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Utilization of pulses byproduct for preparing feed pellets

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Abstract
Animal Feed Mill (AFM) was developed to process 100 kg of byproduct per day. The commercialized technology, PKV mini dal mill gives the recovery of nearly 72 to 75% and 25 to 28% byproduct (brokens + husk + powder). Among the byproduct, the brokens are used for human consumption where as remaining 15-16% is husk and powder. This remaining 15-16% byproduct (husk + powder) contains nearly 18 to 20% of proteins and hence can be used for preparing Animal feed pellets.
The developed Animal feed mill consist of hopper, mixing chamber, compaction chamber, outlet /die, motor and frame. The developed AFM is having capacity nearly 100 kg per day and is operating on 3 HP single phase motor. By pelleting the byproduct the volume is reduced and it becomes easier to handle and store the original material. Optimum proportion of ingredients for making animal feed pellet were by-product (husk + powder) 1 kg, 1/2 lit of water, 50 g (5% of byproduct) of jaggery (Binder) and 20 g (2%) salt. At optimum condition of 50% water content (% byproduct), 5% binder (% byproduct) and 30 rpm of Animal feed mill, the capacity of AFM is 15.6 kg/hr, the efficiency of AFM is 95.9% and firmness/ hardness of pellets is 7.69 kg. The dried animal feed pellets was having moisture content of 8.324% (wb) bulk density of 646 kg/$m^{3,}$ 25% porosity and the water activity is 0.148. The unit cost of processing animal feed pellet is @ Rs 15/kg.

Keywords: Waste, pulse/dal, mill, by-product, feed, pellets

Introduction
Animals are given a wide range of different feed, but the two major types of animal feed are processed animal feed (Compound feed) and fodder. Livestock feed are generally classified according to the amount of specific nutrient that furnish in the ration. They are divided into two general classes-roughages and concentrates. Roughages are bulky feed containing relatively large amount of less digestible material i.e. crude fibre more than 18%. Concentrates are feeds which contain relatively smaller amount of fibre and have a comparatively high digestibility and as a result higher nutritive value per unit weight than the roughages (Banerje, 1978) [2]. Concentrates is usually described as a feed or feed mixture which supplies primary nutrients (protein, carbohydrates and fat), contains less than 18 per cent crude fibre and usually low in moisture (Reddy, 2001) [11]. In general concentrates are rich in either energy or protein and thus are expensive. Energy rich concentrates consists of gram which is a leguminous grain and is fed in India to almost all classes of farm stock. Most of the research works which covered the wide range of qualitative and quantitative nutritional requirements of animals were, however, undertaken during the first half of the 20th century. Since then, the nutritional science has been moving forward at an ever increasing pace (Reddy, 2001) [11].
Usually roughage and concentrate ratio is being maintained as 60:40.For high yielding cows 50:50 roughage: concentrate is usually adequate. Complete feeds are processed in following ways:

- **Chaffed mix:** Finely chopped roughages are mixed with ground concentrate ingredients.
- **Silage mix:** Fine chopped silage is evenly mixed with concentrate mixture at the time of feeding.
- **Mash mix:** Roughages are ground, evenly mixed with concentrate ingredients and converted to pellets using pellet mill.

- **Blocks:** Mixture of roughages (Chopped) and concentrate ingredients are pressed in a block of desired shape and weight. (NDRI, 2010)

For milking cows, yielding milk upto 5 kg (2 kg/day concentrate is feed), for 6-10 kg (4 kg/day of concentrate is feed) for 11-12 kg (8 kgs/day of concentrate feed), for 21-30 kgs, (10 kgs of concentrate feed) and for 31-40 kg, (12 kgs concentrate is feed). (NDRI, 2010)

Pigeon pea (*Cajanus cajan*) is a locally available, affordable and under-utilized grain legume of the tropics and sub-tropics. In Asia, pigeonpea is grown in an area of 4.3 m ha and production of 3.3 m tons (Figure 1). India has the largest area (3.6 m ha) under pigeonpea, followed by Myanmar (560,000 ha), Kenya (196,000 ha), China (150,000 ha), Malawi (123,000 ha), Uganda (86,000 ha), Mozambique (84,000 ha), Tanzania (68,000 ha) and Nepal (21,000 ha). Maturity duration (at 17^0N latitude) varies from about 90 days for extra-early varieties to more than 260 days for long-duration varieties. In Asia, between 1976 and 2006, pigeonpea recorded 56% increase in area (2.76 to 4.32 m ha) 54% increase in production (2.14 to 3.29 m t). (Rao, 2010) [10].

