J. Hortl. Sci.
Vol. 11(1):57-62, 2016

Development and performance of power-operated garlic bulb breaker

B.B. Channabasamma[1], A. Carolin Rathinakumari*, G. Senthil Kumaran and P. Dayananda

Section of Agricultural Engineering
ICAR-Indian Institute of Horticultural Research
Hesaraghatta Lake Post, Bengaluru - 560 089, Karnataka, India
*E-mail: carolin@iihr.res.in

ABSTRACT

A power-operated garlic bulb breaker to separate cloves from whole-garlic-bulbs was developed, its operational parameters optimized and its performance evaluated. The garlic bulb breaker consisted of a feeding chute, two-stage padded rubber rollers, a blower, outlets for cloves and skins, a main frame, power and power transmission system. The garlic bulb breaker was evaluated using three types of rubber padding material viz., plain type, button type and corrugated type, with four levels of clearance between rubber rollers viz., 15, 18, 21 and 24mm, three levels of peripheral speed, viz., 259.2, 302.4 and 345.6 m/min. The machine displayed performance parameters in terms of breaking efficiency at 96%, per cent clumps of cloves 1.22, per cent clove damage 1.7, per cent clove loss 1.08, and bulb-breaking capacity of 780kg/h using corrugated padding material fitted at 18mm clearance and 259.4m/min peripheral speed. Operating cost of the machine was Rs. 0.06/kg against Rs. 2.25/kg incurred with manual clove separation of cloves.

Key words: Garlic bulb, garlic bulb breaker, power-operated, garlic processing machinery

INTRODUCTION

Garlic (*Allium sativum*) is one of the important bulb crops grown for use as a spice or condiment throughout India. As a culinary ingredient, it adds taste and flavour to a wide range of food preparations. Garlic bulbs can be used not only to flavor curries, but, can also be used for making drinks and savouries. It is also used in its processed form, e.g., essential oil, powder, oil macerate, aged extract, paste, pickles etc. Garlic is of higher nutritive value than other bulb crops. It is rich in proteins, phosphorus, potassium, calcium, magnesium and carbohydrates. Ascorbic acid content is very high in green garlic. Garlic is processed to yield dehydrated products like flakes and powder: besides its use as pickles/paste, it is also canned and bottled. Processed products of garlic are in demand in the local market for defense and fast food industries. Garlic is also exported to exotic markets and earns valuable foreign exchange. Garlic also has remarkable preventive and curative properties in health care as a digestive, carminative and anti-rheumatic. It is also used in formulations for curing lung ailments, healing intestinal ulcers and for checking muscular pain and giddiness. Thus, there is a perpetual demand for garlic not only in India, but also around the world.

Garlic is thus an important foreign exchange earner for India. It is widely grown in different parts of the country by all categories of farmers. India produces about 3.5 per cent of the total world production, and is ranked second after China. Garlic is grown in an area of 239,000 hectares in India, with production of 1.22 million tonnes and productivity of 5.69 tonnes/ha (Anon., 2014).

Garlic bulbs are broken into garlic cloves which are then used in pickle and garlic-paste making. Garlic cloves are also required as planting material. Conventionally, garlic cloves are separated by rubbing the bulb between palms, against jute bags or by beating with a wooden stick. These methods are very laborious and time-consuming, often leading to physical injury to the hand (Mudgal *et al*, 2009). A manually-operated garlic bulb breaker developed by Mandhar *et al* (2005) consisted of one set of rollers, a feeding chute, a collection chute and handle for operating the roller. Its bulb breaking capacity was 50kg/h. In view of an increased demand for garlic and its products

[1]Dept of Applied Engineering, Vignan University, Vadlamudi, Guntur, Andhra Pradesh, India

in domestic and export markets, a power-operated garlic bulb breaker was developed by us and evaluated for its performance.

