



paper

CROP RESIDUE BASED DENSIFIED TOTAL MIXED RATION

A user-friendly approach to utilise food crop by-products
for ruminant production



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Contents

Acknowledgements	iv
Executive summary	v
Livestock and rural economy	1
Feed resource scenario	3
DTMRB feeding <i>vis-à-vis</i> conventional feeding in India	5
Development of the technology	11
Machinery needed and the process involved for making DTMRBs	13
Securing biomass from the fields	15
Brief account of the research done in India on DTMRBs	17
Advantages of the DTMRB technology	19
Economic and other benefits to the farmer	23
Extent of use of the technology	25
Densified straw based feed pellets	27
Conclusions	29
References	31

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Executive summary

Livestock play a central role in the natural resource-based livelihood of the vast majority of the population living in developing countries. However, most of these regions face the problem of acute shortage of feed resources. The pastures are degraded and poorly managed and the area under green forage crops is shrinking due to increase in human population and urbanisation. As a result, the bulk of feeds available for ruminants in these regions are the crop residues. The crop residues have low nutritional value and are bulky and fibrous. In addition, these feed resources are also not well managed, especially where these are available in plenty. Availability of crop residues varies with season and region. In some regions there is deficiency of crop residues only in certain seasons, in others a perennial deficiency may prevail, while in some other regions and in particular seasons they are available in abundance but are largely wasted. Thus, straws worth millions of dollars are burnt in the fields in these places after the grain harvest. Apart from the wastage of a potential feed, the burning of straws causes environmental pollution and degradation of soil fertility.

Improvement in the management of crop residues enables efficient utilization of this potentially useful feed resource. One of the options for effective management of the crop residues is to use specially designed pick-up type field balers for securing residual straw from the fields, followed by the use of processing technologies for the commercial manufacture of straw-based complete feed for ruminants. Manufacture of Straw-based Densified Total Mixed Ration Blocks (DTMRBs), also called Densified Complete Feed Blocks (DCFBS) is an innovative technology to supply balanced feeds to the dairy and other livestock farmers in the tropics. This approach is different from the green forage or silage based Total Mixed Ration (TMR), which involves mechanical mixing of forages with concentrate feedings without densification. Since fibrous crop residues and other unconventional feeds such as dried tree leaves and forest grasses are low density feeds, apart from difficulties in their handling and transportation, making of densified blocks from such feedstuffs is challenging. Considerable research efforts have been made, initially in some western countries and lately in India to standardize the optimum conditions for block making, including the designing of different prototype machines for densification. This technology of making DTMRBs has now been commercialized in India and the manufacturing plants have been set up in different states under Dairy Cooperatives and State level Livestock Boards, with Government providing the incentive by way of offering 50% subsidy for setting up of such plants.

The first step in the process of making DTMRBs is the grinding and mixing of concentrate ingredients separately. This is followed by adding concentrate components to chopped straw in desired proportions along with molasses in a mixer, taking care that mixing is uniform and ingredients are not separated due to gravity. Finally, the desired quantity of straw-concentrate mix is transferred to a hydraulic press to convert the mix into a block. Recently, a modified version of the technology has been developed, and the densified total mixed ration is delivered as pellets (DTMRPs). This technology is particularly useful for those residues that are harder than rice and wheat straws, and is also useful for regions in which the crop residues are available in abundance but are wasted. It is also useful in places where feed milling plants are operating at lower than their capacities.

Based on the productivity levels of animals, the DTMRBs or DTMRPs of different formulations can be made using different ingredients, including minerals, vitamins and feed additives. Thus, the technology of straw-based densified complete feed as blocks or pellets 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 and meat production in the tropics apart from having other advantages such as: decrease in environmental pollutants (including methane emission), increase in income of farmers, decrease in labour requirement and time for feeding and reduction in transportation cost of straw. The technology also has the potential to alleviate regional disparity in feed availability, as the block or pellet making units can be set up to act as 'Feed Banks' in regions of abundant crop residue availability. It could also provide complete feed to livestock under emergency situations created by natural calamities and man-made conflicts.

Livestock and rural economy

Livestock production accounts for 40% of the gross value of the agricultural production globally (FAO, 2000), and this figure is likely to go up, as the demand for livestock products is increasing rapidly with the increase in income and urbanization. Between 1980 to 2007, the highest growth in meat production was recorded in East and Southeast Asia (from 19.4 to 106.2 million tonnes/year) with China being the major contributor, followed by Latin America and Caribbean (from 15.7 to 40.3 million tonnes/year). South and South East Asia also took lead in egg production, increasing production from 4.5 to 34.6 million tonnes, followed by Latin America and Caribbean from 2.6 to 6.3 million tones. On the other hand, with regard to milk production, South Asia dominated the scene, increasing its production from 42.7 to 140.6 million tonnes/year with India playing the lead role, followed by Latin America and Caribbean from 35.0 to 68.7 million tonnes/year. Near East and North Africa performed well in meat and egg production as did South Asia, but lagged way behind in milk production. Even Sub-Saharan Africa, which has been facing multitude of man-made and nature created problems, has forged ahead, having doubled its production for all these three livestock products during the same period, though the production was lower than any other region with regard to all these products (FAO, 2009a).

