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Study of physical and drying characteristics of complete feed blocks

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Abstract
The present study was conducted onthe chickpea straw based complete feed blocks with 20 percent tree leaves were prepared to select the suitable binder between molasses and condensed distillers soluble (CDS) at 5.0, 7.5 and 10.0 percent levels. Feed blocks could not be prepared with CDS at all the three levels. Based on the physical and drying characteristics of the complete feed blocks with varying levels of molasses addition, 10 percent addition of molasses had given better feed blocks in terms of bulk density, durability, drying rate, post compression expansion and initial moisture.

Keywords: Bulk density, durability, drying rate

Introduction
Densified complete feed blocks could play an important role in providing balanced rations to livestock in the tropical regions of green forage scarcity. The technology offers a means to increase milk production, decrease in environmental pollutants, increase in income of farmers, decrease in labour requirement and time for feeding and reduction in transportation cost of straw. Binder is necessary in order to solidify the blocks. Liquid binder such as a condensed byproduct from the grain, food or feed processing industries including, for example, Brewex (a condensed molasses-like by-product of the brewing industry), corn steep liquor, condensed porcine solubles, molasses, or condensed distillers solubles will leave the core particles in a damp condition suitable for mixing with a trace mineral and dry binder base mix in block making.

Materials and Methods
Preparation of complete feed blocks with different binders
The chick pea straw was ground in cutter cum grinder and complete diet was prepared by incorporating concentrate mixture. LL leaf meal and AL leaf meal, respectively.
To prepare the blocks, the following two binding materials were tested, *viz.*
a. Molasses
b. CDS

The binders were added at three different levels of 5, 7.5 and 10 percent of the weight of the straw. The blocks were prepared by compacting the materials in an iron mould into sizes of 30 x 30 x 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. Suitable binder was selected based on the physical and drying characteristics.

Determination of physical characteristics of chick pea straw based complete feed blocks
The chickpea straw based blocks were subjected to the following physical tests: bulk density, relative hardness, Durability and post compression expansion.

1 Bulk density
The bulk density of the blocks was calculated by recording the dried weight of the blocks and their three (length x breadth x height) dimensions; and was expressed as the weight per unit volume of the block.

2 Durability

The durability of the blocks was arrived by dropping each block from a height of 2 m on to a concrete floor and recording the weight of the intact block (Butler and Colly, 1959) [3]. This procedure was repeated four times and the final weight that remained intact as a block was noted down. The percent of weight retained to the original weight of the block was expressed as the durability of the block.

3 Post-compression expansion

The expansion of the blocks after compacting in the press was determined by recording the height of the blocks at different time intervals and compared to the initial height of the block (Berwal *et al*., 1993) [2]. Chaffing of chickpea straw was mainly done to reduce the post-compression expansion of the blocks.

4 Determination of drying characteristics

The following drying characteristics of chickpea straw based blocks with different binders were determined: a) initial moisture content b) final moisture content and c) drying rate.

a. Initial and final moisture content

The freshly prepared blocks were placed on concrete floor under direct sunlight and allowed to dry for a period of 16 (8+8) daylight hours for two days. The moisture content of the blocks was then determined as the final moisture content.

b. Assessment of drying rate

To assess the drying rate, the blocks were weighed at every half an hour for 8 daylight hours per day for two days; totaling 16 hours of drying time under the Sun. The total weight loss or moisture evaporated was then calculated as drying rate expressed in g H_2O/hr/kg DM.

Results

As per the objectives of the study, an experiment was designed so as to select the suitable binder among molasses and CDS at 5.0, 7.5 and 10.0 percent levels for preparation of chick pea straw based complete feed blocks with inclusion of tree leaves. Whereas, based on the results of the *in vitro* gas study, 30 percent replacement of concentrate with tree leaves i.e. LL and AL separately was considered as the best level of inclusion of tree leaves. During the course of preparation of chick pea straw based complete feed blocks with 30 percent inclusion of tree leaves, a perfect block could not be formed due to lack of intactness among the particles, hence the level of inclusion was fixed at the next level i.e. 20 percent inclusion of tree leaves. In case of complete feed blocks preparation with CDS as binder at different levels i.e. 5.0, 7.5 and 10.0 percent, the blocks were not formed in good condition. Blocks were very fragile, very weak in intactness, such that they could not be handled, stored or transported. The feed blocks formed using CDS as binder did not fulfill the requirements of complete feed block, thus complete feed blocks with only molasses as binder were prepared and physical characteristics were determined.

