

Design and Evaluation of Rice Straw Bag Filling Machine for Oyster Mushroom (*Pleurotus Florida*) Cultivation

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Oyster mushroom (*Pleurotus florida*) is a simple, fast, and cost-effective variety for cultivation, requiring minimal substrate preparation time and production technology when compared to other edible mushrooms. Its popularity has soared due to its exceptional culinary taste and flavor, surpassing even the well-known button mushroom (*Agaricus bisporus*). As a result, it has become highly recognized and preferred over button mushrooms in India. However, the current manual bag filling process of wet chopped rice straw substrate for *Pleurotus florida* cultivation is laborious and time-consuming, with limited bagging capacity. To address this challenge, a rice straw bag filling machine was designed and developed specifically for oyster mushroom cultivation. This machine comprises a main frame, truncated conical hopper, agitator, single flight tapered end screw conveyor, tubular trough, cylindrical drum, chain and sprocket drive mechanism, and an electric motor. The successful evaluation of this machine revealed that, the maximum bagging capacity of 293 bags/h was found at screw speed of 150 rpm and 200 mm pitch length for rice straw substrate.

Keywords: Agitator, Bagging capacity, Oyster mushroom, Pitch length, Screw conveyor

Introduction

Mushroom cultivation is an innovative practice in the current scenario. Due to its high nutritional value and medicinal properties, it is regarded as a significant horticultural crop. Nowadays mushrooms are considered as potential contributors to the world's food supply. They have the ability to transform nutritionally-useless wastes into rich protein food. The top mushroom-producing countries worldwide include China, USA, Netherlands, Poland, and Spain. Among them, China emerges as the dominant supplier in the global market, contributing to over 60% of the world's total mushroom production.¹ *Pleurotus* species, well known as oyster mushrooms are cultivated worldwide especially in South East Asia, India, Europe and Africa. Indeed, in India, button mushrooms hold a significant position as they are extensively cultivated. Following button mushrooms, oyster mushrooms also have a considerable presence in the country's cultivation practices. Absolutely, in

recent times, oyster mushrooms (*Pleurotus florida*) have gained tremendous popularity in India, mainly due to their outstanding culinary taste and flavor. Their delectable attributes have made them a favorite choice among consumers and culinary enthusiasts alike.

Oyster mushroom (*Pleurotus florida*) is grown well at the temperature range of 18–28°C and relative humidity of 55–70%. It is exhibited remarkable versatility in their cultivation substrates. They can be cultivated on a wide range of materials, including pasteurized rice straw, instant coffee pulp, cotton seed hulls, cassava peels, cormcobs, crushed bagasse, water hyacinth, water lily, beans, wheat straw, oil-palm fiber, as well as paper and cardboard. This adaptability to various substrates contributes to their popularity as they can be grown using a diverse range of organic materials, making them a sustainable choice for mushroom cultivation.^{2,3}

Rice (*Oryzae sativa*) is the commercial crops in Asian countries, which contributes 90.10% of total world's production and 1/5th of the total production in India. It is reported that, in India, the total rice straw

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production is 160 Million Ton from an area of 43.95 Million hectare. However, according to 2018–19 estimates in Karnataka and Andhra Pradesh the production of rice was 2665.7 Metric Ton and 5068.7 Metric Ton with a straw production of 3998.55 Metric Ton and 7603.05 Metric Ton respectively.⁴ Usually, rice straw is disposed by burning, but such practice was under criticism because of air pollution, respiratory problems and also danger of soil erosion due to repeated burning.⁵ In India alone every year about 70–80 Million Ton of straw is disposed-off by burning in the farmers field itself.⁶ Instead, it could also be used as an animal feed, making manure, fuel in biomass power plants, brick kilns, cardboard makings etc. In the recent days, it will use as an ideal choice for cultivation of oyster mushroom by naturally recycling the organic wastes into profitable and protein rich mushrooms.⁷ Hence, rice straw is considered as one of the most preferable substrate for oyster mushroom cultivation. In Karnataka and Andhra Pradesh, rice is majorly grown crop and some portion of the excess rice straw rather than burning in the field, it is utilized for mushroom cultivation because of its copious availability, highest biological yield and economic yield of mushroom.⁸ Furthermore, rice straw powder and sawdust were also used as a major substrate for oyster mushroom cultivation because of its copious availability in this region.

