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Effect of Roller Speed and Inclination Angle on the Stem Cutting Efficiency of Shallot Onion

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Authors' contributions

This work was carried out in collaboration among all authors. Author MTA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author NV managed the analyses of the study. Authors AS and AP managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Shallot or aggregatum onion (*Allium cepa*L. var. *aggregati*on.) is one of the oldest bulb crops known to mankind and extensively grown and consumed in Southern states of India. They are one among the most important commercial vegetable and spice crops, widely used in the south Indian kitchen mainly for seasoning of curries. Aggregatum onion invariably forms afresh cluster of bulbs, often as many as 10 or 15 per cluster. In India, presently about 35 to 40 percent of the onion is estimated to be lost by post-harvest practices during various operations including handling and storage. Presently after harvest onions are processed by hand labor to remove the leaves and the roots. Hand topping has obvious disadvantages including both cost and length of time necessary to process a large number of onions. However, in recent times it is becoming increasingly difficult to

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find sufficient skilled labor to do the job. Farmers and processors need a suitable post-harvest machine for stem cutting of shallot onion. Owing to the practical problem in the processing of shallot onion a stem cutting machine for shallot onion was designed and fabricated. The fabricated machine with different parameters like the slope of the machine and different speeds of the rollers were optimized. Different slopes (10^0, 20^0, 30^0) with two roller speeda (500 to 1500 rpm) were studied, results observed showed that at 20^0 slope and 1000 rpm, the cutting efficiency was very good (100%) with less damage to bulbs (2%).

Keywords: Fabrication; shallots onion; slope; rollers; stem cutting.

1. INTRODUCTION

Shallot onion is one of the most important commercial vegetable and spice crops. It is an export-oriented vegetable and earns a valuable foreign exchange for our country. According to the Directorate General of Commercial Intelligence & Statistics (DGCIS) report during 2018-2019 fresh onion export of India is 21,83,766.45 MT valuing Rs.3,46,887.36 Lacs. The major export is to Bangladesh, Malaysia, UAE, Sri Lanka, and Nepal. Onion belongs to the genus Allium which contains seven cultivated types of the economic importance of which the main type is called “bulb onion or garden onion” and the second one is “shallots or small onion”. Onion is famous for its pungency which makes it more alike to garlic than to common onions. It is a crop of tropical and subtropical region with better tolerance to pest and diseases and have longer storage life than the common onion [1]. This investigation mainly deals with the shallots belonging to *Allium cepa.* It is a native to Israel and Mediterranean region. The shallots are the major onion crop cultivated in Tamil Nadu especially in Trippur, Trichy, Perambalur, and Namakkal districts. Approximately 75 percent of shallots produced in Tamil Nadu comes from these districts.

The mature shallot consists of root, bulb, leaves, stalks, and flowers. The leaf and stalk are usually combined with high intact. After harvesting, the shallots are destalked before marketing, by the farmers, manually using a knife or by hand. The bulb is considered as the edible part and the bulb of the shallot is the marketable produce. Based on market demand and price fluctuations, farmers bring the shallot to the market or store the shallot until to get a desirable price in the market. After harvesting the shallot, it is arranged along with the stalk/foliage in the field itself for curing. The manual process requires more labor and time, further increasing the cost of production. Also in recent times, it is becoming increasingly difficult to find sufficient labor to do the job. Farmers are looking forward to having an appropriate agricultural produce processing machine to alleviate the labor shortage, save time, and improve graded product’s quality. The need of automation in the agricultural sector is necessitated due to the higher competition from across the globe [2]. A garlic cutting machine was designed, fabricated and evaluated for its performance and techno-economic feasibility [3]. Some shearing properties of garlic stem that are pertinent to the mechanical processing were measured and considered in the design of the machine.

