CHAPTER 1

INTRODUCTION

Spices form a major class of ingredients used in most of the food products. Spices and condiments can be defined as dried seed, fruit, bark and vegetable used for flavouring, colour, aroma and preservation of food or beverages. Spices or their extracts find its application in food, medicine, perfumery, cosmetics and other industries. The functional properties of spices or spice extracts as preservatives, antioxidants, antimicrobials, antibiotics and its medicinal value increase the demand worldwide. Flavour is the main attraction of spices which includes a range of olfactory and taste sensation. The annual growth rate of area and production of spices in India is estimated to be 3.6% and 5.6% respectively. The total area under spice cultivation is about 32.2 lakh hector with a production of 37.65 lakh tons (FAO, 2015).

India is called 'The Land of Spices' and Indian spices are known throughout the world. In India spices contribute around 3% of the total agricultural commodities exported and a share of around 0.27% to the total export. Rajasthan, Andhra Pradesh, Kerala, Tamil Nadu and North Eastern states are important for spices production. (Parthasarathy and Kandiannan, 2007). On the basis of economic importance, spices are grouped into two *viz.* major and minor spices. The spices which contribute major share in the spice trade industry of the world are called major spices which includes cardamom, black pepper, chilli, turmeric and ginger. Excluding these five, all other are called minor spices. Minor spices are further divided into five sub groups: seed spices, bulbous spices, aromatic spices, leafy spices and acidulant tree spices.

Garlic (*Allium sativum Linn*), a native of Southern Europe, belonging to Liliaceae family is one of the important bulb crops grown and used as a spice or condiment throughout India. It has been cultivated for centuries all over the world on account of its culinary and medicinal properties. India ranks second after China in world's garlic production with an annual yield of 1.25 MT. In India, Madhya Pradesh ranks first in garlic production with an annual production of 424.5 T. Rajasthan and Gujarat ranking second and third with an annual production of 377.49 T and 318.2 T respectively (NHB,2016). Garlic bulbs are valued for their flavour and command an extensive commercial importance because of their medicinal value and application in food and pharmaceutical preparations. As a classic ingredient in pickles, chutneys, curry powder, meat preparations etc., garlic has a powerful aroma and pungent taste. The use of garlic as a condiment, garlic oil as insecticide, garlic paste as bio fungicide, garlic residue with antibacterial properties, garlic as medicine including use for cancer treatment and in human nutrition are now well recognized.

Garlic bulbs are broken into cloves which are used in pickle and garlic paste and are also required for planting. The garlic cloves are usually separated by hand in household use. But in large scale application it is accomplished by beating with a wooden batten. However, efficient garlic bulb breaking machines both for planting material purpose and processing purpose are not commercially available in Indian market. Breaking the garlic bulb requires special care and skill due to the typical physical characteristics and presence of essential volatile oils in the epidermal cells imparting its characteristics aroma. This conventional method is very laborious and time consuming. Through improved seed production, both yield and quality can be improved, to fetch higher prices in the market. Considering the increasing demand for garlic products in domestic and export market, and large quantities of planting material requirement, efficient mechanical garlic bulb breaker need be developed and evaluated for its performance.

CTAE (Maharana Pratap University of Agriculture and Technology, Udaipur) has developed three separate machines each for bulb breaking, flaking and peeling. With similar technology many machines are available in market, but are not popularised in Kerala.

Till date no machines have been introduced that performs bulb breaking and peeling in a single unit. Using these machines separately would require transfer of products from one machine to another with proper human interventions. Each of these machines are very costly which, may be much higher than the capital investment for setting up a small scale industry that uses garlic as its main raw material, for instance, a pickle industry. Being huge and heavier, these machines would require large floor space. All these factors together with the aim at pickle industry in Kerala necessitates the development of a new machine which facilitates these processes, along with lesser space occupancy, labour, cost, and women-friendly in use.

It was therefore, proposed to develop and evaluate the performance of a garlic bulb breaker cum peeler which could alleviate the problems faced by traditional methods of garlic peeling and aid in boosting the processing of garlic and small scale pickle industries in Kerala.

The project was thus, proposed with the following specific objectives;

1. To determine engineering properties of garlic relevant to bulb breaking and peeling.

2. Fabrication of garlic bulb breaker cum peeler.

3. Performance evaluation of garlic bulb breaker cum peeler

CHAPTER 2
REVIEW OF LITERATURE

This chapter deals with comprehensive review of the research work done by various research workers related to the engineering properties of garlic and garlic bulb breaker and peeler.

2.1 Garlic

Garlic is a hardly, bulbous, rooted perennial plant with narrow flat leaves and bears small white flowers and bulbils. The compound bulb consists of 6-34 smaller bulblets called ‘cloves’, which are surrounded by a common thin white or pinkish papery sheath, skin or membrane. Garlic has a stronger flavour than onion or its other allies. Usually the recovery of usable clove is 86-89%. The pungency in garlic is mostly due to allicin, sulphoxide, and other volatile organic sulphur compounds such as thiols, sulphides, trisulphides and disulphides (average 93.7%) (Pruthi,1998).

Garlic favours a richer soil and a higher elevation (900-1200 m above sea level). A well-drained, moderately clayey-loam soil is best suited for its cultivation. It requires a cool and moist period during growth and a relatively dry period during crop maturing. It takes about 4-5 months to mature and is consequently grown as a late-season irrigated crop. About 125-150 kg of nitrogen per hectare should be applied in two doses for the best results. Garlic is propagated by cloves which are detached individually from the bulb. About 350-500 kg of cloves are required to plant a hectare. For highest yield, the cloves are dibbled at a spacing of 15 cm between row to row and 7.5 cm within the row. The crop is mainly sown from September to November. The crop is ready for harvesting when the tops turn yellowish or light brownish, and shows signs of drying up, usually about a month or so after the emergence of seed stalks.

Plate.2.1 Garlic plant

The plant is cultivated in temperate as well as tropical climates. It is grown from bulblets or cloves as a mixed or monocrop. It requires rich soil. Garlic has been cultivating throughout India as an important minor spice or condiment crop.

Important states producing garlic on commercial scale are Gujarat, Maharashtra, Tamil Nadu, Karnataka, Andhra Pradesh, Madhya Pradesh, Orissa, Uttar Pradesh, and Haryana.

2.2 Taxonomy

Garlic belongs to the family Liliaceae. Common garlic is classified as *Allium sativum*, British wild garlic *as Allium oleraceum*, and American wild garlic as *Allium candense*. The field garlic of Europe and the Americas is classified as *Allium vineale*.

Kingdom	:	Plantae
Subkingdom	:	Tracheobionta
Division	:	Magnoliophyta
Class	:	Liliopsida
Subclass	:	Liliidae
Order	:	Liliales
Familily	:	Liliaceae

Genus	:	Allium
Species	:	sativum

(The plants database, 2000).

2.3 History

Garlic is a native of western Asia and Mediterranean area. It was eaten by Egyptian workmen 5000-6000 years ago, that the Greeks loved it, while the Romans of Caesear's day, did not, although their descendants, the modern Italians, loved it. This has been in cultivation for centuries. Europeans, especially the Spanish and Italians, have used this regularly for 2000 years and more. The Spanish are believed to have brought garlic to the new world (USA), where it became an immediate favourite with Red Indians.

2.4 Production

In 2015 the world production of garlic was estimated at 25 MT with China constituting of 80% of total production. China is the leading producer of garlic accounting for 20 MT followed by India with 1.25 MT per year. The other three top producing countries of garlic include South Korea, Egypt and Russia producing 0.35, 0.26 and 0.26 MT respectively. In the United States, production of garlic is mostly focussed in Gilroy, California dubbed as the garlic capital of the world.

In India, Madhya Pradesh is the leading garlic producing state with production of 424.5 tons. Rajasthan ranks second with production of 377.49 tons followed by Gujarat with 318.2 tons of garlic production. Karnataka, Bihar, Tamil Nadu, Punjab, Haryana and Andhra Pradesh also produce a sizeable quantity of garlic in cooler regions of the states (NHB, 2016)

2.5 Varieties

There are basically two different types of garlic and they are softneck (*Allium sativum*) and hardneck (*Allium ophioscorodon*), sometimes referred to as stiff neck.