1 Control complete feed blocks

a Bulk density (kg/m^3)

Bulk density (kg/m^3) of chickpea straw based complete feed blocks with addition of molasses as binder at three different levels i.e., 5.0, 7.5 and 10.0 percent, respectively is presented in Table Bulk density (kg/m^3) of those blocks ranged from 458.38 to 582.54 and the variation among the feed blocks at three different levels 5.0,7.5 and 10.0 percent with regard to bulk density was significant (p<0.01). It was higher at 10.0 percent of molasses addition.

b. Post compression Expansion (PCE)

Post compression expansion (%) of chickpea straw based complete feed blocks with addition of molasses as binder at three different levels i.e. 5.0, 7.5 and 10.0 percent, respectively is presented in Table. PCE (%) of those blocks ranged from 13.44 to 19.65 and the variation among the feed blocks at three different levels 5.0,7.5 and 10.0 with regards to PCE was significant (p<0.01). It was higher at 10.0 percent of molasses addition.

c. Durability (%)

Durability (%) of chickpea straw based complete feed blocks with addition of molasses as binder at three different levels i.e.5.0, 7.5 and 10.0 percent, respectively is presented in Table. Durability (%) of those blocks ranged from 13.33 to 42.67 and the variation among the feed blocks at three different levels 5.0, 7.5 and 10.0 with regards to durability was significant (p<0.01). It was higher at 10.0 percent molasses addition.

d. Drying rate (g H_2o/h/kg DM)

Drying rate (g H_2o/h/kg DM) of chickpea straw based complete feed blocks with addition of molasses as binder at three different levels i.e.5.0, 7.5 and 10.0 percent, respectively is presented in Table. Drying rate of those blocks ranged from 44.22 to 66.25 (g H_2o /h/kg DM) and the variation among the feed blocks at three different levels of 5.0, 7.5 and 10.0 percent with regards to drying rate was significant. (p<0.01). It was higher at 5.0 percent molasses addition.

e. Initial moisture (%)

Initial moisture (%) of chickpea straw based complete feed blocks with addition of molasses as binder at three different levels i.e. 5.0, 7.5 and 10.0 percent, respectively is presented in Table. Initial moisture content of those blocks ranged from 12.03 to 17.85 and the variation among the feed blocks at three different levels 5.0,7.5 and 10.0 percent with regards to initial moisture was significant (p<0.01). It was higher at 10.0 percent molasses addition.

f. Final moisture (%)

Final moisture (%) of chickpea straw based complete feed blocks with addition of molasses as binder at three different levels i.e. 5.0, 7.5 and 10.0 percent, respectively is presented in Table. Final moisture content of those blocks ranged from 10.20 to 10.37 and the variation among the feed blocks at three different levels 5.0, 7.5 and 10.0 percent with regards to final moisture was not significant ($p \geq 0.05$). It was similar at the three levels of molasses addition.

2. Complete feed blocks with LL tree leaves

a. Bulk density (kg/m^3)

Bulk density (kg/m^3) of chickpea straw based complete feed blocks along with incorporation of LL leaves with addition of molasses as binder at three different levels i.e. 5.0, 7.5 and 10.0 percent, respectively is presented in Table Bulk density (kg/m^3) of those blocks ranged from 465.43 to 579.41 and the variation among the feed blocks at three different levels 5.0, 7.5 and 10.0 with regards to bulk density was significant (p<0.01). It was higher at 10.0 percent of molasses addition.

b. Post compression Expansion

Post compression expansion (%) of chickpea straw based complete feed blocks along with incorporation of LL leaves with addition of molasses as binder at three different levels i.e. 5.0, 7.5 and 10.0 percent, respectively is presented in Table. Post compression expansion (%) of those blocks ranged from 12.81 to 18.33 and the variation among the feed blocks at three different levels 5.0,7.5 and 10.0 with regards to post compression expansion was significant.($p<0.01$).It was higher at 10.0 percent of molasses addition.

c. Durability (%)