MATERIAL AND METHODS

Development of power-operated garlic bulb breaker

Conventionally, the separation of garlic cloves from the compound bulb of garlic is carried out by shearing and by use of impact forces. Based on this principle, a garlic bulb breaker was developed. The garlic bulb breaker consisted of a feed hopper, cloves separating rollers, a blower, outlets for separated garlic cloves and skin, root and stem fractions, power and power transmission systems (Fig. 1). A rectangular feeding chute measuring 820 X 560 mm was provided above the rollers for feeding the garlic bulbs. Two rollers each of 500mm length and 275mm diameter were selected for higher capacity. Materials used and dimensions of various parts of the garlic bulb breaker are presented in Table 1.

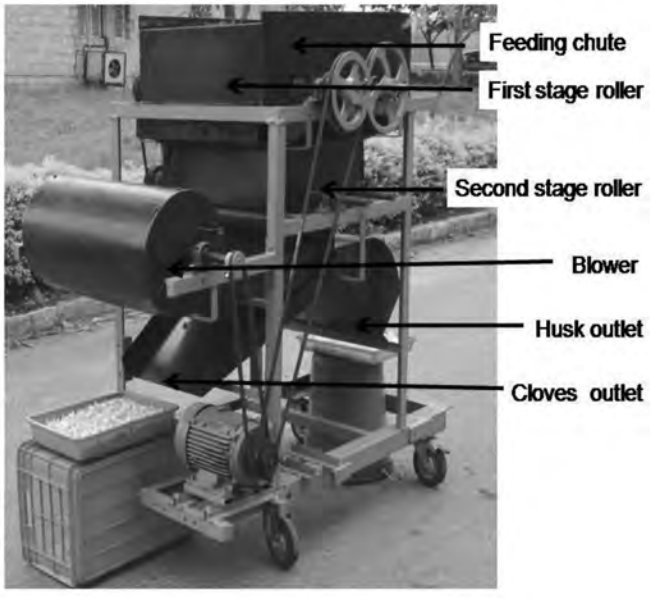

Fig 1. Power-operated garlic bulb breaker

The rollers were made to rotate in opposite directions at different speeds to achieve shearing force required for separation of the cloves. Top surfaces of the rollers were covered with rubber padding material to prevent any damage to the cloves. A straight-blade type blower with a blade of 62mm width and 335mm diameter was selected for cleaning the material passing through the rollers (Sahay and Singh, 1994). A three-phase, 1.5kW, 1440rpm AC Electrical motor was used as the prime mover for operating various units of the machine. Power was transmitted by the belt and pulley arrangement to the roller and blower. All the above components were fitted with necessary supports, and, fittings on a main frame were fabricated out of M.S. angle section of 40×40×6mm. Overall dimensions of the frame were 925mm length, 770mm width and 1030mm height. Four swivel-type caster wheels 150mm in diameter were provided for easy mobility of the machine.

Experimental technique

Experiments were conducted to optimize the clearance between the rollers and peripheral speed of rollers at different rubber padding materials. Three types of rubber padding material, viz., plain, button and corrugated type were used in the study (Fig. 2). As the mean geometric diameter of bulb was 45.69±0.85mm, clearance between the rollers was varied as 15, 18, 21 and 24mm. One of the rollers was fitted in the groove to create required clearance. Different peripheral speeds selected were 259.2, 302.4 and 345.6m/min for the faster roller (Mudgal, 2009). Peripheral speeds were varied by changing the size of the driven pulley. Speed ratio between rollers was 2:5.

