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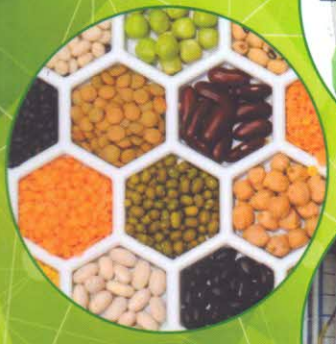
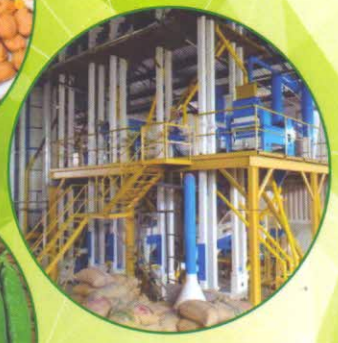
Advancements in Post-Harvest Management of Legumes for Minimizing Losses and Sustainable Protein Availability






Mridula D.
R.K. Vishwakarma
Prerna Nath

ICAR-Central Institute of Post-Harvest Engineering & Technology
Ludhiana-141004 (Punjab)
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Mechanization for Depoding of Green Legumes

Bhushan Bibwe, Manoj Mahawar, Sandeep Dawange and Kirti Jalgaonkar

Horticultural Crop Processing Division, ICAR-CIPHET, Abohar
E-mail: bhushan.bibwe@gmail.com

Introduction

India's diverse climate ensures availability of all varieties of fresh fruits and vegetables. It ranks second in vegetables production in the world, after China with production of 162.89 million MT during 2013-14 (IHB, 2014). Legume crops represent an important component of agricultural food crops consumed in developing countries and are considered a vital crop for achieving food and nutritional security. In countries like India where majority of the population are vegetarians, leguminous vegetables serve as the major source of protein in the diet. In developing third world countries, especially for the poor, the major protein source in the diet are vegetable legumes. Most leguminous vegetables are rich in phosphorus, calcium, iron, number of essential vitamins and also consumed as a significant source of protein, dietary fiber, carbohydrates and dietary minerals. Legumes are also an excellent source of resistant starch which is broken down by bacteria in the large intestine to produce short-chain fatty acids used by intestinal cells for food energy (Birt *et al.*, 2013).

A legume is a plant or its fruit or seed in the family Fabaceae (or Leguminosae). Fabaceae is the most common family found in tropical rainforests and in dry forests in the Americas and Africa. Legumes are the seed of the plant surrounded by a protective seed coat and include beans and peas. In international trade, leguminous vegetables play an important role for foreign exchange. Now days canned and frozen foods, Dry seeds, and processed food products from leguminous vegetables are entering the international market where they are important commodities for foreign exchange. The International Year of Pulses 2016 (IYP 2016) was declared by the sixty-eighth session of the United Nations General Assembly. The Food and Agriculture Organization of the United Nations was nominated to facilitate the implementation of IYP 2016 in collaboration with governments, relevant organizations, non-governmental organizations and other relevant stakeholders. Its aim was to heighten public awareness of the nutritional benefits of pulses as part of sustainable food production aimed towards food security and nutrition. IYP 2016 created an opportunity to encourage connections throughout the food chain that would better utilize pulse-based proteins, further global production of pulses, better utilize crop rotations and address challenges in the global trade of pulses.

In India, green pea (*Pisum sativum*), lima bean, butter bean (*Phaseolus lunatus*), cow pea (*Vigna Ungiculanta*), chickpea, (*Cicer arietinum*) are also used as fresh pod, immature seed for preparation of various vegetable recipes and mature once are used as dry seed. As per Indian Horticulture Database, India produced 162.89 million MT of vegetables during 2013-14, Out of which, *Pisum sativum* (commonly known as peas) is one of the major leguminous vegetable crop contributes approximately 2.5% (3868.6 thousand MT) share of the total vegetable production and 4.6% of the total vegetable producing area in India (NHB, 2014). India is the also the largest producer of chickpea in the world and contributed about 65% of total world production. In India, Madhya Pradesh alone contributed 44.20% of total production followed by Maharashtra (14.90%), Andhra Pradesh (11.32%), Karnataka (7.68%), Rajasthan (7.15%) and Uttar Pradesh (6.81%). The U.N. Food and Agricultural Organization estimates that total commercial production of dried beans was 23.23 million MT worldwide in 2010, harvested from 29.92 million hectares. India was the leading producer, responsible for 21% of total production, followed by Brazil, Myanmar, China, the U.S., and Mexico (USDA, 2012).

