SKUAST Journal of Research 26(2): 174-184; (2024)
(*DOI No: 10.5958/2349-297X.2024.00024.0*); NASS rating: 4.88

Research Paper

Development and performance evaluation of power operated pea depoding machine for small and marginal farmers

Zafira Feroz, Aiman Binti Zahoor, Rakesh Mohan Shukla*, Rishi Richa, Mohd. Muzamil, Shahzad Faisal, Jagvir Dixit

College of Agricultural Engineering and Technology, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar, Srinagar -190025
*e-mail: *shukla_rm2005@yahoo.co.in*

(Received 4 August 2023; accepted October 28, 2023)

ABSTRACT

Peas have an impressive nutritional profile as they are rich in proteins and contain all essential amino acids. They are nowadays being utilized as meat analogues due to their texture and high fibre content. Depoding of green peas is still a manual operation in India, making the operation a labour intensive and time consuming. A study was conducted to develop and evaluate pea depoding machine based on physical characteristics and engineering properties of pea. The average tri-axial dimensions in terms of L, B and T varied as10.61 mm, 9.23 mm and 8.11 mm for large pea, 9.28 mm, 8.55 mm and 7.85 mm for medium pea and 7.91 mm, 6.91mm and 6.26 mm for small pea pods. The corresponding porosity values were 87.27%, 91.91% and 91.45%, respectively. The moisture content was recorded as 80-85%, 70-75% and 60-65% after 24 hours, 48 hours and 72 hours. The mean angle of repose was recorded as 30.11° at 80-85%, 25.26° at 70-75% and 23.75° at 60-65% moisture content, respectively. The pea depoding machine comprised of frame, transmission system, conveying tray, rollers and conveying tray. The pea depoding machine was evaluated in terms of speed (150 rpm, 200 rpm and 250 rpm) and moisture content (80-85%, 70-75% and 60-65%) and responses were measured in terms of depoding capacity (kg h^{-1}), depoding efficiency, damage percentage, labour requirement (Man-h kg^{-1}) and un-depod percentage. The optimized parameters obtained through design expert 11.0 revealed depoding capacity of 15.36 kg h^{-1}, 97.43% depoding efficiency, 2.63% damage percentage, 0.06 Man-h kg^{-1}, labour requirement and 2.57% un-pod percentage. The cost of fabrication of pea depoding machine was ₹10,965 with 47 kg weight. The benefit-cost ratio, break-even point and payback period were calculated as 1.38, 1465 kg and 354.2 hours, respectively. The study can be instrumental for entrepreneurship and income augmentation of small and marginal farmers as well as rural youth.

Key words: Cost economics, depoding, efficiency, entrepreneurship, pea, plastic rollers

Green pea emerges from *Pisum Sativum* plant that falls in the family *Fabaceae*. Globally, pea production surpassed 19.87 million metric tons with China leading from the front (Anonymous, 2022). Along with China, India, USA, France and Egypt are also leading producers of green pea. In Indian context, green pea is cultivated over an area of 590 thousand hectares, generating 6130 thousand metric tons (Agricultural Statistics at a Glance 2022). The state of Uttar Pradesh accounts for 43.36% of green pea production at national level. The union territory of Jammu and Kashmir with an area of 5.09 thousand hectare has the distinction of generating annual production of 30.82 thousand metric tonnes (Indiastat, 2022). There has been a sharp increase in pea production in the past year (Horticulture Statistics at a glance, 2018).

Green peas are essential to fulfill the dietary requirement of households. About 170 g of green peas can provide 62 calories of energy, 11 g carbohydrates, 4 g fibre, 4 g proteins, 34% vitamin A, 24% vitamin K, 13%

vitamin C, 15% thiamine, 12% folate, 11% manganese, 7% iron and 6% phosphorus. Beyond that, green peas are essential to treat chronic diseases such as heart disease, cancer and diabetes.

The depoding of green peas is usually carried out manually. The manual procedure of extracting pea seeds from pods is laborious, tiresome and full of drudgery. According to Sharma and Singh (1989), one person can depod about 3-3.5 kg of green peas in one hour. Hence, there is a need for mechanization. This will not only save time and manpower, but can contribute significantly to value addition. The socio-economic developments in the society have increased the demand of shelled and frozen peas tremendously. Depod peas can be packed and stored for a longer period of time. The machine can be useful for small farmers and help them generate more income. Waghmode *et al.* (2020) developed power operated pea sheller machine with shelling percentage of 95.8% for blanched peas and 90% for unblanched peas. Selvan and Mani (2019) utilized power-operated continuous feeding and vibrating mechanism to shell peas. Kaur (2006) used two wire mesh and punched GI sheet sieve for depoding of peas. However, the efficiency was restricted within 69.5 percent. Khobragade *et al.* (2018) obtained a shelling efficiency of 61.01% at roller speed of 1650 rpm. Sonboier *et al.* (2018) conceptualized motor operated machine with adjustable rollers and vibrator tray system.