2.5.1. Softneck Garlic

There are two common softneck types: Artichoke and Silverskin. Both of these common garlic types are sold in the supermarket. Artichokes are named for their resemblance to artichoke vegetables, with multiple overlapping layers containing up to 20 cloves. They are white to off-white with a thick, hard-to-peel outer layer (Plate 2.2). The beauty of this is their long shelf life- up to 8 months. Some artichoke garlic varieties include: Applegate, California early, California late, Red toch, Galiano, Polished red etc. Silverskins are high yielding, adaptable to many climates and are the type of garlic used in garlic braids. Garlic plant varieties for silverskins include: Polish white, Inchelium, Chet's Italian red, Kettle river giant.

2.5.2 Hardneck Garlic

The most common type of hardneck garlic is 'Rocambole', which has large cloves that are easy to peel and have a more intense flavour than soft necks (Plate 2.3). The easy-to-peel, loose skin lessens the shelf life around 4-5 months. Unlike softtneck garlic, hardneck send out a flowering stem, or scape, that turns woody. Hardneck garlic varieties include: Chesnok red, German white, Persian star, Purple striped, Polished hardneck, Porcelain.

Rajalle Gaddi is slightly bigger size variety grown India. Jamnagar variety is reported to be the biggest and best and is popular in Gujarat, Maharashtra, Andhra Pradesh and Madhya Pradesh. T56-4 variety is well suited to Punjab and Uttar Pradesh condition. G-41 has been recommended for cultivation during rabi season in Maharashtra, Madhya Pradesh, Gujarat and south India.

Plate.2.2 Softneck varieties **Plate.2.3 Hardneck varieties**

2.6. Uses and health benefits

Garlic has been recognized all over the world as a valuable condiment and a popular remedy for various ailments and physiological disorders. Garlic powder has sufficient demand in the processing industries in this country as a condiment. Also, garlic oil is used as a valuable flavouring agent, for use in all kinds of meat preparations, soups, canned foods and sauces.

According to the Ayurveda and Unani systems of medicines, garlic is carminative and is a gastric stimulant, thus in aiding digestion and absorption of food. Also, they are antiseptic and anti-bacterial in action.

The inhalation of garlic oil or garlic juice has been recommended in cases of pulmonary tuberculosis, rheumatism, sterility and impotency. Garlic juice is used for various ailments of stomach, in skin diseases, and as ear drops in ear-ache. Diluted juice with water can be used against duodenal ulcers. Nowadays garlic is used to treat hypertension in patients to reduce their systolic arterial pressure.

There is an increase in the intestinal synthesis of vitamin B, due to consumption of garlic in human beings. Alli-thiamina is formed by the reaction of thiamine (B_2) and allicin, which is also absorbed faster than thiamine in the intestine.

2.7. Chemical composition

Table.2.1 Composition of garlic per 100 gram of cloves (Pruthi, 1979)

Food component	Fresh Peeled Garlic Cloves	Dehydrated Garlic
Moisture	62.8 g	5.2 g
Carbohydrate	29 g	71.4 g
Protein	6.3 g	17.5 g
Fat	0.1 g	0.6 g
Fibre	0.8 g	1.6 g
Minerals	1 g	3.2 g
Calories	142	380
Calcium	30 mg	100 mg
Phosphorous	310 mg	420 mg
Iron	1 mg	4 mg
Sodium	-	19 mg
Potassium	-	110 mg
Vitamin A	0	175 I.U.
Riboflavin	0.23 mg	0.68 mg
Thiamine	0.06 mg	0.08 mg
Niacin	0.4 mg	0.7 mg
Vitamin C	13 mg	120 mg

*I.U: International Unit

2.8. Engineering Properties

Engineering properties are the properties which are useful and necessary in the design and operation of various equipment employed in the field of agricultural processing and also for design and development of farm machinery (Sahay and Singh). The determination of engineering properties of different fruits and vegetables followed by various research workers were reviewed for this study.

2.8.1. Physical properties

The physical properties such as size, shape, surface area, volume, density, porosity, colour and appearance are important in designing a particular equipment.

Mohsenin (1986) selected hundred bulbs randomly and measured the length of garlic through longest dimension and the diameter was measured at the centre of the garlic using digital micrometer to an accuracy of 0.01 mm.

Singh and Shukla (1995) conducted the experiment on physical properties of potato *viz.*, length, breadth and thickness to develop a potato peeler. Vernier calipers were used for measuring these properties.

Bahanasawy *et al.* (2002**)** determined polar diameter and equatorial diameter of the Egyptian onion by using relationships given by Mohsenin (1970) as follows:

$$\text{Geometric mean diameter } (D_{gm}) = (D_e D_p T)^{0.333} \quad \ldots..(2.1)$$

$$\text{Arithmetic mean diameter } (D_{am}) = (D_e+D_p+T) / 3 \text{ ,cm} \quad \ldots..(2.2)$$

$$\text{Cross-sectional area } (A_{cs}) = \pi/4 \times ((D_e+D_p+T)^2 / 9) \text{ , cm}^2 \quad \ldots..(2.3)$$

Where D_e = Equatorial diameter, cm

D_p = Polar diameter, cm

T = Thickness, cm

Shape of onion bulbs were calculated according to the equation (Abd Alla, 1993):

$$\text{Shape index } = D_e / \sqrt{(D_p \times T)} \quad \ldots..(2.4)$$

Jha *et al.* (2006) studied the physical and mechanical properties of mango fruit to determine the maturity. In order to measure the fruit length, width and thickness digital vernier calipers (least count 2 mm) were used

Shamsudin *et al.* (2009) conducted the experiments on physical properties of pineapple fruit. Digital vernier calipers were used for determining the fruit length and diameter for both with and without peel

Maninder kaur *et al.* (2017) determined the geometric mean diameter and sphericity of garlic cloves as a part of study on engineering properties of peeled and unpeeled garlic cloves by using the relationship (Mohsenin 1986)

$$D_p = (abc)^{1/3} \quad \text{.....(2.5)}$$

Where a,b and c are length, width and thickness respectively. The average geometric mean diameter ranges from 11.008 mm to 11.868 mm for the unpeeled cloves and for the peeled cloves, the value lied the range of 11.689 mm to 10.593 mm.

2.8.2 Mechanical and frictional properties

The rolling angle of the onion bulb were found out such a way that for each bulb the average of three angles of rolling were determined, for both stable and non-stable positions (Buyanov and Voronyuk, 1985). In stable position, the highest rolling angle value (31.33°) was recorded for the large size of Giza 6 onion variety on the plywood surface were the lowest value (20.30°) was recorded for the small size of Giza 20 onion variety on the galvanised steel surface.

Guner *et al.* (2003) experimented mechanical behaviour of hazelnut under compression loading to determine the specific deformation, rupture force and rupture energy required to initiate shell and kernel rupture. The highest nut shell specific deformation, rupture force and rupture energy were obtained for Aci-Findik nuts at a deformation rate of 0.52 mms^{-1}. The Tombul and G.uney Karasi varieties had the highest kernel rupture force (200 N for shell and 80 N for kernel) and rupture energy (730 Nmm for shell and 230 Nmm for kernel), respectively.

Bahanasawy *et al.* (2004) studied the crushing load for the complete destruction of onion. The onion was setup on a flat plate until the cross head of a handmade apparatus was brought in contact with the onion and a compression force was applied by adding weights or loads until permanent destruction was caused. For all sizes of white onion, the average crushing load was ranged from 443.3 to 819.7 N. They had also determined the co efficient of friction for onion bulbs on three surfaces: rubber, GI steel and plywood. Coefficient of friction values ranged from 0.85- 1.02, 0.67-1.34 and 0.85-1.15 for the white, red and yellow onions, respectively. The highest co efficient of friction was obtained by the plywood followed by rubber and GI steel surface for all onion size and cultivars. The puncture or penetration load were studied using a head of a flat- end probe (3.0 mm diameter). There were no significant differences between the cultivars in the resistance to penetration. The lowest penetration load was recorded for the white onion cultivars (26.9 N) whereas, the highest value was recorded for the yellow onion (45 N). This may be due to there was no hard scale on the white onion compared to red and yellow onions.

Maduako and Hamman (2004) determined physico-mechanical properties of few ground nut varieties in the design and development of systems and machines for the shelling of ground nuts. The angle of repose for the three varieties was found to range from 27.5-29.5 for tire pods, 20.3-20.8 for the seeds and 33.7-36 for the shells. Co efficient of friction average 0.56 on wood and 0.41 on galvanised steel for the three varieties of ground nut pods.