Pigeon pea varieties has protein content in the range of 23 - 26% (Oshodi *et al*., 1985) [9]. PKV mini dal mill gives the recovery of nearly 72 to 75%, hence the remaining is 25 to 28% is byproduct (Brokens +powder + husk). This byproduct contains nearly 18-20% of proteins and hence can be used for preparing animal feed. It was bit difficult to handle, store and transport husk due to its fluffy nature, besides being underutilized and low value. It was thought to develop animal feed mill, which will convert the husk + powder into pellets form. This pellets can fulfill the nutritional requirement of animals. By pelleting the byproduct the volume can be reduced and is easier for handling and storage of original materials.

The present study was undertaken with the following objectives:

1. To develop a small capacity animal feed mill for compacting dal mill byproduct into animal feed pellets.
2. Testing of the mill for preparing pellets.

Methodology, Result and Discussion

Design and Development of Animal Feed Mill

Hopper Design

Feed hopper: According to the Bureau of Indian standards guidelines on feeding chutes for thresher (IS: 1979), the design criteria for the feed hopper presented by Naravani, (1991) [14] were followed. Following expression was used for determining holding capacity of hopper.

$$V \geq \frac{W}{\rho_b}$$

where,

V = volume or holding capacity of the feed hopper, m^3

W= quantity of byproduct fed into the feed hopper during each filling, kg.

ρ_b= bulk density of the byproduct, kg/m^3

Speed of Animal Feed Mill (AFM)

N1/N2 = D2/D1

Belt speed in m/ s:

$$V = \frac{\text{Screw dia x 3.14 x Rotation/min}}{60}$$

Screw conveyor (Mixing and Compaction chamber) Capacity of screw conveyor

$$Q = \frac{3.14 \times D^2}{4} \times s \times n \times sg \times i \times 60$$

where,

Q = capacity in kg/ hr

D = screw diameter in 'm'

s = pitch in 'm'

n = rotations per minute

sg = specific weight of the material

i = degree of trough filling

Power requirement of screw conveyor for horizontal operation is determined by –

$$P = \frac{Q \times L \times K}{407}$$

where,

P = power in kW

Q = screw conveyor capacity, kg /hr

L = screw conveyor length, m

K = frictional coefficient

B) Fabrication material used for Animal Feed Mill

A small capacity (100 kg/day) mill is developed which can utilize the dal mill by-product and prepare animal feed pellets. Material used for fabrication of animal feed mill along with the specification and required quantity is given below in the Table 1. And components of Animal Feed Mill along with specifications are given in Table 2. Cost of the Animal Feed Mill is Rs 30,000 and weight of mill is 87 kg.

Table 1: Material used for fabrication of the machine

Sr. No.	Material & Quantity	Specification
1	Flange bearing (1)	UCF 207
2	Pillo bearing (1)	UCP 205
3	M.S. Flanges (5)	(Ø) =160 mm
4	MS ERW simless pipe (1)	(Ø) =85 mm, L=1100 mm
5	Bright bar/ shaft (1)	(Ø) =32 mm, L=1700 mm
6	MS flights (40)	(Ø) =85mm
7	'V'belt (1)	B 69
8	Angle "L" (1)	1500 mm- L35 X 35 X 5 mm
9	Sprocket (1)	9.8 cm (Ø).
	Sprocket (1)	29.4 cm (Ø).
10	Counter shaft	35 mm (Ø), L= 450 mm
11	Bearing (PB:204) (2)	600 mm
12	'V' belt pulley (2)	29.4 cm (Ø).
	'V' belt pulley (2)	7.35 mm (Ø).

Table 2: Components of Animal Feed Mill along with Specifications:

Sr. No.	Components of AFM	Specifications
1	Hopper	Upper dia.-27 cm, lower dia.-9 cm, Height -13 cm
2	Mixing chamber	80 cm (L),8.5 cm ϕ
3	Compaction chamber	30 cm (L), 8.5 cm ϕ
4	Die/ outlet	4 holes each of 1 cm ϕ
5	Motor	3 HP single phase motor
6	Frame	156 cm x 23 cm x 92 cm.