Besides the potential of livestock to raise income and improve human nutrition, they have important integrative function in the farming system. The tropical regions of the world vastly differ in climate, natural resources and socio-economic-cultural aspects. These regions have largely remained traditional in their approach to livestock production activities due to their social, economical, geographical and ecological compulsions. Livestock play a central role in the natural resource based livelihood for the vast majority of the population living in the tropics, which predominantly is confined to rural areas. In the rain fed hotter regions of the tropics, livestock are the main sustenance factor for rural economy, contributing to the livelihood of resource poor subsistence farmers in a number of ways: income from products, insurance against drought, emergency cash requirements, household nutrition, fuel for cooking, manure for crops and draught power for farming (Ashley, Holden and Bazeley, 1999). Apart from the hostile hot and hot-humid climate, the region has a large human and livestock population, exerting pressure on land, which, coupled with degraded unmanaged pasture lands result in shortage of feeds and forages. In addition, available feed resources are not efficiently utilized due to lack of information on feeding of balanced rations by smallholder farmers.

Rearing of animals in developing countries forms an integral part of rural economy. For example, India's huge livestock population comprises of 279 million bovines, 66 million sheep, 126 million goats, 14 million pigs and 613 million poultry birds, which produced 112.11 million tonnes of milk, 4.41 million tonnes of meat and 3.2 million tonnes of eggs (FAO, 2009b). The annual milk production for the year 2010–2011 in India has been estimated at 116.5 million tonnes (GOI, 2011). Livestock contribute 24.7% share in agriculture

and allied gross domestic product (GDP), and provide livelihood to 70% rural families. However, 70–80% of the total livestock produce in India is contributed by the under privileged (namely landless, marginal and small holder farmers) families. Rural women in India and in many other developing countries play a major role in raising livestock, contributing 60–70% of the total labour inputs, especially in different dairying operations.

Feed resource scenario

Feed is the major input cost in animal agriculture, accounting for 65–70% of the total rearing cost. Poor nutrition of animals has been identified as the major constraint to animal production across the developing world (FAO, 2000). Due to a variety of reasons, the tropical world is largely faced with the problem of acute shortage of feed resources. With a large animal population to feed, this shortage is further compounded by lack of efforts to increase green forage production and to improve the management of degraded and unmanaged pastures. In India for example, the area under fodder production has remained static at around 4% of the total cultivable land area for the last three decades.

In the most tropical regions, the majority of bovine feeds available are the poor quality crop residues and agro-industrial by-products. Grains have the priority for human consumption. In addition, the grains are also being diverted for biofuel production. The protein rich oil seed meals, e.g. soybean meal, groundnut meal and cotton seed meal, which are already in short supply, are also being exported indiscriminately in large quantities from these regions to earn foreign currency (Walli, 2009a). Most of the resource poor small-holder farmers, that constitute the bulk of the livestock farmers in the tropical regions, are unable to afford good quality feeds due to their high cost, leading to sub-optimal productivity of their animals. Using the multi-dimensional approach for improving the quality and thereby the utilization of food-feed crops, the animal productivity can be enhanced, which can also lead to reduction in animal numbers, feed requirement and the emission of green house gases (Blümmel, Anand and Prasad, 2009).

There is little hope to increase the cultivated area under green forages or to regenerate the degraded pastures through intensive management. This necessitates efficient utilization of crop residues for ruminant feeding. In the developing countries including India, the production of crop residue has steadily increased during the last four decades, as a spill-over effect of 'Green Revolution'. The increase in cereal production also resulted in an increase in the availability of cereal straws. The availability of dry matter through crop residues in India has increased from 211 million tonnes in 1980–81 to 354 million tonnes in 2002–2003, an increase of 65% over a period of two decades (NIANP Feed Disc, 2005). Furthermore, the availability of maize stover has increased by 75% during the same period, which is mainly due to increase in area under maize cultivation. However, a large proportion of maize is now being diverted for biofuel production, But the byproduct: DDGS (distillers dried grain soluble), which forms one-third of the maize kernel, can also serve as a valuable ingredient in ruminant feed, possibly as a source of bypass protein.

MANAGEMENT OF FEED RESOURCES

Improper management of feed resources, especially that of the bulky and fibrous crop residues, is another factor contributing to low productivity of ruminant livestock in the tropical regions. For example, in north-western parts of India, straw worth millions of dol-

lars is burnt in the fields leading to environmental pollution and soil degradation (Photos 1 and 2). It has been estimated that in India alone, burning of crop residues releases CO₂, CO, CH₄, N₂O and SO₂ gases, equivalent to 6 606 thousand tonnes of CO₂ annually (INCCA, 2007). Improving the management of crop residues as animal feed and restricting its wastage through burning, should be one of the main priorities. Thus, there is an urgent need to optimize the use of the limited feed resources, especially straws for ruminant feeding.

The crop residue management should include the use of specially designed balers for collection of straw from the field, followed by the use of processing technologies for the manufacture of balanced complete feed for ruminants. In this respect, the technology for making DTMRBs is an innovative approach, which provides an opportunity for the feed manufacturers and entrepreneurs to remove regional disparities in feed availability and to supply the balanced feed to dairy and other livestock farmers on a large scale. The DTMRBs Technology can also be effective in disaster management and emergency situations that arise due to natural calamities, for example floods, droughts and man-made conflicts. Feed banks could be set up to overcome the problem of feeding animals during these natural calamities, which are common in the tropics (Walli, 2008 a,b; 2009b; 2010; 2011 a,b).