It is widely believed that the design of agricultural machinery requires physical characteristics and engineering parameters of the crop to enhance the working efficiency and efficacy (Mohiuddin *et al.*, 2022). This methodology has been applied in multiple domains of agricultural process machinery like Chilli seed extractor (Mohiuddin *et al*., 2022), willow wicker (Masroor *et al*., 2023), walnut kernel and shell separator (Zarka *et al*., 2023) and maize sheller (Magray *et al.,* 2023). The main thrust lies in the measurement of the physical parameters like length, width, thickness and engineering properties like bulk density, angle of repose, porosity, true density to design the individual working components of agricultural process machinery. In this study, it was envisaged to utilize a similar methological procedure to design and develop pea depoding machine. The main intention was to address the issues of small and marginal farmers with respect to mechanical intervention in green pea depoding process.

MATERIALS AND METHODS

Procurement of pea: The local pea variety was procured from local market of Srinagar city to measure the engineering characteristics relevant to the design of pea depoding machine.

Physical dimensions: Samples of 100 green peas were selected randomly and their principal dimensions in terms of length (L), width (W) and thickness (T) were measured using a digital vernier caliper, Fig. 1.

Fig.1: Measurement of physical dimensions and moisture content of pea

Sphericity: Sphericity serves as the representative of the shape of pea particles. The arithmetic mean and geometric mean of pea was measured by standard formula's. The sphericity (ϕ) was measured by the ratio of geometric mean to length (Mohsenin, 1970).

$$\text{Arithmatic mean}, D_a = \frac{(L+W+T)}{3} \text{ ----------------------------- (1)}$$

$$\text{Geometic mean}, Dg = \sqrt[3]{(LWT)}$$

$$\Phi = \frac{(Geometric\ mean)^{\frac{1}{3}}}{length} \times 100 = \left[\frac{\sqrt[3]{LWT}}{L}\right] \times 100 \text{ --------------- (2)}$$

Moisture content: The moisture content of the pea variety was measured by gravimetric method. The sample was placed in an oven operated at 105 °C for 24 hours (Pandey *et al*., 2019) to measure the moisture content after 24 hours, 48 hours and 72 hours of storage. The results were compared with infrared moisture analyzer (Toshiba and Co.) for validity of the results.

Bulk density: Bulk density of pea was determined by filling a cylindrical container of known volume (500 ml) with green peas, from a height of 150 mm at constant rate, striking off the top level and then weighing the contents using an electronic digital balance with an accuracy of ±0.001g (Mohiuddin *et al*., 2022).

True density: True density was determined using toluene displacement method. Toluene (C_7H_8) was used in place of water as it is absorbed by peas to a lesser extent.

Porosity: The porosity represents the pore/void space in between the particles.

$$\text{Porosity}, \% = 1 - \left(\frac{\text{Bulk density}}{\text{True density}}\right) \text{x } 100 \text{ -------------------------- (3)}$$

Angle of repose: For measurement of angle of repose, the peas were made to flow from a height of 150 mm to assume a natural slope (Mohiuddin *et al*., 2022). The angle of repose (θ) was calculated from the measurements of the height (H) and diameter (D) of the slope using the following relationship:

$$\theta = tan^{-1}\left(\frac{2H}{D}\right) \text{ -- (4)}$$

Development of Pea depoding machine: The individual working components of pea depoding machine were sketched with the help of Solid Edge, Fig. 2. It consists of frame, transmission system, conveying tray, rollers and conveying tray.

Fig. 2: 3-D view of pea depoding machine

Performance evaluation: The developed prototype of pea depoding machine was tested to assess its technical feasibility and economic viability, Table 1.