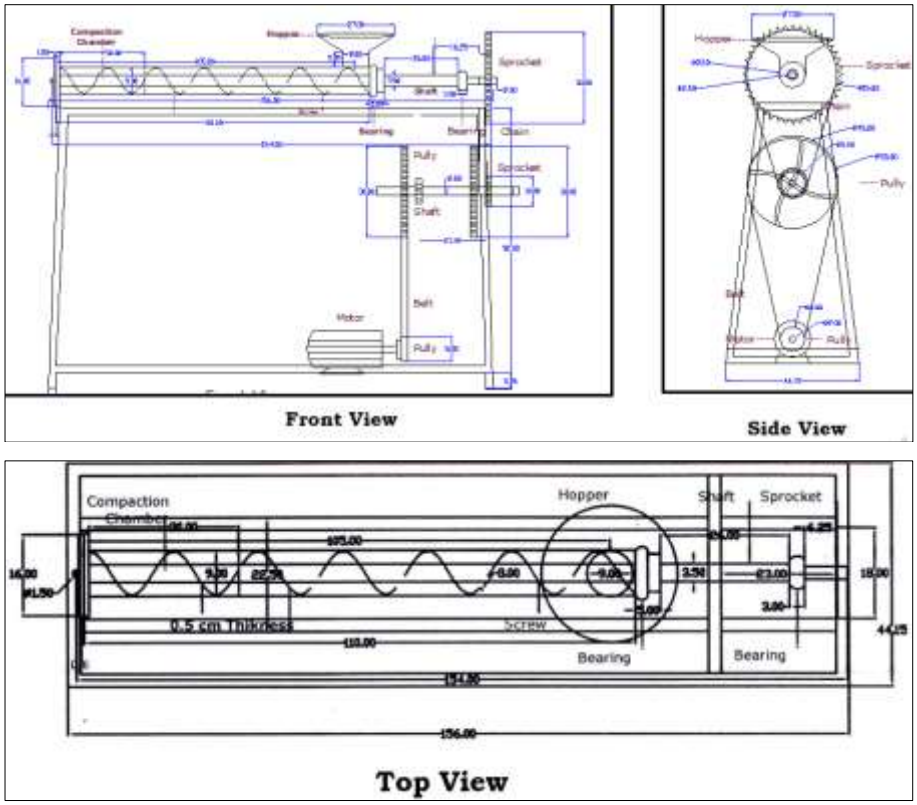

Fig 1: Orthographic drawing of animal feed mill (AFM)

Plate 1: (a) Animal Feed Mill and (b) Animal Feed Pellets

Process for making Animal Feed Pellets from byproduct:

i) Raw Material for pellets

The developed system was used to prepare Animal Feed Pellets using byproduct (Powder + husk) obtained from PKV mini dal mill. The recovery of PKV mini dal mill is nearly 72 to 75% and the byproduct obtained is about 25 to 28%. Amongs the byproduct, the brokens are used for human consumption where as remaining 15-16% is husk and powder. Considering the difficulty in handling, storage and transport of this byproduct, besides low value, it was thought to prepare Animal feed pellets by developing animal feed mill. This byproduct (husk + powder) contains nearly 15-18% of proteins and hence can be used for preparing nutritionally rich Animal feed pellets.

ii) Preparation of animal feed pellets

The byproduct obtained from PKV mini dal mill is gound for a particle size of 0.424 mm and taken in a container (Reddy, 2001) [11]. The separate mixture of jaggery (5% of raw material), salt (2% of raw material) and water (50% of raw material) is prepared, this solvent is then added to the raw material for making a uniform pellet mixture (Thomas 1996) [13]. Jaggery was added as a binder material as well as to impart good taste to feed. This was the minimum possible amount of jaggery, salt and water to form pellets after various trials. The pellet mixture is then conditioned for 2 h.

- The pellet mixture was fed to the animal feed mill at the feed rate of 200 gm/min from feeding hopper.
- The mixture then moved through the mixing chamber with the help of flight conveyer. This chamber ensures the uniform mixing of pellet mixture.
- After uniform mixing the pellet mixture is moved to compaction chamber (continuous screw) where the required pressure is developed for making pellets.
- The pellet mixture is then forced/ pressed out at the outlet/die/flange having dia. of 1cm.