Primary processing such as stem, root cutting, peeling and grading of onion is a very important post-harvest operation as it fetches high price to the grower and improved packaging along with the handling brings an overall improvement in marketing the product. Such type of primary processing machinery for stem cutting of shallot onion is not currently available in the field, owing to the practical problem in the processing of shallot onion as they are in clusters and are of different size and shape. Various parameters were studied during the optimization process in designing the stem cutting machine. Different design variables were studied, the effect of the roller speed and inclination angle on the shallot onion’s stem cutting efficiency is presented in this research. Previously reported the onion grading machine which was developed from a small cylinder type grading machine to suit grading of onion sets crop in which revolving speed and feeding rate where the two main parameters considered for optimization [4]. Designing and manufacturing of onion root and stem cutting with the sorting machine were investigated and developed a prototype for separating onion bulb from the rest of the crop using two rollers and cutters to cut onions that can be collected in bags using chain conveyor for further processing or packaging [5]. Onion leaf cutting machine also designed used conveyer belt and cutters to cut onions [6]. The geometrical properties like size, shape and area of fresh and three months stored aggregatum onion was studied [7], to design the equipment for processing and storage. An onion leaf cutter consisting of rotary cutters with belt conveyer assembly mounted on mild steel movable platform where the onion is moved along the conveyer through forward movement [8]. Therefore, the aim of this study are to evaluate different parameters of the cutting machine designed and manufacture for this purpose.

2. MATERIALS AND METHODS

The samples used for this study were cured shallot onion collected from Chettikulam village, Perambalur District, Tamil Nadu. The samples were kept under shade condition before using for the experiments. The experiments were conducted on the fabricated machine with different parameters [9] like the slope of the machine and different speeds of the rollers with a constant weight of the sample at 10 kg. The slope angle was taken at 10°, 20°, and 30°. It was decided on the preliminary studies conducted on the machine for the retention of shallots on the rollers. The speed of the rollers was set to be from 500 to 1500 rpm with an increment of 100 rpm. Observations for the finished product, uncut shallots, the weight of the stem removed from the shallots, and weight of the damaged shallots were recorded accordingly.

3. RESULTS AND DISCUSSION

3.1 Effect of Roller Angle

The angle setting is an important parameter in the shallot stem removing because without the inclination of the roller the shallots do not fall on the output chute. The angles were set at 10°, 20°, and 30° one by one, and the observations recorded. When the roller angle was 30º and more, the efficiency of the machine was found to be poor and hence it was not considered for further studies.

3.1.1 The angle at 10°

It was found that the flow of shallots on the roller was slow at an angle of 10^0 and the time taken to come out through the output was more than 10 sec. Also, the percentage of damaged shallots is found to be more than the other inclination angle. The cutting efficiency shows increasing pattern along with the speed of the rollers because of less slope and the retention of shallots along the roller length is for more time. This retention of shallots along the roller gives more exposure of stem to the rollers. This ensures cutting off the stem in almost all the fed shallots. The cutting efficiency of 97.8% is achieved in this slope (Fig. 1). But the actual calculation of the machine efficiency depends upon the undamaged stem removed and good bulb of the shallots. Considering this fact, the slope of 10º shows more damage on the edge of the bulb of shallots. The same retention of shallots along the roller gives more damage to the bulb. This damage increased with the speed of the rollers. The speed of the rollers increased the pull of stem between the rollers thus increasing the shearing force also between the rollers. This caused damage to the shallots at a higher speed. The maximum bulb damage of 6.5% was observed in this slope.

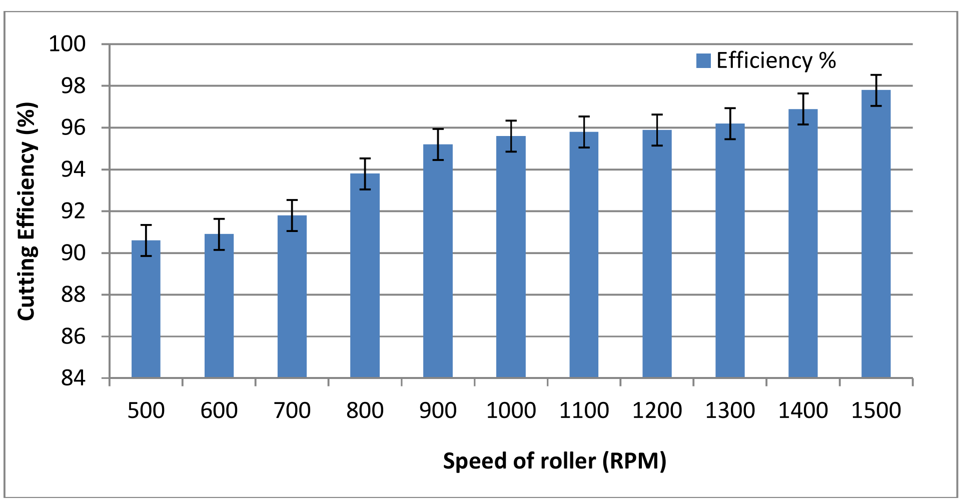

Fig. 1. Effect of speed of roller on cutting efficiency of shallot onions at an angle of 10º