In the process of oyster (*Pleurotus florida*) mushroom cultivation, the chopped rice straw (obtained by sickle/straw chopper) is weighed and soaked in a circular container filled with tap water with a ratio of 1:7. The straw is allowed to soak for 3 h to achieve sufficient moisture (65%).^{2,3} The soaked straw is being removed from the water, spread on the surface of a clean rectangular mesh table under open sun condition and it is allowed for removing excess water to drain and also to reach optimum moisture content of about approximately 65%. The partially dried wet chopped straw is filled into a 1 kg polypropylene bag with dimensions of 300 mm (width) × 420 mm (height) and a thickness of 220 gauge. Coming to filling of rice straw powder and sawdust for growing oyster mushroom, typically substrates mixed with tap water at a ratio of 1:2.5 and 1:1.5 in a segregate container and allowed to reach 65% moisture content (w.b.). The prepared substrates are filled into 1 kg polypropylene bags (220 gauge) having dimensions of 250 × 410 mm for rice straw powder and 200 × 405 mm for sawdust. In the process of bag filling of all the three substrates into 1 kg

polypropylene bag were commonly done by manually. It is very laborious and tedious process and reduced bagging capacity. To overcome of these issues, there is a huge demand from the farmers especially in the rural area for rice straw bag filling machine, which can act as a versatile machine for bag filling of all the three substrates. There are no machines available in the market to perform bag filling operations of these substrates within a single machine so far. To meet this demand by the farmers, an attempt was made and developed rice straw bag filling machine with an objective of design and develop rice straw bag filling machine and evaluated the performance of the machine in terms of its bagging capacity. The machine initially developed only for bag filling of wet chopped rice straw substrate. Later, planned and decided to make it more versatile by utilizing it for wet powder form substrates like rice straw powder and sawdust will increase its usefulness and efficiency. This enhancement will enable the machine to cater to a broader range of substrates, providing flexibility in mushroom cultivation and contributing to the sustainable use of various agricultural by-products. With this versatility, farmers will have more options and opportunities to produce oyster mushrooms and make the cultivation process even more efficient and cost-effective.

Materials and Methods

The machine was designed and fabricated at the Division of Post-Harvest Technology and Agricultural Engineering, ICAR-Indian Institute of Horticultural Research, located in Bengaluru, Karnataka. The performance evaluation of this machine took place in the Mushroom Research Laboratory, where its capabilities and efficiency were thoroughly tested and analysed.

Determination of Engineering Properties of the Rice Straw Substrate

Before start design and development of the machine the determination of Engineering Properties of the rice straw substrate (viz., bulk density and coefficient of static friction) are very much important because they affects the design of the machine.

In the experiment, the average chop length of 2.5 cm of rice straw was considered for oyster mushroom cultivation.⁹ The moisture content of rice straw used in the study was 65%.^{2,3}

Bulk density is an important parameter used for the estimation of pressure exerted by biomass or granular biomass against the structure of the hopper or silo. It

is also necessary for accurate estimation of container capacity.¹⁰ The bulk density of the wet chopped rice straw was found by using a square box having volume of 0.1953 m³. The container was weighed empty to find its mass and then it was filled with the samples and weighed again. The bulk density was determined by dividing the mass of the material to the volume of the container. The bulk density was computed by using the below formula.¹¹

$$\rho_b = \frac{\text{Weight of samples, kg}}{\text{Volume of the container, m}^3} \quad \dots (1)$$

The coefficient of static friction is a critical factor in determining the angle at which the hopper must be positioned to achieve consistent and smooth flow of biomass or granular materials through the hopper/chute with reduced friction.¹² The mild steel surface material was utilized for finding coefficient of static friction of the substrate. The procedure followed is given below. The rice straw substrate was filled into a hollow square box having dimensions of 50 × 50 × 50 mm. The substrates were put in a position parallel to the direction of motion and the table was raised gently by a screw device, the angle at which the samples begin to slide (the angle of inclination) was read from a graduated scale on a tilting plate, this was repeated for three times. The coefficient of static friction (μ) was computed as the tangent of the angle as per Eq. 2.⁽¹³⁾

$$\mu = \tan \alpha \quad \dots (2)$$

where, α is the tilting surface angle

Design and Development of Rice Straw Bag Filling Machine Design Criteria

Based on the measurement of engineering properties of wet chopped rice straw, the design criteria for the electric motor-operated rice straw bag filling machine are established to meet the following demands. The machine should:

- i) Have at least bagging capacity within the range of 200–300 bags/h more than manual bag filling operation of 90 bags/h.
- ii) Design should be simple and user friendly.
- iii) The total cost of machine should be less so that individuals can afford it.
- iv) It should be versatile in nature (i.e used for bag filling of straw as well as powder form substrates also) and it should be operated by unskilled labor also.