Table 1. Broad dimensions of major components and material used in their construction

S. No.	Part	Dimension (mm)	Material /Section
Garlic bulb breaker			
1.	Feed hopper – rectangular shape	L- 820; W- 560; H- 240	Mild-steel sheet 1mm thick
2.	Bulb-breaking rollers		
	i) 1st stage rollers	OD- 275; L- 500	
	ii) 2nd stage rollers	OD- 125; L- 500	Mild-steel pipe 10mm thick;Mild-steel pipe 6mm thick
3.	Rubber padding material: i) Plain type ii) Button type iii) Corrugated type	L- 870; W- 500	Thickness of rubber material - 4mm;Type – EPDM; Hardness – Shore 70A
4.	Main frame	L- 925; W- 770; H- 1030	Mild-steel angle size 40×40×6 mm
5.	Casing (inlet, outlet and blower)	L- 7530; W- 1780	Mild-steel sheet 1mm thick

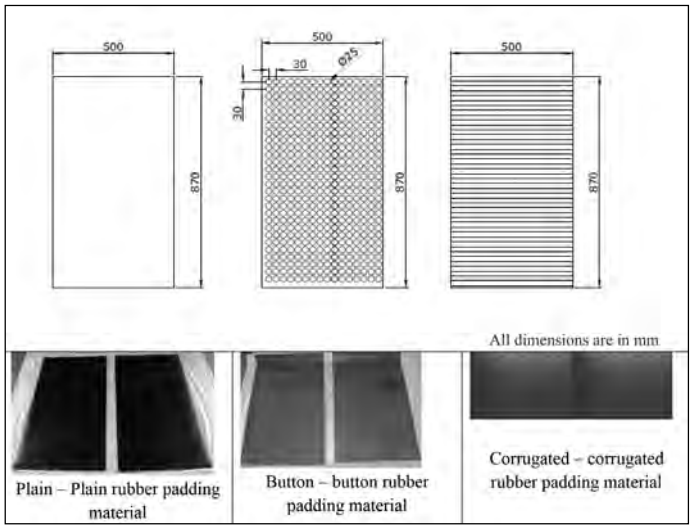

Fig 2. Types of rubber padding material used

Garlic bulbs were procured from a local market. A sample of 500g was used in each trial. The compound bulbs were fed into the rollers through a feeding chute. Time taken by the garlic bulbs to pass through the rollers was noted. Material from both the outlets was collected and separated into different fractions (viz., single-cloves separated, clumps of cloves, damaged cloves, and light-weight fractions, i.e., skin, root and stem). Each trial was replicated thrice.

The following, standard formulae were used for determining performance parameters, viz., breaking efficiency, per cent clumps of cloves, per cent clove damage, per cent cloves lost and breaking capacity:

$$\text{Garlic bulb breaking efficiency} = \frac{\text{Weight of single-cloves separated \& collected in the main outlet (kg)}}{\text{(Total input weight – Weight of chaff collected in the chaff outlet) (kg)}} \times 100 \quad \text{——— (1)}$$

$$\text{Per cent clumps of cloves} = \frac{\text{Weight of clumped cloves (three cloves or more) collected in the main outlet (kg)}}{\text{(Total input weight – Weight of chaff collected in the chaff outlet) (kg)}} \times 100 \quad \text{——— (2)}$$

$$\text{Per cent clove damage} = \frac{\text{Weight of damaged cloves collected at main outlet (kg)}}{\text{(Total input weight – Weight of chaff collected in the chaff outlet) (kg)}} \times 100 \quad \text{——— (3)}$$

$$\text{Breaking capacity} = \frac{\text{Total input weight (kg)}}{\text{Time taken to break the bulbs (h)}} \quad \text{——— (4)}$$

Results on performance of the machine under different treatments for garlic bulb breaking were analyzed using Fischer's factorial completely randomized design with 3 replications, using the statistical package "AGRES". Mean value of the observation was subjected to two-way ANOVA and significance of the means was put to F-test at p=0.05. Based on maximum breaking efficiency, minimum per cent clove damage, per cent clumps of clove and maximum breaking capacity, padding material, clearance between rollers and peripheral speed of the rollers was selected. To further increase garlic bulb breaking efficiency, second stage rollers were fitted just below the first stage rollers. As the second stage rollers had to pass singles cloves, clumps of cloves, and light weight fractions, the diameter was selected was 125mm, while, clearance between rollers was maintained as 10 to 12mm. Speed ratios between the first and second stage rollers was 1:2.