These pellets are then sun dried for 2 days to reach the moisture content of 8.324% (wb).

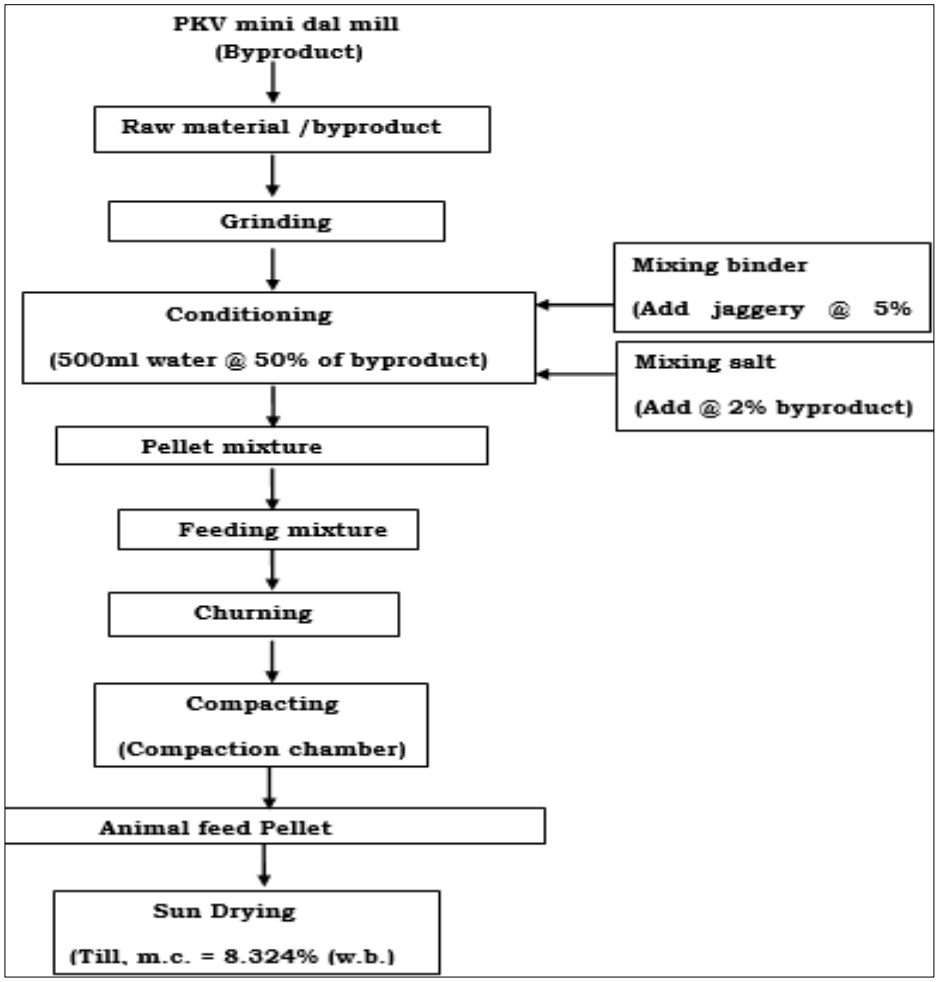

Fig 2: Flowchart for preparing animal feed pellets by using animal feed mill (AFM)

D) Performance evaluation

The Animal feed mill was evaluated for optimization of process parameters used for making Animal feed pellets and also to optimize the speed of Animal feed mill.

i) Experimental Design for making pellets

Table 3: Experimental plan for optimization of process parameters for animal feed pellets.

Parameter	Levels	Values
Design of experiment	-	Completely Randomized Design (CRD)
Technique	-	ANOVA
Levels	3	
Total number of treatment combinations Replication	27 3	
Independent variable	3	Water content (%BP) Binder (%BP) Speed of AFM (rpm)
Dependent/Performance variable	3	
		Capacity of AFM (kg/h) Efficiency of AFM (%) Hardness/ Firmness of AFP (kg)

In all 27 different experimental combinations experiment for optimization of process parameters for animal feed pellets were conducted as below.