Fabrication of Electric Motor Operated Rice Straw Bag Filling Machine

The isometric view including front view, top view and side view of the machine designed by using solid work software 2014 version as shown in Fig. 1 (dimensions in mm).

The developed machine includes various parts like main frame, truncated conical hopper, horizontal agitator, single flight tapered end screw, tubular trough, power source power transmission system, vertical agitator (consists of two wings on the inverted cone) and cylindrical drum ahead of tubular trough (used for bag filling rice straw powder and sawdust substrates). The total weight of the machine was 130 kg. The various components of the machine and their details are given below.

Main Frame

For supporting truncated conical hopper, screw conveyer assembly, cylindrical drum assembly and power transmission unit, a rectangular frame was made of 40 mm × 40 mm × 5 mm MS angle. Correspondingly, the length, width and height of the frame were 900 × 640 × 1110 mm respectively. The four MS angle of similar size legs was welded to the frame to make it a rigid frame and at the bottom of the frame electric motor (2 hp) was provided for power transmission.

Selection of Power Source and Drive System

In this study, the electric motor was opted as power source for driving the machine because of its low cost, low maintenance, and high efficiency. The machine design was done based on the evidence from literatures that pitch length and screw conveyer speed affects the machine performance directly. Srivastava *et al.* (2006) reported that, pitch length is not less than 0.9 and not more than 1.5 times the screw outside diameter and also the output capacity increased directly as the screw speed increased upto 250 rpm, but, beyond this speed, capacity declined due to the act of centrifugal force.¹⁴ In this connection, initially, the single flight tapered end screw speed of 200 rpm was selected for trial run, but at that speed choking of substrate at the bottom of hopper (intake) found due to mat like structure of straw was created in between the agitator and screw conveyer because horizontal agitator was operated at low speed (30 rpm) but screw run at higher speed, so centrifugal force cause to avoid the free flow of straw towards the screw flight. At 150 rpm speed and 30 rpm agitator speed found