First and second stage rollers were covered with the selected padding material. Clearance between first stage rollers was adjusted to the clearance selected and the machine was operated at a selected peripheral speed. The blower was mounted. Fractions other than the cloves, i.e. skin, root and stem were separated by the blower and collected in their respective outlet. Performance of the garlic bulb breaker for breaking efficiency, per cent clumps of cloves, per cent clove damage and breaking capacity was calculated using the above-mentioned formulae. In addition to these performance parameters, per cent clove loss was estimated using the formula given below:

$$\text{Per cent clove loss} = \frac{\text{Weight of cloves collected at the chaff outlet, kg}}{\text{(Total input weight – Weight of chaff collected in the chaff outlet) (kg)}} \times 100 \quad \text{—— (5)}$$

RESULTS AND DISCUSSION

Performance of the garlic bulb breaker with three different types of rubber padding material, viz., plain-plain, button-button and corrugated types at four clearances between the rollers of 15, 18, 21 and 24mm, and three peripheral speeds of the rollers (259.2, 302.4, 345.6m/min.) was evaluated. Performance parameters of the garlic bulb breaker in terms of breaking efficiency, per cent clumps of cloves, per cent damaged cloves and breaking capacity were estimated. Optimized parameters were selected as explained, and are discussed below.

Garlic bulb separation efficiency

From Table 2, it was inferred that the type of padding material and clearance between the rollers had significant effect and the peripheral speed of rollers did not have effect on the clove separation efficiency. The maximum clove separation efficiency of 89.17 per cent was obtained with corrugated-type padding material at 18mm clearance between rollers at 259.2m/min.

Separation efficiency of 89.17 per cent was obtained using a single set of rollers. In order to increase the garlic bulb breaking efficiency, the second stage roller was mounted beneath the existing rollers. Width and thickness of the cloves was: 10.18±0.35mm and 7.42±0.24mm, respectively, a clearance of 10mm was provided between the second stage rollers. As maximum separation efficiency was obtained with use of corrugated rubber padding material, the second stage rollers were also provided with corrugated rubber padding material.

Per cent clumps of cloves

From Table 3, it is inferred that type of padding material and clearance between rollers had a significant effect on per cent clumps of garlic formed. However, peripheral speed of the rollers did not have any effect on per cent clumps of cloves formed. Corrugated-type padding material at 18mm clearance resulted in minimum (0.74) per cent clumps of cloves at a peripheral speed of 302.4m/min.

Per cent damaged cloves

From Table 4, it is inferred that type of padding material, clearance between rollers and peripheral speed of rollers had a significant effect on per cent damaged cloves. Per cent of cloves damaged were least with corrugated-type rubber padding material, and is the range of 0.9 to 3.10 per

Table 2. Effect of rubber padding material, clearance and roller peripheral speed on breaking efficiency

Type of padding material (P)	Clearance between rollers (C) (mm)	Peripheral speed (S) (m/min)		
		259.2	302.4	345.6
Plain rubber material	15	71.80	84.21	70.34
	18	74.41	75.40	69.00
	21	68.45	70.65	68.56
	24	63.37	55.92	64.79
Buttoned rubber material	15	91.28	90.25	82.38
	18	81.38	89.33	85.78
	21	78.00	55.72	75.50
	24	58.50	62.87	65.47
Corrugated rubber material	15	75.38	60.09	64.69
	18	89.17	88.06	65.37
	21	86.15	91.77	86.76
	24	71.32	82.18	84.40
	F – value	SEM	CD (p=0.01)	
P	**	1.24	4.28	
C	**	1.43	4.94	
S	NS	1.24	-	
PC	**	2.48	8.56	
CS	NS	2.48	-	
PS	NS	2.14	-	
PCS	**	4.3	14.82	

**Significant at 1 per cent level

Table 3. Effect of type of padding material, clearance between rollers and peripheral speed of rollers on per cent clumps of cloves formed