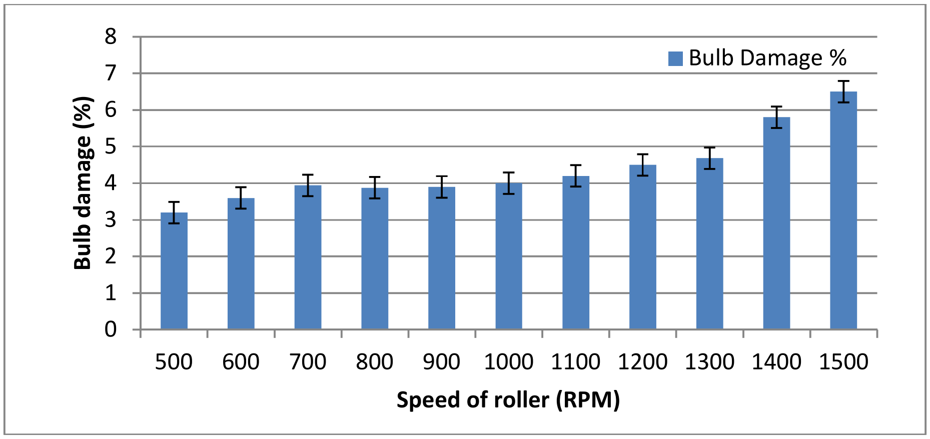

Fig. 2. Effect of speed of roller on bulb damage of shallot onions at an angle of 10º

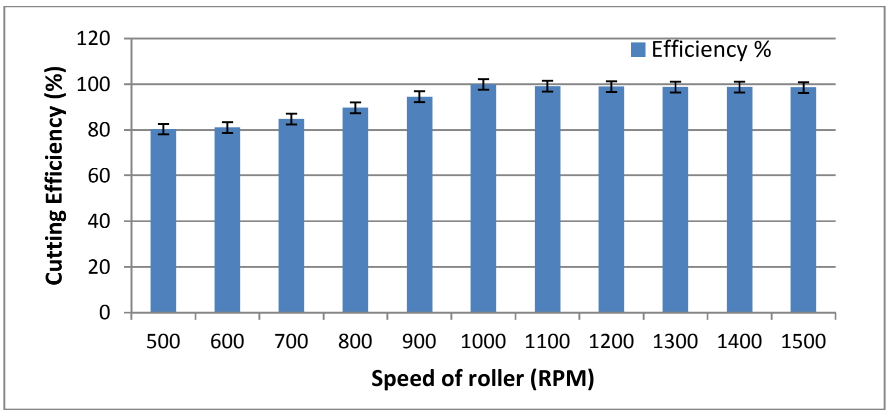

Fig. 3. Effect of speed of roller on cutting efficiency of shallot onions at an angle of 20°

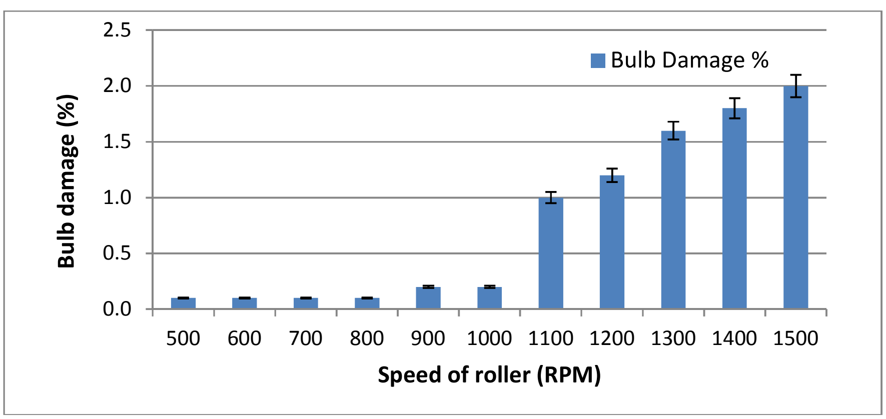

Fig. 4. Effect of speed of roller on bulb damage of shallot onions at an angle of 20°