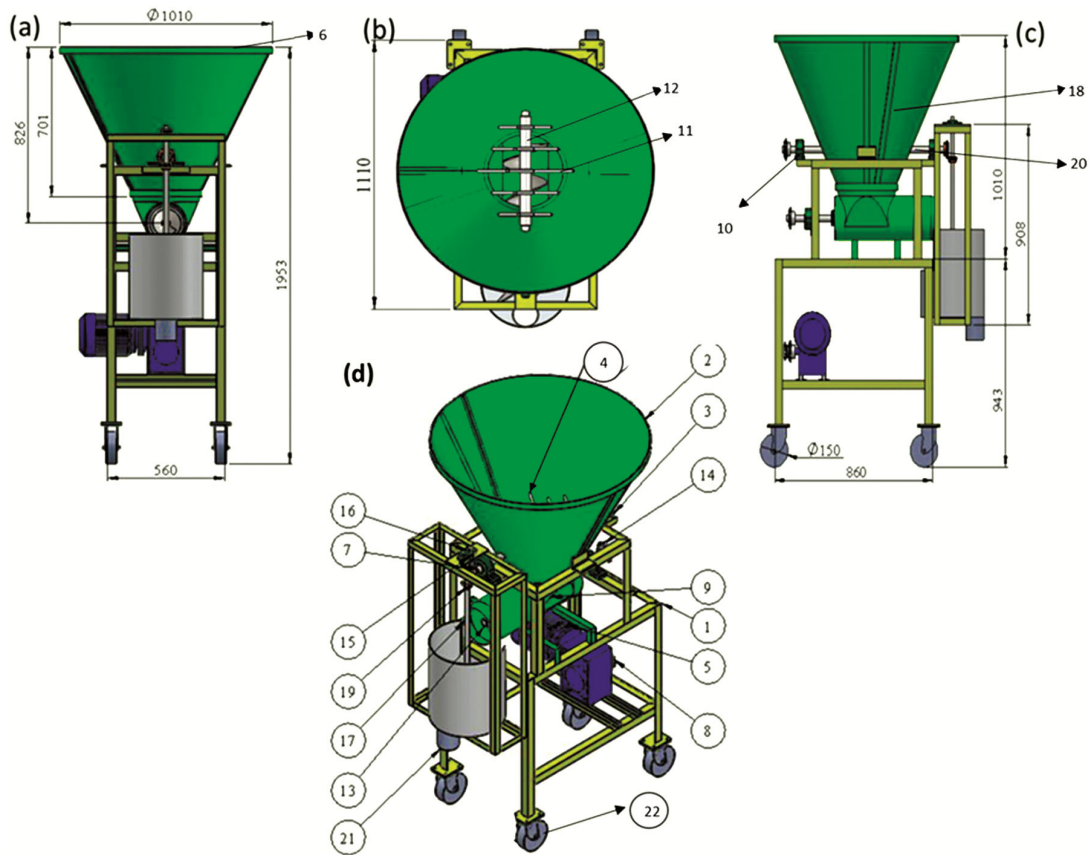


Fig. 1 — Isometric view including front view, top view and right side view of rice straw filling machine: (a) front view (b) top view (c) right side view; (1: Rectangular frame; 2: Conical hopper; 3: Plumber block; 4: Horizontal agitator; 5: Geared motor; 6: Circular flat; 7: Bevel gear; 8: Sprocket of motor; 9: Tubular trough; 10: Plumber block; 13: Screw shaft; 14: Square frame; 15: Plumber block; 16: L- Angle; 17: Vertical agitator; 19: Vertical agitator shaft; 21: Cylindrical drum outlet; 22: Transport wheels)

free flow of straw. Consequently, the single flight tapered end screw conveyer speeds were taken as 100 rpm, 125 rpm and 150 rpm by considering volume occupied in between two flights with varied pitch length and by computing its theoretical weight of chopped rice straw conveyed per second. The screw diameter of 160 mm was chosen based on the diameter of 1 kg bag i.e. 200 mm. On the basis of fixed diameter of screw, the pitch length was taken as 160 mm, 180 mm and 200 mm. The trough tapered outside diameter was fixed as 170 mm, as it is very convenient to insert 1 kg polypropylene bag on the circumference of tubular trough outlet.

In this study, theoretically, the power required to run the machine was computed using Eq. 3.⁽¹⁵⁾

$$P = \frac{W_b \times v}{n \times K_s} \quad \dots (3)$$

where, W_b = Weight of substrate (0.490 kN), V = Velocity of shaft (2.35 m/s), n = Factor of safety (1), K_s = Service factor (1)

Based on the calculation, predicted that 1.2 kW motor sufficient to run the machine. In this context, the trials were conducted in the laboratory at a single flight tapered end screw speeds of 100 rpm, 125 rpm and 150 rpm. A 1.5 kW, 1430 rpm, 3 phase Alternative Current electric motor with energy meter was taken to study the power consumption at different screw conveyer speeds with a varying pitch length (160 mm, 180 mm and 200 mm) of screw. The studies revealed that, the maximum power consumption of 1.06 kW for filling wet chopped rice straw at load condition was observed for a conveyer speed of 150 rpm and 200 mm pitch length. Considering the losses in the power transmission system, a three phase 1.5 kW (2 hp) alternative current electric motor was finally fixed as prime mover for operating the machine.

In this machine, the power from the motor was transmitted to the screw conveyer as well as horizontal agitator. The diameter of the screw and agitator shaft were found by using Eq. 4.⁽¹⁵⁾

$$T = \frac{\pi}{16} \times \tau \times d^3 \quad \dots (4)$$

where, T = Torque transmitted by the shaft, N-mm (47.74 x 10³ N-mm)

τ = Torsional shear stress, MPa (for Mild Steel τ = 42 MPa)¹⁵

d = Diameter of the shaft, mm

The optimum diameter of 25 mm for screw shaft and 20 mm for agitator shaft were fixed in the machine based on the calculation.

