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RESEARCH ARTICLE

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Evaluation of the Physical Characteristics of Complete Feed Blocks Containing Different Binders

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ABSTRACT

Background: Binders play on important role in providing compactness and hardness to the complete feed block (CFB). Hardness of the block is also important to increase the durability of the block. In this view, the present comprehensive study is being taken up to evaluate the effect of different binders on the physical characteristics of the complete feed blocks.

Methods: The complete feed is formulated to contain 10.5% CP and 55% TDN based on ICAR-2013 requirements. Feed blocks were prepared with sorghum stover (Roughage to concentrate ratio 50:50) using different binders such as molasses (M), guar meal (GM) and condensed distillery soluble (CDS) at different levels @ 6%, 8% and 10%. The complete feed mixtures were densified into blocks in horizontal feed block-making machine at 1500 psi for a dwell time of one minute. The feed blocks were stored for 48 hr to dry and evaluated for the physical and drying characteristics.

Result: The bulk density and durability was higher (P<0.001) in M-8, M-10 and GM-10 feed blocks. The GM-8 blocks had higher bulk density (P<0.001) but less durable (P<0.001) than the other feed blocks. Durability and bulk density of GM-10 and M-10 blocks were comparable with M-8 feed blocks but the PCE of GM-10 and M-10 blocks was 11.61 and 10.75% higher than the M-8 blocks, respectively. CDS when included at 6, 8 or 10% as a binder, the blocks could not be prepared. Based on these results it was concluded that molasses at 8% is best for preparation of the CFBs.

Key words: Binder, Complete feed block, Stover.

INTRODUCTION

Complete feed blocks (CFBs) are solidified high density blocks comprising forage, concentrate and other supplementary nutrients in desired proportion capable to fulfill nutrient requirements of animals (Singh *et al.,* 2016). The feed block consists of five basic components *i.e* energy source, nitrogen source, mineral source, structural component and binder. Among these components, binder plays an important role to ensure the correct hardness and compactness to the feed blocks. The use of binders in feed blocks mainly aims to agglutinate the materials and, in contact with water, to form a moldable and malleable mixture, which becomes rigid and resistant after pressed and dried. Such hardness is intrinsic and depends on the type and concentration of binder used and this incorporation allows achieving important properties such as moldability, dimensional stability and adequate mechanical resistance (Furtado *et al.,* 2018). Solidification of the ingredients with a binder will ensure the animal consumes small amounts of the feed block over the day. This intake regulation will result in a controlled supply of nutrients to the animal, stimulate optimum rumen fermentation and thereby improving digestion of low quality diets (Salem and Smith 2008).

Several organic binders like molasses, wheat, starch and inorganic binders like cement, gypsum, bentonite, oxides of calcium and magnesium are in use as complete feed block binder. Among these binders molasses is most commonly used as a binder for densification of feed blocks but the procurement of molasses is difficult as it is an excise commodity so there is a need for alternative binder to molasses. For which, GM and CDS may be used as an alternative to the molasses.

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Guar meal is the by-product of guar gum industry consisting of guar germ material. Guar meal is rich source of protein and contains 50-55% CP and 75-80% TDN. Normally, guar gum is used as a thickener and stabiliser in food and pharmaceuticals and it also used as binder in animal feed preparation (Jongwe *et al.,* 2014). Due to the presence of this residual gum (12%) (Mohit and Sandeep, 2019), GM can be considered as a binder for preparation of complete feed blocks. CDS is a liquid co product of the ethanol industry. This by product sometimes is referred to “syrup” or “corn syrup.” Condensed distillers solubles are high in protein and energy and contain 6 to 20 per cent fat on a dry-matter basis (Sushmitha, 2019) and it is a good source of supplemental protein, phosphorus and trace minerals. It often is used as a ration conditioner and is very palatable. Keeping in this view, this study was conducted to evaluate the use of molasses, GM and CDS as binders in densification of CFBs at different levels on chemical composition, physical and drying characteristics of sorghum stover based complete feed blocks (SSCFB).