Vararshney *et al.* (2005) determined the angle of repose and static coefficient of friction of garlic segment against three surfaces namely teak, wood, aluminium and mild steel sheet. It was measured with a calibrated tilting table.

Maninder kaur *et al.* (2017) as a part of the study of engineering properties of peeled and unpeeled garlic cloves, determined angle of repose and co efficient of external friction against two surfaces *viz.*, plywood and galvanised iron sheet. The average value of angle of repose for the unpeeled clove was 39.881 degrees and for the peeled cloves was 25.529 degrees. The peeled cloves have less angle of repose because of lower moisture content of peeled cloves. To determine the co efficient of internal friction, a tilting table top setup was used. The average values for the unpeeled cloves were 0.366 and 0.772 for wooden and GI surface, respectively. For the peeled cloves, the average values for the plywood and GI surface was found to be 0.664 and 0.812 respectively. The values for the co efficient of internal friction were calculated as 0.570 for the unpeeled cloves and 0.826 for the peeled cloves.

2.8.3 Aero and hydrodynamic properties

Joshi *et al.* (1993) determined the terminal velocity of garlic segments using an air column. For each test, a small sample was dropped into the air stream from the top of air column, up to which air was blown to suspend the material in the air stream. The air velocity near the location of the segment suspension was measured by a digital hot wire anemometer having a least count of 0.1m/s.

Masoumi *et al.* (2003) studied terminal velocity and frictional properties of two common types of garlic cloves (white and pink) in Iran. The white garlic cloves had minimum value of terminal velocity 9.82 m/min at 34.9% (w.b.) and maximum corresponding value was 16.66 m/min at 56.7% (w.b.) for pink cloves. The maximum value of filling angle of repose was 43.5 degrees for white cloves at 55.67% (w.b.) and minimum corresponding value of 36.1 degrees for pink garlic cloves at 35.26% (w.b.).

2.8.4. Moisture content

Moisture content is the quantity of water contained in a material. It is an important chemical property for drying and storage of agricultural produces.

Madamba *et al.* (1993) determined the moisture content of garlic using convection method. Three samples of 15 g each were weighed and placed in an oven. The samples were heated at 100 ± 0.5°C until constant weight was obtained, then the samples were taken out and cooled in desiccators to weigh in electronic balance.

Bahnasawy *et al.* (2004) conducted an experiment to determine the moisture content of Egyptian onion to study the physical and mechanical properties of some Egyptian onion cultivars. It was determined according to ASAE standard.

Maninder Kaur *et al.* (2017) experimentally found out the moisture content of garlic cloves by using hot air oven method to study the engineering properties of peeled and unpeeled garlic cloves. The moisture content of peeled and unpeeled garlic cloves was reported to be 71.3%, 76.29% respectively.

Shiva Holker *et al.* (2018) has found out the moisture content of ginger as per ASAE standard for the design, development and statistical optimization of ginger peeling machine.

2.9. Development and performance evaluation of bulb breakers/ threshers used for various agricultural commodities.

Ige (1978) studied the threshing and separation performance of a locally built cow pea thresher. It was reported that the speed of threshing drum has highly influenced the threshing efficiency. The moisture content of the crop has least influence on the threshing efficiency. The highest percentage of threshed and undamaged grains were obtained at 500 rpm drum speed and at the fan speed of 1400 rpm, the separation loss was reduced to 5 per cent from 16 per cent.

Joshi and Singh (1980) developed a multi-crop peg tooth type thresher for wheat. They reported that the capacity, cleaning efficiency and visible damage increased with increase in cylinder speed at 10-14 per cent moisture content.

Sharma and Devnani (1980) studied the threshing of cowpea. Threshing efficiency increased with the increase of cylinder speed but decreased with the increase of feed rate and concave clearance. Energy consumption was directly proportional to cylinder speed and feed rate and remained constant at selected concave clearance. At higher speeds the visible grain damage was 5 per cent and the germination percentage was low. It was recommended that for consumption, the thresher had to be operated at 496.00 m/min cylinder tip speed with 8.00 mm concave clearance and for seed purpose it had to be threshed at 288.50 m/min cylinder tip speed and 8.00 mm concave clearance, at 6.50 percent moisture content of cowpea.

Jadhav and Despande (1988) designed and developed a hold-on pedal operated phule sunflower thresher. The manually operated hold-on sunflower thresher consisted of threshing, cleaning and power transmission units. The output capacity, threshing efficiency and cleaning efficiency were about 40 kg seeds/hr, 100 per cent and 96 to 98 per cent respectively.

Desta and Mishra (1990) developed and conducted performance evaluation of a sorghum thresher. They studied feed rate at three levels (6, 8, 10 kg/min), cylinder concave clearance at two levels (7 and 11mm) and cylinder speed at three levels (300 rpm (17.50 m/s), 400 rpm (10.10 m/s) and 500 rpm (12.60 m/s). The result of the performance analysis showed that threshing efficiency increased with an increase in cylinder speed for all feed rates and cylinder concave clearances. The threshing efficiency was found in the range of 98.30 to 99.90 per cent. At the recommended speed of 400 rpm (10.1 m/s), the power required for operating the thresher was 4.95 kW and the maximum output of the thresher was 162.70 kg/hr.

Duraisamy and Manian (1990) developed and evaluated a hand/power operated caster bean sheller. It consisted of a feed hopper, a screw auger, shelling discs, flywheel and blower. The unit was operated by 0.5 HP electric motor with blower. The output and shelling efficiency of power/hand operated castor bean sheller was 163.00 and 52.65 kg/hr, 97.29 per cent and 98.72 per cent with a kernel breakage of 0.82 per cent and 0.88 per cent, respectively.

Kachru and sheriff (1992) evaluated a power operated axial-flow vegetable seed extractor for its performance with 5 wet vegetable fruits: tomato, aubergine, watermelon, muskmelon and pumpkin. The capacity of the machine ranged between 220-960 kg/hr. Seed loss and mechanical damage ranged between 0.82 and 15.02 per cent and 0.97 and 5.79 per cent, respectively. Germination was

93.0 per cent for tomato and 59.80 per cent for aubergines. The cost of seed extraction varied between 0.88 and 5.73 Rs per kg.

Dakshinamurthy (1993) reported that neem seeds could be decorticated in a neem seed decorticator to obtain kernels. A person could decorticate about 2-3 kg/hr by hand shelling. The hand operated sheller had the capacity of 30-35 kg/hr and the power operated unit had a capacity of 90-100 kg/hr.

Jain and Sivala Kumara (1997) designed and developed a cashew nut sheller based on the principles of compression and shear. The rated capacity of the sheller was observed to be 18 kg/hr of roasted nuts at a shelling efficiency of 70 per cent. The yields in terms of whole, half-splits and brokens were 50, 22 and 28 per cent respectively.

Mandhar *et al.* (2005) designed and developed a hand operated garlic bulb breaker. Garlic bulb breaker consisted of two rubber rollers of 175 mm diameter and length was 185 mm rotating in opposite direction. The garlic bulbs were fed in between the rubber rollers rotating at 20 rpm. The type of rubber sheet was natural sponge rubber sheet, shore hardness was 25-30 and the surface finish was mat finish. The capacity of garlic bulb breaker was found to be 50 kg/hr and visible mechanical damage to clove was 1.90 per cent.

Mudgal and Sahey (2009) developed a low cost and highly efficient garlic bulb breaker and evaluated for its performance and techno economic feasibility. The developed garlic bulb breaker consisted of beater cylinder, concave aspirator, power transmission unit and feeding chute. A 0.37 kW single-phase AC motor was used for operating the beater cylinder and aspirator with the help of belt and pulley arrangement. Average outputs of 800 kg/hr and separation efficiency of 92.16 per cent were obtained with a rubber strip as a padding material at an optimum speed of 340 and 135 rpm of beater and aspirator respectively. Maximum separation of individual cloves with minimum damage of 1.10 per cent and optimal removal of skin and root fraction was observed at optimized parameters. The garlic bulb breaker was found techno-economically feasible with operating cost of Rs. 0.05/kg as compared to Rs. 2.25 /kg for manual operation for clove separation. Return on investment was calculated to be 41.1 per cent with payback period of three months.