The number of teeth sprocket placed on screw shaft and agitator shaft was determined using Eq. 5.

$$N_1 T_1 = N_2 T_2 \quad \dots (5)$$

where, N₁ = Speed of driving sprocket (150 rpm), N₂ = Speed of driven sprocket (50 rpm), T₁ = Number of teeth on driving sprocket (31), T₂ = Number of teeth on driven sprocket (10)

Length of the chain was determined by Eq. 6.

$$L = K \times p \quad \dots (6)$$

where, K = Number of chain links (83.48), p = Pitch of the chain, (19.05 mm)

A 31 teeth sprocket was constantly mounted on the motor shaft and the sprocket of single flight tapered end screw shaft was changed as per the speed required.

Truncated Conical Hopper/Frustum

The truncated conical hopper was preferred over trapezoidal shape hopper (due to choking issues). It receives, store and feed wet chopped rice straw to the single flight tapered end screw with the aid of agitator. The wet chopped rice straw was manually fed into the hopper. The truncated conical hopper, which holds the substrates, was fabricated using 2 mm thick mild steel sheet. It has a top diameter of 1110 mm, a bottom diameter of 300 mm, and a height of 700 mm. The conical shape allows for efficient and controlled flow of the substrate towards the screw conveyer assembly. It can accommodate nearly 48 kg of rice straw and composed of agitator inside to agitate and push the material towards the single flight tapered end screw.

Horizontal Agitator

A horizontal agitator was placed in the truncated conical hopper to agitate and push rice straw towards single flight tapered end screw. It was mounted on a shaft of Ø 25 mm, length of 750 mm and at a height

of 290 mm from the bottom of hopper. Agitator also consisted of varying height cylindrical rod which was mounted on shaft with the spacing of 120 mm and it was supported by pedestal bearings at the two end of shaft.

Single Flight Tapered End Screw

A tubular screw conveyer was chosen, because, it is more versatile, operate at a different speed, elevated at angles up to the vertical and perform well at higher fill ratios. Initially, single flight ribbon screw was developed and found choking in it (Fig. 2a). Hence, in this study, single flight tapered end screw conveyer was preferred rather than single flight ribbon screw. A single flight tapered end screw designed and fabricated by considering the size of 1 kg polypropylene bag and also its simple in structure, high efficiency, low cost and less maintenance required. Single flight tapered end screw receive and convey wet chopped rice straw from the inlet section to the outlet through tubular trough into the 1 kg polypropylene bag. It consists of screw flights and the screw pipe and made up of MS sheet, having length of 600 mm. The trough outside diameter was given as 180 mm with screw diameter of 160 mm provided upto 400 mm length of screw, later trough was tapered to 170 mm from the length of 400 mm to 600 mm with tapered screw diameter of 120 mm. The tapering of screw and trough was done based on diameter of polypropylene bag (200 mm). Therefore, tapered trough outside diameter and screw diameter were taken as 180 mm and 120 mm, because at that diameter it was very convenient to insert and hold the bag without facing any difficulties on the outside trough surface. The clearance of 8–10 mm should be provided between trough inner surface and screw flight edge to overcome choking problem inside the trough while conveying straw during the operation. Furthermore, the clearance was fixed based on after

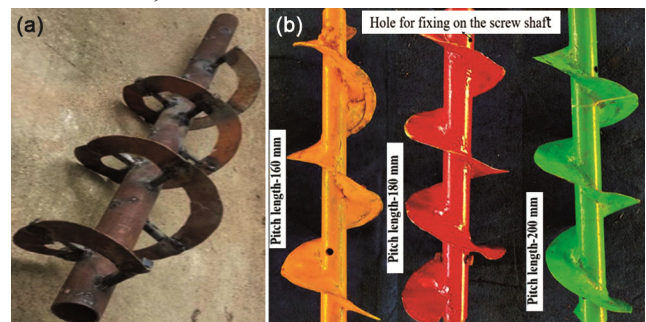


Fig. 2 — Screw conveyer: (a) Ribbon flight screw conveyer, (b) Different pitch length single flight tapered end screw conveyer

Table 1 — Experimental plan			
Variables	Levels	Wet chopped rice straw	Wet rice straw powder and sawdust
		Independent variable	
single flight tapered end screw speed (SFTSS), rpm	3	100, 125 and 150	20,40 and 60
Pitch length (PL), mm	3	160,180, 200	
		Dependent variable	
Bagging capacity, bags/h			