Durability (%) of chickpea straw based complete feed blocks along with incorporation of LL leaves with addition of molasses as binder at three different levels i.e.5.0, 7.5 and 10.0 percent, respectively is presented in Table. Durability of those blocks ranged from 10.86 to 41.27 and the variation among the feed blocks at three different levels 5.0,7.5 and 10.0 with regards to durability was significant ($p<0.01$). It was higher at 10.0 percent molasses addition.

d. Drying rate (g H_2o/h/kg DM)

Drying rate (g H_2o/h/kg DM) of chickpea straw based complete feed blocks along with incorporation of LL leaves with addition of molasses as binder at three different levels i.e.5.0, 7.5 and 10.0 percent, respectively is presented in Table. Drying rate (g H_2o/h/kg DM) of those blocks ranged from 43.41 to 67.24 and the variation among the feed blocks at three different levels 5.0,7.5 and 10.0 percent with regards to drying rate was significant. ($p<0.01$). It was higher at 5.0 percent molasses addition.

e. Initial moisture (%)

Initial moisture (%) of chickpea straw based complete feed blocks along with incorporation of LL leaves with addition of molasses as binder at three different levels i.e. 5.0, 7.5 and 10.0 percent, respectively is presented in Table. Initial moisture of those blocks ranged from 12.03 to 17.5 and the variation among the feed blocks at three different levels 5.0, 7.5, and 10.0 percent with regards to initial moisture was significant ($p<0.01$). It was higher at 10.0 percent molasses addition.

f. Final moisture (%)

Final moisture (%) of chickpea straw based complete feed blocks along with incorporation of LL leaves with addition of molasses as binder at three different levels i.e. 5.0, 7.5 and 10.0 percent, respectively is presented in Table. Final moisture of those blocks ranged from 10.20 to 10.37 and variation among the feed blocks at three different levels 5.0, 7.5 and 10.0 percent with regards to final moisture was not significant ($p\geq0.05$). It was similar at the three levels of molasses addition.

3. Complete feed blocks with AL leaf meal

a. Bulk density (kg/m^3)

Bulk density (kg/m^3) of chickpea straw based complete feed blocks along with incorporation of AL leaves with addition of molasses as binder at three different levels i.e. 5.0, 7.5 and 10.0 percent, respectively is presented in Table. Bulk density (kg/m^3) of those blocks ranged from 434.15 to 527.45 and the variation among the feed blocks at three different levels 5.0, 7.5 and 10.0 with regards to bulk density was significant ($p<0.01$). It was higher at 10.0 percent of molasses addition.

b. Post compression expansion

Post compression expansion (%) of chickpea straw based complete feed blocks along with incorporation of AL leaves with addition of molasses as binder at three different levels i.e. 5.0, 7.5 and 10.0 percent, respectively is presented in Table. Post compression expansion (%) of those blocks ranged from 13.88 to 17.48 and the variation among the feed blocks at three different levels 5.0, 7.5 and 10.0 with regards to post compression expansion was significant ($p<0.01$). It was higher at 7.5 and 10.0 percent of molasses addition.

c. Durability (%)

Durability (%) of chickpea straw based complete feed blocks along with incorporation of AL leaves with addition of molasses as binder at three different levels i.e.5.0, 7.5 and 10.0 percent, respectively is presented in Table. Durability of those blocks ranged from 12.08 to 43.03 and the variation among the feed blocks at three different levels 5.0, 7.5 and 10.0 with regards to durability was significant ($p<0.01$). It was higher at 10.0 percent molasses addition.

d. Drying rate (g H_2o/h/kg DM)

Drying rate (g H_2o /h/kg DM) of chickpea straw based complete feed blocks along with incorporation of AL leaves with addition of molasses as binder at three different levels i.e.5.0, 7.5 and 10.0 percent, respectively is presented in table. Drying rate (g H_2o /h/kg DM) of those blocks ranged from 44.07 to 67.45 and the variation among the feed blocks at three different levels 5.0, 7.5 and 10.0 percent with regards to drying rate was significant ($p<0.01$). It was higher at 5.0 percent molasses addition.

e. Initial moisture (%)