Photo 1.
Burning of straw causes wastage of the feed resource and environmental pollution



Photo 2.
Burning of straw also causes degradation of soil fertility

DTMRB feeding *vis-à-vis* conventional feeding in India

CONVENTIONAL FEEDING PRACTICES FOR BOVINES IN INDIA

Separate feeding of roughage and concentrate

This practice is followed mostly in the rural areas of southern, eastern and western parts of India. The farmers often do not chaff and soak the straws or stovers, and offer them dry and in un-chopped or semi-chopped form (Photo 3).

This is because the hand driven chaff cutters, which are owned by most of the livestock keepers in North India, are not still popular in the other regions of India (Chander, 2011). Concentrate components of the ration are given separately. The animals are mostly low producing and are offered different types of crop residues like rice or gram straw, stovers of sorghum, maize or finger millets. Six to seven kg per day of the dry roughage is offered to adult bovines which form approximately 70% of the ration. Apart from this, small quantity of greens, between 0.5 and 1.0 kg dry matter, limited amount of cakes and brans (rice and/or wheat), non-food grade broken pulses (1–2 kg per day) and some kitchen waste, as the concentrate ingredients are also offered. The un-chopped straw provides complete choice to the animal for selectively consuming the more digestible parts and leaving behind the less digestible parts, which consequently leads to substantial feed wastage (Bhargava, Ørskov and Walli, 1988). In addition, the animal might need to spend more energy for chewing the un-chopped straw, than the chopped straw (Chander, 2011).

In the peri-urban and urban areas, dairy owners keep medium producing crossbred dairy cows, yielding on an average 10–15 kg of milk per day. Due to shortage of green forages, these farmers practice higher concentrate feeding in order to get as much milk as possible from the animals. The concentrate may form 60–65% of the total ration. The



Photo 3.
A farmer offering semi-chopped sorghum stover to his animal in Tamil Nadu state of India

roughage consists mainly of straws or stovers with negligible amount of greens. These farmers generally use the ready-made concentrate mixture marketed by the feed factories. The use of ready-made feed is more prevalent in Southern and Western India than in Northern and Eastern India. Although the total requirement of compound feed (which includes feed for ruminants, non-ruminants, poultry and fishes) is around 55 million tons in India, only 8 million tonnes of compound feed is produced, out of which only 50% is manufactured by the organized sector. The feed produced by the unorganized sector is generally of lower quality.

Chopped roughage and soaked concentrate mixed together

A simple process of feeding bovines, called "Sani" making, is the most prevalent feeding practice followed in north-western parts of India as well as in Pakistan. The chopped green fodder (maize, oats, sorghum, berseem, alfa alfa) is mixed with chopped straw/stover (wheat, paddy, maize, sorghum), in the proportion of 35–40 : 65–60, on dry matter basis. The mixed forage is sprinkled with some water, which is followed by addition of concentrate ingredients, e.g. oilseed cakes, rice or wheat bran, maize or wheat flour and some legume *chunies* (broken seeds of pulses with some husk) like Bengal gram (*Cicer arietinum*) or moong (*Vigna radiata*), to the extent of 25–30% of the total ration. All the ingredients are then mixed and fed to the animals as manually prepared total mixed ration. This definitely is an improvement over the separate feeding of roughage and concentrate. The chopping may save some energy required for chewing, soaking could increase palatability of the feed and consumption of mixed feed increases digestibility of feed by improving rumen function. However, the selection of feed components by the animals could still take place partially and this could lead to some feed wastage.

STRAW BASED DTMRBs AS A COMPLETE FEED

Ingredients of DTMRBs

The ingredients of DTMRB can be divided into major and minor components. The major components are forage and concentrate, added in different ratios, depending upon the level of production while the minor component constitutes micronutrients and feed additives.

The forage part is generally the crop residues such as wheat, ragi or paddy straw, sorghum stalk, sugarcane tops, maize stover. In hilly areas, even the non-conventional forages like forest grasses and tree leaves have been used in place of crop residues. This has been done in the North–Eastern region of India, especially in Nagaland, where the feed blocks, based on tree leaves and dried forest grasses have been successfully fed to Mithun, a bovine species resembling buffaloes (Das, Haque and Rajkhowa, 2009). Studies have shown that sugarcane bagasse can be used economically as an alternative source of forage to replace 30% of wheat straw in feed block, without any adverse effect on the growth of crossbred calves (Singhal, 2009). A number of trials have also been conducted in the arid regions of India, especially in Rajasthan, where the forage part of the block constituted tree leaves or gram (*Cicer arietinum*) straw (Jakhmola, 2005). Singh, Lohan and Rathee (1998) used dried berseem as a part replacement for wheat straw in the diet of buffalo calves. Nagpal, Arora and Singh (2005) used gram straw as a part replacement for wheat straw for crossbred calves, while Nagpal and Arora (2002) successfully used groundnut haulms as part of the roughage in the feed block.

The second major component of the DTMRBs is the concentrate part. The proportion of the straw and concentrate in the block varies with the type of animal to which it is to be fed. As a survival ration for use during natural calamities and disasters, the straw component could be very high. To meet the challenges during emergency situations, straw blocks have generally the following composition: 86 parts straw, 10 parts molasses, 2 parts mineral mixture, 1 part urea and 1 part salt, which could meet the maintenance requirement of the animals. The proportion of straw for animals yielding up to 5–10 kg milk per day, should be reduced to 60%, for 10–15 kg milk per day, up to 50% and for 15–20 kg milk per day, up to 40%. A similar kind of range has to be maintained in the crude protein (CP) content of the block, varying from 7–14%, and in the total digestible nutrients (TDN) content varying from 45–65%. A superior quality block of 14 kg has sufficient nutrients for the production of 20 kg of milk per day. Since buffaloes are heavier in weight and their milk having a higher fat content, a 15 kg block of the similar composition is suggested for buffaloes with respect to above three categories. The ingredients of the concentrate mixture are: oil cakes/meals as protein source; molasses, grains, grain by-products as energy sources; and supplements such as bypass protein or bypass fat. Bypass nutrients can be added for the higher yielders to enhance the direct supply of amino acids and fatty acids to the host animal as concentrated protein and energy sources respectively.

