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Original Research Paper

Design and development of a detopping mechanism for onion detopping machine

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ABSTRACT

Onion detopping is one of the unit operations involved in the cultivation of onion crop. Manual onion detopping is time consuming and highly drudgery. Therefore, an onion detopping machine was designed and developed for higher efficiency. An efficient detopping mechanism designed to achieve the maximum performance parameters in terms of detopping efficiency, per cent damage of onion bulbs and capacity of the onion detopping machine. By considering the crop parameters and functional requirement, four types of shearing designs of detopping tool namely, lead screw, square shaft with two cutting edges, square shaft with four cutting edges and helical roller were designed, developed and evaluated. Among four different shearing mechanisms, the helical roller type detopping tool was found to be effective in detopping the onion leaves. The helical roller type detopping tool had a detopping efficiency (98.44±1.07%), per cent damage (2.05±0.45%), conveying efficiency (97.60±1.02 %) and capacity (372.60±13.95 kg/h), respectively.

Keywords: Detopping mechanism, detopping, machine, mechanisation, onion

INTRODUCTION

Onion is one of the important commercial vegetable crop grown in India. The production and the market value of this commercial vegetable is increasing day by day. Globally, India occupies second position in onion production with a share of 14% (www.agriexchage.apeda.gov.in). In India, the area, production and productivity of onion was reported to be 19.14 lakh ha, 312.72 lakh MT and 16.34 MT/ha, respectively (www.indiastat.com, 2021-2022). Onions are harvested when 50% tops begins to collapse on the ground before the foliage dries down completely. After digging, the onions are field cured for 3-5 days, cut the necks for separation of onion from the tops, graded, shed cured and stored. Separation of onion bulbs from tops is called de-topping, women labourers are engaged for this operation and individual onion is de-topped by sickle thus makes it highly drudgery. Manual onion de-topping is highly labour intensive operation to an extent of 12.5 woman-hrs/t.

Bhanage et al. (2015) developed a power operated onion de-topper. The detopping mechanism consisted of plain cutters (two numbers) and one serrated cutter. The plain cutters and the serrated cutter counter rotated. The average de-topping efficiency was observed as 86.59 per cent with 315.03 kg/h output capacity. The power requirement was found to be 0.5 kW. The cost of operation was Rs.18.84 per quintal. Mozaffary & Kazmeinkhah (2014) designed, constructed and evaluated an onion topping mechanism. Three types of onion topping mechanisms *viz*., flail, rotary and roller topper were designed and tested at three rotational speeds of 1500, 1700 and 2000 rpm. It was reported that the flail topper was the most suitable mechanism for onion topping with the results of 87.7% acceptable top at 2000 rpm in stage one and 83.9% acceptable top at 1500 rpm in second stage. Rani & Srivastava (2012) designed and developed an onion de-topper with oscillating conveyor, rotating fingers and a rotating cutter. The cutter was provided at the downward side of the oscillating conveyor cut the onion leaves. The onion de-topper had a capacity of 300 kg/h with the de-topping efficiency of 79%.

The key component of onion detopping machine is detopping mechanism. Different researchers have designed and developed various detopping mechanisms and developed the onion detopping machine. The efficiencies of onion detopping machines developed in India ranges from 79% to 86.59%. Hence, it was felt that by designing and developing an efficient detopping mechanism, the detopping efficiency could be further increased. This paper discusses the approaches involved, design and development of an efficient detopping mechanism to achieve higher detopping efficiency of onion detopping machine.

MATERIALS AND METHODS

Design considerations

A onion detopping machine comprising the major components i. inlet (feed) chute, ii. outlet (collection) chute, iii. detopping unit (consists of set of rollers), and iv. power with necessary speed reduction systems (Fig. 1) was designed and developed.