Type of padding material	Clearance between rollers (mm)	Peripheral speed (m/min)		
		259.2	302.4	345.6
Plain rubber material	15	18.10	9.82	10.36
	18	18.27	19.22	19.00
	21	25.14	26.65	26.04
	24	33.76	41.93	33.73
Buttoned rubber material	15	2.10	4.78	8.83
	18	11.44	6.89	8.75
	21	17.00	33.86	19.90
	24	27.22	30.39	29.93
Corrugated rubber material	15	21.75	33.18	21.73
	18	11.73	0.74	19.50
	21	10.97	6.51	10.14
	24	27.78	15.59	13.27
	F – value	SEM	CD (p=0.01)	
P	**	1.16	3.95	
C	**	1.34	4.56	
S	NS	1.16	—	
PC	**	2.32	7.89	
CS	NS	2.32	—	
PS	NS	2.02	—	
PCS	NS	4.04	—	

**Significant at 1 per cent level

Table 4. Effect of type of padding material, clearance between rollers and peripheral speed of rollers on per cent damaged cloves

Type of padding material	Clearance between rollers (mm)	Peripheral speed (m/min)		
		259.2	302.4	345.6
Plain rubber material	15	10.10	5.97	19.30
	18	7.32	5.38	12.00
	21	6.41	2.70	5.40
	24	2.87	2.15	1.48
Buttoned rubber material	15	6.62	4.97	8.79
	18	7.18	3.78	5.47
	21	5.00	10.42	4.60
	24	14.28	6.74	4.60
Corrugated rubber material	15	2.87	6.73	13.58
	18	2.10	11.20	15.13
	21	2.88	1.72	3.10
	24	0.90	2.23	2.33
	F – value	SEM	CD ($p=0.05$ / $p=0.01$)	
P	**	0.58	1.95	
C	**	0.76	2.25	
S	**	0.58	1.95	
PC	**	1.15	3.90	
CS	**	1.15	3.90	
PS	**	1.00	3.38	
PCS	**	1.99	6.75	

**Significant at 1 per cent level

Table 5. Effect of rubber padding material, clearance and roller peripheral speed on breaking capacity

Type of padding material (P)	Clearance between rollers (C) (mm)	Peripheral speed (S) (m/min)		
		259.2	302.4	345.6
Plain rubber material	15	469.3	500.68	592.54
	18	495.93	553.79	577.34
	21	536.25	581.43	592.54
	24	510.95	494.48	582.67
Buttoned rubber material	15	488.08	568.12	524.15
	18	511.52	581.43	559.11
	21	510.95	527.91	577.94
	24	536.25	536.25	536.25
Corrugated rubber material	15	622.92	638.29	697.00
	18	639.92	649.27	732.82
	21	652.92	678.01	790.42
	24	694.92	697.00	825.03
	F – value	SEM	CD (p=0.05)	
P	**	5.18	17.56	
C	**	6.00	20.28	
S	**	5.18	17.56	
PC	*	10.36	35.12	
CS	*	10.36	35.12	
PS	**	9.00	30.42	
PCS	**	18.00	60.83	

*Significant at 5 per cent level; **Significant at 1 per cent level

cent. This low range was obtained at 21 and 24mm clearance and 259.2 and 345.6m/min peripheral speed of rollers, and these were on par. However, 2.87 per cent clove damage was observed with corrugated rubber padding material at 18mm clearance and 259.2m/min peripheral speed. Maximum (37.02) per cent cloves got crushed with plain-type rubber padding material at 15mm clearance and 259.2m/min peripheral speed.

Garlic bulb breaking capacity

From Table 5, it is inferred that type of padding material, clearance between rollers and peripheral speed of rollers had a significant effect on garlic bulb breaking capacity. Highest capacity was obtained with corrugated-type rubber padding material and was in the range of 622.92 – 825.03kg/h. It was also observed that the capacity increased with increase in clearance and peripheral speed. Plain-type padding material gave the lowest capacity of 469.30kg/h at 15mm clearance and 259.2m/min. This variation in capacity among padding materials may be due the characteristics of the padding material. As the corrugated-type padding material behaved like a conveyor, it carried the garlic bulbs positively for further separation, thus leading to highest garlic bulb breaking capacity.

