International Journal of Agriculture, Environment and Biotechnology
Citation: IJAEB: 9(1): 137-144 February 2016
DOI Number: 10.5958/2230-732X.2016.00020.6

AGRICULTURAL ENGINEERING

Development and performance evaluation of rotary drum grader for tomato

P. Preetha* , R. Pandiselvam, J. Deepa and N. Varadharaju

Department of Food and Agricultural Process Engineering, Tamil Nadu Agricultural University, Coimbatore, India

*Corresponding author: preethafoodtech@gmail.com

Paper No. 422 Received: 15 August 2015 Accepted: 4 February 2016

Abstract

Grading is one of the most important unit operations in packing houses by which it enables to obtain a good and appealing packing system. To standardize the tomatoes for export or marketing in local markets the rotary drum grader was developed in Tamil Nadu Agricultural University. It consists of a drum in which the holes are made based on the standard size of tomatoes. It is manually operated using a handle fitted to the shaft which is mounted on the main frame using a wooden block. The performance evaluation was done to optimizing the peripheral speed, inclination angle and feed rate. As the tomatoes are fed through the hopper into the rotating drum, it gets separated according to size. It is portable and can be used in the field. By conducting different study the efficiency of grader was found to be 80% at 16º inclination angle, 175 kg.h^{-1} feed rate and 15 rpm peripheral speed.

Highlights

- Rotary Drum grader for tomato were developed in TamilNadu Agricultural University.
- Grader is used for local markets to grade tomato according to its size
- Based on size, tomato fetch higher prices in market.

Keywords: Tomato, grader, sorter, degree of grading, fraction yield, peripheral speed, inclination angle

Tomato is one of the most important "protective foods" because of its nutritive value. It is one of the most versatile vegetable with wide usage in Indian culinary tradition. PKM 1 is the most popular variety grown in Tamil Nadu due to suitability for all seasons and yields around 32 tonnes/ha. The tomato producing areas in Tamil Nadu are Salem, Coimbatore, Dharmapuri, Trichy, Erode and Krishnagiri. Depending on their internal and external characteristics of tomatoes are extensively used for the preparation of many products and it can also be processed and preserved in the form of puree, paste, ketchup, sauce and other ready-to-eat products. It is also used as a salad vegetable. It has good domestic and export markets.

Grading is one of the most important unit operation for fruits and vegetables in marketing (Mangaraj *et al*. 2006). Grading may not only standardize fruit product but also promote management of the fruit tree in orchard and product quality (Haisheng Gao, 2003; Lite Li *et al*. 2003).Grading and sorting of vegetables and fruits ensures that derived products meet the defined grade requirements for sellers, and the expected quality for buyers (Heinemann *et al*. 1996). It is important for tomatoes because the size, shape and color depend greatly on environmental conditions and handling, and is performed primarily by human labor who assess the tomato based on "color" or "size" denote a particular quality attribute. However, there are some disadvantages to using human labor, including inconsistency, short supply of labor, and the expense of the large amounts of time and money is required due to the huge volume of production and there may be a chance for improper grading and cross contamination. (Narvankar and Jha 2005). Automated systems in most cases are faster and more precise (Narendra and Hareesh 2010).

Both the consumers and farmers are benefited, if the tomato is sold with standard grade. Factors such as size, uniformity, shape, color, firmness, disease, cut surfaces and moisture content determine the final grade of a tomato.Grading of fruits enables to sell the fruits or vegetables in a good appealing manner through uniform packages (Varshney *et al.,* 2002). Product experts characterize tomato defects and diseases based on size, color and shape features, and thus mechanical grader may improve grading results and be able to take over the visually intensive grading work from human labor. New trends in marketing as specified by World Trade Organization (WTO) demand high quality graded products. Farmers are looking forward to having an appropriate agricultural produce-grading machine in order to alleviate the labor shortage, save time and improve graded product's quality (Londhe *et al.* 2013). In view of the above considerations, the mechanical fruit grader is a useful option that maintains uniformity of product and adds value to the final product (Kachru *et al.,* 1986). Mechanical grading of the fruits and vegetables is done based on weight, shape and size.Hence an economical and simple size based mechanical grader for tomato is the need of hour for the tomato growing farmers. The objective of this present investigation was to develop a grader for tomato and evaluate its performance.

Materials and methods

The rotary drum grader consisted of a frame, transmission system, circular sieves, central shaft, hopper, collector and cover as shown in Figure 1 (a) and (b).