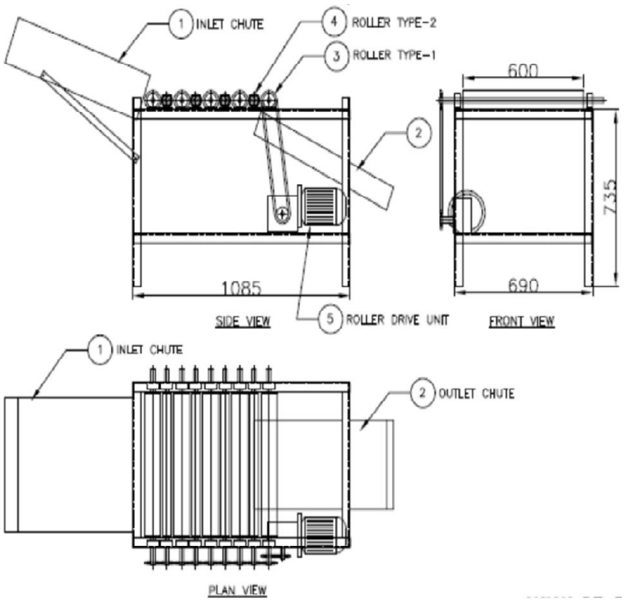

Fig. 1 : Onion detopping machine. All dimensions are in mm

Detopping unit is the key component of the machine. Design criteria for this component were, i. to hold the onion bulbs firmly for successful shearing of onion leaves, ii. sharp edge to shear the onion leaves and iii. to push/pull and hold the leave in downward orientation for convenient and successful shearing of leaves. All these functions are to be done simultaneously for efficient shearing off onion leaves to achieve the maximum performance parameters in terms of detopping efficiency, per cent damage of onion bulbs, capacity of the onion detopping machine.

The onion bulb is spherical in shape as its shape index is 1.15 (Carolin Rathinakumari & Jesudas, 2015). From this, it evident that a ‘v’ or ‘smooth ‘v’ shape trough has to be formed to hold the onion bulbs and the trough size should be able to accommodate minimum 3 cm neck portion of the onion for facilitating the shearing effort (Fig. 2 & 3).

Fig. 2 : ‘V’ type trough for holding the onion

Fig. 3 : Smooth ‘v’ type trough for holding the onion

From this, it was evident that the design of a detopping unit should be set of rollers. Each set of roller should comprise of one plain cylindrical roller and one roller designed to detop the leaves of the onion crop. The plain cylindrical roller functions as a support to the onion bulb firmly to achieve successful detopping as well facilitates conveying the detopped onion bulb by pushing them forward (Fig. 4). These rollers should be counter rotating by which the onion leaves are pulled in between the counter rotating elements thus making the onion leaves downward orientation and also holds the onion bulbs firmly between the rotating elements. The detopping roller design should have sharp edges to achieve meaningful throughput capacity coupled with less damage to the detopped onion bulbs.

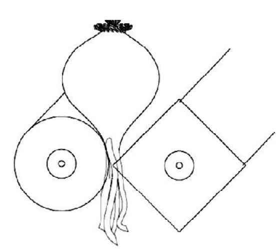

Fig. 4: Concept of detopping function

Apart from the above design requirements, the cost involved in the detopping is also considered to be minimum possible and easy fabrication. This directly leads to less cost of machine thus input cost involved in the onion cultivation will be reduced in multiple folds. Small scale manufacturers will come forward for commercial production of the machine and machine can be manufactured by any local industries.

Design, development and performance evaluation of different detopping tool

Keeping the above points in view, as a first step a commercially available lead screw was procured from the market, fitted in the machine and the performance of machine on detopping of onion was evaluated. The performance of the tool was found to be non-satisfactory. Based on the observations made, another detopping tool was designed, fabricated, fitted in the machine and performance was evaluated. Though this design could detop the onion leaves efficiently, it was noticed that there was further scope for improving the detopping efficiency with slight modification in the existing design. Accordingly, the same design was modified, fabricated, fitted and performance was evaluated. Though there was slight improvement in the detopping efficiency, it was not significant. However, the per centage of damaged onion was found to be higher side for which the designed needed to be improved. From the above observations, the merits and demerits of the three designs were analysed. A detopping tool was designed to address the demerits of the problems in the above three designs. The performance of this detopping tool was found to be satisfactory. The design, construction, merits and demerits of the above four types detopping tools are presented below.

Type I: Lead screw (Acme thread form)

As a first approach, commercially available lead screws (Acme thread form), were purchased, machined and fitted in the onion detopping machine. This type of lead screws has 29° thread angle. The lead screw rod had a diameter of 40 mm and pitch of 10 mm (Fig. 5). The teeth had a width of 7.75 mm and depth of 5.45 mm. The performance of the machine was evaluated and it was observed that this mechanism could not achieve efficient detopping of onion leaves.