MATERIALS AND METHODS

The experiment was carried out at the College of Veterinary Science, PVNR Telangana Veterinary University, Rajendranagar, Hyderabad (17°12′ N, 78°18′ E, 545 m above sea level) during 2019 in India. Nine complete diets (mash form) were formulated with sorghum stover (SS) as sole roughage source and concentrate at 50:50 ratio consisting of either molasses or GM and condensed distillers soluble (CDS)as binders at 6.0, 8.0 or 10.0 percent. The complete feed was formulated to contain 10.5% CP and 55% TDN based on ICAR 2013 requirements. The blocks were prepared by compacting the feed materials (mash) in an iron mould into sizes of 15 × 15 × 10 cm using a specially designed semi-automatic hydraulic press fitted with a manual ejection system at a pressure of 1500 psi. The blocks were then taken out of the mould and allowed to dry under the Sun. The ingredient composition of experimental rations is presented in Table 1. The SSCFB containing different binders were subjected to the following physical tests *viz.*, bulk density, durability and post compression expansion (PCE) and drying characteristics such as initial and final moisture content.

The bulk density of the blocks was calculated by recording the dried weight of the blocks and their three (length × breadth × height) dimensions. Durability of the blocks was arrived by employing procedure of Butler and McColly (1959). The expansion of the blocks after compacting in the press was determined by recording the height of the feed blocks at different time intervals and compared to the initial height of the block (Berwal *et al.,* 1993). Initial moisture content was determined for a sample of freshly prepared mixture (pre-densification). The final moisture content of the blocks was determined after sun-drying for a period of 16 (8+8) daylight hours for two days. The samples of feed were analysed for proximate principles, as per the protocol described in AOAC (1997). Fiber fractions were determined as per the method of Van Soest *et al*. (1991). The data obtained in the study was subjected to analysis through software (Version 15.0; SPSS) by applying one-way analysis of variance. The treatment means were ranked using Duncan’s multiple range test with a significance at 5% level (Duncan, 1955). All the statistical procedures were done as per Snedecor and Cochran (1994).

RESULTS AND DISCUSSION

Chemical composition of experimental diets

The chemical composition (% DMB) of nine experimental diets containing different binders at different levels for selection of suitable binder is represented in Table 2. The percentages of OM, CP, EE, CF, NFE and TA in SSCFB ranged from 89.96 to 93.57; 10.20 to 11.45; 2.15 to

Table 1: Ingredient composition (per cent) of experimental diets containing molasses, guar meal and condensed distillers soluble (CDS) as binders at different levels.

Ingredient	M6	M8	M10	GM6	GM8	GM10	CDS6	CDS8	CDS10
Sorghum stover	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
Maize	12.8	7.4	6.1	41.6	38.4	39.4	12.0	12.5	13.0
Groundnut cake	9.0	9.0	9.3	1.8	0.0	0.0	5.6	5.1	4.4
Deoiled rice bran	21.6	25.0	24.0	0.0	3.0	0.0	25.8	23.8	22
Molasses	6.0	8.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0
Guar meal	0.0	0.0	0.0	6.0	8.0	10.0	0.0	0.0	0.0
CDS	0.0	0.0	0.0	0.0	0.0	0.0	6.0	8.0	10.0
Mineral mixture[1]	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Salt	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

M6: Molasses @ 6%; M8: Molasses @8%; M10: Molasses @ 10%; GM6: Guar meal@ 6%; GM8: Guar meal@ 8%; GM10: Guar meal@ 10%; CDS6: CDS @ 6%; CDS8: CDS @ 8%; CDS10: CDS@ 10% CDS: Condensed distillers soluble.