Frame

Frame is the important component of any machine which has the capability of resisting all the forces acting over it and protects the other fragile components of the machine from breakage or damage. The dimension of the frame is 133×45 cm. The height of the frame is 56 cm on the hopper side and 53 cm on the other side. This denotes that the drum is placed at an appropriate angle based on the angle of repose of the tomatoes. The other side of the stand has a length of 60 cm and breadth of 45 cm.

Fig. 1: (a) Rotary drum grader

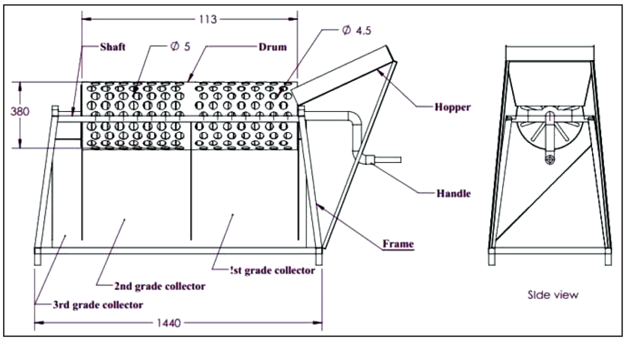


Fig. 1: (b) Front and side view of rotary drum grader

Transmission system

It is hand operated machine in which a handle is fitted to the main central shaft. The handle was connected to the centre shaft made up of mild steel. It diameter is about 2.5 cm.

Circular sieves

The circular holes were made on the poly carbonate sheets. The first chamber has a hole of about 4.5 cm diameter and second chamber has the holes of 5 cm diameter. A single drum is bifurcated into two sections by means of a thin strip of mild steel sheet. The first chamber has totally 99 numbers of holes and arranged alternatively with 6 holes in one row and 5 holes in other row. In the second section have 72 holes and alternatively arranged with 5 holes as one row and 4 holes as other row. The diameter of the drum is 38 cm. The length of the drum is 113 cm positioned in the frame.

Central shaft

The central shaft is a mild steel rod whose length is about 169 cm which consist of flights at three positions at the two ends and in place separating the drum into two chambers. The drum is rotated by means of the shaft which runs through the entire length of the drum. It is mounted on the frame by mean of wooden piece of dimension 15.5 x 5 x 8 cm.

Hopper

Hopper is constructed for easy handling of tomatoes into the drum. The dimension of the hopper is 57×51×11 cm. It is made of mild steel sheet supported on the frame by means of the mild steel flat of length 7 cm on both side. It is also supported by two more mild steel flat. The slope of the hopper is fixed on the basis of angle of repose of the tomato. For efficient grading the height from which the tomato is feed was optimized based on the height of the hopper from the base, thereby the angle was also varied accordingly. The hopper is placed at an angle of 10º.

Collector

Three collectors are used in the grader. The first collector has a dimension of 40×71 cm which collects the 1st grade tomatoes of less than 4.5 cm size. The second collector has a dimension of 44×71 cm to collect the next grade of size 5 cm and the final collector is 13.5×71 cm to collect the rest of the grade i.e, 3rd grade of size greater than 6 cm. It is covered by smooth PVC sheet which enables free falling of the tomatoes.

Cover

A circular cover made of PC sheet of 0.8 cm is provided. It is used to cover the drum. On this Polycarbonate cover the holes were made.

Performance evaluation of the grader

Method of operation

Grader was placed on the leveled ground. Tomatoes were weighed and its size was measured manually. It is fed through the hopper into the rotating drum. The drum was rotated at a required speed manually. As the tomato pass through the drum the desired sized tomatoes were collected in the desired collector. The final weight and number of tomatoes in each grade was noted. This experiment was repeated for three times.

Speed of the drum

The grading was performed by varying the speed as 10, 15 and 20 rpm. The optimum speed for the effective grading was evaluated.

Angle of the drum

The angle at which the drum has been inclined to the frame is measured. In this the angle formed between the base line and the height of the drum from the base is calculated as 15º and the grading of tomatoes were performed by varying the angle as 15º, 16º and 17º.