Initial moisture (%) of chickpea straw based complete feed blocks along with incorporation of AL leaves with addition of molasses as binder at three different levels i.e. 5.0, 7.5 and 10.0 percent, respectively is presented in Table. Initial moisture of those blocks ranged from 11.66 to 15.27 and the variation among the feed blocks at three different levels 5.0, 7.5 and 10.0 percent with regards to initial moisture was significant ($p<0.01$). It was higher at 10.0 percent molasses addition.

f. Final moisture (%)

Final moisture (%) of chickpea straw based complete feed blocks along with incorporation of AL leaves with addition of molasses as binder at three different levels i.e. 5.0, 7.5 and 10.0 percent, respectively is presented in Table. Final moisture of those blocks ranged from 10.30 to 10.33 and the variation among the feed blocks at three different levels 5.0, 7.5 and 10.0 percent with regards to final moisture was not significant ($p\geq0.05$). It was similar at the three levels of molasses addition.

Table 1: Physical characteristics of chickpea straw based complete feed blocks (Control feed blocks)

Parameter	CM1	CM2	CM3	SEM	P value
Bulk density (kg/m$^{3)}$	458.38^{c}±1.5	514.24^{b}±2.79	582.54^{a}±4.11	8.75	0.001
Post compression expansion (%)	13.44^{c}±1.08	16.29^{b}±0.37	19.65^{a}±0.57	0.60	0.001
Durability (%)	13.33^{c}±0.06	24.02^{b}±0.26	42.67^{a}±0.17	2.05	0.001
Drying rate (g H_20/h/kg DM)	66.25^{a}±0.02	59.64^{b}±0.01	42.22^{c}±0.06	1.71	0.001
Initial moisture (%)	12.03^{c}±0.05	13.73^{b}±0.18	17.85^{a}±0.03	0.42	0.001
Final moisture (%)	10.20±0.06	10.33±0.09	10.37±0.07	0.04	0.276

CM1 –molasses @ 5%; CM2- molasses @ 7.5%; CM3- molasses @ 10%
^{a,b,c}Means with different superscripts in a sub column differ significantly:, p<0.01.
SEM: Standard Error Mean; P value: Probability value

Table 2: Physical characteristics of chickpea straw based complete feed blocks with incorporation of LL leaves

Parameter	SM1	SM2	SM3	SEM	P value
Bulk density (kg/m^{3})	465.43^{c}±1.12	514.72^{b}±1.08	579.41^{a}±1.02	7.91	0.001
Post compression expansion (%)	12.81^{c}±0.39	16.07^{b}±0.32	18.33^{a}±0.18	0.42	0.001
Durability (%)	10.86^{c}±0.06	26.80^{b}±0.09	41.27^{a}±0.09	2.10	0.001
Drying rate (g H_20/h/kg DM)	67.24^{a}±0.02	60.01^{b}±0.01	43.41^{c}±0.05	1.69	0.001
Initial moisture (%)	12.03^{c}±0.05	13.73^{b}±0.18	17.85^{a}±0.03	0.42	0.001
Final moisture (%)	10.20±0.06	10.33±0.09	10.37±0.07	0.04	0.276

^{a,b,c}Means with different superscripts in a sub column differ significantly: p<0.01.
SEM: Standard Error Mean; P value: Probability value;
SM1 –Molasses @ 5%; SM2- Molasses @7.5%; SM3- Molasses @ 10%.

Table 3: Physical characteristics of chickpea straw based complete feed blocks with incorporation of AL leaves

Parameter	AM1	AM2	AM2	SEM	P value
Bulk density (kg/m$^{3)}$	434.15^{c}±0.85	484.40^{b}±1.28	527.45^{a}±0.60	6.47	0.001
Post compression expansion (%)	13.88^{b}±0.32	17.32^{a}±1.04	17.48^{a}±0.26	0.46	0.001
Durability (%)	12.08^{c}±0.09	22.93^{b}±0.11	43.03^{a}±0.07	2.17	0.001
Drying rate (g H_20/h/kg DM)	67.45^{a}±0.02	60.36^{b}±0.01	44.07^{c}±0.05	1.65	0.001
Initial moisture (%)	11.66^{c}±0.05	12.92^{b}±0.07	15.27^{a}±0.05	0.26	0.001
Final moisture (%)	10.30±0.02	10.32±0.04	10.33±0.03	0.02	0.797

^{a,b,c}Means with different superscripts in a sub column differ significantly: p<0.01.
SEM: Standard Error Mean; P value: Probability value;
AM1 –Molasses @ 5%; AM2- Molasses @ 7.5%; AM3- Molasses @ 10%

Discussion

Complete feed blocks are solidified high density blocks comprising forage, concentrate and other supplementary nutrients in desired proportion capable to fulfill nutrient requirements of animals (Pankaj Kumar Singh *et al*., 2016) [12]. The hardness can be controlled by changing the proportions of the ingredients, such as increasing the percentage of molasses, or reducing the percentage of the gelling agent or binder (Makkar *et al*. 2007) [7].