Table 1: Assessment of technical feasibility and economic viability of pea depoding machine

Technical feasibility			Economic viability
Parameter	**Levels**	**Response**	
Speed	3 (150 rpm, 200 rpm and 250 rpm)	❖ Depoding capacity, kg h^{-1} ❖ Depoding efficiency	• Operating cost, Rs h^{-1} • Benefit cost ratio • Payback period
Moisture content	3 (60-65 %, 70-75% and 80-85%)	❖ Damage percentage ❖ Labour requirement, Man h kg^{-1} ❖ Un-depod percentage	

Dependent parameters: The experiments were planned in completely randomised block design, having two factors of three levels each with three replications. A total of 27 experiments were conducted.

a) **Depoding capacity:** The capacity of the machine was determined by using the following formula (Shaik *et al*., 2016; Sonboier *et al*., 2018):

$$\text{Capacity}\left(\frac{\text{kg}}{\text{h}}\right) = \frac{\text{weight of pods (kg)}}{\text{time of operation (h)}} \quad ------- (5)$$

b) **Depoding efficiency:** After operation of the machine, the shelled, unshelled and damaged peas collected in collecting trays were weighed for the determination of depoding efficiency (Singh, 2003 and Kamboj *et al*., 2012):

$$\text{Depoding efficiency}(\%) = \left[1 - \frac{\text{mass of unshelled pod}}{\text{total mass of pods}}\right] \times 100 \quad ------- (6)$$

c) **Damage percentage:** From the sample of shelled peas, whole seeds and broken seeds were separated and weighed individually. The damage was computed according to relation used by (Gore *et al.*, 1990).

$$\text{Damage}(\%) = \frac{\text{mass of damaged sample}}{\text{total mass of sample}} \times 100 \quad --------- (7)$$

d) **Labour requirement:** The man hours required to shell one kg of pea was calculated from depoding capacity of the machine (Mohiuddin *et al*., 2022).

$$\text{Labour requirement}\left(\frac{\text{Man}-\text{h}}{\text{kg}}\right) = \frac{1}{\text{capacity (kg/h)}} \quad ------- (8)$$

e) **Un-depod percentage:** Un-depod percentage was determined by the procedure used by (Gore *et al.*, 1990):

$$\text{Un}-\text{depod}(\%) = \frac{\text{mass of un}-\text{depod sample}}{\text{total mass of sample}} \times 100 \quad -------- (9)$$

RESULTS AND DISCUSSION

Engineering properties of pea

Moisture content: The moisture content was measured after 24 hours, 48 hours and 72 hours of storage. It was observed that moisture content varied as 80-85%, 70-75% and 60-65%, respectively.

Bulk density: The bulk density of pea pods varied from 556.0 kg m^{-3} to 589.4 kg m^{-3} with mean value of 567.0 kg m^{-3}, Table 2. It implies that 0.0017 m^3 was required to handle one kilogram of pea pods. It was used to decide the capacity of pea depoding machine.

True density: The true density varied from 977.84 kg m^{-3} to 992.31 kg m^{-3} with average value of 986.0 kgm^{-3}, Table 2.

Porosity: The porosity served as the reflection of bulk density and true density. It changed from 40.19% to 43.88% with mean value of 42.49% respectively.

Table 2: Engineering parameters relevant to the design of pea depoding machine

Pea variety	Bulk density, kg m^{-3}	True density, kg m^{-3}	Porosity, %
Local pea variety	567.2	992.31	42.84
	562.8	983.36	42.76
	556.0	990.91	43.88
	589.4	985.60	40.19
	559.6	977.84	42.77
Mean	**567.0**	**986.00**	**42.49**

Angle of repose: The angle of repose for pea with 80-85 % moisture content ranged from 30.05 to 30.20 degrees, which was comparatively higher than angle of repose at 70-75% moisture content and 60-65% moisture content, Table 3. The angle of repose was used to select the angle of inclination of feeding hopper of pea depoding machine.

Table 3: Angle of repose of green pea at different moisture content

Type	Height of slope (H)	Diameter of slope (D)	Angle of repose
Pea (80-85%)	4.6	15.9	30.05
	4.2	14.5	30.08
	3.9	13.4	30.20
Pea (70-75%)	4.2	17.4	25.77
	4.0	16.6	25.73
	4.3	17.8	25.78
Pea (60-65%)	3.8	17.3	23.74
	4.0	18.2	23.73
	3.9	17.7	23.78

Physical dimensions: The physical characteristics were measured in terms length, width and thickness. The pea particles were segregated on the basis of size to select the clearance between the rollers. The results highlighted the mean value of length, width and thickness as 9.13 mm, 8.23 mm and 7.41 mm, Table 4. The physical dimensions were used to finalize the clearance between rollers.