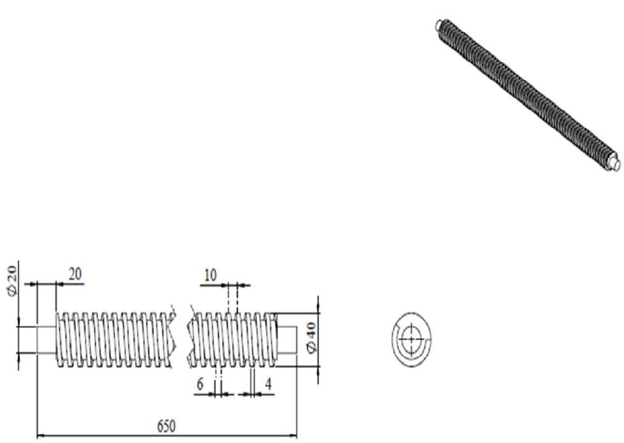

Fig. 5 : Type I: Lead screw type onion detopping tool. All dimensions are in mm

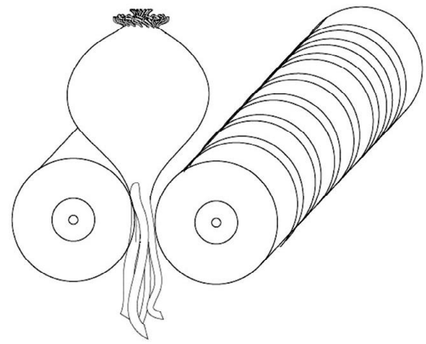

Fig. 6 : View of onion held for shearing of leaves

Type II: Square shaft with two cutting edges

As a second approach, a square shaft was fabricated by welding two ‘L’ Angle sections, thus two blunt and two sharp edges were formed having 40 mm square section (Fig. 7). In this case, the sharp edge had 0° helix angle. The lead screw fitted in the machine was replaced with square shaft with two cutting edges and the performance was evaluated. As this tool had two sharp edges, it was aimed to further increase the detopping efficiency by having four sharp edges.

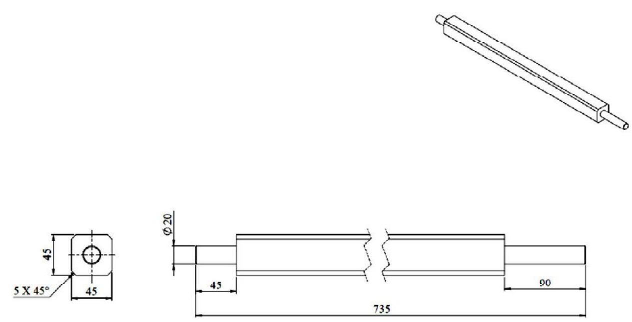

Fig. 7 : Type II: Square shaft with two sharp edges type detopping tool. All dimensions are in mm

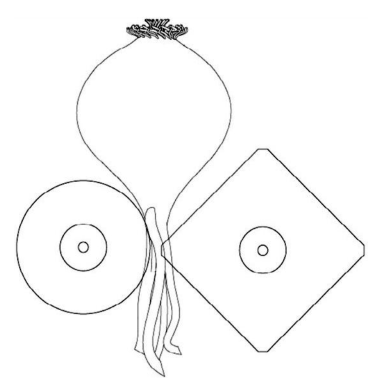

Fig. 8 : View of onion held for shearing of leaves

Type III: Square shaft with four cutting edges

A square shaft with four cutting edges was fabricated out of solid square shaft having 40 mm square section

(Fig. 9). A bore of 25 mm was made throughout the length of the shaft to reduce the weight of the shaft. This was necessary to reduce the machine weight as well to reduce the impact to the onion bulbs while detopping. Further all the four edges were sharpened by surface grinding with helix angle of 0˚. This tool was fitted in the onion detopping machine and the performance was evaluated (Fig. 10).

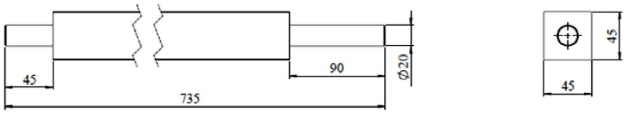

Fig. 9 : Type III: Square shaft with four sharp edge type detopping tool. All dimensions are in mm

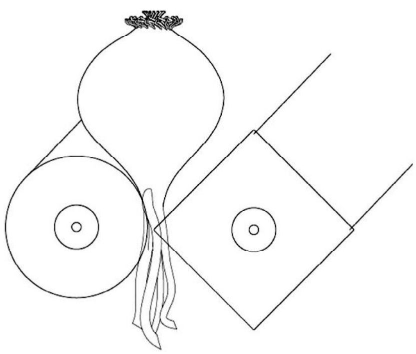

Fig. 10 : View of onion held for shearing of leaves

Type IV: Helical roller

From the above designs and their performances, it was clear that a tool having a cylindrical shape (as in lead screw) coupled with sharp edge along its periphery (as in square shafts) having wider helical angle would be able to detop onion leaves efficiently. Accordingly, a helical roller was fabricated having a helical angle of 45˚. The diameter of the helical roller is 40 mm (Fig. 11). This tool was fitted in the detopping machine and its performance was evaluated.

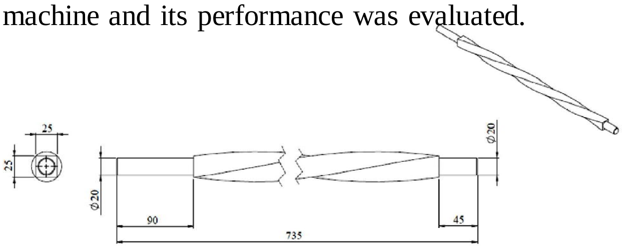

Fig. 11 : Type IV: Helical roller type detopping tool. All dimensions are in mm.