Ghafari *et al.* (2011) designed and developed a walnut cracking machine and evaluated for its performance. The developed walnut cracker consists of a hopper fitted with a flow rate control device, a cracking unit, a sorter and power system. It operated on the principle of attrition using crushing force from a cylinder and helix. The percentage of whole kernels produced was 66.66 per cent. The capacity of the machine was estimated to be about 25.20 kg/hr. A device of this nature can be manufactured for small entrepreneurs and industrial-level applications in the developing countries where bulk of the world walnut is produced.

2.10 Development of peelers used for agricultural commodities.

Gardiner *et al.* (1963) tested a milling cutter with a cylindrical cutting edge combined with a disc which supports the cylindrical cutting edge and which was provided with apertures sharpened in the plane of the disc, so as to cut the ribbon of peel transversely into smaller portions making it easier to discharge it. Although the problem of clogging was solved, the peeling production was not sufficient. Similar limitations were experienced by Polk (1972) who used a large rotary milled edge and rotary vegetable holder.

Tardif and He (1999) released a machine equipped with blades to peel vegetables. The vegetable, which is located in the hollow base of the machine, can be rotated by a threaded rod on the top. The rod is rotated manually by a handle. A blade, which is coupled to the supporting rod and urged by a spring, moves towards the vegetable to be peeled. While the vegetable is rotated, the blade removes the peel.

Bagher Emadi *et al.* (2008) developed a new innovative peeling method named the "abrasive-cutter brush" for the mechanical peeling of pumpkins. It could utilise the benefits of the current peeling methods. The flexibility of brushes could provide easy access of the brush's protrusions to different areas of the produce. Each protrusion on the brush, as a small cutting unit, cut and removed the abrasively the peel pieces. The cutting action caused effecting peeling while the abrasive action showed higher production rate compared with the existing methods. The optimised results revealed peeling effects of 18.60% /min and 20% /min for concave and convex areas, respectively at 0.18% /min peel losses. The optimum conditions of independent variables were 550 rpm for rotational velocity of brushers, 5 rpm for rotational velocity of vegetable holder, 20 mm lower than the middle horizontal plane of produce for the position of brushes, and medium for brush coarseness.

Dhananjay G. Dange *et al.* (2015) presented the methodology for design and fabrication of garlic peeling machine. The study specified factors influencing the garlic peeling process and recommends a number of design options for garlic peeling machine. These are based on a systematic study of the garlic peeling process and testing of a prototype model of garlic peeling machine.

Shiva Holker *et al.* (2018) presented a research on design, development and statistical optimisation of ginger peeling machine which can peel the outer skin of ginger with less mass loss. Machine and product parameters for the developed ginger peeler were optimised. Fresh gingers with moisture content 87.47% and pre-treated at 1% NaOH solution exhibited highest peeling efficiency (70.20%), followed by hot water soaking and overnight soaking. At constant moisture content, reverse trend was observed for mass loss. The highest mass loss of about 4.13% was seen with hot water soaked samples, followed by overnight soaking and NaOH treatment. The optimum peeling efficiency was 66.62% for the ginger having 79.28% moisture content treated with NaOH (70°C, 10 minutes).

2.11 Methods of peeling

2.11.1 Hand peeling

This is one of the common method of peeling bulbous spices like onion and garlic in home scale uses as in Plate.2.4 where the quantity required is very less.

2.11.2 Flame peeling

It is one of the common method used for peeling bulbous spices (onion and garlic). Peeler consists of a conveyor belt which carries and rotates food through a furnace heated to higher than 1000°C. The outer layer and root hairs are burned off, and charred skin is removed by high-pressure water sprays. In this method the average product losses are estimated to be 10%.

2.11.3 Lye peeling

In lye peeling, fruit is passed through a 1 to 2% dilute lye solution (solution of NaOH, KOH, etc.). Lye solution is heated to 100° C to 120° C. This process softens skin, and skin is removed by high-pressure water sprays. Product losses are of the order of 17%. Although once popular for root crops, this method causes change in colour of some products and incurs higher costs. It is now largely replaced by steam flash peeling. A development of lye peeling is named dry caustic peeling. Food is dipped in 10% NaOH and softened skin is removed with rubber discs or rollers. This reduces both water consumption and product losses.

2.11.4 Hot water blanching

This is the traditional form of peeling which involves the product being held in hot water (85-100° C) until the enzymes are inactivated, and then water cooled. The most common form of machinery for water blanching is reel blancher, which is also known as rotary hot water system. Tunnel type system is also used for hot water blanching.

2.11.5 Oven peeling

It is a method in which the garlic cloves are placed inside a microwave oven so as to loosen the skin from the garlic by heating. In this method the oven is heated up to 400° F. Set a rack in the middle position of the oven on which the cloves are placed. As it gets heated the skin begins to loosen from the clove

surface and the skin can be easily removed by using fingers.

2.11.6 Smashing with a knife

It is mainly used in large restaurants. It is a simple method by using a large flat knife blade to quickly peel garlic cloves as in Plate.2.5. Place the clove of garlic on the table's surface or a cutting board and bring down the knife and whack its blade on the clove. This will cause its skin to loosen up considerably.

2.11.7 Silicon garlic peeler

A garlic peeler is essentially a rubber tube or silicon tube having both sides open as depicted in Plate.2.6. It is an ideal gadget for loosening up the skin of the garlic to enable to peel it easily. Put the garlic cloves inside the tube and roll the tube back and forth on the countertop. This rolling action removes the garlic skin so can be peel it easily.

Plate 2.4 Hand peeling of garlic **Plate 2.5 Knife peeling**

Plate 2.6 Silicon garlic peeler

2.12 Available equipments used for garlic processing

Rapid expansion of industry during the past five years has resulted in labour shortage both in agricultural and industrial sectors. The food processing factories, both big or small, which garlic is used as part of their process, also face this labour problem due to still processing garlic manually. To solve of mentioned situation of labour shortage the garlic processing machine has been designed and

developed.

Bulb breaking i.e. separation of individual cloves from garlic bulbs is the first and foremost unit operation in processing of garlic. Further, the individual cloves are also used as seed material. The garlic bulb breaker developed by CTAE (College of Technology and Engineering), Udaipur as in Plate 2.7 consists of a hollow cylinder with cushioned battens, a concave, an aspirator and a prime mover. The cloves are separated because of the beating action of battens and friction between bulb and concave. Aspirator separates the light paper skin, root and middle stem of bulb. Clean cloves are collected along the chute below the concave. A manual operated model with 50kg/hr capacity is also available for small entrepreneurs and farmers. It has generated lot of interest in garlic cultivation belt of Madhya Pradesh and Rajasthan for separating individual cloves for seed purpose. It is available in two models: (1) Hand operated, (2) Power operated (0.5 HP single phase motor). The light stem, root and peels are then winnowed to collected clean cloves. In power operated models, an aspirator is provided to remove the lighter substances. This machine has an additional utility as the separated individual cloves could also be used as seed material.

A garlic clove flaking machine has been developed by CTAE, Udaipur to press the cloves gently in order to facilitate faster drying. The machine has two rollers fixed in horizontal plane side by side with clearance adjustment to accommodate maximum size individual garlic clove. The roller rotates in opposite direction with the help of chainsprocket arrangement. Roller clearance of 5 and 10 mm was found optimum for flaking of normal and bold sized cloves, respectively. The machine can also be operated manually with capacity 80-100 kg/hr. The approximate cost of machine having 1 HP motor is Rs.2,50,000/- per unit.

In the garlic peeling machine (Plate 2.8) developed by K.D.K.C.E (Karmavir Dadasaheb Kannamwar College of Engineering), Nagpur in 2015, the technology is fairly simple in which full garlic is put into the hopper and enters a stainless steel drum inside which a vertical shaft with rubber pads is rotating. The garlic gets in contact with the rubber pads and with other garlic and the skin gets skimmed off and falls. The peeled garlic is collected at the outlet through the collection box without the skin. The developed garlic peeler consisted of a feed hopper, roller and concave mechanism, blower and power transmission system. The performance of the garlic peeler was evaluated at different level of combinations of the study variables namely, cylinder speed, concave clearance, concave mechanism and moisture content. Based on the results, optimal values of study variables were recommended for the prototype garlic peeler on the basis of peeling efficiency, yield of peeled and unpeeled garlic, damage, energy requirement, peel separation performance and capacity (Dhananjay G. Dange, *et al.*, 2015).