Table 4: Experimental details with coded values:

Sr. No	Independent variable	Code	Levels		
			1	2	3
1	Water content (%BP)	W	40	50	60
2	Binder (%BP)	B	3	4	5
3	Speed of AFM (rpm)	S	30	36	45

ii) Capacity of Animal feed Mill

$$\text{Capacity of AFM (kg/h)} = \frac{\text{Quantity of pellets at the outlet, kg}}{\text{Time required, h}}$$

iii) Efficiency of AFM (%) = 100 –% un-treated feed material

$$\text{Un – treated feed material (\%)} = \frac{C}{D} \times 100$$

where,
C = Weight of un- treated feed material, g
D = Total weight of the feed material used for making pellet.

iv) Firmness of Pellets (kg)
The average compression force required for calculating the firmness/hardness of pellets was determined with the help of Texture Analyser (Make: Stable Micro System, Model: Texture Export) with following settings
Pre-test: 2.0 mm/s
Test speed: 2.0 mm/s
Post-test speed: 10.0 mm/s
Distance: 2.5 mm
Trigger type : Auto – 100 g
Tare Mode: Auto
Data Acquisition: 200 pps
Accessory: 35mm cylinder probe (P/35) using 50 kg load cell.

Result and Discussion
Physical properties of mini dal mill byproduct (husk and powder) and animal feed pellets properties are given in the following table.

Table 5: Some properties of animal feed pellets

Moisture content of raw material (husk+ powder)	7.720% (wb)
Moisture content of mixture	49.941% (wb)
Moisture content of pellets	8.324% (wb)
Particle size of raw material (husk+ powder)	0.424 mm
Bulk Density of raw material	571 kg/m3
Bulk Density of pellets	646 kg/m3
True Density of pellets	858 kg/m3
Porosity of pellets	25%
Water activity of Animal Feed pellets (aw)	0.148
Water activity of commercial pellets (aw)	0.384
Angle of Repose	43.91º

Analysis of data: The data on Capacity of AFM (kg/h), Efficiency of AFM (%) and Firmness of pellets (kg) were analyzed using completely randomized design (CRD).

Table 6: Performance of Animal feed mill:

Sr. No.	Water content (%BP)	Binder (%BP)	Speed of AFM, rpm	Capacity (kg/hr)	Efficiency of AFM,%	Hardness/Firmness of AFP, (kg)
1	40	3	30	13.09	92.20	6.65
2	40	3	36	12.24	90.43	7.52
3	40	3	45	12.21	90.30	7.57
4	40	4	30	13.21	92.33	6.79
5	40	4	36	13.09	91.36	6.55
6	40	4	45	12.01	90.58	6.99
7	40	5	30	13.41	93.37	7.28
8	40	5	36	12.47	91.20	7.14
9	40	5	45	12.63	90.64	7.61
10	50	3	30	11.02	92.08	7.03
11	50	3	36	12.68	91.70	7.21
12	50	3	45	11.36	90.83	7.37
13	50	4	30	11.79	94.00	7.66
14	50	4	36	12.89	93.67	7.02
15	50	4	45	13.60	92.14	7.61
16	50	5	30	15.60	95.90	7.69
17	50	5	36	14.74	94.13	7.85
18	50	5	45	13.28	92.20	7.93
19	60	3	30	11.04	91.08	6.70
20	60	3	36	10.64	91.37	6.63
21	60	3	45	10.01	90.93	6.36
22	60	4	30	12.60	90.82	6.85
23	60	4	36	10.80	90.90	6.84
24	60	4	45	9.910	90.65	6.32
25	60	5	30	12.29	91.2	6.94
26	60	5	36	9.62	92.07	6.25
27	60	5	45	10.32	89.57	6.27
Max				15.60	95.90	7.93
Avg				13.09	92.20	6.65

Analysis of variance was performed to estimate the variables that contributed significantly (P=5%) to the Capacity (kg/h) and efficiency of Animal feed mill (%) and firmess/ hardness of Animal feed pellets. The variables considered were water content (%BP), binder (%BP) and speed of Animal feed mill.