Selection of optimized parameters

From the above discussion, it is observed that:

a. Maximum garlic bulb breaking efficiency (89.17 per cent) was obtained with corrugated-type rubber padding material at 18mm clearance and 259.2m/min peripheral speed

b. Minimum per cent of clumps of cloves formed (0.74) was obtained with corrugated-type rubber padding material at 18mm clearance and 302.4m/min peripheral speed

c. Minimum per cent of damage of cloves (0.9) was obtained with corrugated-type rubber padding material at 24mm clearance and 259.2m/min peripheral speed

d. Maximum garlic bulb breaking capacity (825.03kg/h) was obtained with corrugated-type rubber padding material at 24mm clearance and 345.6m/min peripheral speed

Of all the padding materials used, corrugated-type padding material resulted in the best performance. As for clearance between rollers, minimum per cent of damage of

cloves and maximum garlic bulb breaking capacity was obtained at 24mm clearance. However, garlic bulb breaking efficiency was low (71.32 to 84.40 per cent) at 24mm clearance between rollers which is an important machine-parameter. Minimum per cent of damaged cloves and maximum garlic bulb breaking capacity was 2.14 and 732.82kg/h, respectively, at 18mm clearance. In the case of peripheral speed of rollers, no significant effect was seen on performance-parameters. Thus, corrugated rubber as padding material at 18mm clearance between rollers and 259.2m/min peripheral speed of rollers was found to be optimal for obtaining maximum efficiency.

Evaluation of performance of garlic bulb breaker with optimized operational parameters

The garlic bulb breaker developed with optimized operational parameters was evaluated for performance. The garlic bulb breaker had 96 per cent clove separation efficiency, 1.22 per cent clumps of clove formation, 1.7 per cent clove damage, 1.08 per cent clove loss and 780kg/h bulb breaking capacity. These values are very similar to the performance of garlic bulb breaker developed by Mudgal (2009).

CONCLUSION

A power-operated garlic bulb breaker with two stages of garlic bulb breaking rollers was developed for separating garlic cloves from the compound garlic bulb. Experiments were laid out to optimize the design and operational parameters of the machine using three types of roller padding material (plain-plain, button-button and corrugated-corrugated), at four clearances between the first stage rollers (15, 18, 21 and 24mm) and at three roller peripheral speeds (259.2, 302.4 and 345.6m/min). Corrugated-type padding material at 259.4m/min peripheral speed gave percent cloves at 1.22, per cent clove damage 1.7, per cent clove loss 1.08 per cent and bulb breaking capacity 780kg/h. Cost of operation was found to be Rs. 0.06 per kg against Rs. 2.25 per kg by the manual method of clove separation.

ACKNOWLEDGEMENT

The authors thank Director, IIHR, Hesaraghatta, Bengaluru, for providing facilities for carrying out the research work.

REFERENCES

Anonymous. 2014. Indian Horticulture Database. National Horticulture Board, Ministry of Agriculture, Government of India, Delhi

Mandhar, S.C., Carolin Rathinakumari, A. and Senthil Kumaran, G. 2005. Design and development of a hand-operated garlic bulb breaker and garlic peeler. *J. All India Food Processors' Assoc.*, **59**:76-81

Mudgal, V.D. and Sahay, S.B. 2009. Development and performance evaluation of a garlic bulb breaker. *J. Agril. Mechanization in Asia, Africa and Latin America*, **40**:32-35

Sahay, K.M. and Singh, K.K. 1994. In: Unit Operations of Agricultural Processing. Vikas Publishing House Pvt. Ltd., New Delhi, pp. 42-54

(MS Received 24 August 2015, Revised 26 November 2015, Accepted 29 December 2015)