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Studies on engineering properties of total mixed ration for block making

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Abstract
The studies on engineering properties of total mixed ration for development of block making machine was carried out at the Department of Farm Machinery and Power Engineering, College of Agricultural Engineering, University of Agricultural Sciences, Raichur. The different formulation of total mixed ration is affected by engineering properties. The properties of total mixed ration play a fundamental role in design of components for block making machine. Nine total mixed rations were formulated with sorghum stover and paddy straw as roughage sources and standard concentrates of varying ratio at 50:50, 60:40 and 70:30 consisting of molasses as binding agent at 5.0, 7.5 and 10.0 percent. In this study, observed parameters *i.e.,* particle size, moisture content, co-efficient of static friction and initial bulk density for varying ratio of roughage and concentrate of total mixed ration with different percent binding agent were determined.

Keywords: Binding agent, paddy straw, sorghum stover, concentrates, roughages, total mixed ration

Introduction
In developing nations like India, large ruminant animals are primarily maintained on crop residues which are not ideal for sustaining superior health and production. To obtain maximum production, easily available feed is a essential which should fulfils the nutrient requirements of animals. Providing adequate food and feed to farm animals is important in terms of increasing their productivity. Feed cost accounts about 65 to 70% of the total cost of ruminants and other livestock which is one of the main inputs of livestock. Lack of proper nutrition has been identified as the biggest hurdle to livestock production in developing countries. India is the world's largest animal producing country with cattle accounting for about 57.3% and cows accounting for about 14.7% of the world total (Ahuja, 2012) [1]. The number of labour force engaged in livestock is 20.5 million. Most of workers are marginal, small and semi-medium operational holdings farmers (<4 hectares) of which about 87.7% having milch animals and significant source of subsidiary income to them by means of engaging in dairying. At current prices, the total contribution of the livestock sector to the GDP is close to 4.11% (Anon, 2017) [2]. Cows are naturally raised and most of the feed comes from grazing. The major causes of reduced livestock productivity in a conventional feeding system are malnutrition and a lack of feed. But, there has been steady shift to new system from traditional i.e., total mixed ration which supply the balanced nutritional to dairy cows and many advantages rather than traditional practice such as cost reduction, decline in feed loss, better availability of nutrients and improves cows performance over supplying feed ingredients individually (Garg *et al.,* 2012) [3]. In India, farmers generally follow the local methods of feeding to the animals. The farmer's awareness level about the feeding of animals is relatively low apart from being resource poor farmers which may results in below optimal level of production from dairy animals. The majority of raw feed ingredients necessary for undertaking formulation of mixed ration are locally available but farmers lack in making ration and blocks. However, the major restrictive reason to capture the complete advantage is the lack of existing, affordable blocks for feeding to animal. In sight of the above facts, the total mixed rations were formed with locally available roughages and standard concentrates with varying ratios by mixing different proportion binding agent. The various engineering properties of total mixed ration were studied for development of functional components of the machine.

Materials and Methods

The study was undertaken for determination of engineering properties of total mixed ration which becomes necessary as these properties affect the development of functional components of fodder block making machine. Nine total mixed rations were formed with sorghum stover and paddy straw as roughage sources and concentrates of varying ratio at 50:50, 60:40 and 70:30 consisting of molasses as binding agent at 5.0, 7.5 and 10.0 percent. The feed ingredient used for making total mixed ration and their composition are presented (Table 1). The selection of raw materials was done by considering the local availability, season, farmer's practice, cost, nutritive value of feed ingredient and standard recommendation (Indian Standard, 2009) [5]. Especially sugarcane molasses is being used in cattle feeding to improve ration acceptability, rumen microbial activity, to reduce dustiness of ration, as a binder for block formation and as a source of energy. The high sugar content of molasses enhances the palatability of the feed. Additionally, molasses can mix the components of the finely ground feed and reduce its dustiness (Senthilkumar *et al*., 2016) [9]. Molasses is utilized in amounts not to exceed about 10 to 15% of the ration. High quantity of molasses will cause the feed to turn out to be messy and un-manageable as well as create digestive trouble (Gopalakrishnan and Lal, 1985) [4]. In order to utilize crop residues in the rations of ruminants, crop residue i.e., roughages have to be subject to at least a minimum processing like chaffing/grinding. The particle sizes of the crop residues such as paddy straw and sorghum stover are reduced by using the chaff cutter. The raw ingredients used for concentrates i.e., groundnut cake and maize grains are grounded by grinder to properly mix with the rations. The moisture content of the roughages was found out by using hot air oven method and expressed in percentage on wet basis (% wb). A sample of 10 g was oven dried at 103 ± 2^0 for 24 hours and cooled in a desiccator (AOAC, 2010). The weight of the sample dried was noted. The moisture content of the ration was determined by using the following formula,

$$\text{Moisture content (\%, Wb)} = \frac{M_2-M_3}{M_3-M_1} \times 100$$

Where,
M_1 = Weight of moisture box (g)
M_2 = Weight of moisture box + sample before drying (g)
M_3 = Weight of moisture box + bone dried sample (g)