RESULTS AND DISCUSSION

The four types of detopping tools were developed (Fig. 12, 13, 14 and 15). From the experiments, the following observations were made.

Lead screw type detopping tool had 2.86±0.43%, 2.14±0.45%, 67.40±1.85%, and 247.80±16.75 kg/h, detopping efficiency, per cent damage, conveying efficiency and output capacity, respectively. This indicated that this design was not able to shear the onion leaves instead the onion crop was conveyed. Hence, it was observed that this type of mechanism behaved as conveyor roller only and could not be used for shearing/cutting the onion leaves in the onion detopping machine. From this, it was evident that though the screw had a sharp edge, the thread angle of 29˚ was unable to shear the onion leaves. The roller shape had the advantage of efficient conveying coupled with very less damage to the onion bulbs.

Fig. 12: Lead screw type detopping tool

Fig. 13: Sqaure shaft with two sharp edges type detopping tool

Fig. 14: Square shaft with four sharp edges type detopping tool

Fig. 15: Helical roller type detopping tool

Square shaft with two cutting edge resulted 95.42±2.15%, 21.60±3.38%, 69.00±3.34% and 243.00±33.29 kg/h, detopping efficiency, per cent damage, conveying efficiency and output capacity, respectively. This detopping mechanism was able to achieve the detopping of onion leaves successfully. However, due to the 'V' shape trough formed between shafts (Fig. 8), the detopped onions could not be conveyed which affected the detopping capacity of the machine.

Square shaft with four cutting edge had 96.00±1.67%, 23.20±1.83%, 58.00±2.68% and 218.60±23.84 kg/h, detopping efficiency, per cent damage, conveying efficiency and output capacity, respectively. As this mechanism had four cutting edges, the detopping efficiency could be achieved, however, it had very low conveying efficiency which lowered the detopping capacity of the machine.

Per cent damage of 21.60% and 23.20% were observed in the above two mechanisms and it was also noticed that the damaged onion were smaller in size (< 25 mm diameter). This was also due to the 'V' shape trough formed between shafts (Fig. 8 & 9.).

Helical roller detopping tool had 98.44±1.07%, 2.05±0.45%, 97.60±1.02% and 372.60±13.95 kg/h detopping efficiency, percentage damage, conveying efficiency and output capacity, respectively. From this, it was clear that, the combination of detopping tool having cylindrical shape coupled with shearing edge of wider angled helix shape on its periphery was able to achieve the following crucial functions to detop the onion leaves, i. holding the onion bulb firmly, ii. pulling the onion downward orientation, iii. shearing the onion leaves, iv. too little damage to the onion bulbs, v. suitable for all sizes of onion bulbs and vi. conveying the detopped bulbs. It is summarised that

i) Lead screw type detopping tool could not shear the onion leaves due to blunt edge though it performed as an efficient conveyor coupled with near to very less damage to the onion bulbs.

ii) Square shaft with two cutting edge and four cutting edge detopping tools could achieve the desired detopping efficiency. As both mechanisms formed a 'V' shape trough, it resulted very poor conveying efficiency led to low capacity of machine. Also higher percentage of damage of onion were recorded in both mechanisms.

iii) Helical roller detopping tool could detop the onion leaves efficiently with negligible damage to the onion bulbs and conveyed the detopped onion bulbs continuously. This facilitated to achieve maximum possible throughput capacity of the machine. These functions were possible due to the appropriate and unique profile and angle of helical shape.

CONCLUSION

The key component in the detopping machine was detopping mechanism. An efficient detopping mechanism to achieve highest onion detopping efficiency was designed and developed. Based on the functions required for efficient shearing of onion leaves, starting from semi skill and low cost detopping tool were designed and each design was evaluated. From the results, the detopping tool was designed for improving its performance. Thus, four designs *viz*., lead screw, square shaft with two sharp edges, square shaft with four sharp edges and helical roller were conceptualised, fabricated and evaluated for their performance in terms of detopping efficiency, per cent damage, conveying efficiency and output capacity. It was concluded that helical roller could achieve the maximum required performance parameters. The helical roller design detopping tool had a detopping efficiency, per centage damage, conveying efficiency and output capacity of 98.44±1.07%, 2.05±0.45%, 97.60±1.02% and 372.60±13.95 kg/h, respectively. Further, there is scope to increase the capacity of the present machine by changing the mounting orientation of detopping unit pattern. As this modification also requires alteration in fabrication, a machine with altered detopping unit mounting pattern can be developed and validated in future studies.

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