

Studies on Compaction of Crop Residues

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The compaction of agricultural residues is a value adding process. Compaction of straw from different crops, with additives of molasses, minerals, concentrates and other diet supplements, into animal feed blocks and pellets is highly useful in animal nutrition management, transportability and storage. Compaction of fodders and straws into large blocks could save the storage space and transportation cost by the same factor as achieved in the compaction process. Wheat, paddy straws mixed with molasses (2%, 4%, 6%, 8%) were compacted into square section blocks of (0.08 × 0.08) m with application of pressure from 210 kg/cm² to 420 kg/cm². Mustard, guar and bagasse samples at moisture content ranging from 5 % (wb) to 22 % (wb) were also compacted into similar blocks applying the pressures mentioned above. Bulk density relationships with moisture contents and applied pressure were observed to be almost linear for all the materials with a high degree of correlation coefficient. The resiliency was also evaluated at different moisture/molass content and application pressure. The blocks formed with higher moisture content were most unstable while those formed at the lowest moisture content were stable. It was concluded that a number of moisture-molass-pressure combinations could be used to formulate animal feed blocks with significant volume reduction and stability.

Keywords : Crop residues; Compaction; Bulk density; Resiliency

INTRODUCTION

Currently, India has more than 53% of the world buffaloes, 20% goats, 15% cattle, 4% sheep and poultry and 1% pigs¹. The productivity of these animals is very low compared to their counterparts in western countries. This is mainly because of very poor and imbalanced diet. More than 70% farmers in our country are marginal, small and medium farmers. Their capacity to produce and store animal hays is very limited. As a result, they have either to procure them from outside or, in majority of cases, the animals are fed on survival basis. The spectacles of drought, floods and earthquakes are not uncommon wherein casualty of animal population due to starvation is highly significant.

India currently produces 540 Mt of crop residues², which could be used for feeding to the animal population of the country. However, a number of useful crop residues are often burnt for lack of appropriate storage and use. The bulk density of the residues is very low, requiring very large storage spaces. Transportation of these crops fodder is a very serious problem. Nutritional quality of these residues is poor. Several works have been reported on nutritional improvement of roughage based feed resources. Treatment with sodium hydroxide^{3,4}, hydrogen peroxide^{5,6} and urea/ammonia⁷⁻⁹ have been reported to improve the intake as well as nutrient digestibility. Some available studies¹⁰⁻¹⁵ indicate that these residues can be formed into compact and ready-to-eat feed blocks, which can be stored conveniently over long periods of time. The feed blocks can also be transported economically over any distance conveniently, without any losses, to meet the exigencies in disaster areas. The advantages of using complete feeds¹⁰ have been reported to be useful to induce animals to consume proper proportions of roughages and concentrates for optimum performance.

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The crop residue based feed blocks is prepared through densification. The behaviour of the materials during densification is dependent on their physical and biochemical properties and the variables of the processing plant. The design of compression plants requires knowledge of the force and pressure needed to obtain a desired compressed density. The density levels, to which the agro materials can be compacted, determine the economy in storage and transportation of these materials. The present study was undertaken to evaluate the compactibility characteristics of animal feed derived from wheat, paddy, mustard, guar and bagasse.

MATERIALS AND METHODS

Four commonly used crop straws, *namely*, wheat, paddy, mustard and guar and also, the sugarcane bagasse were used in the study. A vertical compaction machine was designed and fabricated with hydraulic cylinder as compactor. The machine had the capacity to apply loads up to 420 kg/cm² on straws filled in a square cross section cylinder up to 0.25 m height. The machine is shown in Figure 1.

A sample of the given biomaterial was taken and filled in a square cross section cylinder with internal dimensions of 0.08 m × 0.08 m. The hydraulic machine had its vertical crosshead fitted with a piston-punch to fit into the compaction mould for load application. Vertical load was applied on the sample of straw at a rate controlled manually. The rate of vertical travel of hydraulic cylinder could be calibrated for different speeds for compression of the samples, it was maintained at 0.046 m/s. Compression load was applied on the sample till the desired pressure level was achieved. The pressure was read off the dial of a pressure gauge.