In Indian context, Uttar Pradesh, Bihar, Jharkhand, Punjab, Haryana, Madhya Pradesh and Himachal Pradesh are the major pea and beans producing states where peas, beans are grown and farmers mostly sold it in local mandies at very low price of 15-20 Rs/kg depending upon the quality. Legume vegetables beans are highly perishable in nature due to high moisture content of pods. In case of green peas, fresh unshelled peas may be kept for two weeks at 0°C with 90-95% RH whereas processed peas *i.e* shelled frozen peas can be stored at -23 to -18°C for one year when packed in gas tight packaging. Currently, shelled frozen green peas costs around 150-170 Rs/kg in the market, which means it can offer high return to farmers if it is processed by farmers. The shelling of legume pods

usually being done manually at field level in India. The machineries available for de-poding are of large capacity and costly for the marginal farmers and also lead to the damage or splitting of kernel during operation.

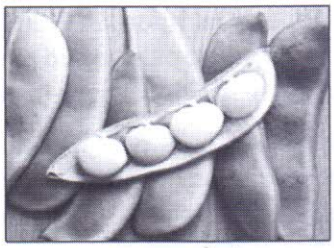
In the view of commercialization, manual method of shelling pods founds to be time consuming, laborious operation, have low operational capacity and also found difficulty of labours at peak harvesting season. In mechanical methods of shelling peas, commonly pea pods are taken from the field to a viner station and fed to stationary viners, which works on principal of shearing, crushing and impact. The threshing action of the viners beats the peas from the pods and they are separated from the pods in the viner and subsequently cleaned by winnowing or meshing and washing. The beating action of the viner was shown to damage the peas by Moyer et al., (1954) and Casimir *et al.* (1967). Damage predisposes peas to development of off-flavour (Lynch *et al.,* 1959; Eriksson and Sydow, 1964). Damaged peas tend to split during factory operations, and resultant losses can be appreciable. Some institutes, universities like JNKVV Jabalpur, AICRP-PHT, Akola, PAU Ludhiana and few food equipment companies already worked on the development and commercialization of depoding machines based on the principle of beating/ threshing or on roller stripping. The commercial depoding machines are also available in the market with large capacity (minimum 1.0 tonne/h). The principle, working mechanism of such developed depoding machines are described in this article. The depoding machine not only helps to reduce the time for depoding of pea pods, but can also be used as good opportunity for small farmers by packing the depoded bean grain to fetch more income on investment.

Green legumes as a source of vegetable

Green pea (मटर)
(*Pisum sativum* or *arvense*)

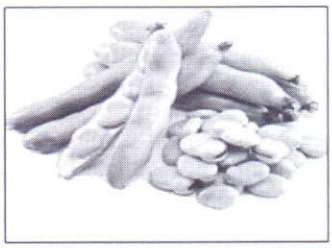
Chickpea (चना)
Bengal gram (*Cicer arietinum*)

Cow pea (लोबिया/ चवली)
(*Vigna unguiculata*)



Lablab bean (सेम)
hyacinth (*Lablab purpureus*)

Lima bean (लोबिया)
Butter bean (*Phaseolus lunatus*)



Broad bean (बाकला)
(*Vicia faba*)

Shelling/ hulling/ depoding mechanisms

- Manual shelling
- Tumbler/ impact and beating mechanism
- Roller mechanism

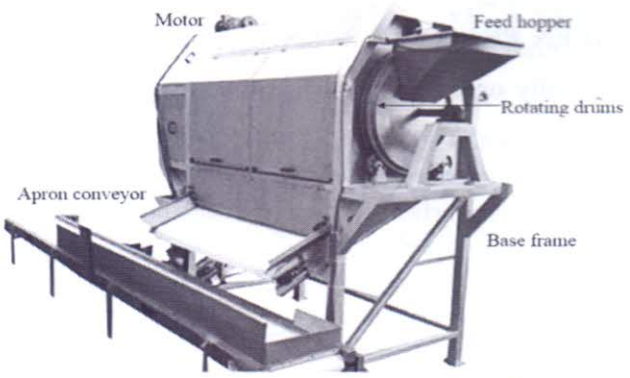
Manual shelling

The process of removing seed/beans from their pods (also known as 'shelling' or 'dehulling') is an incredibly time consuming task when done by hand. Due to the fact that there are few beans contained in each bean pod, the time required to process any deliverable quantity of produce makes bean farming very costly for small farms. Manual removal of kernels from green peas is time

consuming, laborious as one person can depod about 3-3.5 kg of green peas from pods in one hour (Sharma and Singh, 1989).