Pea depoding machine: The pea depoding machine comprised of frame, transmission system, conveying tray, plastic rollers and conveying tray (Kamboj *et al*., 2012). It works on the principle of passing the pea through the clearance between two rollers operating in opposite direction. The frame was made of angle iron, having overall dimensions of 25 x 25 x 5 mm**.** The frame was designed to support the weight of the various components and provide strength to the system. The base of the frame had 609.6 mm length and 470 mm breadth. Three angle iron pieces, each of length 559 mm are welded at a height of 280 mm from the bottom of the frame to provide the base for motor. Thus, the shape of the frame is cuboidal, having overall dimensions of 609.6 x 470 x 915 mm. The transmission system was designed in order to obtain the appropriate rpm of rollers. A 63.5 mm diameter pulley was fixed on the motor (1440 rpm) and was connected to the pulley of 203.2 mm diameter, on the main shaft through a 1524 mm length v-belt. Two spur gears (3:2 ratio) were fixed on two roller shafts which get power from the motor pulley. The depoding unit consists of two rollers, which are grooved along the length. The clearance between the rollers is adjusted in order to accommodate peas of varying sizes. The rollers of 63.5 mm diameter and 330.2 mm length are supported on two cylindrical shafts that provide rotation to the rollers. The shafts are supported by bearings fixed to the frame with the help of nut and bolt. A conveying tray of galvanized iron sheet is used to transport material to the roller mechanism. The conveying tray is corrugated to facilitate proper conveyance of peas. The GI sheet of 26 gauge was used. The tray has dimensions of 508 x 330.2 mm and side walls of 101.6 mm height are provided in order to prevent feed from falling off the sides. Two collecting trays are used, one for the green pea seeds and others for the removed shell. Their purpose is to receive and temporarily store the product. These are made from GI sheet of 26 gauge. Two collecting trays made from 26 gauge were used. The dimensions of seed collecting tray are 432x 254 mm with 101.6 mm high side walls to facilitate removal of shells from one side. The weight of the machine was recorded as 47 kg with the help of weighing machine.

Table 4: Physical characteristics of pea variety relevant to the design of pea depoding machine

Type	Length, mm	Breadth, mm	Thickness, mm	Arithmetic mean, D_a	Geometric mean, D_g	Sphericity, ϕ
Large	11.96	9.55	7.86	9.79	9.65	80.66
	10.66	10.00	9.45	10.03	10.02	94.04
	10.84	9.14	8.00	9.32	9.25	85.37
	10.12	9.05	8.08	9.08	9.05	89.38
	10.77	8.72	8.63	9.37	9.32	86.57
	11.32	10.45	8.72	10.16	10.10	89.26
	10.15	8.96	6.82	8.65	8.53	84.02
	9.93	8.62	7.77	8.77	8.73	87.90
	9.81	8.61	7.68	8.70	8.66	88.24
Mean	**10.61**	**9.23**	**8.11**	**9.31**	**9.26**	**87.27**
Medium	9.45	8.24	7.08	8.25	8.20	86.77
	9.11	8.22	8.14	8.49	8.48	93.07
	9.04	7.40	7.25	7.89	7.86	86.91
	9.38	8.88	7.19	8.48	8.43	89.86
	9.03	8.09	7.93	8.35	8.34	92.32
	9.75	9.33	9.00	9.36	9.35	95.95
	9.42	8.87	8.62	8.97	8.96	95.16
	9.27	9.04	7.29	8.52	8.49	91.53
	9.14	8.90	8.22	8.75	8.74	95.67
Mean	**9.28**	**8.55**	**7.85**	**8.56**	**8.54**	**91.91**
Small	8.52	7.80	7.62	7.98	7.97	93.55
	8.56	7.23	6.86	7.55	7.52	87.80
	7.11	6.59	5.33	6.34	6.30	88.57
	6.7	5.97	5.71	6.12	6.11	91.23
	7.40	7.12	6.97	7.16	7.16	96.77
	7.21	6.87	6.60	6.89	6.89	95.55
	5.28	4.80	4.06	4.71	4.69	88.75
	8.22	7.67	7.21	7.70	7.69	93.54
	8.59	8.18	6.00	7.59	7.50	87.29
Mean	**7.51**	**6.91**	**6.26**	**6.89**	**6.87**	**91.45**

Effect of speed and moisture content on depoding capacity: The depoding capacity increased with the increase in speed and reduced with an increase in moisture content, Fig. 3. The maximum value of depoding capacity of 16.07 kg h^{-1} was observed at 60-65% moisture content and 250 rpm speed. The lowest depoding capacity was observed at 150 rpm and 80-85% moisture content. The reason can be attributed to the fact that higher moisture content results in slippage between pea pods and rollers, thereby, increasing the time of travel from feeding hopper to collecting tray. The statistical analysis through ANOVA highlighted that both the moisture content and speed were significantly influencing the depoding capacity at 5% level of significance.