Four levels of pressure (P), as indicated in the Table 1, were applied to the samples of each of the crop materials, to obtain compacted blocks of different bulk densities at different moisture (M)/molass (W) content. The bulk density of the compacted blocks was calculated with the sample weight and the measured volume in each case. The volume was determined by the fixed cross section area and variable

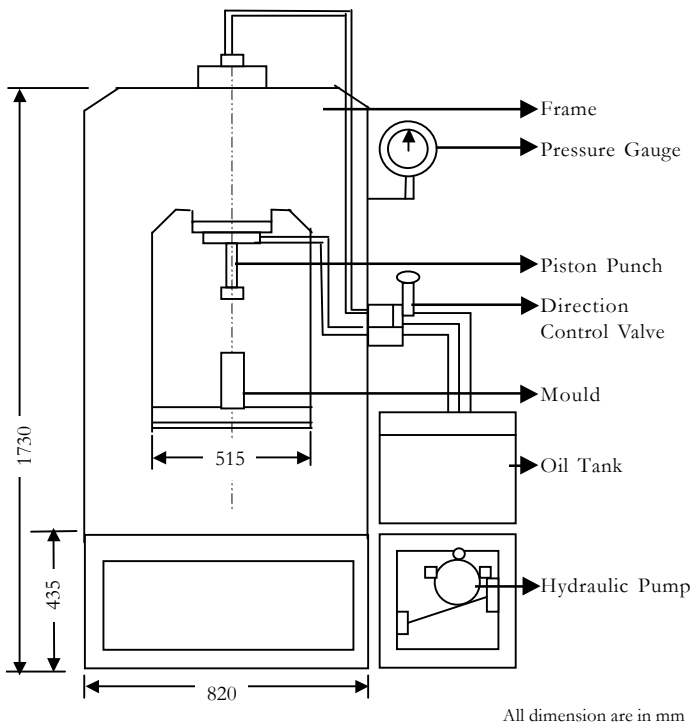


Figure 1 Laboratory model animal feed block formation machine

Table 1 Plan of experiments

Size Range, m	Biomaterial*	Molass Content, W, %	Moisture Content, M, % wb	Applied Pressure, P, kg/cm ²
0.01-0.06	Wheat straw	2, 4, 6, 8	10.0	210, 280, 350, 420
0.01-0.02	Paddy straw	2, 4, 6, 8	13.5	
0.01-0.12	Mustard straw	-	8.08, 10.5, 13.5, 22	
0.01-0.08	Guar straw	-	12.24, 16.16, 22.38	
0.02-0.13	Sugarcane bagasse	-	5.08, 8.09, 13.59	

Note: * is the sample weight for the wheat, paddy, mustard and bagasse was 0.15 kg and for guar 0.25 kg at their respective moisture contents.

thickness of the blocks obtained after 24 h of its compaction. The thickness of the blocks was measured initially and then after 24 h. The volume ratio of the two samples was obtained as an indicator of the resiliency of the compacted samples. It was observed that the sample expanded the maximum within half an hour but continued till 24 h of its compaction and attained stability of its dimensions thereafter.

The bulk density against moisture/molass content was also determined for each of the biomaterial. It was determined by weighing the biomaterial filled in a known volume of the container. In each case a replication of three observations was averaged and the average value was reported. The regression equations were obtained for each of the dependent variables using Ms Excel and the statistical package 'SYSTAT'.

RESULTS AND DISCUSSION

Bulk Density of Loose Feed Materials

Initially, the bulk density of different loose feed materials was determined as a function of moisture/molass content. This is considered important to determine the degree of compaction during feed block formation. The maximum level of moisture for mustard,

guar and bagasse was kept such that after application of pressure a block of the material did not open up completely; for wheat and rice straw the maximum molass content was kept such that no oozing of molass was caused by application of high pressure.