A power operated garlic peeler developed by IARI (Plate 2.9) consisted of hopper, cylinder concave unit, blower and power transmission system. Peeler works on the principle of the cylinder-concave mechanism. The cylinder surface covered with high quality rubber and it is as called rubber roller. It rotates inside the concave surface and the garlic gets peeled due to compression and shear forces.

Cleaning and discharge unit consists of blower, conveying and discharge assembly. Peel separation and discharge of peeled and unpeeled mixture takes place in this unit which is mounted at the bottom side of the concave. The mixture of peel, peeled and unpeeled garlic which comes from peeling unit was subjected to a stream of air supplied by a blower. The peel was blown out through peel outlet and the peeled and unpeeled garlic fell down through discharge channel. Unpeeled garlic segments were separated manually from peeled garlic and fed again into peeling unit for peeling.

A garlic peeling machine has been developed by CTAE, Udaipur using a novel concept of gentle impact of compressed air. The developed system consists

of a cylindrical peeling chamber with an inlet for feeding cloves and an outlet at the bottom for discharge of peeled clove. The chamber has an opening for entry of compressed air. About 500-750 g conditioned cloves are filled in the batch prototype at a time and compressed air is injected for 45-60 s. A garlic bulb breaking machine for separating individual cloves, a dryer for conditioning the cloves and an air compressor for supplying compressed air to the peeler are essential pre-requisite for the peeling system.

Plate 2.7 Garlic bulb breaker **Plate 2.8 Garlic peeling machine**

Plate 2.9 IARI model Garlic peeler

CHAPTER 3

MATERIALS AND METHODS

This chapter describes the materials used in the study, methods used for the determination of relevant properties of garlic, fabrication procedure of the

garlic bulb breaker cum peeler, and the procedures adapted for the evaluation of the machine.

The fabrication procedure of the garlic bulb breaker cum peeler, the details of the components and the procedures adopted for evaluation are explained in this chapter. The machine was fabricated in the workshop of KCAET, Tavanur in 2018.

3.1 Raw material

Fresh and matured hardneck variety of garlic *Allium sativum* belongs to the family Liliaceae, procured from the local market were used for the study

3.2. Determination of engineering properties of garlic

Prior to the development of machine various physical, mechanical and frictional properties of garlic bulbs were determined as per the standard procedures.

3.2.1 Physical properties

The size of garlic bulb and clove is essential for fixing the clearance of roller and concave mechanism. Seven cloves were taken from each bulb and the principal dimensions (length, width and thickness) were measured using a digital vernier caliper having a least count 0.01mm and its average value was calculated.

Sphericity may be defined as the ratio of the diameter of a sphere of the same volume as that of the particle and the diameter of the smallest circumscribing sphere or generally the largest diameter of the particle. Considering the volume of the particle is equal to the volume of an ellipsoid having three axes with intercepts L, W, T the geometric diameter (D_g) and sphericity (S); which is necessary for estimating the clearance in bulb breaking unit which was determined using the following formula (Mohsenin,1986).

$$D_g = (LWT)^{1/3}$$

$$S = (LWT)^{1/3} / L \qquad \text{.....(3.1)}$$

Where D_g = Geometric mean diameter

S = Sphericity

3.2.2 Mechanical properties

The compressive force is relevant in studying bulb breaking, garlic peeling, energy requirement in processing operation, material resistance and mechanical damage (M. Manjunatha et al,2008). Texture Analyser (Stable Micro Systems) with a P/100-100 mm aluminium platen cylinder probe was used. Analysis was done for different sized garlic cloves and garlic cloves having different maturity. The garlic segment was compressed with the moving upper probe (P/100-100 mm aluminium platen cylinder probe) and the maximum load

was noted.

Plate3.1 Texture Analyser

3.2.3 Frictional properties

Frictional properties such as angle of repose and static coefficient of friction are necessary for the design of feed hopper.

3.2.3.1 Static coefficient of friction

The static friction may be defined as the frictional forces acting between surfaces of contact at rest with respect to each other (Varshney *et al.*, 2005). The static coefficient of friction of garlic segment was determined against three surfaces namely, wood, aluminum and mild steel sheet.

A fixed weight of garlic is kept in a container which has a false bottom. This false bottom cylinder is placed on a horizontal plane of wood. Then weights are added to the weight hanger until the false bottom cylinder just start moving and this weight is noted. The experiment is repeated for aluminium and galvanized iron sheet. If F is the force of limiting friction and R is the normal reaction, then coefficient of friction is given by the following equation.

Coefficient of friction, $\mu = F/R$ ……(3.2)

Where, F = Total mass in weight hanger × g, N

R = Mass of garlic taken in cylinder × g, N

Where g is the acceleration due to gravity, 9.81 m/s^2

3.2.3.2 Angle of repose

The angle of repose is the angle between the base and the slope of the cone formed on a free vertical fall of the granular material to a horizontal plane. Dynamic angle of repose of garlic bulb and cloves were measured by the ‘emptying method’. A metal container with a removable front panel was used for the determination of angle of repose. The container was filled with garlic, levelled and then the front panel was quickly slide upward allowing the garlic bulbs/cloves to flow out. The angle of repose was calculated from the movement of the maximum depth of free surface of the sample and length of the box by using the formula,

$$\tan \phi = H/L \qquad \text{.....(3.3)}$$

$$\phi = \tan^{-1} H/L \qquad \text{.....(3.4)}$$

where, ϕ = Angle of repose

H = Maximum depth of free surface of the sample, mm

L = Length of the box, mm

3.3 Experimental study

Prior to the fabrication of garlic bulb breaking and peeling unit preliminary studies were conducted in the machines available which are working on the principle of impact, shear, compression and abrasion.

3.3.1. Bulb breaking unit

First attempt in bulb breaking was tested with a shelling machine working on the principle of impact force. When garlic bulbs were fed into the sheller, the bulbs got crushed and were damaged excessively due to the impact force and the high speed of the rotor.

Next trial was in a thresher which works on the principle of compression and shear force between the roller and its concave. When garlic bulbs were fed into this machine, individual cloves were obtained at the outlet with little damage. Hence, it was found that the principle of compression along with shear force and with proper clearance and also provision of rubber cushioning surrounding the cylinder will reduce the damage.

3.3.2. Garlic clove peeling unit

For developing a garlic clove peeling unit, various trials were carried out to determine the best method of clove peeling. Initial testing was done with a seed coat remover works on the principle of abrasion due to emery coating shows a greater damage with less efficiency. Hence the second trial was done with compressed air in a vessel which is provided with two opening, one for air inlet at the bottom and the other for peel exit at top. A 2 HP compressor with 100 L capacity cylinder was used and was found that the peels get removed at certain pressure of compressed air. In order to increase the efficiency pre-treatment to garlic cloves were tried like:

(a) Control
(b) Drying alone
(c) Oil conditioning
(d) Oil conditioning and dried

3.4 Development of bulb breaker cum peeler

After finalizing the principle of operation by conducting the preliminary studies the garlic bulb breaker cum peeler was developed and fabricated at the workshop of Kelappaji College of Agricultural Engineering &Technology, Tavanur.

3.4.1 Garlic bulb breaking unit

The bulb breaking unit consists of a feed hopper, a roller and a concave unit both lined with rubber cushion and a motor. The shaft of the roller is connected with 0.25 HP single phase motor using a pulley and belt. The roller is having the diameter of 145 mm and a length of 250 mm was made with a galvanised iron pipe. A concave unit which surrounds the roller was made using a galvanised plane (GP) sheet. The clearance between the roller and concave was of 63.5 mm at the top and 15 mm at the bottom. Both roller and concave were provided with rubber rod having square cross-section and a thickness of 15 mm for cushioning effect. These rubber rods were bolted at 60° around the roller and were affixed as a continuous layer along the concave. In order to increase the breaking efficiency and also to reduce the clove damage additional rubber rods were fixed in between the previous rubber rods at an angle of 30° around the roller. Due to compression and shearing force between the roller and concave, garlic bulbs splits into individual cloves.