3.1.2 Angle at 20°

At an angle of 20^0, it was found that the flow of shallots on the roller was moderate and the flow was uniform along with the roller and almost all shallots were in contact with the roller. This made the shearing action easy. The cutting efficiency showed an increasing pattern up to a certain speed and declined later. This might be because of the high centrifugal force acting on the shallots when it contacted the roller body, but the difference was not significant. The maximum efficiency of 100% was attained at the mid-range speed of the rollers. Again the damage of the bulb shows increasing trend along with speed but comparatively less percentage than 10°. The maximum damage was found to be two percent.

3.1.3 Angle at 30º

At this angle, it was found that the flow of shallots on the roller was faster than 20° slope and the flow was not uniform along with the roller, and jumping of shallots over one another occurred. This might be due to the inclination of angle which matches to the shallots. The cutting efficiency showed increasing pattern up to a certain speed and declining later like 20° slope but the uncut shallot percentage was more than 20° slope. This may be because of slopes and centrifugal forces of rollers. The maximum efficiency was found to be 92.9%. The bulb damage increased with speed and angle higher than 20° slope. This is because of the higher shearing force and faster movement of the shallots. The maximum damage was found to be 3.9%.

Among the three slopes 10°, 20°, and 30°, the 20° slope gave better results when compared with other two slopes. The cutting efficiency of 100% was attained at 20° slope and also fewer damage shallots were observed. The damage of shallots showed more in 10° and 30°, hence the optimum slope for the shallots stem cutting is 20°. Cedomir [10] designed a gadget for leaf cutting especially for root vegetables, specifically onions. The gadget had a shaper part with more sharp edges and a partner component the squeezed the slicing material to be cut. A vegetable cutting instrument was designed and fabricated by Nishanth and co-workers [11] which was automated to lessen the human effort. This machine works on the principle of rotation motion and crank lever mechanism with the aid of electric DC motor.

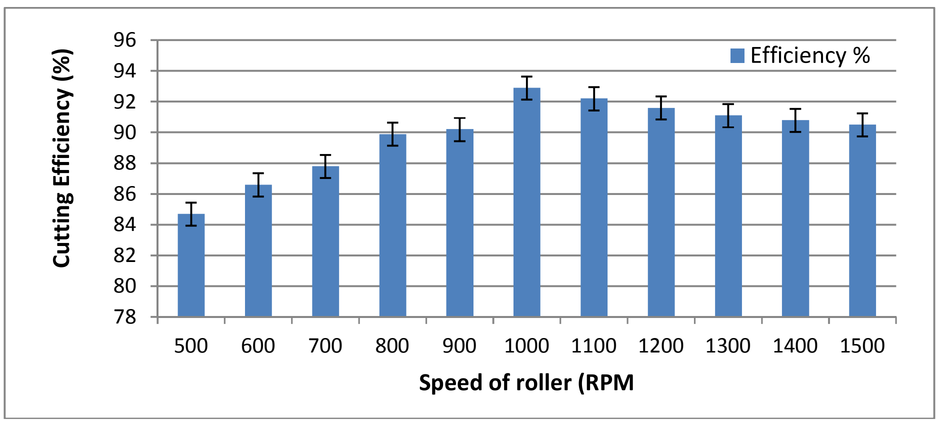

Fig. 5. Effect of speed of roller on cutting efficiency of shallot onions at an angle of 30º