Table 7: Capacity (kg/hr) of Animal feed mill

S.V.	D. F.	S.S	M.S.S	S.E. (M)	S.E. (D)	C.D (5%)	Fcal	C.V.
Fact. A	2	76.691	38.346	$8.5613x10^2$	0.1211	0.2397	193.764 S	3.656%
Fact. B	2	16.966	8.483	$8.5613x10^2$	0.1211	0.2397	42.864 S	
Fact. C	2	12.805	6.402	$8.5613x10^2$	0.1211	0.2397	32.351 S	
Fact A*B	4	22.311	5.578	0.148	0.209	0.415	28.184 S	
Fact A*C	4	13.039	3.260	0.148	0.209	0.415	16.472 S	
Fact B*C	4	7.036	1.759	0.148	0.209	0.415	8.889 S	
Fact A*B*C	8	15.041	1.880	0.257	0.363	0.713	9.500 S	
Error	54	10.687	0.1979					

Table 7 show ANOVA results for capacity (kg/h) of Animal feed mill. It is clear from the Table 7 that the three factors, moisture content, binder and speed of AFM are independent in their effects for capacities (kg/h) of Animal feed mill. The calculated F values for all the properties are higher than table F values indicating significance of the variables at 5% level. So, moisture content, binder and speed of AFM all the factors play significant role in influencing the Capacity (kg/h) of Animal feed mill. The highest, lowest and mean value for capacity was 15.60, 9.20 and 12.17 kg/h respectively. It was found to be maximum of 15.60 kg/h capacity of Animal feed mill was obtain at moisture content of 50% (BP), binder proportion of 5% (BP) and speed of Animal feed mill at 30 rpm.

Table 8: Efficiency (%) of Animal feed mill:

S.V.	D. F.	S.S	M.S.S	S.E.(M)	S.E. (D)	C.D (5%)	Fcal	C.V.
Fact. A	2	60.5	30.25	0.109	0.154	0.3057	94.014 S	0.6181%
Fact. B	2	14.875	7.438	0.109	0.154	0.3057	23.115 S	
Fact. C	2	38.875	19.438	0.109	0.154	0.3057	60.410 S	
Fact A*B	4	18.563	4.640	0.189	0.267	0.529	14.423 S	
Fact A*C	4	12.25	3.063	0.189	0.267	0.529	9.518 S	
Fact B*C	4	7.063	1.766	0.189	0.267	0.529	5.487 S	
Fact A*B*C	8	4.625	0.578	0.327	0.463	0.917	1.797 S	
Error	54	17.375	0.322					

Effect of process conditions *viz*, moisture content, binder and speed of AFM on the capacities (kg/h) of Animal feed mill were studied as per CRD design. The calculated F values in table 1.8 for all the properties are higher than table F values indicating significance of the variables at 5% level. So, moisture content, binder and speed of AFM all these factors play significant role in influencing the efficiency (%) of Animal feed mill. The highest, lowest and mean value for efficiency was 95.90%, 90.07% and 91.765 kg/h respectively. It was found to be maximum efficiency of Animal feed mill was 95.90% at moisture content of 50% (BP), binder proportion of 5% (BP) and speed of Animal feed mill at 30 rpm.

Table 9: Hardness (kg) of Animal feed pellets:

S.V.	D. F.	S.S	M.S.S	S.E.(M)	S.E. (D)	C.D (5%)	Fcal	C.V.
Fact. A	2	11.357	5.678	$4.567x10^2$	$6.460 x10^2$	12.788	100.804 S	3.361%
Fact. B	2	1.026	0.513	$4.567x10^2$	$6.460 x10^2$	12.788	9.105 S	
Fact. C	2	0.177	$8.8500x10^2$	$4.567x10^2$	$6.460 x10^2$	12.788	1.571 S	
Fact A*B	4	2.551	0.638	$7.912 x10^2$	0.112	0.222	11.321 S	
Fact A*C	4	2.448	0.612	$7.912 x10^2$	0.112	0.222	10.864 S	
Fact B*C	4	1.089	0.272	$7.912 x10^2$	0.112	0.222	4.836 S	
Fact A*B*C	8	1.205	0.151	0.137	0.194	0.384	2.674 S	
Error	54	3.042	$5.633 x10^2$					

Table 9 show ANOVA results for hardness (kg) of Animal feed pellets. It is clear from the Table 9 that the three factors, moisture content, binder and speed of AFM are independent in their effects for hardness (kg) of animal feed mill. The calculated F values for all the properties are higher than table F values indicating significance of the variables at 5% level. So, moisture content, binder and speed of AFM all these factors play significant role in influencing the hardness (kg) of Animal feed mill. The highest, lowest and mean value for capacity was 7.94, 6.25 and 7.06 kg respectively. It was observed that the hardness of animal feed pellet for process conditions *viz*. moisture content of 50% (BP), binder proportion of 5% (BP) and speed of Animal feed mill at 30 rpm. was 7.69 kg which shows that the hardness of the pellet is in the acceptable range.