The bulk density can be defined as the ratio of the mass of the material to total volume of the material. The bulk density was measured by measuring the cylinder with known mass and the volume. The container was filled with material to full volume without compaction and excess material was leveled off and weighed (Subramanian and Viswanathan, 2007) [11]. The static coefficient of friction of total mixed ration was determined on typical surface such as mild steel sheet using the standard apparatus. The known weights of samples were filled in a wooden container attached with a string having loading plate at its one end and placed on mild steel sheet. The weights were gradually added to the extension plate until container filled with sample moved slightly from its place. The procedure was repeated for total mixed ration for three times. The coefficient of static friction was calculated using the following formula (Subramanian and Viswanathan, 2007) [11].

$$\mu=\frac{F_2-F_1}{N}$$

Where,
μ = Coefficient of the static friction
F_1 = Force to cause empty container to slide, N
F_2 = Force to cause filled container to slide, N
N = Sample Weight, N

Results and Discussion

The observation of the engineering properties of the total mixed ration in general showed that there were variations in the results of the observed variables. This variation is mainly due to the different proportion of binding agent percentage, as well as different proportion of roughage concentrate ratios of total mixed ration. While variations that occur at each observed variable of engineering properties was revealed by standard deviation.

Particle size is a significant feedstock variable which affects the quality and strength of blocks. Studies have shown that in order to make denser blocks, smaller particles sizes must typically be used when preparing total mixed rations. According to National Dairy Development Board (NDDB) in Anand, Gujarat, India, for making mixed cattle feed, various feed materials i.e., concentrates need to be mixed in the desired rations to prepare the total mixed rations which is subsequently ground into a uniform particle size of ≤ 3 mm. In this investigation, sieving was done with a screen size of 3 mm to guarantee the consistent particle size of mixture. The maximum size of feed mixture particles measured was less than 3 mm, and roughages ranged in length varied from 1-5 cm.

The moisture content of total mixed ration is important which affects the physico-chemical properties (Mahapatra *et al.* 2010) [7] and stability of fodder blocks. Determining the ideal moisture content of the mixture is crucial since the density and coefficient of friction depend on the moisture content of the entire mixed proportion (Shrinivasa *et al*., 2021) [10]. The average moisture content of the total mixed ration at various binding agent and roughage concentrate ratio is recorded and shown in Table 2. It was observed that the average moisture content at 5.0 percent binding agent was observed to be 8.31, 8.12 and 7.98 percent for roughage concentrate ratios of 50:50, 60:40 and 70:30 respectively. At 7.5 percent binding agent the average moisture content was found to be 8.64, 8.38 and 8.21 percent for roughage concentrate ratios 50:50, 60:40 and 70:30 respectively. In similar manner, at 10.0 percent binding agent the average moisture content was found to 8.81, 8.57 and 8.41 at the same above mentioned roughage concentrate ratio conditions, respectively. The decrease in percent of average moisture content of the ration was observed by increasing the roughage concentrate ratio. However, the increase in percent of average moisture content was noticed by increasing the binding agent from 5.0 to 10.0 percent at constant roughage concentrate ratio.

Co-efficient of Static friction is friction which is experienced when an object is placed on a surface. The static co-efficient friction of total mixed ration was determined with regards to mild steel surfaces as this material is mainly utilized for development of mould for block making machine. The main factor which affects the motion of surfaces in contact is friction and heat produced between particles in motion is caused by friction which increases power requirement. In order to select magnitude of power source required for fodder block making machine, one have an idea of co-efficient of friction the fodder mixture occurrence over mild steel surface. Hence, co-efficient of static friction of fodder mixture was found out using the co-efficient of friction apparatus. The measured average co-efficient of static friction values (Table 2) were 0.41, 0.46, 0.50; 0.44, 0.56, 0.58 and 0.64, 0.72, 0.79 for 5, 7.5 and 10 percent binding agent against the roughage concentrate ratio of 50:50, 60:40 and 70:30 respectively. The increase in average co-efficient of static friction of total mixed ration observed by increasing the roughage concentrate ratio. Also in the same manner, the increase in average co-efficient of static friction of total mixed ration was noticed by increasing the binding agent from 5 to 10 percent at constant roughage concentrate ratio.