Variation in depoding efficiency with independent parameters: The maximum depoding efficiency of 97.43% was recorded at 250 rpm with pea pods moisture content at 60-65%. The minimum depoding efficiency (91.76%) occurred at 150 rpm and 80-85% moisture content, Fig. 3. Statistically, the rotational speed and moisture content were significantly influencing the depoding efficiency at 5% level of significance. However, the interactive effect of moisture content and rotational speed were found to be non-significant at 5% level of significance. The results were in line with the observations recorded by Sharma and Singh (1989).

Effect of speed and moisture content on damage percentage: The experimentation revealed that damage occurred due to high moisture content of pea pods. The data highlighted that damage percentage increased with an increase in moisture content and rotational speed. The lowest damage percentage of 1.87% was recorded at a speed of 150 rpm and 60-65% moisture content, Fig. 4. The maximum damage of 6.46% occurred at rotational speed of 250 rpm 80-85% moisture content. According to Gore *et al.*, 1990, the damage might have resulted due to soft nature of pea pods, low clearance and high centrifugal force of rotating rollers.

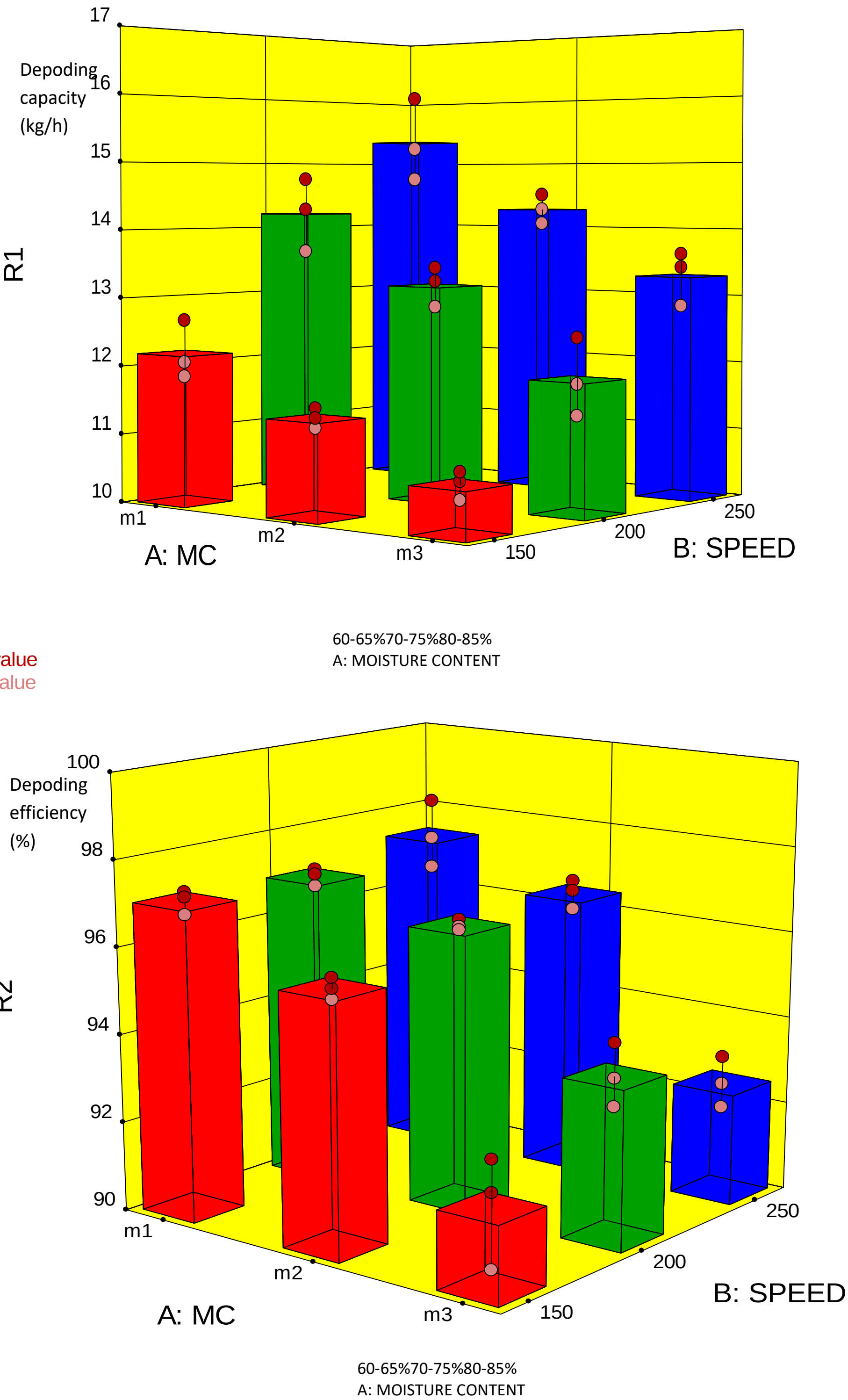

Fig. 3: Variation in depoding capacity and depoding efficiency

Effect of speed and moisture content on labour requirement: As the labour requirement is inversely proportional to the depoding capacity, it decreases with an increase in rotational speed. The labour requirement of 0.065 Man-hours per kilogram was recorded at 250 rpm with pea pods at 60-65% moisture content, Fig. 4. The highest labour requirement of 0.093 Man-hours per kilogram occurred at 150 rpm and 80-85% moisture content. The moisture content and rotational speed were significantly influencing labour requirement at 5% level of significance.

Influence of speed and moisture content on un-depod percentage: Un-depod percentage occurred due to slippage between pea pods and rollers and falls in the category of loss. The low speed of 150 rpm and high moisture content (80-85%) created a situation at which pea pods were unable to pass through the clearance between rotating rollers, thereby, contributing to un-depod percentage to the tune of 8.24 percent, Fig. 5. The moisture content and rotational speed were significantly influencing labour requirement at 5% level of significance.

Cost economics: The cost parameters of pea depoding machine were calculated on the basis of market rate and assumptions, Table 5. The cost of pea depoding machine was calculated with the help of bill of materials.

The manufacturing cost of pea depoding machine was recorded as Rs. 10,965 with operational cost of Rs. 5 per kg.

The benefit-cost ratio was observed as 1.38, breakeven point 1465 kg and 354.2 hours payback period