The bulk density increased with increase in the moisture content of mustard, guar and bagasse. For wheat and rice straw the bulk density increased with increase in molasses content. The relationships presented in Table 2 were obtained for bulk density and moisture/molass content of all the five materials. A very high value of the correlation coefficient between bulk density and the moisture/molass content indicated a very strong relationship between the two values.

Bulk Density of Feed Blocks

The feed blocks were prepared using the loose crop residues at different compression pressure and moisture/molass content. Regression equations of bulk density as a function of pressure and moisture content are included in Table 3. The bulk density of feed blocks of all the materials increased almost linearly with increase in compression pressure. Bulk density as a function of compression pressure and molass content of a typical sample of wheat is shown in Figure 2. For wheat and paddy straw blocks, the bulk density at a given level of applied pressure increased with increase in the molass content. The increase in molass content from 2% to 4% caused a rapid increase in the bulk density of wheat straw blocks but further increase in molass content caused increase in density at a slow rate. For paddy straw, the increase in molass content from 2% to 4% did

Table 2 Relationship between moisture content and bulk density of crop residues

Material	Relationship	Correlation Coefficient (R ²)
Wheat straw	32.80 + 0.95W	0.99
Paddy straw	52.20 + 0.88W	0.99
Mustard straw	35.20 + 0.90M	0.99
Guar straw	164.70 + 1.30M	0.99
Bagasse	53.49 + 0.88M	0.99

Table 3 Regression equations for bulk density of blocks of crop residues

Material	Relationship	Correlation Coefficient (R ²)
Wheat straw	240.56 + 0.03P + 12.37W	0.907
Paddy straw	253.13 + 0.43P + 17.25W	0.882
Mustard straw	646.01 + 0.47P - 20.70M	0.941
Guar straw	569.66 + 0.65P - 6.57M	0.928
Sugarcane bagasse	587.90 + 0.190P - 19.63M	0.987

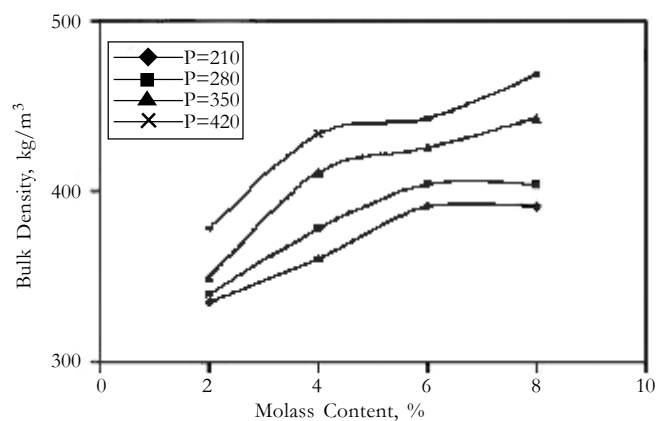


Figure 2 Effect of molass content on bulk density of wheat straw at different compaction pressure

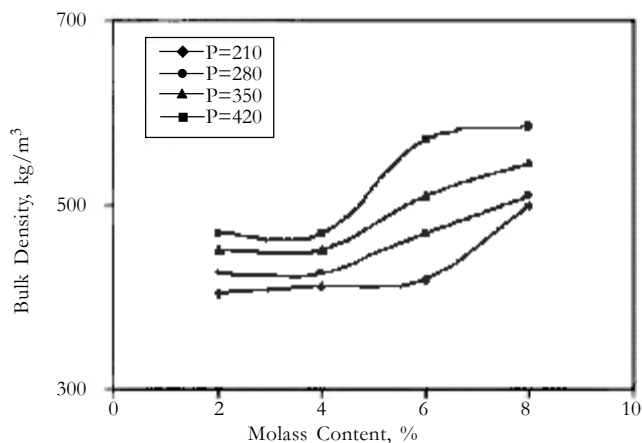


Figure 3 Effect of molass content on bulk density of paddy straw at different compaction pressure

not make much difference in the bulk density whereas, molass content higher than 4% caused a rapid increase with increase in the molass content as given in Figure 3.