Tumbler/ impact and beating mechanism

Shelling machines that use the tumbler method consist of a slowly rotating inner mesh cylinder which contains a quickly rotating shaft with attached paddles and an external wall. The pods are loaded into the inner cylinder which rotates and directs the pods to fall into the spinning shaft which breaks up the pods through contact with the rotating paddles. The shelled beans then fall through the inner cylinder mesh and are collected from the external wall, while the empty pods remain within the inner cylinder to be later collected and discarded. The commercially available tumbler style machines are designed mainly for industrial scale and therefore are of large capacity and expensive. Large scale harvesting combines use this method by tumbling the bean pods inside of a rotating screen. When used for their intended applications and scale both methods work effectively and provide a favorable ratio of cost to productivity.



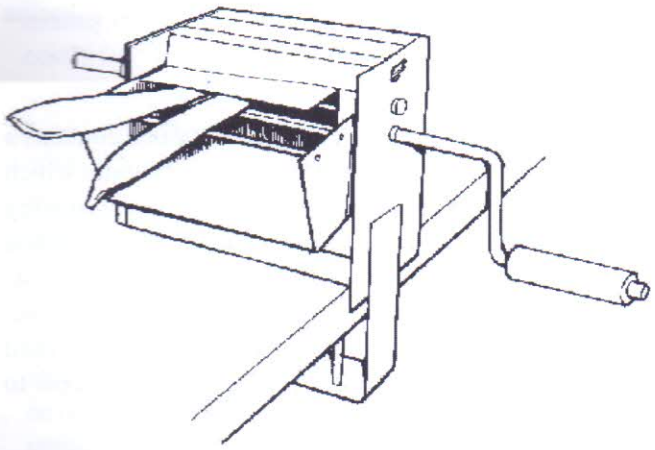
In some other designs of tumbler/beating type depoding machines, two counter rotating concentric cylinder drums are used for pea shelling. The adjustable wooden beaters/ SS blades are mounted on the inner drum, whereas outer drum is generally perforated or made up of wire mesh. The pea pods are fed in between the drum space where, due to beating action of the blades/wooden beaters the grains are removed from the pods. The pea grains fall through the perforated wiremesh drum on to the apron conveyor. The apron conveyor being inclined, the pea grains slide down and some peels and pea pods stick on the belt of the apron conveyor. They are collected on separate chutes on the reverse side of the apron conveyor.

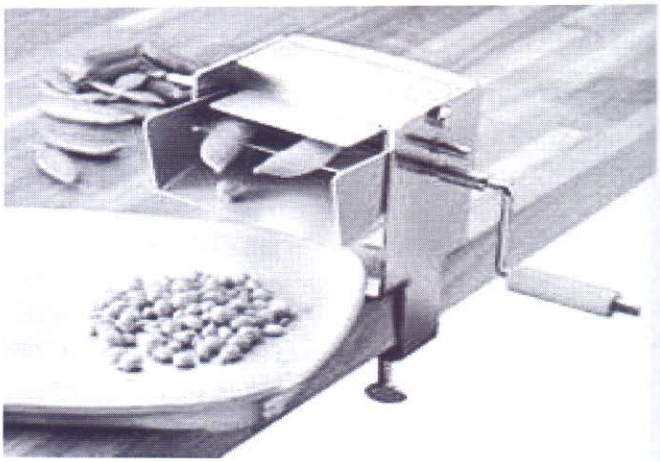
The unit consists of the following:

- Frame made of SS square pipes
- Rotor made of SS sheets with SS blades mounted on it. Adjustable blades.
- Drum made of MS rings, SS square pipes and SS perforated sheets
- Support structure for smooth movement of drum consisting of adjustable rollers, SS frame for mounting rollers at both ends etc.
- Apron conveyor consisting of SS rollers, SS body, SS mounting frame, PVC food grade belt, support structure for the belt etc.
- Separate drive arrangements for rotor, drum and apron conveyor. Drive arrangement consists of geared motor, sprockets, chain etc.
- Feed hopper, discharge hoppers, covers etc. all made with SS sheets

Roller method

The roller method of bean shelling can be found in several readily available hand crank and/or table top models; these machines are designed to shell fresh peas in the pod. The pea pods are fed into two very closely spaced rotating rollers, which squeeze the peas out of the pod and then pull the empty pods through the roller mechanism to be collected and discarded. Most of these devices are of medium to small scale and are designed specifically for fresh peas. This system works well for garden sized produce yields but becomes inefficient when dealing with a more substantial volume.