Determination of feed rate

The known quantity of tomato was taken and fed in to the feed hopper. The machine was operated and the time taken for complete grading of the sample was noted for different feed rate and finally the feed rate of the machine per hour is calculated as

$$Feedrate\ (kg/h) = \frac{Q}{T} \tag{1}$$

Where, Q is quantity of the sample in kg and t is time taken in h

Effectiveness test

A known quantity about 5 kg of tomato were taken. The mass of the individual fractions of the material corresponding to the sizes of the holes at 4.5 cm, 5 cm and greater than 5 cm were analyzed as W_1, W_2 and W_3 respectively. The individual fractions were mixed and fed into the grader and the handle was rotated. The time taken for grading was noted down.

After grading the feed material let the mass of the products obtained through the outlets are taken as Q_1, Q_2 and Q_3.

Thus,

$$W_1+W_2+W_3=W_T \tag{2}$$

$$Q_1+Q_2+Q_3=W_T \tag{3}$$

The material other than the specified size in the products Q_1, Q_2 and Q_3 of each outlet were separated manually and their masses were separately found as q_1, q_2 and q_3.The purity of the product obtained at different outlets after grading was found out using the following relation

$$P_1 = \frac{Q_1 - q_1}{Q_1} \tag{4}$$

$$P_2 = \frac{Q_2 - q_2}{Q_2} \tag{5}$$

$$P_3 = \frac{Q_3 - q_3}{Q_3} \tag{6}$$

Where,

P_1 = purity of the product obtained in the outlet 1

P_2 = purity of the product obtained in the outlet 2

P_3 = purity of the product obtained in the outlet 3

Q_1 = fraction of the feed material through the outlet 1

Q_2 = fraction of the feed material through the outlet 2

Q_3 = fraction of the feed material through the outlet 3

q_1 = fraction of the material other than the desired size in outlet 1

q_2 = fraction of the material other than the desired size in outlet 2

q_3 = fraction of the material other than the desired size in outlet 3

The fraction yield was calculated as follows:

$$F_1 = \frac{Q_1}{Q_T} \tag{7}$$

$$F_2 = \frac{Q_2}{Q_T} \tag{8}$$

$$F_3 = \frac{Q_3}{Q_T} \tag{9}$$

Where,

Fr_1 = fraction yield at outlet 1

Fr_2 = fraction yield at outlet 2

Fr_3 = fraction yield at outlet 3

W_T = total mass of feed to be graded

The fractions of each size corresponding to the holes in the total feed was calculated by,

$$a_1 = \frac{W_1}{W_T} \tag{10}$$

$$a_2 = \frac{W_2}{W_T} \tag{11}$$

$$a_3 = \frac{W_3}{W_T} \tag{12}$$

Where,

a_1 = raction of each size corresponding to the grade 1 in total feed

a_2 = fraction of each size corresponding to the grade 2 in total feed

a_3 = Fraction of each size corresponding to the grade 3 in total feed

W_1 = mass of individual fractions of feed material in grade 1

W_2 = mass of individual fractions of feed material in grade 2

W_3 = mass of individual fractions of feed material in grade 3

The degree of grading which is the ratio of the amount of the component in the yield fraction to the amount of the same component in the initial mixture is given by

$$Ex_1 = P_1 \frac{Fr_1}{a_1} \tag{13}$$

$$Ex_2 = P_2 \frac{Fr_2}{a_2} \tag{14}$$

$$Ex_3 = P_3 \frac{Fr_3}{a_3} \tag{15}$$

Where,

Ex_1 = degree of extraction of grade 1

Ex_2 = degree of extraction of grade 2

Ex_3 = Degree of extraction of grade 3

Overall efficiency

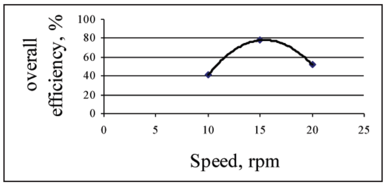
$$E = \sum_{i-1}^{n} Fri \frac{(p_i - a_i)}{(1 - a_i)} \times 100 \tag{16}$$

The experiments were carried out with different feeds rates and peripheral speed. The effectiveness was calculated for each trial.