3.4.2 garlic clove peeling unit

Initial trial was done with a bottle and a 100 L, 2 HP air compressor as in Plate.3.2. This system had a limitation that the capacity was less and air leakage was noticed through the inlet and outlet provided in the bottle. This was cleared by providing a SS vessel with a height of 450 mm and a flat top with a 20 mm diameter

Plate.3.2 Garlic clove peeling using compressed air

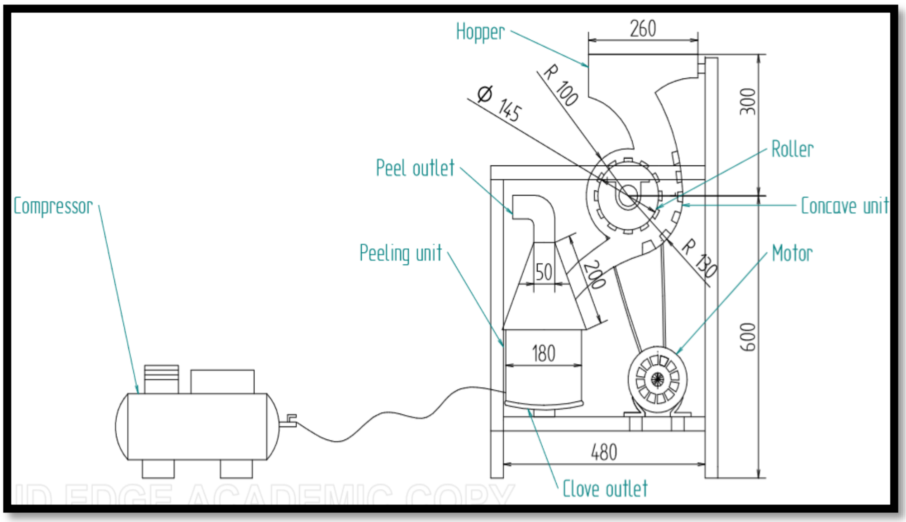
Compressed air was given using a 6 mm hose and was connected by means of pipe connector. On testing, peels after peeling were retained within the vessel as the height of the vessel was more and also flat top acted as an obstruction for the peels to go out of the vessel. Hence this was rectified by using a round bottom stainless steel vessel of diameter 180 mm and height 160 mm. A conical top of 170 mm height with a 50 mm opening connected to a same diameter bend pipe.

3.5 Development of Garlic bulb breaker cum peeler.

The two separate systems for bulb breaking and clove peeling was combined together to form a single unit that can perform both the functions. General layout and details of the machine is as follows.

The machine consists of mainly 6 components

1. Frame assembly
2. Feed hopper
3. Roller and concave
4. Peeling unit
5. Motor
6. Compressor



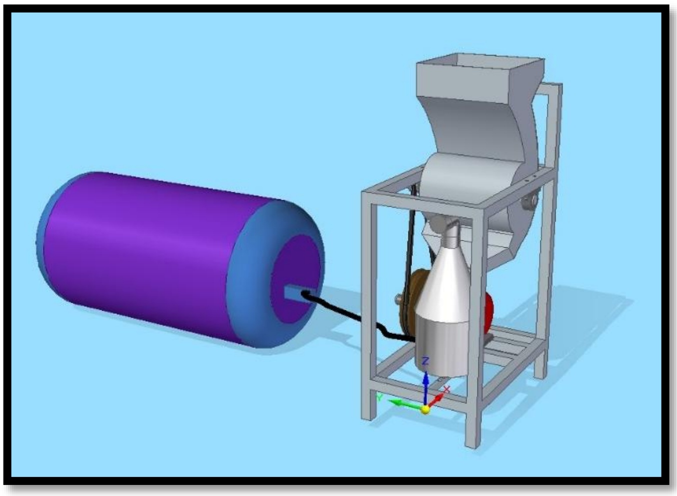


Fig 3.1 Design of garlic bulb breaker cum peeler

Fig 3.2 3D image of garlic bulb breaker cum peeler

3.5.1. Frame assembly

Frame was fabricated by using GP (galvanized plane sheet) square pipe of 1.0 mm thickness and 30.0 mm width.

3.5.2. Feed hopper

It is made up with GP sheets of 1 mm thickness having a size of 270 x 260 mm.

3.5.3. Roller and Concave

Roller is a GI cylindrical pipe of 145 mm diameter and 250 mm length. It is bolted

with 12 rubber rods of square cross section and 15 mm thickness at an angle of 30°

around the roller. It is made to rotate anti-clock wise with the help of a motor.

Concave is a GP sheet of 2 mm thickness bent to form a concave around the roller to provide a clearance for the bulb breaking. The clearance reduces from top to bottom as 63.5 mm at the top and 15 mm at the bottom. To increase the efficiency concave is affixed with rubber rods as a continuous layer

When the roller rotates, the garlic bulbs entering the space between roller and the concave would experience compression and shear forces due to which it breaks and the cloves get separated. Individual cloves leave the concave to the next unit.

3.5.4. Peeling unit

Peeling unit is a round bottom stainless steel vessel of 180 mm diameter and 160 mm height. The top covering is a stainless steel sheet of 1.0 mm thickness bent to form a conical shape having a height of 170 mm with a 50 mm top opening. A SS bend pipe of 50 mm diameter is connected to the top opening to covey the peel along with air to outside. A closure mechanism with a handle is provided at the junction between breaking and peeling unit so as to prevent the leakage of air through breaking unit while peeling. To collect peeled clove a lid is provided at the bottom of peeling vessel with a lever mechanism. An inlet for the compressed air is provided using pipe connector.

During bulb breaking, the closure mechanism is kept open so that the cloves enters the peeling unit and once bulb breaking is over, the same is closed using handle. Compressed air is forced on to the cloves through narrow inlet and due to the pressure of the air the cloves circulates, rub against each other and the peel is removed. Being light weight, the peels move along with air to outside through bent pipe. Once peeling is done, the cloves are collected by opening the bottom lid using the lever.

3.5.5. Motor

The machine is equipped with a single phase 230 V, 0.25 HP motor of 1275 rpm which was mounted at the bottom on the frame assembly. The motor is connected to the shaft of roller by means of a 47-inch rubber belt and a bearing of inner diameter 20 mm.

3.5.6. Air Compressor

The most important unit to accomplish peeling is the air compressor. A 150L air compressor with a working pressure range of 80- 240 psi and a cut off pressure of 80 psi is used. It is equipped with a motor of 1.5 HP and 230 V. The compressed air is conveyed to the peeling unit through a 6 mm diameter hose. The diameter is kept narrow in order to obtain a high pressure inside the peeling unit.

(a) Roller (b) Concave

Plate 3.3. Roller and Concave

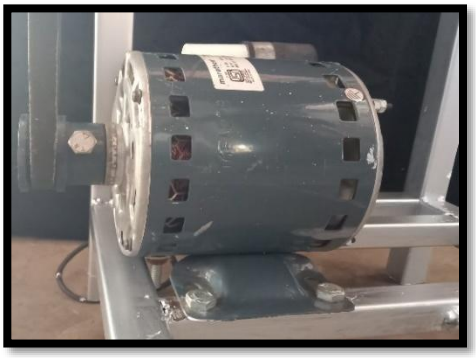
Plate 3.4 Motor **Plate.3.5 Air compressor**

3.6 Performance evaluation

3.6.1 Bulb breaking efficiency

The garlic bulb breaking efficiency was calculated by using the following formula (Channabasamma, 2014)

Breaking efficiency (%) =



$$\frac{(S \text{ or } D \text{ or } T \text{ or } \square T)}{(I - F)} \times 100 \qquad ....(3.5)$$

Where,

S= Singles good cloves weight, kg

D= Doubles good cloves weight, kg

T= triples good cloves weight, kg

□T= More than triples good cloves weight, kg

I = total input weight, kg

F= Total weight of chaff collected from outlet, kg

3.6.2 Garlic clove damage

It was estimated by separating the total damaged cloves from the sample collected at the outlet using the following formula (Channabasamma 2014)

Percentage of damaged cloves (%) = (E/A) × 100 …..(3.6)

Where,

E= Quantity of damaged cloves collected at main outlet per unit time, kg

A = Total cloves output per unit time by weight, kg

Clove damage in each fraction viz., singles, doubles, triples and more than triples were estimated.