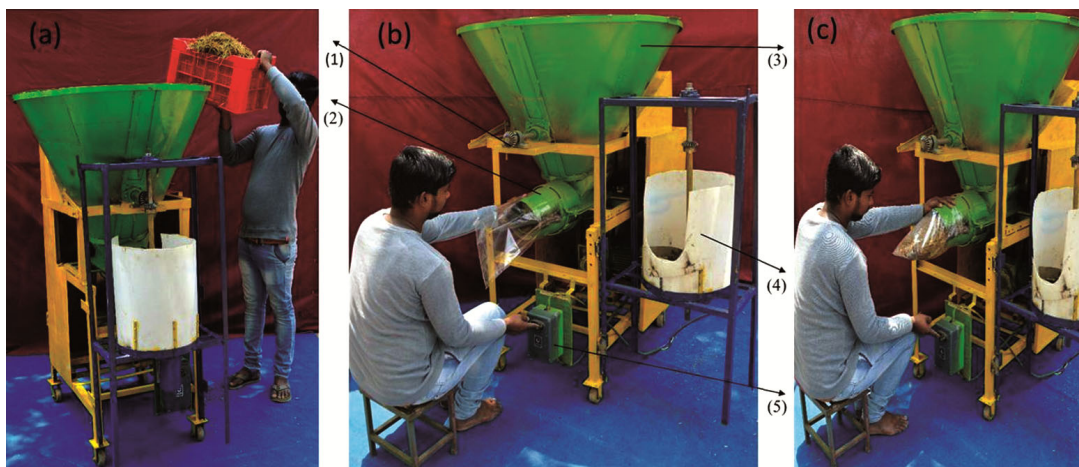


Fig. 3 — Sequence of operation of rice straw filling machine used for bag filling of wet chopped rice straw substrate: (a) Feeding the wet chopped rice straw inside the hopper, (b) Holding the polypropylene bag on the tubular trough outlet end & Switch on the starter to bag filling, (c) After bag filling switch off the starter (1: horizontal agitation shaft; 2: Tubular trough with screw conveyor; 3: Truncated Conical hopper; 4: Cylindrical Drum with Vertical agitator; 5: Motor starter)

conducting few clearance adjustment trials. Screw flights having width of 60 mm and tapered end having 40 mm with thickness of 2 mm which was fastened to the circular pipe by welding. The hollow pipe was mounted on shaft of having 30 mm diameter and length of 1000 mm and supported by two pedestal bearings at the one end of shaft and other end was freed for conveying of rice straw. The fabricated conveyer (Fig. 2b) was evaluated to know its performance and observed that developed screw conveyer conveyed wet chopped rice straw more efficiently.

Vertical Agitator

A vertical agitator was provided at the tubular trough outlet end to agitate and push substrates towards the hole provided at one end of the bottom of cylindrical drum. It was placed accurately at the center of the cylindrical drum made up of polypropylene sheet having diameter, height and thickness of 400 × 430 × 3 mm. It consists of inverted cone (Ø 180 mm) with fastened two vertical trapezoidal shape plates having height of 170 mm. It was directly attached or mounted to the horizontal

agitator through the aid of bevel gears having teeth of 20. The cylindrical drum with vertical agitator was fabricated and installed at the outlet end of the machine as an additional component of existing machine (the trough having a fixed diameter of 180 mm) for filling substrates such as rice straw powder and sawdust in the 1 kg polypropylene bag, because existing machine was only suitable for bag filling of wet chopped rice straw substrate in the 1 kg polypropylene bag. The wet sawdust bag filling was done on a bag size of 200 mm, so, as per the size of the bag, the outlet size of a drum was kept only Ø 160 mm. During the operation the substrates were fed manually into the cylindrical drum provided with vertical agitator. The vertical agitator produces rotary action to push the substrates towards the outlet having Ø 160 mm and height of 140 mm whereon one person holds the 1 kg bag for bag filling the wet powder form substrate by switching ON and OFF the starter motor.