GREEN PEA SHELLER/HULLER/ PEELERS DEVELOPED IN INDIA

Manually operated Green pea shelling machine at AICRP-PHT, Jabalpur centre

Sharma and Mandhyan (1986) developed a manually operated Green Pea Shelling Machine at AICRP on Post Harvest Technology Scheme, Jabalpur centre. Investigations were carried out on the effect of roller inclinations, roller abrasive surface on shelling efficiency. The four roller inclination viz. 0°, 13°39', 15°15' and 16°48' with three roller surfaces viz. punched tin sheet, cycle tyre treads and gunny bag having coefficient of friction values as 0.839, 0.649 and 0.810 respectively. Highest recovery of undamaged kernel (92.7%) was obtained by shelling peas with punched tin sheet roller at roller inclination 16°48', followed by 89.8% at inclination of 15°15'. The third highest recovery of 88.4% was 10 obtained at roller inclination of 16°48' with gunny bag abrasive surface. In the entire three abrasive surfaces it was observed that the recoveries were highest at roller inclination of 16°48', followed by 15°15' and 13°39'. It was also observed that the abrasive surface made of punched tin sheet and tyre treads give 100% shelling efficiency at all roller inclinations. The capacity of developed green pea peeler was 25 kg/h. The peeler was suitable to peel green pea pods (80.2% wb moisture) at roller-concave clearance of 12 mm and roller speed of 45 rpm.

Power operated green pea shelling machine at AICRP-PHT, Jabalpur centre

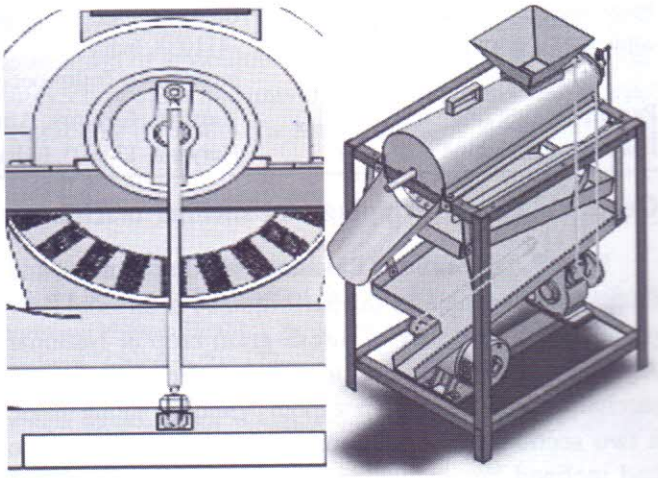
Singh and Sharma (1987) optimized the various design parameters and crop parameters on developed power operated green pea shelling machine at AICRP-PHT Scheme, Jabalpur centre using Arkel cultivar. The roller clearance was fixed at 12 mm, speed of roller to be 50 rpm, roller inclination angle to be 16°8' and studied the effect of moisture contents (76-82 % wb.) of pea pods on efficiency and capacity of machine. It was reported that whole kernel recovery of green pea pods was highest (95.5-96%) and in moisture range of 73-74%, capacity of machine was found 50 kg/h. The unit cost of operation is Rs. 40 per hour. The machine yields a time saving of 900 % over tradition manual peeling method and also a saving of Rs. 2772/- per day in terms of labour cost is reported as compare to traditional manual peeling method. At reduced women drudgery, the capacity of peeling increased from 2 - 3 kg/ person/ hour to more than 30 kg/ person/ hour.

Singh (2003) evaluated the performance of power operated green pea sheller using Arkel and JM-1 green pea cultivar. It was reported that, shelling efficiency with Arkel cultivar (98.94% at 65.14% wb moisture) was higher as compared to JM-1 pea cultivar.