Bulk density is important engineering properties to design the capacity of the functional components of fodder block making machine. The design of handling and storage systems for bulk materials necessitates data on bulk density (Jasmal *et al.* 2015) [6]. The measured average initial bulk density of total mixed ration at 5 percent binding agent was found to be 92.84, 72.17 and 55.78 kg m^{-3} for the roughage concentrate ratio of 50:50, 60:40 and 70:30 respectively. At 7.5 percent concentration binding agent, the mean initial bulk density was 110.74, 94.48 and 81.07 kg m^{-3} for the roughage-concentrate ratios of 50:50, 60:40 and 70:30 respectively. In similar way at 10 percent binding agent, the mean initial bulk density 123.69, 108.51 and 97.08 kg m^{-3} was observed for the roughage concentrate ratio of 50:50, 60:40 and 70:30 respectively. It was found from the above results that the initial bulk density of total mixed ration decreased with increase in roughage concentrate ratio. On the contrary, the initial bulk density of total mixed ration was increased by increasing the concentration of binding agent.

Table 1: Feed ingredients for making total mixed ration and their composition

Roughage-Concentrate ratio	50:50 (R_1)	60:40 (R_2)	70:30 (R_3)	50:50 (R_1)	60:40 (R_2)	70:30 (R_3)	50:50 (R_1)	60:40 (R_2)	70:30 (R_3)
Roughages (percent)									
Rice straw	22.50	27.50	32.50	21.25	26.25	31.25	20.00	25.00	30.00
Sorghum stover	22.50	27.50	32.50	21.25	26.25	31.25	20.00	25.00	30.00
Molasses	5.00	5.00	5.00	7.50	7.50	7.50	10.00	10.00	10.00
Concentrates (percent)									
Cereals –Maize	12.50	10.00	7.50	12.50	10.00	7.50	12.50	10.00	7.50
Wheat bran	18.50	14.80	11.10	18.50	14.80	11.10	18.50	14.80	11.10
Oil cake	17.50	14.00	10.50	17.50	14.00	10.50	17.50	14.00	10.50
Mineral mixture	1.00	0.80	0.60	1.00	0.80	0.60	1.00	0.80	0.60
Salt	0.50	0.40	0.30	0.50	0.40	0.30	0.50	0.40	0.30

Table 2: Engineering properties of total mixed ration with varying percentage of binding agent

Properties	Moisture content (%)			Co-efficient of static friction (μ)			Initial bulk density (kg m^{-3})		
Mixed Ration	**Mean**	**SD**	**CV**	**Mean**	**SD**	**CV**	**Mean**	**SD**	**CV**
R_1B_1	8.31±0.05	0.09	0.01	0.41±0.03	0.06	0.01	92.84±1.39	2.41	5.79
R_1B_2	8.64±0.06	0.10	0.01	0.44±0.04	0.07	0.01	110.74±1.54	2.66	7.08
R_1B_3	8.81±0.11	0.19	0.04	0.64±0.03	0.05	0.01	123.69±1.73	3.00	9.00
R_2B_1	8.12±0.09	0.15	0.02	0.46±0.01	0.02	0.01	71.17±1.74	3.01	9.03
R_2B_2	8.38±0.07	0.13	0.02	0.56±0.02	0.03	0.01	94.48±1.48	2.56	6.55
R_2B_3	8.57±0.11	0.19	0.03	0.72±0.11	0.18	0.03	108.51±1.18	2.04	4.16
R_3B_1	7.98±0.06	0.10	0.01	0.50±0.06	0.10	0.01	55.78±1.59	2.76	7.63
R_3B_2	8.21±0.14	0.24	0.06	0.58±0.08	0.13	0.02	81.07±1.76	3.05	9.29
R_3B_3	8.41±0.09	0.16	0.02	0.79±0.01	0.01	0.01	97.08±1.22	2.11	4.45

[R_1 – Roughage concentrate ratio (50:50), R_2 – Roughage concentrate ratio (60:40) and R_3 – Roughage concentrate ratio (70:30)]

[B_1 – Binding agent at 5.0%, B_2 – Binding agent at 7.5% and B_3 – Binding agent at 10.0%]

Conclusions

It was concluded from the present investigation that the at 10 percent binding agent with 50:50 roughage concentrate ratio the highest initial bulk density and moisture content were observed. However, the highest co-efficient of static friction was found at 10 percent binding agent with 70:30 roughage concentrate ratio. The decrease in percent of average moisture content and initial bulk density of the ration was observed by increasing the roughage concentrate ratio. On the contrary, the increase in average co-efficient of static friction of total mixed ration observed by increasing the roughage concentrate ratio.

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Conflict of Interest

The authors declare that they have no known competing monetary interests or special relationships that may affect the work reported in this article.

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