Molasses is high in energy as concentrated form of 'fermentable carbohydrates' and provides a range of trace minerals and a complete mixture of vitamins. In addition to the nutritional role, this by-product is considered as a binder, which renders the block sticky, and increases its palatability (Salem and Nefzaoui, 2003) [8]. Condensed distillers solubles are a liquid co product of the ethanol industry. This byproduct sometimes is referred to "syrup" or "corn syrup." Condensed distillers solubles are high in moisture and must be handled with pumps and tanks. Condensed distillers solubles are high in protein and energy and contain 6 to 20 percent fat on a dry-matter basis. Condensed distillers solubles are a good source of supplemental protein, phosphorus and trace minerals. It often is used as a ration conditioner and is very palatable.

Chemical composition of diets used in binder study

The dry matter percentage of complete feed blocks ranged from 87 to 91. The chemical composition of the experimental diets was similar with respect to tree leaves and binder each separately. Similar observations were reported by Samanta *et al*. (2003) [10] with regard to complete diets formulated with 60:40 roughage concentrate ratio including LL leaf meal in the concentrate part. Contrarily, Raghuvansi *et al.* (2007) [4] reported that the inclusion of tree leaves increased CP and lignin content, but reduced organic matter content.

2. Physical and drying characteristics of complete feed blocks

Earlier, the chick pea straw based complete feed blocks with 30% tree leaves were prepared based on the results of the *in vitro* gas study with respect to the level of tree leaves inclusion. But due to the lack of intactness among the particles of the tree leaves and with other particles, the blocks could not be formed. Hence, the next level of inclusion of tree leaves i.e. 20% was included in the chick pea straw based complete feed blocks. Another experiment was planned to arrive at the suitable binder between molasses and Condensed distillers soluble at the best level of inclusion i.e. 5.0, 7.5 and 10.0 percent in the chick pea straw based complete feed blocks with incorporation of two types of tree leaves LL and AL at 20% separately. Physical and drying characteristics of those blocks were estimated to arrive at the best level of binder. But during the preparation of feed blocks with condensed distillers soluble as binder, it was found out practically that, complete feed block could not be prepared as condensed distiller soluble could not give minimum intactness or binding at all the levels i.e. 5.0, 7.5 and 10.0 percent which was necessary for block formation. This might be due to the lower dry matter or higher moisture content in the condensed distillers solubles when compared to molasses. In case of complete feed blocks preparation started using CDS, block was not formed in good condition. Block was very fragile, very weak in intactness, such that it could not be handled, stored or transported. Reported that the soluble carbohydrates in CDS as 47.87% and it was reported that the soluble sugars in molasses as 85-90% by Perez (1995). Hence, due to the lower content of soluble carbohydrates in CDS it was unable to prepare a complete feed block with CDS as binder and the feed block formed using CDS as binder did not fulfill the requirements of complete feed block.

a. Bulk density (kg/m^3)

Bulk density (kg/m3) of the chickpea straw based complete feed blocks (control) with addition of molasses as binder at 3 different levels 5.0,7.5 and 10.0 percent ranged from 458.38 to 582.54. Bulk density was significantly (p<0.05) higher at 10 percent of molasses addition. Bulk density (kg/m^3) of chickpea straw based complete feed blocks along with incorporation of LL leaves with addition of molasses as binder at three different levels i.e., 5.0, 7.5 and 10.0 percent ranged from 465.43 to 579.41. The bulk density was significantly (p<0.05) higher at 10 percent of molasses addition. The choice of appropriate binder and its proportion in the ingredient mixture is important. A harder block makes the animal lick the feed block continuously. This releases small amounts of the main nutrients relatively continuously into the rumen, in short bursts depending on the licking frequency, which would be catalytic for microbial activity and stimulate digestion of poor quality feedstuffs. Moreover, this also avoids urea intoxication (Makkar *et al.*, 2007) [7]. Bulk density (kg/m^3) of chickpea straw based complete feed blocks along with incorporation of AL leaves with addition of molasses as binder at three different levels i.e., 5.0, 7.5 and10.0 percent ranged from 434.15 to 527.45.The bulk density was significantly (p<0.05) higher at 10 percent of molasses addition.