Testing and Evaluation of Rice Straw Bag Filling Machine

The machine performance parameters such as machine bagging capacity were recorded during the

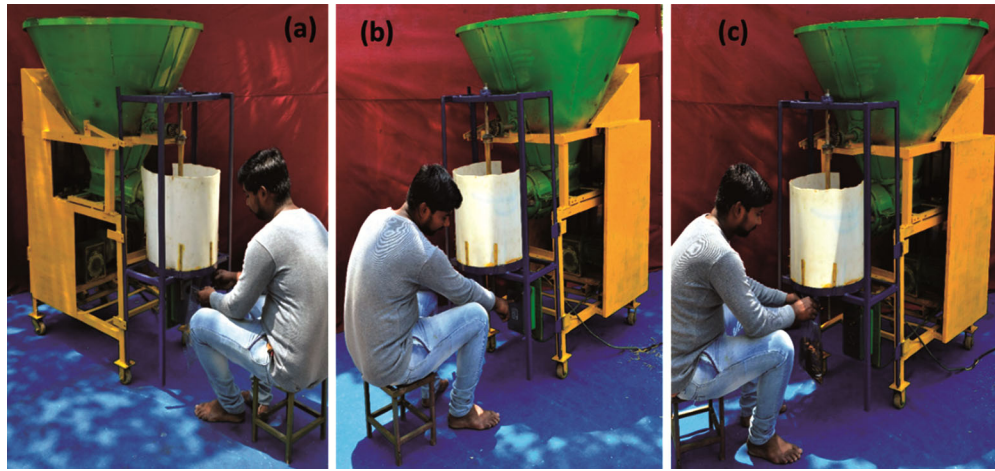


Fig. 4 — Sequence of operation of rice straw filling machine used for bag filling of wet rice straw powder and sawdust substrates: (a) After feeding the substrates inside the cylindrical drum polypropylene bag hold at the outlet (b) Switch on the starter to bag filling, (c) After bag filling switch off the starter

Table 2 — Engineering properties of wet chopped rice straw

Sl. No	Properties	Mean \pm SEM value	
		Wet chopped rice straw	Significant level
1	Bulk density (kg m^{-3})	163.48 ± 6.87	**
2	Coefficient of static friction Mild steel	0.73 ± 0.02	**

** = Significant at 1% level
* = Significant at 5% level

lab tests. A two factor completely randomized block design (general factorial design) used to analyze the effect of single flight tapered end screw speed and pitch length on the parameters such as machine bagging capacity by using Stat-Ease version 7.7.0 Design-Expert software (Table 1). The evaluation of the machine is depicted in Fig. 3 & 4. The evaluation procedure of the machine is given hereunder.

Evaluation of Bagging Capacity of Rice Straw Bag Filling Machine

The bagging capacity of rice straw filling machine was determined by weighing the amount of rice straw substrate filled inside the polypropylene bags per unit of time. The machine output is expressed by bags/h. It is expressed by using the below formula.¹⁶

$$\text{Design capacity (kg h}^{-1}\text{)} = \frac{\pi}{4} \times n \times \rho_b \times (\text{OD}^2 - \text{CD}^2) \times \text{lp} \times \text{filling factor} \times 60 \quad \dots (7)$$

where, OD = Screw outer diameter, m
CD = Screw center pipe diameter, m
lp = Pitch length, m

n = screw rotational speed (rev/s)
 ρ_b = Bulk density, kg/m^3

Results and Discussion

Engineering Properties of Wet Chopped Rice Straw

The results of engineering properties of rice straw obtained and statistically analysed by using single factor ANOVA design in AGRES Software. The mean values of bulk density and coefficient of static friction were determined and shown in Table 2.

Effect of Design and Operational Parameters on Bagging Capacity

The maximum bagging capacity of the machine was observed at a screw speed of 150 rpm and pitch length of 200 mm for rice straw substrate followed by 60 rpm and pitch length of 200 mm for wet rice straw powder and sawdust substrates. The percentage of increase in bagging capacity for rice straw substrate at 125 rpm as compared to 100 rpm was 21%, for 150 rpm 59% respectively. Similarly, increase in bagging capacity for rice straw powder substrate at 40 rpm as compared to 20 rpm was 60% and for 60 rpm as compared 40 rpm 13%. For sawdust

Table 3 — Effect of screw speed and pitch length on bagging capacity of rice straw bag filling machine used for bag filling of wet chopped rice straw substrate, wet rice straw powder and sawdust substrate