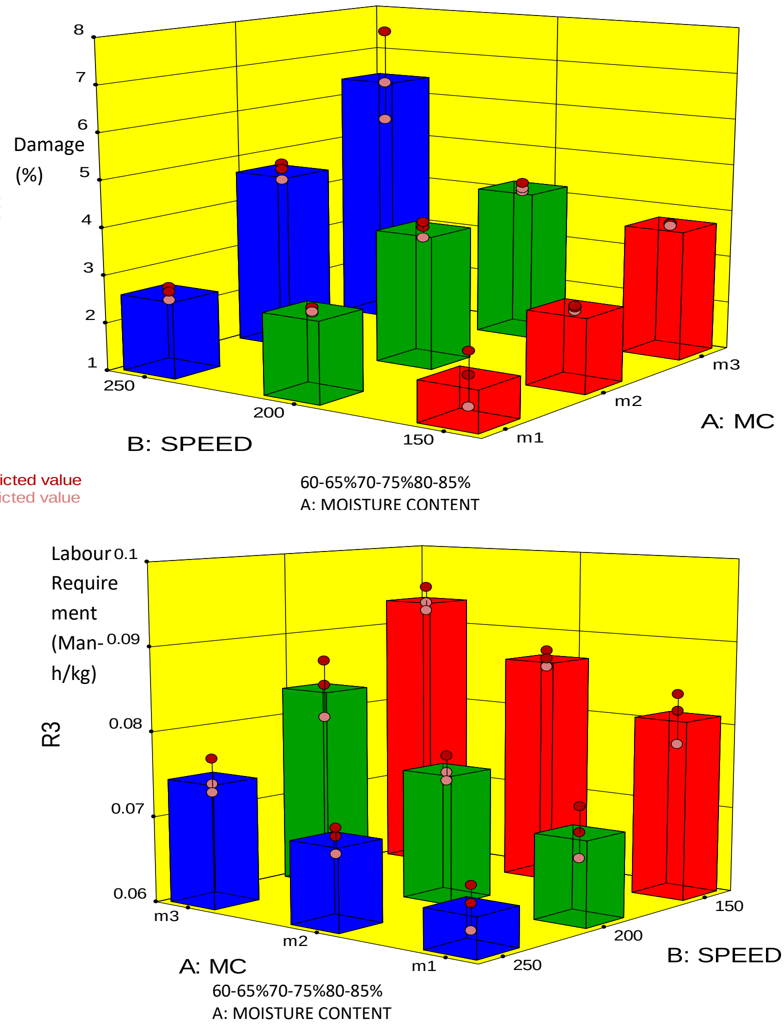

Fig.4: Change in damage percentage and labour requirement

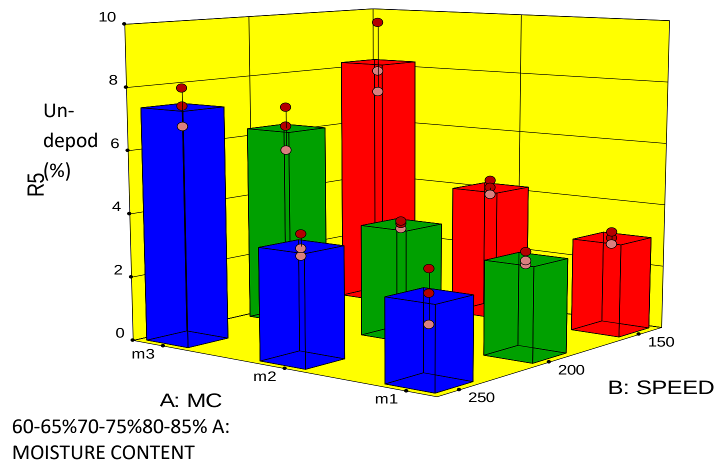

Fig.5: Variation in un-depod percentage with independent parameters

Table 5: Quantity of material and cost parameters of pea depoding machine

	Components	Material	Quantity	Price (₹)
Quantity of materials	Frame	Angle iron MS	10 kg	880
	Pulleys	Cast Iron	2	650
	Spur gears	Cast Iron	2	1500
	V-Belt	Canvas	1	300
	Brackets	Flat iron (MS)	4	30
	Bearings	Cast Iron	4	1000
	Nuts and Bolts	MS	12	30
	Rollers	Silicone	2	1700
	Shafts	MS	4.5 Kg	405
	Motor	-	1	3000
	Collecting tray	GI	2	275
	Conveying tray	GI	1	200
	Fabrication Charges	15% of material cost		995
		Total Cost		**10,965**
Cost economics	Operating cost, Rs. h^{-1}		81.2	
	Cost of depoding, Rs. kg^{-1}		5.0	
	Benefit-Cost Ratio		1.38	
	Break-Even Point, kg		1465	
	Payback Period, hours		354.2	

Optimization of working parameters: The optimization with the help of Numerical optimization technique (Design Expert Software version 10.0.1, Stat-Ease Inc., Minneapolis, USA) revealed the depoding capacity of 15.36 kg h^{-1}, depoding efficiency 97.43%, 2.63% damage percentage, 0.06 Man-hours per kg labour requirement and 2.57% un-depod percentage at rotational speed of 250 rpm and 60-65% moisture content. The desirability was calculated as 0.87, Table 6.

Table 6: Optimization of parameters of pea depoding machine

Parameters	Goal	Lower Limit	Optimum values
Depoding Capacity (kg/h)	Maximize	10.46	15.36