Similar values for the bulk density of the complete feed block with molasses as binder at 10 percent inclusion were reported as550–600 kg/m^3.The increase in the bulk density of the complete feed blocks was 3.3–3.9 times (Samanta *et al*., 2003) [10]. Sihag *et al*. (1991) [11] who also noticed 3.19–3.83 times higher bulk density during densification of roughage-based complete feed. Hozhabri and Singhal (2006) [6] reported similar results that the bulk density of complete feeds containing wheat straw and concentrate mixture in 60:40 ratio (CF1), 40% of wheat straw in CF1, replaced by sugar cane bagasse (w/w) (CF2) or the untreated mustard cake in CF2, replaced by formaldehyde treated mustard cake (CF3) were on densification increased to 422.48, 550.25 and 549.37 kg/m^3.

Samanta *et al*. (2004) [9] reported similar pattern of bulk density (kg/m^3) of complete feed based on wheat straw (Roughage: Concentrate, 6O:40) and concluded that bulk density was a function of hydraulic pressure as well as type of roughage used in making the complete feed blocks. Singh *et al*. (2004) [9] reported higher bulk density of Sugarcane bagasse based complete feed *block* (567.5 kg/m^3).The differences in the weight, thickness and durability may be attributed to the differences in the bulk density of the roughages and roughages cum concentrate mixtures.

Similar results were also found that with molasses as binder, the bulk density of sorghum straw blocks varied from 71.07 to 88.66 kg/m^3. The sorghum straw blocks with molasses 5%, had significantly higher (p<0.05) bulk density of 86.50 kg/m^3 (Berty Edwin. 2005) [5]. With molasses as binder, the bulk density of ragi straw blocks varied from 61.61 to 71.29 kg/m^3. The ragi straw blocks with molasses (5%), as binder had significantly higher (p<0.05) bulk density of 68.59 kg/m^3. Such difference may be attributed to the difference in particle size of these roughages, which is largely influenced by their processing (Berty Edwin. 2005) [5].

The highest bulk density (562.2kg/m^3) was observed in rice straw (50% inclusion level) based complete feed block. (Singh, 2016) [12]. The blocks made by hydraulic press (pressure of 300 kg/cm^2 and moisture content of 12%) resulted in increase in bulk density or decrease in volume (Bakshi *et al*, 2018) [1]. The bulk density of the blocks of about 210 kg/m^3 was reported by Sonu Chaudhary *et al* (2017) [4] for paddy straw based complete feed blocks containing kinnow-mandarin waste, which is very poor as compared to the 450 kg/ m^{3}density recommended by FAO (2012) for the straw-based feed blocks.

b. Post compression expansion

Post compression expansion (PCE) (%) of chickpea straw based complete feed blocks with addition of molasses as binder at 5.0,7.5 and10.0 percent, respectively with regards to control, LL leaves and AL leaves separately was significant (p<0.005) and it was higher at 10 percent molasses addition.

These results are similar to that as no significant variation was observed in the PCE of molasses based blocks at all levels of concentration with regards to sorghum straw blocks (16.06 to 18.56) (Singh *et al.* (2016) [12]. The PCE of ragi straw blocks varied from16.36 to 19.44% with addition of molasses as binder and indicating PCE was highest at 10% concentration (Edwin, 2005) [5]. It can be seen from the results that the PCE of the blocks was generally higher with higher molasses when compared to other binders. Similar results were reported by Hozhabri and Singhal (2006) [6] with wheat straw and concentrate at 60:40 ratio of complete feeds. This difference observed in PCE of blocks may be attributed to variation in level of binder in the feed block.

c. Durability

The durability of chick pea straw based feed blocks with regards to control or LL leaves or AL leaves was significantly different (p<0.05) with different molasses levels and it was higher at 10 percent molasses level.