The third component provides strategic and catalytic supplements, such as micronutrients and other feed additives, for example vitamins, minerals, bentonite (binder), probiotics, enzymes, antioxidants, immune-protective agents, antitoxins and herbal extracts, among others. The varied role of these components in the feed block is to increase the productive and reproductive efficiency of the animal, enhance its immuno-protective ability, reduce helminthic load and decrease ruminal methanogenesis. There is much scope for the value addition of the feed blocks through R&D efforts on feed additives, which should be driven by economic and environmental sustainability of the technology.

Roughage and concentrate binding – a hallmark of the DTMRB technology

The making of feed block requires proper processing and can be manufactured on a large scale in a factory, using a hydraulic press. The process of densification causes physical attachment of the minute concentrate particulate matter to fibrous straw particles with the help of a binder, so much so that there is hardly any opportunity for the animal to select the feed components. This not only brings uniformity to the feed, but also increases the palatability of the straw based feeds and minimizes the feed wastage. The process of densification may also slightly improve the digestibility of straw, as each straw particle has the concentrate component attached to it through molasses, which may facilitate the cellulolytic microbes to grow faster and enhance fiber degrading activity in rumen.

Although the rate of release of energy and nitrogen in the rumen from DTMRBs depends on the nature of ingredients used, the feeding of DTMRBs generally allows a synchronized supply of nutrients to rumen microbes including rumen anaerobic fungi, resulting in their enhanced growth (Samanta *et al.*, 2003). Ensuring the synergy between the nutrient demand of rumen microbes and the release of adequate level of the nutrients for their optimal growth is the hallmark of straw based densified complete feeds. Since

the ingredients in DTMRBs remain more or less the same over a longer period of time, the daily supply of these blocks having uniform composition also ensures a steady supply of nutrients to microbes, which brings stability in the rumen eco-system for optimal microbial fermentation. This also results in uniform supply of precursors for milk and muscle (meat) synthesis, and consequently may enhance efficiency of nutrient use.

A new concept in nutrient delivery system for ruminants in the tropics

In many developing tropical countries, the livestock owners hardly follow any feeding standards as they are unable to scientifically compute a balanced ration for their animals, mainly due to lack of knowledge and also the means to do so. This results in poor utilization of feed resources and sub-optimal production from their animals. Densified TMR is a new concept in delivering nutrients as a complete balanced ration to dairy animals and other ruminant stock in the tropics. Each feed block is a total ration for a cow or a buffalo for 24 hours and supplies all the nutrients, including micronutrients required by the animal (Photos 4, 5 and 6).

Although TMR based feed blocks are superior in many ways compared with the traditional feeding, it has been observed in India that in areas where farmers have enough



Photo 4.
Sheep consuming straw based TMR feed at a research station



Photo 5.
A buffalo eating straw based TMR feed as block at a farmer's house



Photo 6.

A cow eating straw based TMR feed as block at a farmer's house

biomass (dry forages) to feed their animals round-the-year, they do not prefer to buy these complete feed blocks. This is because the transportation of the straw to the processing unit and that of the densified blocks back to their farms costs money and time. Based on these experiences, feeding of the complete feed blocks could be mainly recommended for those areas/regions that have shortages of both green as well as dry forages and where the crop residues are transported from outside.

Development of the technology

The DTMRB technology has mostly been developed in India, through the collaborative efforts of animal nutritionists and feed technologists. It is different from the green forages or silage based complete feeds (Schroeder and Park, 1997; Kononoff, 2005). Since the fibrous crop residues are low density feeds, apart from difficulties in its handling and transportation, making a densified block from this loose and lighter stuff is challenging. A different approach and machinery are required for making such blocks from these residues and other dried roughages such as tree leaves and forest grasses.

The first step in the process of making straw based feed blocks is the grinding of concentrate ingredients, followed by their mixing and addition of the feed additives. This is then followed by mixing of these ingredients and straw in proper proportions along with addition of molasses in a specifically designed TMR mixer, taking care that mixing is uniform and ingredients are not separated due to gravity. Finally, the weighed quantity of the mixed stuff is transferred into a hydraulic press to get the final product – the DTMRB.

The technology of feed densification attracted the attention of the animal nutritionists and feed technologists in India during mid 80s. Initially, work on the development of straw based feed blocks was focused on studying the optimum conditions for densification, with respect to moisture level, hydraulic pressure application, dwell time, grinding and mixing and molasses level (Singh, Singh and Rajpal, 1986; Yadav, Rathee and Lohan, 1991; Berwal *et al.*, 1993). However, for the development of the prototype machines for block making, especially the mixing and pressing of the feed ingredients, only a few organizations took the real initiative, notable among these being Indian Grassland Research Institute (IGFRI), Jhansi UP, (Gupta, Goyal and Chattopadhyay, 1998); Indian Agricultural Research Institute (IARI), New Delhi (Singh and Jha, 2009) and the Poshak Agrivet Pvt. Ltd, Karnal (Zombade, 2009). Over the years, these organizations redesigned and upgraded the mixing and pressing units to make these machines energetically more efficient, increasing output at lower energy inputs (in terms of horsepower) and lowering labour requirement for the commercial production of densified complete feed blocks. Efforts were also made to upgrade the manual models to automated models and to make the process overall energetically more efficient, commercially more profitable and environmentally sustainable. Currently, the technical know-how is fully available in India for setting up feed block plants of different capacities (from 5–30 tonnes per day) on turnkey basis.