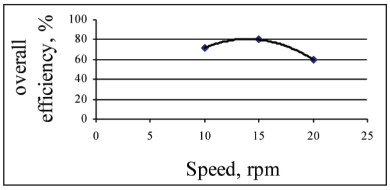
Results and discussion

Effect of peripheral speed on the efficiency

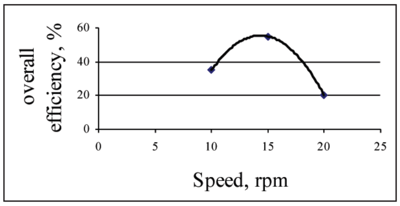
The grading efficiency mainly depends on the peripheral speed of operation. Figures 2 (a), (b) and (c) shows the effect of peripheral speed on the overall efficiency of the grader at 15º, 16º and 17º inclination angle respectively. The maximum efficiency of the grader observed at the peripheral speed of 15 rpm at an inclination angle of 15º, 16º and 17º for 78, 80 and 55% respectively. From the Figures also observed that as the peripheral speed increases the efficiency increases initially and then decreases. With increase in speed, the grading efficiency decreases since smaller tomatoes may move faster into bigger holes. Also the increase in speed increases the damage of tomato.



(a)



(b)

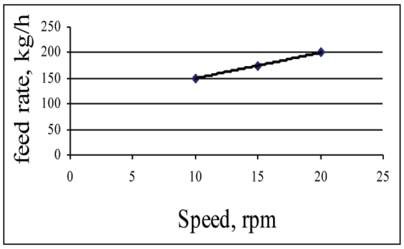


(c)

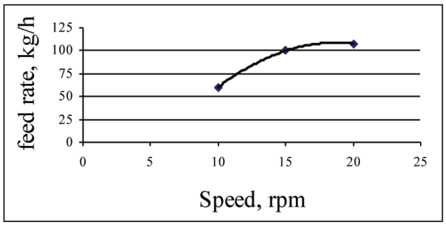
Fig. 2: Effect of peripheral speed on the overall efficiency of the grader at 15º (a), 16º (b) and 17º inclination angle (c)

Effect of peripheral speed on the feed rate

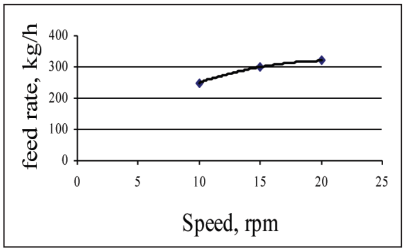
Figures 3 (a), (b) and (c) shows the effect of peripheral speed on the feed rate of the grader at 15º, 16º and 17º inclination angle respectively. If the peripheral speed increases the feed rate also increase. Hence maximum feed rate obtained for an inclination angle 15º, 16º and 17º at the peripheral speed of 20 rpm was found to be 100, 200 and 320 kg/h respectively. It is evident from the graph that as the peripheral speed increases the feed rate also increases and the time consumed for the completion of the process is less which ultimately resulted in increased feed rate. Tomato is a delegate vegetable it is prone to many damages during grading process. Proper care is required while rotating.



(a)



(b)

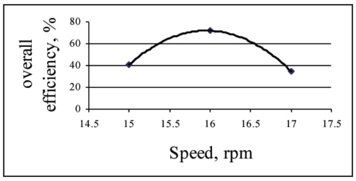


(c)

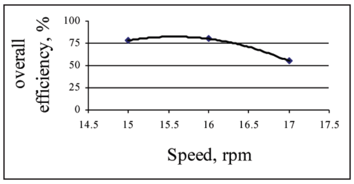
Fig. 3: Effect of peripheral speed on the feed rate of the grader at 15º (a), 16º (b) and 17º (c) inclination angle

Effect of inclination angle on efficiency

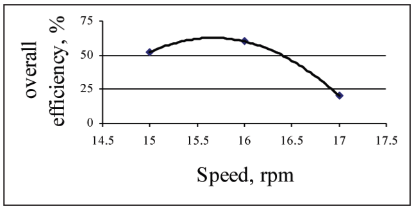
In this graph is drawn for three peripheral speeds as 10, 15 and 20 rpm related with overall efficiency (Fig. 4) at 15º, 16º and 17º inclination angle. The maximum efficiency is obtained at an inclination angle 16º. The inclination angle increases as 15º, 16º and 17º the efficiency was found to be 49, 71 and 45 per cent respectively. Increase in slope or inclination angle, the overall efficiency increases initially and then start decreases. Lower slope resist the flow of tomato and higher slope roll the tomatoes at faster rate. Hence 16º is optimum for operation of grader.