Small scale de-poding machine, PAU, Ludhiana

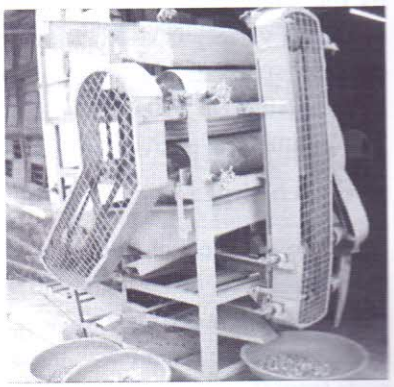
Kaur (2006) developed pea shelling machine based on the principle of force of friction between L shaped blades and two types of sieves viz., wire mesh and punched GI sheet sieve. The test efficecny was 69.5 per cent. Goyal

(2007) modified the pea de-poding machine designed by Kaur (2006) by changing L-shaped blades by wooden depoders. It was reported that, 102 rpm of wooden depoders and 4.3 concave clearance were best suited for better efficiency.



Design and fabrication of pea depoding machine was undertaken by PAU, Ludhiana using computer aided design software. Main components of this machine were base frame, sieve, L-shaped blades, conveying blades, hopper, trays, motor and gear box. Depoding of pea grain was done based on the principle of friction generated by rubbing action of blades with the pea pods on sieves which helps in opening the pods of peas and cutting action of conveying blades. The depoding efficiency was reported as 95.4%, whole grain efficiency was 91.3% with 2% damage at 60 rpm, 10 mm concave clearance by using 63.5 m blade size aligned at 180°. The average throughput capacity of the machine was 30 kg/h.

Green pea shelling machine, AICRP-PHT, Akola centre



Pea shelling machine based on counter rotating rollers was developed by AICRP-PHT, Akola centre. The capacity of the developed machine was 35 kg/h, with shelling efficiency of 75-77 % and damage percentage was approximately 7 - 8 %. The cost of the machine was Rs. 75,000/-. The versatility of this machine was also tested for green chickpea pod shelling with suitable modification enhanced. The reported capacity of the developed machine was 25 kg/h, with shelling efficiency of 76.4 % and damage percentage was approximately 12-16 %.

Green pea de-poder machine, ICAR-CIPHET, Abohar

The work of development of technology for de-poding of green pea is under progress at Horticultural crop processing division, ICAR-CIPHET, abohar based on the mechanism of roller stripping. The pods will be aligned vertically to feed them between the counter rotating rollers of nylon and PU rubber rollers at set roller rpm. The machine consist of vibratory feeder of 20 V- shaped channels, counter rotating rollers, AC motor, motor variable frequency drive, spur gear etc.

Industrial scale depoder machines

The commercially available industrial scale machines mostly work on the tumbler or beating mechanism. These are of large capacity and needs high initial investments. Large scale harvesting combines also use this method by tumbling the bean pods inside of a rotating screen. When used for their intended applications and scale both methods work effectively and provide a favorable ratio of cost to productivity.

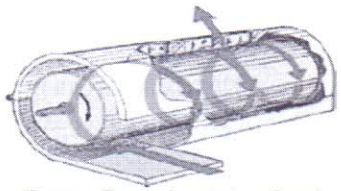
Some leading manufacturers /suppliers of depoding machines in India

Equipment	Manufacturer/Supplier
Peas processing plant	**Varaj Engineering, Bhosari,** Plot No. 9/1, G- Block, Near Midc Corner Chowk, Ycm Hospital Road, Midc Bhosari, Bhosari, Maharashtra-411026, India http://www.varajengineering.net/
Green peas process plant	**Guru Engineers, Pune,** Plot No 232, Sector 10, Pcntda, Near Lumax Company, Midc, Bhosari, Pune, Maharashtra -411026, India
Peas processing plant Pea depoding machine	**Jwala Techno Engineering Pvt.Ltd,** 195/2, Khetan Kutir, Jawahar Nagar, Goregaon (West), Near Mangal Co-Operative Bank, , Mumbai, Maharashtra -400062, India http://www.jwalaengineering.co.in