In corroboration with the present results, Singh *et al.* (2016) [12] reported that durability of sorghum straw blocks varied from 9.59 to 74.20% and the higher levels of concentration of molasses had significant effect (p<0.01) on the durability of the blocks. The durability was highest at 10% concentration. In contrast to our results, durability of about 91.32% was reported for rice straw based complete feed blocks for cattle by Sivajanani and Jeyalingawathani (2018) [13]. The durability of the blocks was poor as 17.36% for paddy straw based complete feed blocks containing kinnow-mandarin waste reported by Chaudhary *et al.* (2017) [4], indicating poor binding. It has been suggested that 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. Solid bridges may also be formed between particles due to crystallization of some ingredients, chemical reaction, hardening of binders, and solidification of melted components.

d. Drying rate (g H_2o/hr/kg DM)

The drying rate (g H_2o/hr/kg DM) of chickpea straw based complete feed blocks of control, LL and AL tree leaves with addition of molasses at 5.0,7.5 and 10 percent level was significantly (p<0.01) different and it was higher at 5.0 percent molasses level of addition. The drying rate of molasses based blocks was significantly slower (p<0.01) at higher concentrations. In accordance with the present results, Sonu Chaudhary *et al.* (2017) [4] reported that, the sorghum straw blocks with molasses (5%), as binders had significantly higher (p<0.05) drying rate 53.88. Drying rate 10.13 g H_2O/h/ kg DM was reported by (Chaudhary *et al*. 2017) [4] for paddy straw based complete feed blocks containing kinnow-mandarin waste and the drying rate of ragi straw block varied from 47.09 to 53.93g H_2O/h/ kg DM.

e. Initial moisture (%)

The initial moisture (%) of chickpea straw based complete control feed blocks with inclusion of LL and AL tree leaves and addition of molasses at 5.0,7.5 and10.0 percent was significantly (p<0.01) higher at 10 percent molasses addition. Similar findings were reported with sorghum straw block and it was varied from 51.53 to 52.47 which was higher at 10 percent concentration. Sonu Chaudhary *et al*. (2017) [4] reported the initial moisture content of ragi straw blocks varied from 51.14 to 52.55 and about 23.07% for paddy straw based complete feed blocks containing kinnow-mandarin waste.

f. Final moisture (%)

The final moisture (%) of chickpea straw based complete feed blocks of control, LL leaves and AL leaves with addition of molasses at 5.0, 7.5 and 10.0 percent was not significant (p>0.05).

The present results are in agreement with the values reported by Chaudhry *et al.* (2017) [4] for paddy straw based complete feed blocks. In contrast to the present results, the sorghum straw blocks with molasses (5%) as binders had significantly lower (p<0.05) final moisture content i.e. 18.76% and the final moisture content of the blocks was significantly lower (p<0.01) with lower concentration of 5 or 7.5% molasses.

Concussion

In order to select the best binder at optimum inclusion level, chick pea straw was used as roughage source at 60 percent, LL and AL dried leaf meal each was included at 20 percent replacement of concentrate mixture. Two types of binders i.e., molasses and condensed distillers soluble (CDS) were used at three different levels i.e. 5.0, 7.5 and 10 percent to prepare the complete feed blocks.

During the preparation of complete feed blocks with condensed distillers soluble as binder, blocks could not be formed with at least minimum intactness due to high moisture content and lower soluble carbohydrates in CDS when compared to molasses. Hence, complete feed blocks were prepared with molasses as binder at three different levels i.e. 5.0, 7.5 and 10 percent. The blocks were prepared by compacting the materials in an iron mould into sizes of 30 x 30 x 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. Complete feed blocks were prepared and evaluated in terms of physical and drying characteristics i.e., bulk density, post compression expansion (PCE), durability, drying rate, initial moisture and final moisture. Statistical analysis revealed that good results were obtained at 10 percent addition of molasses based on the significant differences (p<0.05 or p<0.01). Addition of molasses at 10 percent significantly improved the bulk density, PCE, durability, drying rate and initial moisture of the blocks prepared with control diet as well inclusion of tree levees. Based on the results, molasses was selected as binder at 10 percent level to prepare the complete feed blocks.

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