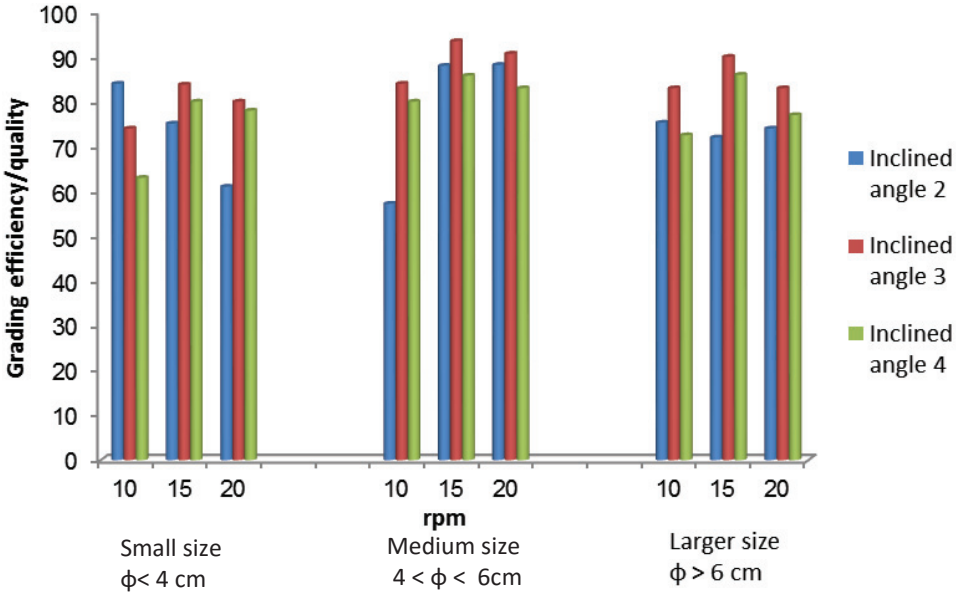


Figure 3:Variation in grading efficiency/qualityfor 3 grades within clined angles and rotational speed of the grading cylinder

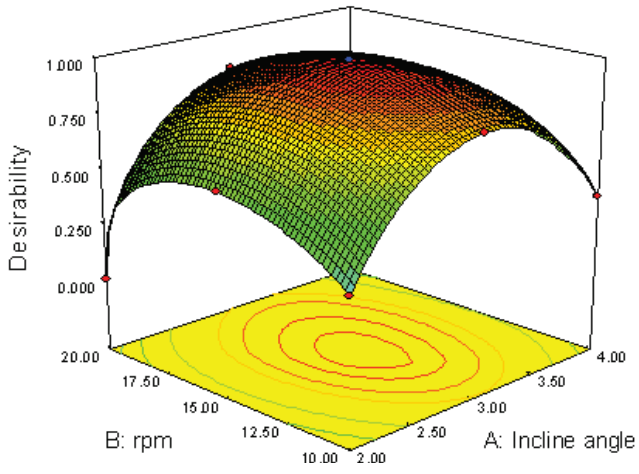


Figure 4: Desirability contour plots for overall grading efficiency

Table 1. Criteria for optimization and the selected optimum operational parameters.

Predicted optimized adjustments						
Process parameters	Target	Experiment range		Importance	Optimization	
					Optimum conditions	Desirability
rpm	is in range	10	20	3	14.45	
Inclined angle	is in range	02	04	3	2.99	
Response					Predicted values	0.991
Grading Quality of Small grade	Maximum	63.65	84.47	3	84.06	
Grading Quality of medium grade	Maximum	57.18	93.46	3	94.71	
Grading Quality of large grade	Maximum	65.41	90.14	3	89.97	

Selected optimized adjustments				
Treatment	Grading quality of small size	Grading quality of medium size	Grading quality of large size	Desirability
15 rpm and inclined angle 3º	84.47	93.46	90.14	0.990

The results were revealed that 3º inclined angle adjustment of the grading cylinder and rotational speed of 15 rpm was optimum adjustment to obtain maximum grading efficiency. Hence, under these operational conditions grading capacity was observed 630 Kg/hr

4.0 Conclusion

The combination of rotational speed of 15 rpm and 3º inclined angle against horizontal axis of grading cylinder reported optimum adjustment of grader to work out at the highest performance of size grading of big onion bulbs. The capacity of the grader under optimum operation conditions was 630 Kg/hr and grading efficiency/qualities of small, medium and large grades were 84.47%, 93.46% and 90.14 respectively.

5.0 References

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