Depoding Efficiency (%)	Maximize	90.4	97.43
Damage (%)	Minimize	1.28	2.63
Labour requirement (Man-h/kg)	Minimize	0.06	0.06
Un-depod (%)	Minimize	1.72	2.57
Desirability			**0.87**

CONCLUSION

A pea depoding machine consisting of frame, transmission system, conveying tray, rollers and conveying tray was designed and developed. The optimization of parameters revealed that operating the machine at 250 rpm and maintaining pea pods moisture content at 60-65% resulted in depoding capacity of 15.36 kg h^{-1}, depoding capacity 97.43%, 2.63% damage percentage, 0.06 Man-hours per kg labour requirement and 2.57% un-depod percentage. The cost of pea depoding machine was calculated as Rs. 10, 965 with operational cost of Rs. 5 per kilogram with net weight of 47 kg. The benefit-cost ratio was observed as 1.38, breakeven point 1465 kilogram and 354.2 hours payback period. The pea depoding machine can serve the needs of small and marginal farmers.

ACKNOWLEDGMENT

The authors would sincerely like to acknowledge the help provided by the faculty and technical staff of College of Agricultural Engineering and Technology, SKUAST-K for fabrication and evaluation of pea depoding machine.

REFERENCES

Anonymous,2022. Global Production of Vegetables in 2020, by type. *(https://www.statista.com/statistics/264065/global-production-of-vegetables-by-type/)*

Gore, K. L., Gupta, C. P. and Singh, G. 1990. Development of power-operated groundnut sheller. *Agricultural Mechanization in Asia, Africa and Latin America (Japan)*, **21**: 38-44.