The difference in bulk densities due to pressure and molasses addition in wheat and paddy straw were caused due to the lower straw size of wheat and the higher surface roughness of paddy straw. The finer the particle size and lesser the surface roughness, the higher was the compactibility of the straw. The addition of molasses caused visibly drastic increase in the compactibility of straw into blocks because of its binding property. The influence of molasses addition on bulk density in wheat was more than the influence of applied pressure. The bulk density of paddy at 4% molasses increased from 411 kg/m³ to 468 kg/m³ as the pressure increased from 210 kg/cm² to 420 kg/cm². On the other hand the bulk density increased from 411 kg/m³ at 4% molass to 488 kg/m³ at 8% molass content at a pressure level of 210 kg/cm². At 350 kg/cm² pressure the bulk density was 468 kg/m³ and 585 kg/m³, respectively at 4% and 8% molasses content. Similar trends were observed in wheat. For mustard, guar and bagasse, the bulk density consistently reduced at all levels of applied pressure with increase in moisture content. For these materials, the maximum bulk density, with compaction was attained when dry; the bulk density reduced with increase in moisture content. This was due to an expansion of the compacted samples. The expansion was higher for high values of moisture content. A moisture content level of 10% (wb) to 12% (wb) was found to be optimum for compaction into blocks for almost all the materials.

The influence of moisture content on bulk density was more than the influence of applied pressure for mustard, guar and bagasse. At 210 kg/cm² pressure and 8% moisture content of mustard, the bulk density was 585 kg/m³ reducing to 260 kg/m³ at 22% moisture. The corresponding values at 420 kg/cm² were 808 kg/m³ and 378 kg/m³, respectively at 8% and 22% moisture content. Similar results were observed for guar and bagasse.

For all the five crop materials it could be concluded that the wetting agent of molasses and moisture had a greater influence on bulk density compared to the influence of the compaction pressure.

Resiliency of Feed Blocks

The stability of the feed block is a very important quality. Resiliency

Table 4 Regression equations for resiliency of blocks of crop residues

Material	Relationship	Correlation Coefficient (R ²)
Wheat straw	33.45 - 0.011P - 0.51W	0.918
Paddy straw	36.02 - 0.009P - 1.06W	0.935
Mustard straw	7.66 - 0.019.3P + 2.03M	0.992
Guar straw	20.95 - 0.023P + 0.54M	0.974
Sugarcane bagasse	11.91 - 0.009P + 2.23M	0.962

gives a relative measure of stability of block. The higher the resiliency, less stable is a compacted block. Resiliency indicates the tendency of a compacted block to expand in volume. After the block was removed from the die, the resiliency was measured with time, varying from 5 min to 24 h. It was observed that the maximum resiliency occurred within 30 min but was followed by very slow increase till 24 h. Resiliency increased with increase in the moisture content of the feed but decreased with increase in compression pressure and molass content. Regression equations of resiliency as a function of pressure and moisture content are given in Table 4.

CONCLUSIONS

The following conclusions were drawn from the study:

1. Well formed compacted blocks of wheat and paddy could be obtained with addition of molasses and compaction pressure of 420 kg/cm². The blocks retained their shape at compaction for long duration.
2. Guar, mustard and bagasse formed into stable blocks when compacted at a natural dried moisture content and 420 kg/cm² pressure. The increase in moisture contents of the materials caused very high resiliency, hence, instability of the compacted blocks.
3. The most stable blocks were formed with high compaction pressures of 420 kg/cm². The blocks formed at lower compaction pressures had much higher resiliency, hence less stability.
4. The equations of bulk density and resiliency in terms of moisture/molass content and compaction pressure were obtained with sufficiently high correlation coefficients of more than 0.88. In most cases the bulk density, and resiliency varied linearly with moisture/molass and pressure.

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