Thus, from the data analysis it was observed that the optimized process conditions *viz*, moisture content, binder and speed of AFM were 50% (BP), binder proportion of 5% (BP) and 30 rpm speed of animal feed mill in order to get the maximum capacity of 15.60 kg/hr and maximum efficiency of 95.90% of animal feed mill. Also, the hardness of the pellet was found to be 7.85 kg which was in the acceptable range at the same optimum conditions.

The Animal feed pellets obtained from Animal feed mill and sun drying till required moisture content was analyzed for biochemical composition i.e protein, crude fibre, fat, ash by standard method. Also, the analyses was carried out for Animal feed pellet, commercial product and byproduct of (Raw material). The composition is shown in Table 10.

Biochemical composition

Table 10: Average proximate composition of different feed stuffs (%)

	Initial cost of machine	**:**	**30,000 Rs.**
1	Expected life	:	15 years
2	Salvage value	:	10%
3	Working days/year	:	120
4	Working hours/day	:	10
5	Labour requirement	:	1
6	Wages per day	:	Rs.120 per labour
7	Electricity charges Rs/unit	:	Rs. 7
8	Rent of Shade(@ Rs 500/month) for 4 months	:	Rs 2000/-
A.	Fixed cost	:	
a.	Cost of the machineries & equipments	:	30,000
b.	Rent of Shade @ Rs 500/month	:	500 x 4 = 2000
c.	Interest on fixed capital excluding land and building (@ 12%)	:	3,600
d.	Depreciation /year	:	1800
e.	Insurance, if any (@ 2%)	:	600
	Total fixed cost /year, Rs	:	8,000
	Total fixed cost/day, Rs		67
B.	Variable cost	:	
i.	a) Cost of raw material (husk + powder) @ Rs 10/kg	:	10 x100 x 120= 1,20,000
	b) Cost of jaggery (5% of raw material) @ Rs 30/kg	:	30 x 5 x 120 = 18,000
	c) Cost of salt (2% of raw material) @ Rs 10/kg	:	10 x 2 x120 = 2,400
	Total cost of raw material, Rs	:	1,40,400

DM basis).

Particulars	**DM**	**CF**	**CP**	**EE**	**NFE**	**TA**
Animal feed pellets	91.68	17.40	19.68	2.13	53.81	6.98
Commercial Pellets	92.04	24.94	18.91	1.40	47.73	7.02
Mix of Tur husk & powder	92.28	16.76	20.3	2.39	53.34	7.21

Cost economics analysis of Animal feed mill

The estimation of cost of Animal feed mill for making Animal feed pellets is assessed below

ii.	Average annual electricity charges @ Rs 7/ unit	:	(7 x 1 x 10)x120 = 8400
iii.	No of labour	:	1
iv.	Labour charges @ Rs 120/day	:	120 x 120 = 14,400
v.	Repair and maintenance cost	:	500
vi.	Miscellaneous cost	:	500
	Total variable cost /year, Rs	:	1,64,200
	Total variable cost/day, Rs	:	1,368
	Total cost/day, Rs	:	67+1368 = 1435
	Unit cost (Rs/kg)	:	14.35 = Rs 15/kg

Conclusions

- Animal Feed Mill is developed having capacity nearly 100 kg per day operating on 3 HP single phase motor.
- At optimum condition of 50% water content (% byproduct), 5% binder (% byproduct) and 30 rpm of Animal feed mill, the capacity of AFM is 15.6 kg/h, the efficiency of AFM is 95.9% and firmness/ hardness of pellets is 7.69 kg.
- Optimum proportion of ingredients for making animal feed pellet were by-product (husk + powder) 1 kg, 1/2 lit of water and 50 g (5% of byproduct) of jaggery (binder) and 20 g (2%) salt.
- The dried animal feed pellets were having moisture content of 8.324% (wb), bulk density of 646 kg/$m^{3,}$ 25% porosity and the water activity is 0.148. The unit cost of processing animal feed pellet is @ Rs 15/kg.

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