3.6.3 Peeling efficiency

The peeling efficiency was calculated by using the following formula given by Sharma and Madhyan (1988)

Peeling efficiency, %= $[(1-m_u/ m_t) \times (1-m_d/ m_t) \times (1-m_l / m_t)] \times 100$ …(3.7)

Where,

m_u = No. of unpeeled garlic cloves

m_t = No. of total garlic cloves used for peeling

m_d =No. of damaged garlic cloves

m_l =No. of lost garlic cloves

3.6.4 Material loss in peeler

Material loss during the entire process can be calculated using the following formula

Material loss (%) = $\frac{(W - Z)}{Z} \times 100$ …..(3.8)

Where,

W= Total number of cloves fed into peeler

Z = Total number of peeled cloves without damage

3.6.5 Capacity of the machine

Capacity of the entire machine is calculated by noting the weight of the peeled garlic and the time taken for the entire process of bulb breaking and peeling. It was then expressed in kg/hr.

CHAPTER 4

RESULTS AND DISCUSSION

This chapter deals with the results of experiments conducted to evaluate the performance of garlic bulb breaker cum peeler and its comparative performance with the manual method.

4.1 Size of the garlic cloves

Garlic having different size and maturity has been collected and its length, breadth and thickness were measured. The geometric mean diameter and sphericity were measured using these parameters. The obtained values are given in table 4.1.

Table.4.1 Specifications of garlic clove

Length (mm)	Breadth (mm)	Thickness (mm)	Geometric mean diameter (mm)	Sphericity
17.87	12.64	11.26	13.65	0.764
29.9	12.08	11.72	16.17	0.541
28.96	10.4	9.51	14.2	0.49
14.93	8.57	6.59	9.44	0.633
32.2	13.75	12.5	17.68	0.549
18.41	10.22	7.18	11.05	0.6004
20.19	3.64	5.05	7.18	0.355

It was found that the average length, breadth and thickness of garlic cloves are 23.20 mm, 10.18 mm, and 9.11 mm respectively. The average geometric mean diameter and sphericity were calculated as 12.77 mm and 0.562 respectively.

4.2 Coefficient of static friction

The coefficient of static friction of garlic on wood, aluminium and stainless steel surfaces were calculated and it is given in table 4.2.

Table 4.2. Coefficient of friction on different surfaces

Sl. No.	Force of limiting friction (F) in N						Coefficient of static friction					
	Garlic cloves			Garlic bulb			Garlic cloves			Garlic bulb		
	Wood	Al	SS	Wood	Al	SS	Wood	Al	SS	Wood	Al	SS
1	50	70	50	100	70	50	0.33	0.466	0.33	0.66	0.46	0.33
2	60	70	70	90	90	90	0.4	0.466	0.466	0.6	0.6	0.6
3	65	50	60	80	50	80	0.433	0.33	0.4	0.53	0.33	0.53
4	65	50	50	90	50	100	0.433	0.33	0.33	0.6	0.33	0.66
5	70	60	70	70	70	100	0.466	0.4	0.466	0.46	0.46	0.66

(*The normal reaction, R is taken as 150 N.) The average coefficient of friction of garlic cloves on wood, aluminium and steel surfaces were 0.412, 0.398 and 0.398 and that of garlic bulbs were 0.573, 0.44 and 0.56 respectively.

4.3 Angle of repose

Angle of repose was measured using emptying method. The experiment was repeated 5 times with both the bulbs and cloves. Angle was calculated by using the formula 3.4 and the mean was calculated.

Table 4.3 Angle of repose of garlic bulbs and garlic cloves

Sl No	BULB			CLOVE		
	H (cm)	L(cm)	Φ (degree)	H (cm)	L (cm)	Φ (degree)
1	35.7	25	55	19.2	25	37.5
2	33.4	25	53.2	20.5	25	39.3
3	32.9	25	52.8	19.8	25	38.5
4	37.2	25	56.1	18.7	25	36.8
5	33.7	25	53.5	21	25	40.1

Mean value of angle of repose for bulbs were found to be 54.12° and that for the garlic cloves were found to be 38.44°

4.4 Garlic clove peeling

When compressed air was given to the garlic with different pre-treatments, we could arrive at the following results. When garlic without any pre-treatments were subjected to compressed air for a fixed duration of time, the efficiency of peeling were low, being around 25% of the total cloves given. When same procedure was repeated with oil treatment alone, efficiency was very low, being less than 25%, when tried after cooling garlic cloves, around 50% of the given cloves got peeled with compressed. Cooling treatment could give a good result but would require a separate cleaning unit as the separated peels were not carried away by the air. Maximum results were obtained when the experiment was repeated with both air dried and with oil treated dried cloves being around 75%.

From some research paper reference, the drying temperature for garlic was found to be from 58 to 90° C, and hence a temperature of 75° C was setup in a cabinet dryer. The experiment was repeated with heating for 3 minutes, 5 minutes, 7 minutes and 9 minutes. It was found that best results were obtained with 7 minutes of heating as further increase in temperature caused change in colour and flavour.

4.5 Performance evaluation

4.5.1 Bulb breaking efficiency

The bulb breaking efficiency were calculated on the basis of the weight of good single clove, double clove, triple clove and more than triple.

Table.4.4 Weight of different fractions obtained during bulb breaking

Total weight (g)	Single cloves (g)	Double cloves (g)	Triple cloves (g)	More than triples (g)	Chaff (g)
500	410	50	-	-	40
500	434	-	21	-	45
500	385	42	25	-	48
500	400	57	-	-	43
500	380	47	28	-	45

The bulb breaking efficiency in terms of single clove were 88.12%, double were 8.56% and triple were 5.43%. During bulb breaking more than triple were not found.

4.5.2 Garlic clove damage

Percentage of garlic clove damage is calculated by determining weight of damaged cloves and weight of cloves obtained at the output. Table.4.4 shows the same.

Table.4.5 Percentage damage of garlic cloves during bulb breaking

Sl. No.	Initial weight of garlic bulbs (g)	Total cloves at output(g)	Damaged cloves at output (g)	Percentage of clove damage (%)
1	500	446	14	3.13
2	500	446.5	13.5	3.02
3	500	445	15	3.37
4	500	445.75	14.25	3.19
5	500	446.25	13.75	3.08

Average value of percentage clove damage were found to be 3.158%. When the total input garlic is considered, the damage is very less. The main reason for the damage is that each garlic bulb is of different size and individual cloves of each bulb are also of different size. The clearance requirement of garlic thus varies and could be adjusted only based on their average size.

4.5.3 Peeling efficiency

The garlic segments were peeled by the peeler. The unpeeled garlic segments were separated manually from the mixture and then weighed. Damaged garlic segments were manually separated from the mixture and then weighed. The garlic segments lost through bend pipe were also separated manually and weighed.

Table.4.6 Peeling efficiency of garlic peeler

Sl. No.	No. of cloves fed in peeler	No. of unpeeled garlic	No. of damaged garlic	No. of garlic lost through bend pipe	Peeling efficiency
1	100	4	2	2	92.1
2	100	4	3	3	90.3
3	100	3	2	3	92.1
4	100	4	2	2	92.1

5	100	4	1	3	92.1

Average peeling efficiency of the peeler was found to be 91.74%.

4.5.4 Material loss in peeler

Material loss in peeler is an indicative of the efficiency of the peeler. Number of damaged cloves and the number of garlic cloves that has been lost through the outlet along with the peel and air are estimated to calculate the material loss.

Table.4.7 Material loss observed during peeling

Sl. No.	**No. of cloves fed in peeler**	**No. of peeled cloves without damage**	**Percentage material loss**
1	100	92	8
2	100	90	10
3	100	92	8
4	100	92	8
5	100	92	8

Average percentage material loss was observed to be 8.4

4.5.5 Capacity of the machine

Table.4.8 Capacity of the machine

Sl. No	**Weight of bulb fed into machine (g)**	**Weight of peeled garlic (g)**	**Time taken for peeling (s)**	**Capacity (Kg/hr)**
1	500	475	130	13.15
2	500	463	124	13.45
3	500	468	129	13.07
4	500	477	133	12.92
5	500	470	128	13.23

Average capacity of the machine was found to be 13.16 Kg/hr. Capacity depends on the maturity of the bulbs and time taken.