[1]Mineral mixture contained (per kg): Calcium 220g, Phosphorus 100g, Magnesium 40g, Iron6g, Zinc 2.2g, Copper 2g, Iodine 200mg, Cobalt 100mg, Vitamin B1 1300mg, Vitamin B6130mg, Vitamin B12 3000mg, Vitamin A 750000IU, Vitamin D3 150000 IU and Vitamin E 975 IU.

2.93;20.07 to 24.95; 52.32 to 60.32 and 6.44 to 10.04, respectively. Similarly, the percentages of NDF, ADF, hemicellulose, cellulose and ADL of the experimental diets ranged from 47.52 to 52.37; 27.41 to 32.39; 19.31 to 20.55; 23.17 to 25.24 and 3.66 to 5.64, respectively. The CP content (%) of the complete diet (10.20 - 11.45%) was fixed to meet the crude protein requirements of rams (25 kg) based on the recommendation of ICAR (2013) feeding standards. Incorporation of molasses, GM or CDS at different levels in concentrate mixtures did not affect the CP, EE, hemicelluose and cellulose content of the complete diets. The CF, TA, NDF and ADF content was lower and OM, NFE content was higher in GM incorporated diets, which could be due to higher inclusion of maize in these diets to balance for the energy and protein.

Physical and drying characteristics of sorghum stover based complete feed blocks with different binders

In the present study, CFBs with CDS as binder were not obtained at any inclusion level as it was unable to hold the feed particles together which might be due to the lower dry matter or higher moisture content in the CDS (70%) when compared to molasses (20-30%) (Satheesh, 2016). CFBs with CDS, resulted in poor block formation and the blocks were very fragile and very weak in intactness, such that it could not be handled, stored or transported. Another possibility for the fragile CFB may be due to lower soluble sugar content in CDS when compared to the molasses. The soluble carbohydrates in CDS are 47.87% (Satheesh, 2016) where as in molasses it is 85-90% (Perez. 1995). Hence, due to the lower content of soluble carbohydrates and low DM content in CDS, it failed to form the compact block. According to the current study, CDS is not suitable to make complete feed blocks. The physical and drying characteristics of SSCFB with molasses and GM is presented in Table 3 and 4, respectively and overall comparison among 6 diets is detailed in Table 5.

The bulk density (kg/m^3) of SSCFB with different binders (Table 5) varied from 487.74 to 579.69kg/m^3. With molasses as binder, significantly (P<0.01) lowest bulk

Table 2: Nutrient composition (%DM) of sorghum stover based complete feed blocks containing molasses, guar meal andcondensed distillers soluble (CDS) as bindersat different levels.

Constituent	M-6	M-8	M-10	GM-6	GM-8	GM-10	CDS-6	CDS-8	CDS-10
Proximate constituents									
Dry matter	88.00	91.55	91.72	90.43	91.8	88.36	89.91	88.15	88.73
Organic matter	90.91	90.50	90.61	93.57	93.19	93.47	89.96	90.03	90.09
Crude protein	10.22	10.21	10.20	10.24	10.62	11.45	10.22	10.26	10.25
Ether extract	2.61	2.69	2.89	2.30	2.15	2.22	2.47	2.72	2.93
Crude fibre	24.21	24.82	24.60	20.07	20.64	20.16	24.95	24.54	24.15
Nitrogen free extract	53.87	52.77	52.91	60.32	59.78	59.64	52.32	52.51	52.76
Total ash	9.09	9.50	9.39	6.44	6.81	6.53	10.04	9.97	9.91
Cell wall constituents									
Neutral detergent fibre	51.44	51.98	51.43	47.52	48.58	48.36	52.37	51.56	50.78
Acid detergent fibre	31.78	32.39	32.13	27.41	28.10	27.81	32.33	31.79	31.26
Hemicellulose	19.66	19.58	19.31	20.11	20.48	20.55	20.04	19.77	19.52
Cellulose	23.84	24.15	24.89	23.52	23.78	23.17	24.78	25.24	25.19
Acid detergent lignin	5.38	5.60	5.50	3.73	3.90	3.66	5.64	5.46	5.29

Each value is the average of duplicate analysis.