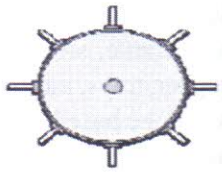
Frozen pea (IQF) line capacities 1-5 tons/hr.	**Shiva Engineers, Pune** T-Block, P.N.533, MIDC Bhosari,, Pune, Maharashtra -411038, India http://www.fruitproccessingmachinery.com
Pea processing line	**Rana Perforators, Ambala** 23-D, Near Arya Chowk, Police Line, , Ambala,
Pea peeling machine	Haryana -134003, India

Green chick pea stripping and shelling machines

NARS, Islamabad (Pakistan) model: Anwar and Gupta (1990) evaluated the performance of an axial flow grain legume thresher to thresh gram crop at National Agricultural Research Centre, Islamabad. Threshing mechanism consisted of a peg tooth cylinder rotating inside a two section cylindrical concave. The upper concave had inclined lugs which moved the threshing material axially. The material was fed into the opening between the cylinder and lower concave. The pegs on the rotating cylinder hit the material separating the grain from pod and straw, and at the same time accelerated them around the initial impact but further threshing was performed while the material moved axially until the straws were discharged by the straw-paddles at the opposite end. An axial flow grain legume thresher (AGAD Model C) was tested on chickpea variety CM-72. Modifications were made to improve its performance. The thresher worked best with a cylinder speed of 580 rev/min, feed rate of 430 kg/h and a concave clearance of 3 cm, at which the thresher capacity was measured at 190 kg/h with a threshing efficiency of 93% and fuel consumption of 5.7 liter/ h. The total loss and grain damage was 9.1% and 2.2%, respectively.



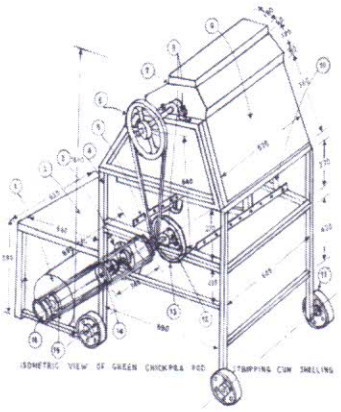
Crop flow in a typical axial-flow thresher

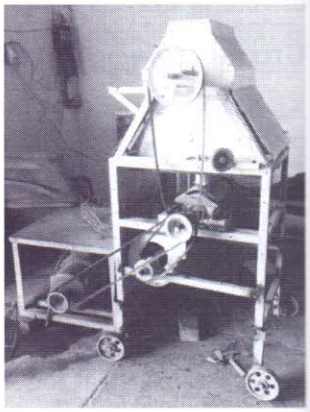


Pegtooth threshing drum (axial-flow thresher)

Green chickpea pod stripping cum shelling machine, JNKVV, Jabalpur model (2012)

A green chickpea pod stripping cum shelling machine was developed at Department of Post Harvest Process and Food Engineering, JNKVV, Jabalpur. Use of jigsaw as a stripping element was used to detach the chickpea pods from the plants then shelling unit removes the green chickpea kernels from pod with minimum damage. The shelling unit consisted of an abrasive roller and a stationery concentric drum over it. Increased path of travel for pods in between shelling roller's abrasive surface and drum facilitated increased shelling efficiency. Use of dotted type rubber mate prevented from physical damage to the kernels. The stripping unit of the machine was constructed, tested as per BIS NO.3327-1965 and the shelling unit was tested as per BIS NO.8824-1977. The stripping efficiency of green chickpea pod stripping cum shelling machine varied between 87.63 to 100% dependent upon feed rate, size, weight and maturity of the pods and twist and sweep action on bunch of chickpea plant on stripping element. The shelling efficiency of green chickpea pod stripping cum shelling machine ranged between 76.60 to 92.57%. The shelling efficiency was dependent upon size of the pods, shelling roller speed, coefficient of wholeness and moisture content of pods. Overall machine efficiency ranged between 80.20 to 89.69% at 70.12% moisture content of pods with a capacity of 36 kg/h.





Epilogue

Agriculture mechanization played a significant economic role by increasing agriculture production and reducing cost of cultivation. The agricultural research and development, use of advanced cultivars and agricultural mechanization has improved productivity to great extent, still post-harvest value addition to the raw product in India is very less as

compared to other countries, which may be mainly due to lack of technologies. There is a dire need to develop more processing machinery for post harvest processing and value addition of agricultural produce for food security. The legume bean shelling machines developed by different institutes, companies and universities will be definitely useful for mechanization of green legumes for value addition, reduction of resources and generation of income and employment to the farming community.

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