Machinery needed and the process involved for making DTMRBs

MACHINERY NEEDED

- A grinder (hammer mill) and a mixer is required for making a normal concentrate mixture (Photo 7).
- A specially designed TMR Mixer is required for mixing weighed quantities of low density crop residue (straws, stovers, bagasse, dried forest grasses, dried tree leaves etc.) and the high density concentrate. Molasses and any other liquid feed additive are also added at this stage. The mixing is done through vertical motion, so that there is no separation due to gravity (Photos 8 and 9).



Photo 7.
Grinder and mixer for making normal concentrate mixture



Photo 8.
TMR mixer – single vat system for mixing straw and concentrate

- Weighed quantity of the mixed ingredients is transferred into densification machine (works on the principle of hydraulic compression) which compresses the forage and concentrate mixture into densified complete feed block (Photo 10).

Machines of different capacities and different efficiencies are available in India. Installed capacity can vary from 0.5 to 3 tonnes per hour, which requires a motor of 20–40 horse power having a power consumption of 12–16 KW per tonne. These machines can produce feed blocks weighing from 7 kg to 30 kg.



Photo 9.
TMR mixer – twin vat system for mixing straw and concentrate



Photo 10.
Densification machines based on the principle of hydraulic compression for making feed blocks

Securing biomass from the fields

For making densified feed blocks, securing biomass from the fields is a pre-requisite. Depending on crop condition, season and scale of operation many straw recovery/securing options and machines are available. Following two types of straw-securing devices are used in India:

- Pick-up type field balers (Photo 11)
- Flail mower cum loader (Photo 12)

The pick-up type field baler is driven by a minimum 50 HP tractor. It picks up a swath width of about 165 cm. Straw recovery rate with this machine is about 1 to 2 tonnes per hour depending on crop and swath. Size of the bales can be adjusted from 10 to 20 kg. Small bales are easy to handle and can be transported to transit storage points with ease and minimum drudgery. Loading, unloading and stacking becomes very convenient after field baling. Also, onward handling is quite convenient. For tall varieties, additional disc,



Photo 11.
Pick-up type field balers



Photo 12.
Flail mower cum loader

drum or sickle type mower is required before the baler. For high moisture straws (for example, paddy straw) collection cum inversion rake (Photo 13) is also required so as to sundry the biomass before picking it up. The machine can work on almost all types of biomass. About 10 tonnes of straw can be secured in one day in baled form. In a year (say 50 days harvesting period) one field baler set can secure about 500 tonnes of straw. Approximate cost of the baling set is Indian rupee (Rs.) 1 400 000 or US\$28 000 (1 US\$ = ca Rs.50). The straw recovery and stacking cost with this machine is about Rs.3.50 or US\$0.70 per kg. Mechanisms used in the machine and its operation are somewhat complex and therefore, skilled workers and operators are required for this type of straw recovery set.

Flail mower cum loader is driven by a minimum 50 HP tractor. It has a pick-up swath width of about 150 cm. Straw recovery rate with this machine is about 1 to 1.50 tonne per hour depending on crop and swath. The machine has option of blowing back the biomass into fields for sun drying. For high moisture situations collection cum inversion rake (Photo 13) is also required so as to sundry the biomass before picking it up. The machine can work on almost all types of biomass. Also an added advantage of this machine is the inbuilt chopper which is useful if the recovered biomass is used for silage or hay making. About 10 tonnes of straw can be picked up in one day with this mower in loose form – without baling. In a year (say 50 days harvesting period) one flail mower can secure about 500 tonnes of straw. Approximate cost of the straw recovery set is Rs.800 000 or US\$16 000. The cost of straw recovered and stacked with this machine is about Rs.3.00 or US\$0.60 per kg. Mechanisms used in the machine and its operation are very simple. Therefore, low skill level worker and operator can run this type of straw recovery set. This type of operation may be popularised among the farmers through farmers' cooperatives, federations and service providing organizations, who could provide such services to farmers at nominal costs.

Both types of devices can be operated in dry and wet seasons. The first device cuts the biomass and bale it, while in the second device there is no provision of baling. In dry season the biomass can be directly secured from the field and first type of the device can be used to pick up and bale the straw, while the second type would pick up the straw and load it in a trolley. In wet season the biomass is harvested from the field and left in the open for some time for drying before baling and therefore second type of the device is generally more useful. For large scale operations the first device is more useful; whereas, for small scale operations the second device could be appropriate.