On dry matter basis except for dry matter.

M-6 -Molasses @ 6%; M-8- molasses @8%; M-10- molasses @ 10%; GM-6- Guar meal@ 6%; GM-8- Guar meal@ 8%; GM-10- Guar meal@ 10%; CDS-6 -CDS @ 6%; CDS-8-CDS @ 8%; CDS-10- CDS@ 10%.

Table 3: Physical and drying characteristics of sorghum stover based complete feed blocks with molasses as binder.

Attribute	M-6	M-8	M-10	SEM	P value
Bulk density (kg/m^3)	487.74^b	561.06^a	551.25^a	9.269	0.001
Durability (%)	14.16^b	29.09^a	26.91^a	2.605	0.033
Post compression expansion (%)	22.50^a	17.40^b	19.27^{ab}	0.772	0.017
Initial moisture (%)	12.11^b	12.44^b	15.27^a	0.459	0.001
Final moisture (%)	8.28^b	9.45^b	12.00^a	0.671	0.021

Each value is a mean of 8 observations.

SEM: Standard Error Mean; P: Probability value.

^{abc}Means with different superscripts in a row differ significantly: P≤0.05 and P≤0.01.

M-6 -Molasses @ 6%; M-8- Molasses @ 8%; M-10- Molasses @ 10%.

density was observed at 6% level compared to 8 and 10% inclusion levels and the bulk density in latter two groups was comparable. In case of CFBs with GM as binder, bulk density (kg/m^3) was comparable (P≥0.05) among three levels of GM addition. Between the binders, CFBs containing 6% molasses had significantly (P<0.01) lower bulk density than the other feed blocks. However, there was no significant difference in bulk density between the M-8, M-10, GM-6, GM-8 and GM -10 feed blocks. Samanta *et al*. (2003) recorded the bulk densities of CFBs with 10% molasses as 550-600 kg/m^3 corroborating with present results These findings were also within the range given by Hozhabri and Singhal (2006) with the wheat straw based CFBs with 10% molasses and the bulk density values were ranged from 422.48 to 550.25 kg/m^3. Current results are in agreement with Yasir *et al*. (2008), who recorded the bulk densities (kg/m^3) of paddy straw, maize stover and oats straw based CFBs as 533.76, 600.52 and 489.2, respectively. These values are also within the range given by Singh *et al.* (2016) where the bulk density of the rice straw and wheat straw based CFBs ranged from 484.4 kg/m^3 to 562.6 kg/m^3. The bulk density of the blocks of about 210 kg/m^3 was reported by Chaudhary *et al.* (2017) for paddy straw based CFBs containing kinnow-mandarin waste, which is very low as compared to the 450 kg/ m^3 density recommended by FAO (2012) for the straw based feed blocks.

The durability of SSCFB with different binders varied from 10.50 to 35.64 The CFB's containing 10% GM, 8 or 10% molasses had significantly (P<0.01) higher durability compared to other feed blocks. The durability in other feed blocks *i.e* prepared with 6% molasses and 6 or 8% GM was comparable. The durability of the blocks was increased with increasing level of binders in the diet. The results of the present study were in agreement with findings of Sushmitha (2019), who observed increased (P<0.05) durability of complete feed blocks with increased level of molasses in chickpea straw based complete feeds and highest durability was observed at 10% level. In corroboration with the present results, Edwin (2005) also reported higher durability values with inclusion of molasses at 10% level in SSCFB. In comparison to the present study, the durability values obtained by Singh *et al*. (2016) with wheat and rice straw, Sivajanani and Jeyalingawathani (2018) with rice straw and Hozhabri and Singhal (2006) with wheat straw were higher and the values varied from 70.3 to 91.32%. During densification process, due to the application of high pressures and temperatures, solid bridges may be developed by diffusion of molecules from one particle to another at the points of contact. In this study, low durability (%) of the CFBs might be due to the poor development of solid bridges between the feed particles as temperature rise during densification was negligible (Chaudhary *et al.,* 2017) or may be due to the inadequate pressure created by the feed block making machine (Saleem *et al.,* 2003).Similarly, higher durability was also recorded by Yasir *et al.* (2008) with paddy straw, maize stover and oats straw based CFB

Table 4: Physical and drying characteristics of sorghum stover based complete feed blocks with guar meal as binder.