(a)



(b)



(c)

Fig. 4: Effect of peripheral speed on the overall efficiency of the grader at 15º (a), 16º (b) and 17º inclination angle (c)

Effect of peripheral speed on damage

Figure 5 shows the effect of peripheral speed on the tomato damage. If the peripheral speed ranges from 10, 15 and 20 rpm the damage percentage was found to be 3.2, 2.4 and 4 per cent respectively. Thus, due to the speed increases the damage first decreases and then slightly increases. Also the damage percentage decreases initially and then increases as the slope increases. The peripheral speed of 15 rpm at 16º inclination angle the damage percentage was found to be less.

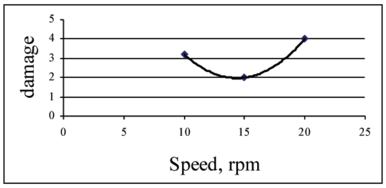
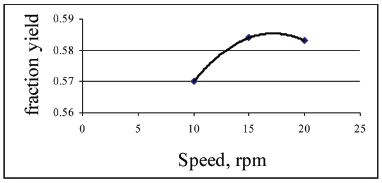


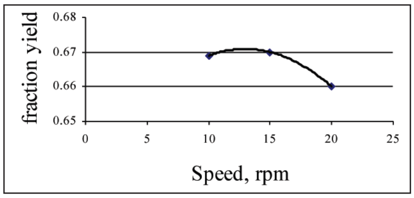
Fig. 5: Effect of peripheral speed on the tomatoes damage at 16º inclination angle

Effect of peripheral speed on the fraction yield

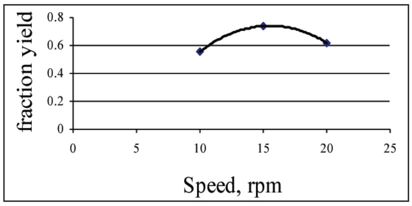
Figure 6 shows the relationship between peripheral speeds on fraction yield at an angles 15º (a), 16º (b) and 17º (c). For the peripheral speed ranges from 10, 15 and 20 rpm the fraction yield at angles 15º, 16º and 17º was found to be 0.58, 0.67 and 0.64 respectively. It was found that as the peripheral speed increases the fraction yield also increases and then slightly decreases. As the speed increases the yield as per the required size gets reduced since some higher peripheral speed is required to perform the required grading. The efficiency optimized at 15 rpm and 16 º inclination angle.



(a)



(b)

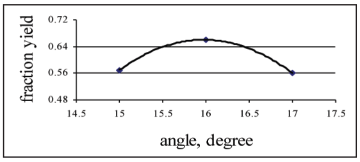


(c)

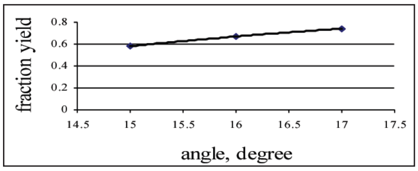
Fig. 6: Effect of peripheral speed on the fraction yield of the grader at 15º (a), 16º (b) and 17º inclination angle (c)

Effect of inclination angle on fraction yield

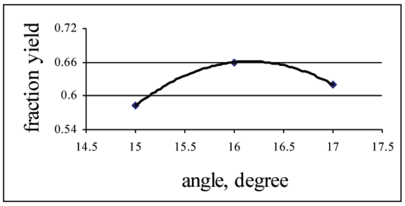
Figure 7 shows the relationship between inclination angle and fraction yield.The fraction yield at an inclination angle 15º, 16º and 17º for the peripheral speed 10, 15 and 20 rpm was found to be 0.6, 0.67 and 0.62 respectively. From these graphs observed that as the angle in creases the fraction yield also increases initially and then decreases. An optimum fraction yield is obtained at 16º inclination angle.



(a)



(b)

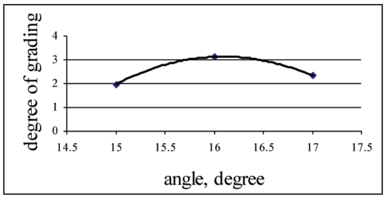


(c)

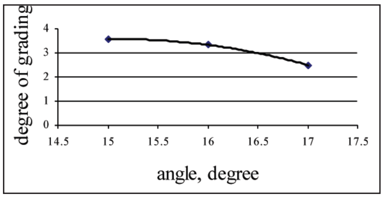
Fig. 7: Effect of inclination angle on the fraction yield at 10 (a), 15(b) and 20 rpm (c) peripheral speed

Effect of inclination angle on degree of grading

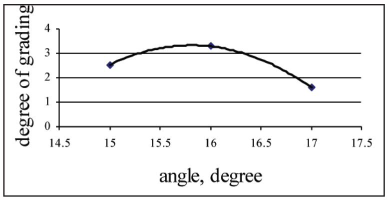
Figure 8 shows the effect of inclination angle on degree of grading.The fraction yield at angle 15º, 16º and 17º for the peripheral speeds 10, 15 and 20 rpm was found to be 1.9, 3.2 and 2.3 respectively. From these graphs it is also observed that as the inclination angle is increases the degree of grading increases initially and then decreases. From the figures optimum degree of grading was found to be 16º.