Photo 13.
*Straw collection cum
inversion rake*

Brief account of the research done in India on DTMRBs

The research on different aspects of densification was taken up at a number of research institutions in India, for example, National Dairy Research Institute (NDRI), Karnal (Haryana); Indian Veterinary Research Institute (IVRI), Bareilly (Uttar Pradesh); Indian Grassland and Fodder Research Institute (IGFRI), Jhansi (Uttar Pradesh); Central Sheep and Wool Research Institute (CSWRI), Avikanagar (Rajasthan); Central Institute for Research on Goats (CIRG), Mathura (Uttar Pradesh); Central Institute for Research on Buffaloes (CIRB), Hisar (Haryana); National Dairy Development Board (NDDB), Anand (Gujarat) and Bhartiya Agro Industry Foundation (BAIF), Pune (Maharashtra), including some state agricultural universities like Haryana Agricultural University (HAU), Hisar (Haryana); G.B. Pant Agricultural University, Pantnagar (Uttara Khand) and Andhra Pradesh Agricultural University, Hyderabad/Tirupati (Andhra Pradesh). The work on optimization of composition, preparation of the blocks and evaluation of the impact of the feeding has been pursued more vigorously at IGFRI, Jhansi; CSWRI Regional Station, Bikaner and HAU, Hisar. The subject has been recently reviewed by Lohan (2005), Kundu *et al.* (2005), Jakhmola (2009) and Kundu and Mani (2009).

The evaluation of the nutritional quality of the straw based DTMRBs has been done on different animal species: growing buffalo (Singh *et al.*, 1998; Verma *et al.*, 1996; Diwedi, Goyal and Singh, 2003; Lailer *et al.*, 2006); milch buffalo (Lailer *et al.*, 2009; Sehgal and Jha, 2008); growing cattle (Pachauri *et al.*, 1999; Singh *et al.*, 2004; Das *et al.*, 2004); milch cattle (Berwal, Lohan and Yadav, 1997); growing sheep, goat and camel (Jakhmola, 2005) and growing Mithun (Das, Haque and Rajkhowa, 2009).

The results of most of these studies demonstrate that the feeding of densified complete blocks significantly improves nutrient utilization, N-retention and animal growth and milk production performance (Tables 1 and 2). The overall efficiency of nutrient utilization is better in animals fed complete feed blocks.

The blocks have also been used as carriers for different bioactive compounds and special nutrients. Recently, bypass protein and bypass fat supplements and non ionic surfactants as feed additive have been added to the feed blocks to enhance the nutritional value for feeding to high yielding cows and buffaloes (Walli, 2008 a,b). The spores of anaerobic rumen fungi (*Orpinomyces* and *Piromyces* spp.) isolated from wild blue bull have also been incorporated in wheat straw based densified feed block, which resulted in significant increase in growth rate and milk yield of buffaloes (Sehgal and Jha, 2008).

TABLE 1
Effect of feeding complete feed blocks on dry matter intake (DMI), dry matter digestibility (DMD) and average daily gain (ADG) of ruminants

Type of Feed	Species	CP (%) in the whole ration	Roughage (%) in the whole ration	DMI (kg/100 kg BW)	DMD (%)	ADG (g/day)
Natural grasses + Concentrate	Sheep	-	51	-	-	78.3
(MS + KL + PL + Concentrate (as CFB)	Sheep	12.3	60	5.08	52.8	101.3
Natural grasses + Concentrate	Crossbred calves	10.7	60	2.18	54.8	175.9
Natural grasses + Concentrate (as CFB)	Crossbred calves	10.7	60	2.69	56.5	252.5

Source: Jakhmola (2005)

CP: Crude Protein; BW: Body Weight; CFB: Complete Feed Block; MS: Millet Stover; KL: Khejri Leaves (*Prosopis cineraria*); PL: Pala Leaves (*Zizyphus nummularia*)

TABLE 2
Effect of feeding complete feed blocks on dry matter intake (DMI), dry matter digestibility (DMD) and milk production of cattle

Type of Feed	CP (%) in the whole ration	Roughage (%) in the whole ration	DMI (kg/100 kg BW)	DMD (%)	Milk yield (litre/day)
WS + Concentrate	9.6	60	3.26	51.2	6.24
(WS + Concentrate (as CFB)	9.6	60	3.29	53.8	6.52
Pasture grasses	13.0	100	2.79	56.3	3.96
Pasture grasses + Concentrate (as CFB)	13.2	70	3.90	60.1	6.93

Source: Jakhmola (2005)

CP: Crude Protein; BW: Body Weight; CFB: Complete feed block; WS: Wheat straw

Advantages of the DTMRB technology

The densified complete feed block technology offers a variety of benefits to the farmers and the feed manufacturers. This could be a promising technology for the regions where there is a perennial shortage of green forage and the dry forage is also in short supply and is being transported from outside. Based on the available literature, our own experiences, and from the feed-back received from farmers who fed these blocks to animals, the following advantages have been identified (Walli, 2008 a,b; 2009b; 2010; 2011 a,b).

A promising way to feed a balanced ration to ruminants

In India and other developing tropical countries, normally it is difficult for illiterate or semi literate farmers to compute a balanced feed for the animal. In fact, except at some organized farms, practice of feeding balanced rations is almost non-existent in many developing countries. The DTMRB is a complete balanced feed. By feeding an animal a balanced feed, one can expect improved nutrient supply and their utilization, leading to improved animal productive and reproductive performances.

An efficient nutrients delivery system – less feed wastage

While feeding DTMRB, the animal is given less opportunity to select more digestible feed components. This reduces the feed wastage and thus, is an efficient delivery system of supplying feed nutrients to the animal, which in itself is economically advantageous to the farmer.

Time as well as labour saving – respite to women

Feeding of DTMRB to animals is a simple, hassle-free exercise. Through its feeding, the expenditure on labour with respect to feeding is reduced by 30–40%. Being a readymade feed, the farmers find it easier to feed them. According to a farmer “it takes him just 20–30 minutes to feed 20 animals, as against two hours for feeding the same number of animals in a conventional manner”. This could also be a clear advantage to the women, who generally look after the feeding and management of dairy animals, spending best part of their lives in drudgery, by cutting, collecting and transporting huge loads of grasses from forest or road-sides on daily basis.