Horticultural Statistics at a Glance, 2018. Horticulture Statistics Division, Department of Agriculture, Cooperation & Farmers' Welfare, Ministry Of Agriculture & Farmers' Welfare.

Indiastat 2023. Online databases. *(https://www.indiastat.com/table/jammu-and-kashmirstate/agriculture/selected-state-wise-area-production-productivity-p/1442086).*

Kamboj, P., Singh, A., Kumar, M. and Din, S.. 2012. Design and development of small-scale pea depoding machine by using CAD software. *Agric Eng Int: CIGR Journal,* **14**: 40-48.

Kaur, S. 2006. Development of Pea Depoding Machine. B. Tech. project report, Punjab Agricultural University, Ludhiana India.

Khobragade, H. M., Borkar, P.A. and Dhote, M. K. 2018. Performance evaluation of mini green pea pod shelling machine. *PKV Res. J.*, **42**: 103-110.

Kumar, A., Muzamil, M. and Dixit, J. 2023. Smart vermicomposting bin for rapid transformation of Dal lake aquatic weed into fortified vermicompost. *International Journal of recycling of organic waste in agriculture*, **12**: 221-233. *(https://doi.org/10.30486/ijrowa.2022.1955835.1445)*

Magray, M. A., Fayaz, A., Muzamil, M., Rasool, S., Nath, S., Banday, R.Z. and Faisal, S. 2023. Development and performance evaluation of low-cost cylinder type maize sheller for small farmers of Jammu and Kashmir. *SKUAST Journal of Research*, **25**: 22-33. (*10.5958/2349-297X.2023.00003.X*)

Malik, M. A., Faisal, S., Muzamil, M., Langoo, B. A., Shukla, R. M., Monica, R., Bhagyashree, D. and Hussain, S. Z. 2023. A low-cost portable willow wicker peeling machine: An innovative mechanical intervention in the wickercraft industry of Kashmir. *Journal of Institution of Engineering (India): Series A,* **104**: 271-280. doi:10.1007/s40030-023-00726-9

Mohiuddin, M., Muzamil, M., Dixit, J., Faisal, S. and Khan, I. 2022. Engineering properties of Chilli fruit relevant to the design and evaluation of Chilli seed extractor for hilly region of Kashmir valley. *Journal of Institution of Engineering (India): Series A,* ***103****: 433-443.* (*doi.org/10.1007/s40030-022-00617-5)*

Mohsenin N. N. 1970. Physical properties of plant and animal materials. New York: Gordon and Breach Science Publishers, 51-87.

Pandey, O. M., Mishra, B. K. and Misra, A. 2019. Comparative study of green peas using with blanching and without blanching techniques. *Information Processing in Agriculture***, 6**: 285-296.

Pocket Book of Agricultural Statistics, 2020. Government of India, Ministry of Agriculture & Farmers Welfare, Department of Agriculture, Cooperation & Farmers Welfare Directorate of Economics & Statistics, New Delhi

Rashid, Z., Faisal, S., Muzamil, M., Dixit, J., Shukla, R. M. and Khan, I. 2023. Development of an innovative universal walnut cracking and separating machine for farmers and walnut industry of Kashmir Valley. *Journal of Institution of Engineering (India): Series A,* **104**: 271-280. (*https://doi.org/10.1007/s40030-023-00726-9*)

Selvan, M. M. and Mani, I. 2019. Development of power operated continuous feed green pea sheller. Indian *Journal of Agricultural Sciences*, **90**: 396-400.

Shaik, N. H., Rao, D. B., Bhagath, B. B. and Vardhan, S. V. 2016. Design and Development of Multi Seated Aonla Deseeding Machine. *Advances in Life Sciences*, **5**: 8749-8753.

Sharma, S. K. and Singh, S. K. 1989. Design, development and testing of pea shelling machine. *Annual Report of AICRP on Post-Harvest Technology, Jabalpur Centre*.

Sonboier, K. K., Mahilang, K. K. S., Minj, P., Porte, P. and Taran, T. 2018. Some physical properties of green pea. *Int. J. Pure App. Biosci*, **6**, 573-579.

Waghmode, A. S., Ghadge, A. S., Ghule, A. B., Fatale, V., Kolekar, A. and Sawashe, S. 2020. Development of power operated pea sheller. *International Journal of Current Microbiology and Applied Sciences*, **9**: 2691-2698.