(a)



(b)

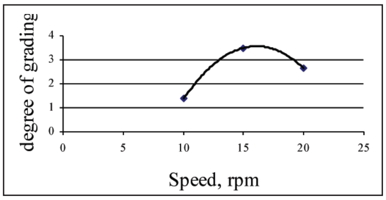


(c)

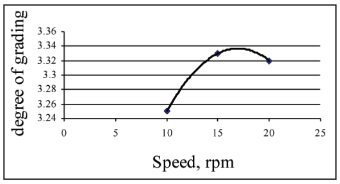
Fig.8: Effect of inclination angle on degree of grading at 10 (a), 15 (b) and 20 rpm (c) peripheral speed

Effect of peripheral speed on degree of grading

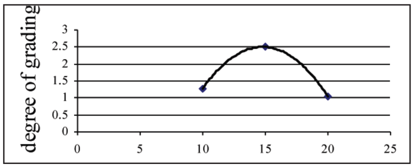
Figures 9 (a), (b) and (c) shows the relationship between peripheral speed and degree of grading at 15, 16 and 17º inclination angle respectively.For this the peripheral speed 10, 15 and 20 rpm the degree of grading at an inclination angles 15º, 16º and 17º was found to be 2.52, 3.3 and 1.6 respectively. It was found that as the speed increases the degree of grading increases initially and then slightly decreases. As the speed increases the degree of grading get reduced due to the corresponding change in the fraction yield. But the grading should require some external force. Hence the efficiency is optimized at 15 rpm and 16º inclination angle.



(a)



(b)



(c)

Fig. 9: Effect of peripheral speed on degree of grading at 15 (a), 16(b) and 17º (c) inclination angle

Conclusion

Grading of fruits is a very important unit operation as it fetches high price to the grower and improves packaging, handling and brings an overall improvement in marketing system. It could reduce handling losses during transportation. Vegetable grader is used to solve these problems. The developed rotary grader for tomato operated with perfection, accuracy, faster rate of grading and less labor requirement. The cost of grading of tomato was found to be Rs.16 per quintal.

References

Haisheng, G. 2003. Pursuing breakthrough in storage of fruit and vegetables in China. *China Food Newspaper* 7.7(A4).

Heinemann, P.H., Pathare, N.P. and Morrow, C.T. 1996. An automated inspection station for machine-vision grading of potatoes. *Machine Vision and Applications* **9**: 14–19. http://dx.doi.org/10.1007/BF01246635

Kachru, R.P., Bist, B.S., Srivastava, P.K. and Ojha, T.P. 1986. 100 Bankable Post harvest equipment developed in India, Central institute of Agricultural Engineering, Bhopal.

Londhe, D., Ganesh Pawar, S.N., Atkari, V. and Wandkar, S. 2013. Grader: A review of different methods of grading for fruits and vegetables. AgricEngInt: *CIGR Journal* **15**(3): 217-230.

Li, L., Wang, J. and Dan, Y. 2003. State and new technology on storage of fruit andvegetables in China. *Journal of Wuxi University of Light Industry* **22**(3): 106-109.

Mangaraj, S. and Varshney, A.C. 2006. Fruit grading in India – A review. *Indian Food Industry* **25**(3).

Narvankar, D.S. and Jha, S.K. 2005. Development of rotating screen grader for selected orchard crops. *Journal of Agricultural Engineering* **42**(4).

Narendra, V.G. and Hareesh, K.S. 2010. Quality Inspection and Grading of Agricultural and Food Products by Computer Vision-*A Review International Journal of Computer Applications* **2**(1): 43-65. http://dx.doi.org/10.5120/612-863

Varshney, A.C., Mangaraj, S. and Birla, S.L. 2002. Fruit grading practices-Status and future assessment. Technical Bulletin No. CIAE/2002/90. Central institute of Agricultural Engineering, Bhopal, India.