Plate 4.1 Unbroken Garlic bulbs **Plate 4.2 Unpeeled garlic cloves**

Plate 4.3 Peeled garlic using compressed air

Plate 4.4 Developed Garlic bulb breaker cum peeler

CHAPTER 5

SUMMARY & CONCLUSION

Garlic (*Allium sativum*) belongs to the family Liliaceae, is one of the important bulb crop grown and used as a spice or condiment throughout India. India produces about 4.1 per cent of total world production and ranked second after China. Garlic is grown in an area of 2.48 lakh hectares in India with the production of 12.59 lakh tonnes and productivity is 5.09 tonnes/hectare (NHB, 2016). The important garlic growing states are Maharashtra, Punjab, Rajasthan, Haryana, Gujarat, Uttar Pradesh, Orissa and Madhya Pradesh.

Garlic bulbs are to be broken into single cloves for planting material purpose, for processing industries to make pickles, paste etc. Usually garlic bulbs are broken into single cloves manually in home applications. For large scale garlic processing, the garlics are placed on a horizontal plane surface and are beaten by wooden sticks to separate the cloves and doing this within a short period is labour intensive. The traditional peeling method of garlic is mainly by hands which is more time consuming, laborious and cost intensive. To overcome these difficulties in bulb breaking and peeling an attempt was made to develop a power operated garlic bulb breaker cum peeler.

The first attempt was to develop a bulb breaking unit. For this initially an experiment was conducted by introducing the garlic bulbs into a machine which works on the principle of impact force. The clove damage was much higher in this method and hence it was revealed that this principle is not suitable for the development of an efficient garlic bulb breaker. Next attempt was made on a machine which works on the principle of shearing and compression force between a rotating roller and concave mechanism. Very good efficiency was obtained from this method. Applying this principle, a power operated garlic bulb breaker was developed and to decrease the clove damage a rubber cushioning was provided on roller and concave.

For the development of garlic peeling unit, initially the principle of abrasion was tried using an emery coated surface. The clove damage was much higher as the garlic peel is very thin and are attached tightly on to the garlic cloves. When compressed air at a pressure range of 4-6 Kg/cm^2 was applied in a cylindrical vessel efficient peeling was achieved without any damage. Different experiments were conducted on this principle by giving certain pre- treatments to the garlic cloves. It was found that compressed air application to dried cloves gives almost 95-97% efficiency. Hence an efficient garlic peeler was developed by applying this principle.

By combining the bulb breaking and peeling unit a power operated, prototype and compact garlic bulb breaker cum peeler was developed. The bulb breaker unit was driven by a 0.25 HP single phase motor. The capacity of the machine is 13.14 Kg/ hr with an efficiency of 91.74%. This women friendly machine could be very much useful in small scale pickle industries, especially the ones run by kudumbashree units. This cost effective machine could make the tiring jobs in the pickle industry easier and could thereby promote small scale pickle industries in Kerala.

The present efficiency of the machine could be improved by the provision of a heating system in between the breaker and peeler so that after a partial removal of moisture, peeling is done. This would detach the peel from the clove which would enhance the peel removal and thereby the efficiency of the machine.

CHAPTER 6
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APPENDIX I

COST ESTIMATION

Initial Cost (C)

Fabrication cost of Garlic bulb breaker cum peeler

including cost of materials	= Rs. 25650/-
Average life of machine	= 10 years
Working hours per year	= 3650
Salvage value	= 10% of initial cost

A) FIXED COST

1. Depreciation $= \frac{C-S}{LH}$

$= \frac{25650-2565}{10\times3650}$

= 0.632

2. Interest on investment @ 12% $= \frac{(C+S)\times12}{2\times H\times100}$

$= \frac{(25650+2565)\times12}{2\times3650\times100}$

= 0.4638

Total fixed Cost = 1.0958

B) VARIABLE COST

1. Labour wage = Rs.600/ day of 8 hr
2. Cost of electrical energy

Unit cost of electricity = Rs. 7.5/kwh

Energy consumption of machine = 0.2

Cost of electricity = 1.5/h

3. Repair and maintenance cost

@ 10% of initial cost p.a. = $\frac{25650\times10}{3650\times100}$

= 0.7027/ h

Total variable cost = 77.2027/h

Total operating cost = 78.2985/h

DEVELOPMENT AND PERFORMANCE EVALUATION OF GARLIC BULB BREAKER CUM PEELER

By,

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MIDHILA P K (2015-06-013)

NASIM BANU B (2015-06-014)

Department of Process and Food Engineering

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PROJECT REPORT

Submitted in partial fulfillment of the requirement for the degree

Bachelor of Technology

In

Food Engineering

Faculty of Agricultural Engineering and Technology

Kerala Agricultural University

Department of Process and Food Engineering

KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY

TAVANUR-679573, MALAPPURAM

KERALA, INDIA

2019

DECLARATION

We hereby declare that this project report entitled **"DEVELOPMENT AND PERFORMANCE EVALUATION OF GARLIC BULB BREAKER CUM PEELER"** is a bonafide record of project work done by us during the course of project and that the report has not previously formed the basis for the award to us of any degree, diploma, associateship, fellowship or other similar title of any other university or society.

Place: Tavanur

Date:

Archana P

(2015-06-006)

Midhila P K

(2015-06-013)

Nasim Banu B

(2015-06-014)

CERTIFICATE

Certified that this project report entitled **"DEVELOPMENT AND PERFORMANCE EVALUATION OF GARLIC BULB BREAKER CUM PEELER"** is a record of project work done jointly by Archana P (2015-06-006), Midhila P K (2015-06-013) and Nasim Banu B (2015-06-014) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, associateship, fellowship to them.

Tavanur

Dr. Santhi Mary Mathew
Chairman & Head
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ACKNOWLEDGEMENT

Words are no substitute for thoughts and feelings. It is more so when we, the project team, wish to express our sincere thanks to our project guide, **Dr. Santhi Mary Mathew**., Professor, Head of the Department of PFE, KCAET, Tavanur, for her valuable guidance, encouragement and advice throughout the project work.

We also extend our sincere thanks and gratitude to **Dr. Rajesh G K.**, Associate Professor and **Smt. Sreeja R**., Assistant Professor, Department of PFE for their support and encouragement. We are extremely thankful to our co- guide **Er. Sariga S** and **Er. Nithin K**., Assistant Professors, Department of PFE for their support and valuable suggestions in the completion of our project successfully.

Also we thankfully remember the services **Mr. Vipin P**., Technician, **Mr. Lenin.**, Technician and **Smt. Jojitha K C**., Computer Assistant, KCAET Tavanur, for their immense help and their continuous support throughout the project.

We would also like to thank our **parents** for their love and support throughout the project. We also extend our thanks to all the **faculties of library**, KCAET, for their help and support. Last but not the least we thank our sincere friends for their ever willing help, support and cooperation that helped us to complete the project successfully.

Above all, we bow our head before **The Almighty**, whose grace and blessings have empowered us to complete this toil.

Archana P

Midhila P K

Nasim Banu B

DEDICATED TO OUR

PROFESSION OF

FOOD ENGINEERING

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ABSTRACT

Garlic is a bulbous spice which is used as an important ingredient in pickles, curries, meat preparations etc. It has Its medicinal applications as gastric stimulant, increase the digestion and absorption process of food, in curing skin diseases etc. The bulb breaking and peeling process of garlic manually is a time consuming, labour intensive and causes drudgery. Therefore, a simple, power operated garlic bulb breaker cum peeling machine which is easy to operate, maintain and economical was fabricated. The bulb breaking unit separates individual cloves and the peeling unit removes the peel from the cloves effectively. The machine consists of mainly a feed hopper, a roller and a concave mechanism, a motor, a peeling unit and a compressor. The roller is driven by a 0.25 HP single phase motor having 230 V and 1275 rpm. The bulb breaking unit consists of a roller and concave mechanism both lined with a cushioning of rubber rods having 15 mm thickness in order to avoid clove damage. The roller is rotating in anti-clockwise direction. The peeling unit consists of a round bottom stainless steel vessel of 180 mm diameter and 160 mm height which is covered at the top with a conically bent SS sheet with 170 mm height and 50 mm top opening. A bend pipe having 50 mm diameter is welded on this top opening for peel outlet. A lid is provided at the bottom of this vessel to collect the peeled cloves. An inlet for compressed air of pressure 4-6 Kg/cm^2 is provided at the bottom using a pipe connector. The garlic bulb breaker cum peeler was fabricated by combining these two unit which has a capacity of 13.14 Kg/hr with less material loss and high efficiency (91.74%) which is simple, compact, and women-friendly in use.