Attribute	GM-6	GM-8	GM-10	SEM	P value
Bulk density (kg/m^3)	565.03	579.69	551.24	5.432	0.097
Durability (%)	10.50^b	17.67^b	35.64^a	2.445	0.001
Post compression expansion (%)	8.52^b	12.50^b	19.42^a	1.326	0.001
Initial moisture (%)	11.04	12.82	11.64	0.380	0.150
Final moisture (%)	6.85^b	6.62^b	7.97^a	0.245	0.033

Each value is a mean of 8 observations.

SEM: Standard error mean; P: Probability value.

^{abc}Means with different superscripts in a row differ significantly: P≤0.05.

GM-6- Guar meal@ 6%; GM-8- Guar meal@ 8%; GM-10- Guar meal@ 10%.

Table 5: Over all physical and drying characteristics of the sorghum stover based complete feed blocks containing molasses and guar meal as binders at different levels.

Parameter	M-6	M-8	M-10	GM-6	GM-8	GM-10	SEM	P value
Bulk density (kg/m^3)	487.74^b	561.06^a	551.25^a	565.03^a	579.69^a	551.24^a	5.803	0.001
Durability (%)	14.16^b	29.09^a	26.91^a	10.50^b	17.67^b	35.64^a	1.774	0.001
Post compression expansion (%)	22.50^a	17.40^a	19.27^a	8.52^c	12.5^b	19.42^a	0.885	0.001
Initial moisture (%)	12.11^{bc}	12.44^{bc}	15.27^a	11.04^c	12.82^b	11.64^{bc}	0.328	0.001
Final moisture (%)	8.28^{bc}	9.45^b	12.00^a	6.85^c	6.62^c	7.97^{bc}	0.411	0.001

Each value is a mean of 8 observations.

SEM: Standard error mean; P: Probability value.

^{abc}Means with different superscripts in a row differ significantly: P≤0.001.

M-6 -Molasses @ 6%; M-8- Molasses @8%; M-10- Molasses @ 10% ; GM-6- Guar meal@ 6%. GM-8- Guar meal@ 8%; GM-10- Guar meal@ 10%.

as 76.83, 78.74 and 70.16%, respectively and higher durability in this study might be due to the inclusion of tree leaves at higher proportion (30%) or due to the urea treatment of test crop residues for preparation of feed blocks that lead to low resilience characteristics resulting in low PCE and high durability of straw based feed blocks. Moreover, tree leaves are rich in soluble carbohydrates and proteins that might have acted as additional binding agents. The durability of the paddy straw based complete feed blocks containing kinnow-mandarin waste as reported by Chaudhary *et al.* (2017) was 17.36%.

Post compression expansion (%) of sorghum stover based complete feed blocks with molasses and guar meal as binders (Table 5) ranged from 8.52 to 22.50. The sorghum stover based complete feed blocks with 6% GM had significantly lower (P<0.01) PCE of the 8.52% followed by GM-8 feed blocks (12.50%) and there was no significant variation in the PCE of M-6, M-8, M-10 and GM-10 based complete feed blocks. Variations in PCE of complete feed blocks might be attributed to the different resilience characteristics of roughage sources and also to the moisture content of material, which determines the resiliency of the compacted briquette (Yasir *et al*., 2008). Low (P<0.01) PCE in GM-6 and GM-8 feed blocks may be due to low final moisture content in the feed blocks. Sushmitha (2019) also recorded similar range of PCE (12.81 to 19.65%) for chickpea straw based complete feed blocks prepared with molasses (5, 7.5 and 10% level) as binder. While Singh *et al*. (2016) observed higher PCE (28.18 to 37.79%) for wheat and rice straw based complete feed blocks. Similarly, Samanta *et al.* (2004) and Hozhabri and Singhal (2006) also recorded higher PCE for wheat straw based complete feeds (35.4% and 45.6%, respectively) than blocks with other roughages which could be attributed to the higher capacity of wheat straw particles to attain their original shape than those of other roughage sources after the removal of pressure.