Feed as blocks require lesser storage space

The process of densification increases the bulk density of the straw based feed by three times, and at the same time it reduces its volume by the same proportion. Accordingly, lesser storage space is required to store the bulky feed, especially straw. The farmer could use the saved space for other farm activities.



Photo 14.
Transportation of straw on a high way – a common scene in Punjab and Haryana states of India

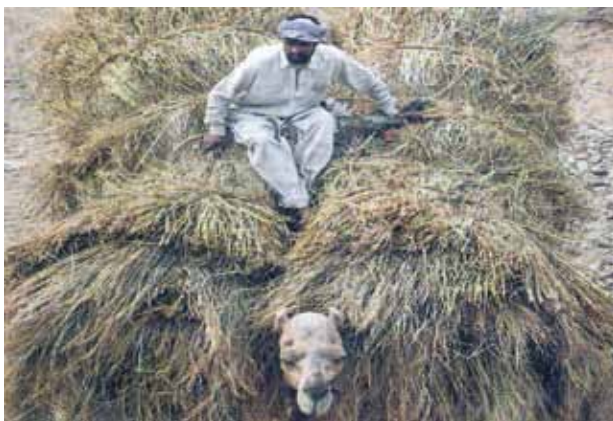


Photo 15.
Gram (Cicer arietinum) straw being transported in a camel cart in Rajasthan state of India



Photo 16.
A truck load of densified TMR blocks being transported in Uttra Khand state of India

Densified feed cheaper and easier to transport

In north-western parts of India, plying of “bulging” trucks and animal carts, over-filled with straw, is a common scene (Photos 14 and 15). This practice is hazardous and causes large number of accidents on the roads. Since the feed blocks occupy approximately one-third lesser space and volume than the original components in the uncompressed state, more feed (by weight) can be accommodated and transported within the same space. This makes the transportation of feed block much easier and cheaper than the straw (Photo 16).

Better way to manage crop residues and reduce pollution

In many regions in India as well as in other parts of Asia, straw worth millions of dollars is also burnt in the field after harvesting of the grains. If the residual straw left in the field is mechanically collected and converted into feed blocks, not only this valuable feed resource could be effectively used, but the emission of green house gases, caused by burning of straw could also be avoided. In addition, the high temperature generated during the burning of straw kills the soil microorganisms, affecting adversely the soil fertility. Also there is less dust pollution when the feed is transported as blocks rather than as loose straw.

Improved productive and reproductive performance

Feeding of DTMRB has a positive effect on production as well as reproduction of the animals. Based on the feedback collected from farmers in Uttra Khand (India), who fed straw based complete feed blocks to their growing and lactating animals, it was observed that the growth rate of calves could increase by 25–35%, while the milk yield could increase by 15–20% (Walli, 2009b). There could also be some increase in fat content of milk. After feeding densified TMR, the milk yield of the animal persists at a higher level over a longer period, resulting in increase in total lactation yield. This may be explained by the fact that the feeding of straw based complete feed blocks eliminates any day to day dietary fluctuations thus providing the rumen microbes a constant supply of the same type of feed/substrates, bringing stability in the rumen environment and making ruminant system overall more efficient.

Because of the faster growth rate, feeding of DTMRBs could result in early maturity and early age at first calving for the animals. The feedback collected from Uttra Khand (India) farmers also suggested that the age of heifers at first calving may decrease by about 4–6 months (Walli, 2009b), which is a distinct advantage in lowering the cost of rearing animals. The farmers reported that the feeding of TMR blocks reduces calving interval and animals generally conceive within 3 months after calving. As a result of these positive changes, overall reproductive efficiency of the animal also increases. Apart from optimum supply of energy and protein through complete feed block, the animals get proper amount of minerals and vitamins as per their requirement, which enhances reproductive efficiency. The occurrence of reproductive problems such as late maturity, anestrus and repeat breeding condition can also be reduced in animals fed DTMRBs.

Lesser methane emission from animals

The inclusion of concentrate to straw diet is known to reduce methane emission from the rumen. The emission of methane can be reduced by 10–15%, simply by feeding a balanced

diet prepared by mixing straw, concentrate ingredients and minerals (Garg and Bhandari, 2011).

Better health status

The optimum supply of nutrients and micro-nutrients through DTMRB also has a positive impact on the maintenance of good animal health. The feeding of TMR blocks provides immuno-protection against infectious diseases and also decreases the occurrence of metabolic and reproductive disorders. Consequently, this may also reduce the farmer's expenditure on treatments and on maintaining proper health of the animals.

Feed banks can be set up as a pre-emptive disaster management measure

With the advent of feed block technology, it is possible to set up feed banks nearer to feed deficit areas. Because of easy handling, transportation and storage of the straw based feed blocks, the technology could improve preparedness against natural calamities, and save animals from hunger and death during these emergency situations. The blocks can even be air lifted to the remotest places to avert disasters.

Scope for value addition – blocks as a vehicle for medicine or nutraceutical administration

There is substantial room for improving the quality of straw based complete feed blocks. Its value addition could be a continuous exercise through extended research, trying different supplements, newer feed additives, nutraceuticals, anthelmintics and herbal extracts to improve their overall nutritional quality. However, it has to be ensured that the non-nutrient additives are used within the specified limits, so that they do not cause any major dilution of macro- or minor-nutrients in the feed blocks, which could reduce nutritional quality of the blocks.