Single flight tapered end screw speed (rpm)	Pitch length (mm)	Rice straw substrate Bagging capacity (Bags/h)	Single flight tapered end screw speed (rpm)	Pitch length (mm)	Rice straw powder substrate Bagging capacity (Bags/h)	Sawdust substrate Bagging capacity (Bags/h)
100	160	140	20	160	113	109
	180	145		180	127	128
	200	152		200	153	154
125	160	167	40	160	154	141
	180	169		180	181	161
	200	184		200	246	226
150	160	200	60	160	240	227
	180	240		180	247	241
	200	293		200	278	265

Table 4 — Analysis of variance table for bagging capacity of rice straw bag filling machine used for rice straw substrate

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	Term	Coeff. Estimate	df	Std. Error	
Model	70287.63	8.00	8785.95	34.95	< 0.0001	Significant	Intercept	188.81	1.0	3.00
A-SFTESS (rpm)	49820.52	2.00	24910.26	99.1	< 0.0001		A[1]	-42.93	1.0	4.24
B-PL (mm)	18409.19	2.00	9204.59	36.62	< 0.0001		A[2]	-15.48	1.0	4.24
AB	2057.93	4.00	514.48	2.05	0.1306		B[1]	-19.81	1.0	4.24
Pure Error	4524.67	18.0	251.37				B[2]	-3.81	1.0	4.24
Cor Total	74812.3	26.0					A[1]B[1]	13.93	1.0	5.99
							A[2]B[1]	13.48	1.0	5.99
Std. Dev.	15.85		R-Squared	0.9395			A[1]B[2]	2.93	1.0	5.99
Mean	180.37		Adj R-Squared	0.9126			A[2]B[2]	-0.19	1.0	5.99
C.V. %	8.79		Pred R-Squared	0.8639						
PRESS	10180.5		Adeq Precision	16.824						

substrate was 46% and 17% respectively. It was found that the effect of all the screw speed and pitch length of machine on bagging capacity was significant at 1% level of significance. From the Table 3, came to know that the bagging capacity increased as the single flight tapered end screw speed and pitch length increased. Srivastava *et al.* reported that the bagging capacity increased linearly with the screw speed upto 250 rpm.¹⁶ Beyond this speed the centrifugal force acted and restricted the flow of straw at the inlet, due to this the capacity decreased. Similar trends were reported for few biomass materials like wood pellet, sawdust, hog fuel and wood shaving.^{17–20} The bagging capacity increased as the pitch lengths increased because, at higher pitch length the volume of material occupied in between the flight increased consequently mass flow rate increased.¹⁶ In comparison with machine and manual bag filling operation of rice straw, rice straw powder and sawdust, an average manual bag filing capacity was found to be 90 bags/h, 110 bags/h and 110 bags/h respectively. It is 2–3 times quite less than the machine capacity.

The analysis of variance (ANOVA) and estimated coefficient values for the bagging capacity of rice straw filling machine by using wet chopped rice straw as substrate is given in Table 4. The model (2FI) F-value of 34.95 is highly significant, with a p-value of less than 0.0001. This indicates that the proposed model is well-fitted to the experimental data and can effectively predict the bagging capacity based on the input variables. In this case, A and B were significant model terms. Values greater than 0.1 indicate that the model terms were not significant. The statistical analysis suggested that the proposed models fitted the experimental data with R² value of 0.93, whereas the optimized predictive model had an R² value of 0.86 and was in close agreement with the “Adj R-Squared” of 0.91. The Adeq Precision ratio, which measures the signal-to-noise ratio, was calculated to be 16.82. A value greater than 4 is desirable, indicating that the model has a high signal relative to noise, making it reliable and useful for predicting the bagging capacity. The same trend of results was also found for wet rice straw powder and sawdust substrates (Table 3)

Conclusions

The developed machine is having higher bagging capacity and versatile in nature. This machine can be recommended in rural areas/small scale industries because of its low cost (₹ 52,397) and also helps to revamp mushroom production in rural areas. The capacity of the machine is increased by providing an automatic feeding system instead of feeding manually. Further modification can be done in power unit and drive system by utilizing solar panel for extracting solar energy rather than electric motor is very much essential to increase its utility in remote areas where electricity is intermittent. Furthermore, an automatic sensing device need to be developed for accurate weighing the substrate and bag filling. Indeed, the study findings convey valuable message regarding the economic and practical benefits to the farmers in terms of saving time, cost and labor and also promote to use bag filling machine for both straw and powder form substrates.

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