Initial moisture (%) of SSCFB with two different binders (molasses and guar meal) ranged from 11.04to 15.27 (Table 5). Significantly (P<0.01) highest initial moisture (%) was recorded with the blocks containing 10% molasses (M-10) and lowest (P<0.01) was observed at 6% guar meal (GM-6). Strength and durability of the densified products increased with increasing moisture content until an optimum is reached. Reece (1966) found that, alfalfa hay with moisture contents of 10 to 23% produced wafers with durability of 80 to 90%. He observed that it was difficult to make wafers when the moisture content was 25% and above. At high moisture, probably due to the incompressibility of water, moisture trapped within the particles may prevent complete flattening and the release of natural binders from the particles (Pickard *et al*., 1961). The moisture content in the current study was within range as prescribed by Reece (1966) and it can be considered as an optimum for making of durable complete feed blocks. Sushmitha (2019) reported significantly (P<0.05) higher initial moisture (%) at 10 per cent molasses with the chick pea straw based complete feed blocks and the values were ranged from 11.66 to 17.85% corroborating with the present findings. Chaudhary *et al.* (2017) reported higher initial moisture (23.07%) for paddy straw based complete feed blocks containing kinnow-mandarin waste (KMW) which could be due to hygroscopic nature of KMW.

Final moisture (%) of sorghum stover based complete feed blocks with two different binders (Table 5) ranged from 6.62 to 12.00. The SSCFB with 10% molasses (M-10) as binder had significantly (P<0.01) higher final moisture (12%) than the other feed blocks**.** The final moisture (%) content is relatively higher in molasses based CFBs when compared to GM based feed blocks which may be due to the hygroscopic nature of molasses. Final moisture level of the blocks achieved in the present study after 16 h drying was optimum for safe storage (6-12%). The present results are in agreement with the values reported by Chaudhry *et al*. (2017) for paddy straw based complete feed blocks (12.13%). Similar results were also reported by Sushmitha (2019) with chick pea straw based CFBS and the values were ranged from 10.20 to 10.37%. Edwin (2005) recorded higher final moisture (%) when compared to the present study with sorghum stover blocks with molasses as binder and values were varied from 18.76 to 21.85% which could be due to the hygroscopic nature of molasses which makes it difficult to dry under humid conditions.

The binder which produced the blocks with higher bulk density and durability along with lower PCE was selected as the best binder. The bulk density and durability was higher (P<0.001) in M-8, M-10 and GM-10 feed blocks. The GM-8 blocks had higher bulk density (P<0.001) but less durable (P<0.001) than the other feed blocks. Durability and bulk density of GM-10 and M-10 blocks were comparable with M-8 feed blocks but the PCE of GM-10 and M-10 blocks was 11.61 and 10.75% higher than the M-8 blocks, respectively. As per the cost economics molasses (Rs. 6/kg) is cheaper than the guar meal (Rs.35/kg). By considering all these parameters we have selected molasses at 8% as a best binder for preparation of the feed blocks.

CONCLUSION

Based on the results of the present study it was concluded that molasses at the level of 8% is optimum for preparation of complete feed blocks with sorghum stover. However, in case of non-availability of the molasses, guar meal at 10% can be used as binder alternatively, as the physical characteristics of guar meal were comparable to that of molasses.

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