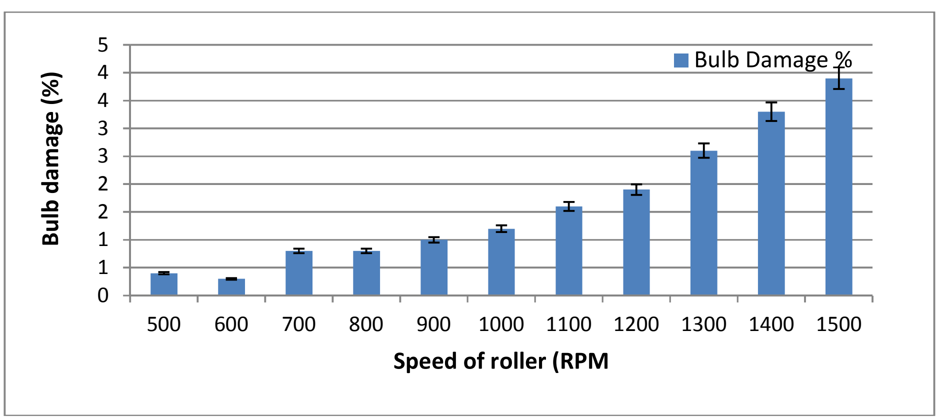

Fig. 6. Effect of speed of roller on bulb damage of shallot onions at an angle of 30º

3.1.4 Effect of roller speeds

The speed of the rollers also plays an important role in the stem cutting mechanism as like setting of angle in the rollers. The roller speed was set up from 500 to 1500 rpm with an increment of 100 rpm i.e., 500, 600, 700, and so on up to1500 rpm. The speed creates the shearing force on the stem as well as pulls the stem in between the rollers. The cutting efficiency almost showed an increasing trend, but for the final product, the damaged and undamaged shallots should be considered.

The roller speed plays a vital role in the shearing mechanism. Lower speed showed a lower percentage of the finished product like an undamaged bulb and vice versa. Also, the lower speed showed lesser damage to the shallot bulb and higher speed showed more damage. The lower speed of the roller showed lesser shearing action and because of that the damage and uncut shallots were observed more in the final product. The stem was pulled faster in between the rollers and stem was cut due to shear force created in between the rollers. In combination with angle and speed, the damaged and undamaged showed a different pattern. The cutting speed was directly proportional to the specific cutting power, while the cutting torque was inversely proportional to the moisture content [12].

At an angle of 10º, the shallots stay longer time along with the roller because of the insufficient slope to fall out at outlet. In this stage, the lesser roller speed shows 69.1% undamaged bulb and 3.20% damaged bulb. As the speed increased the percentage of the damaged bulb and undamaged bulb also increased. At the speed of 1000 rpm, the percentage of undamaged bulbs reached maximum i.e., 75.4% then started decreasing. The percentage of damaged bulbs kept on increasing along with speed. In overall percentage calculation, the increase in damaged bulb percentage shows an impact on the reducing undamaged bulb percentage. The maximum percentage of the damaged bulb (6.50%) was found in a higher speed of 1500 rpm.

At an angle of 20º, the shallots showed the rolling action and stay lesser time on the rollers. This shows a very less percentage of the damaged bulb at the lower speed i.e., 0.1% which was almost nil percentage and undamaged percentage of 67.1%. The rolling action may cause the uncut shallot percentage was little more than the previous one. The same pattern was found in the percentage of the damaged bulb and undamaged bulb as the previous one. The maximum percentage was found at 1000 rpm i.e., 81.8% with a minimum percentage of damaged (0.2%). The maximum percentage of the damaged bulb (2.0%) was found in a higher speed of 1500 rpm. In a study conducted earlier [13] in onion grading machine, the inclined angle against the horizontal axis was within a range of 2 to 4 inches. The revolving speed of the grader was from 10 rpm to 20 rpm. The optimum result was obtained at the revolving speed 15 rpm and an inclined angle of 3º. The grading efficiency/qualities of the small, medium and large grades were 84.47%, 93.46%, and 90.14% respectively.

At an angle of 30º, the shallots start rolling faster than the previous angle because of the increase in the inclination angle. As compared with the previous angle it also showed less damaged bulb percentage at the lower speeds. 0.3% of the damaged bulb percentage was found in a lower speed. The trend was found to be the same as earlier slopes. The maximum undamaged bulb percentage of 75.4% was found at 1000 rpm. This was lesser than 20º because of more inclination and rolling action. The maximum percentage of the damaged bulb (3.9%) was found in a higher speed of 1500 rpm.

4. CONCLUSION

Overall, the speed of the rollers showed better results at 1000 rpm in all inclinations. But considering the damaged bulb percentage, the inclination of 20º slope with 1000 rpm of roller speed gave better results and cutting efficiency.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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