Better economic returns through providing stability in feed and milk prices

The benefit provided by easier storage of feed blocks makes it possible to supply uniform quality of the feed throughout the year, with lesser price fluctuation, as against the large price fluctuation and irregular supply of straw and other feed ingredients in different seasons. This could also have an impact on stabilizing milk prices, irrespective of seasons, and could produce milk of uniform quality. Better performance of the animals obtained on feeding the DTMRB would obviously bring better returns to the farmer.

Economic and other benefits to the farmer

Based on the milk yield and feed cost observations made in the field on feeding DTMRBs, benefits accrued by the farmers were calculated (Walli, 2009b). In northern parts of India, a cow (body weight, 450 kg) yielding on an average 10 kg of milk per day over a period of 300 days of lactation, is generally fed: 20 kg of green maize, 5 kg of wheat straw and 4 kg of concentrate per day, amounting to the feed cost of US\$2 per day or US\$600 for 300 days. At other places, where green fodder is not available, the same type of animal is offered approximately 7 kg of wheat straw and 5 kg of concentrate per day, costing almost the same amount as in the previous case. With the present selling price of US\$0.50 per litre of milk, the farmer gets US\$1 500 in 300 days, giving a net return of US\$900.

If the same type of animal is offered medium type of feed block (Weight 14 kg; Moisture 10%; CP 12%; and TDN 55%, straw to concentrate ratio of 52 : 48), the feed cost per day is US\$2.5, amounting to US\$750 for 300 days of feeding. The feeding of DTMRB increases the average milk yield from 10 kg to 11.5 kg per day (Walli, 2009b) The extra milk yield was supported through slightly higher DM intake from a better balanced feed). This gives a total US\$1 725 to the farmer in 300 days, giving a a net return of US\$975 or an additional income of US\$75 over the conventional feeding.

In addition to the direct monetary benefit that the block feeding gives, it also offers other benefits to the farmer for example early calving and regularity in calving, reduction in feed wastage and saving on labour and time required for feeding and cleaning of mangers. There is also saving on purchase of medicines and treatment of animals, as the animal generally maintains better health.

Extent of use of the technology

For large scale production (up to 3 tonnes/hour) of feed blocks, a couple of private companies in India have produced hydraulic press that caters to the needs of state level dairy cooperatives, dairy federations and livestock development boards. So far, at least 10 such big units have been set up in various states of India on turnkey basis, and many more such units are being set up. At present, the technology appears to have more acceptability in the areas deficient in green fodder resources such as hilly terrains and arid/semi-arid zones, or in places that face the shortage of both green as well as dry forages, e.g. Kerala State of India. Under emergency situations this technology has been used to save the animals from hunger and death. Due to many advantages this technology offers, it is slowly becoming popular amongst farmers in India.

Densified straw based feed pellets

Recently, a variant of the densified feed block technology has been developed. Using this technology, densified total mixed ration is delivered as pellets and not as blocks (Photo 17). This technology is particularly useful for those materials that are hard. Also it is a useful technology for regions in which feed milling plants are operating at a low capacity and biomass is available in abundance.

Straws that are highly lignified with hard fiber can be easily crushed and converted into TMR pellets. Straws of wheat, soybean, mustard and cotton can be used for production of straw-based pelleted feed. The feed pellets may contain 30–35% crushed straw, 10–12% molasses, 35–40% de-oiled rice bran, 10–15% oilseed meals, 1% each of urea and common salt, 1.5% calcite powder and 1% mineral mixture. The production cost of these pellets could be in the range of Rs.3.50 to 4.00 per kg where the availability of the biomass and other feed materials is not a constraint. If 6–8 kg of these pellets are fed per animal per day, it is possible to support body maintenance and 3–4 kg per day milk production. Depending up on the level of milk production, level of roughage component can be reduced and that of concentrates increased. For example, for the animals yielding about 15 kg of milk per day, straw-based pellets may contain 15–20% straw, 25% crushed grains, 30% oilseed meals, 10–15% rice polish, 10% molasses, 2% mineral mixture and 1% each of common salt and calcite powder.

In northern states of India, a large numbers compound cattle feed making plants exist. These plants are running at less than 50% of their capacities and in Punjab State of India alone an additional 1 500 tonnes of pelleted feeds can be produced per day if full capacities of the plants could be utilized. Agencies in the straw deficit areas need to get in touch with such private entrepreneurs in the areas of surplus, well in advance, for securing the



Photo 17.
Pellet mill for enriched straw

surplus biomass for the production and supply of straw-based pelleted feed. Some of the farms in India are producing and storing biomass in this manner. During the recent floods in eastern parts of India, straw-based pelleted feed was sourced from some of such feed mills.

During the scarcity periods densified straw-based pellets are produced and supplied by some of the millers in northern India. Straw-based pellet making plants are now being installed at Malabar union and Kerala Livestock Development Board in southern India with the technical support of NDDDB.

Flat-die has the potential to pelletize almost all kinds of straws having chop length up to 40 mm provided the proportion of straw is maintained below 50% in the feed mixture. Straw internodes are crushed thoroughly and the die of sizes 20 to 32 mm diameter is used in the pellet making plants. Using the device, hay and straws such as bagasse, groundnut shells, cotton balls, maize, millets, alfalfa etc along with other concentrate feed ingredients such as oil seed meals can be pelletized.

India and other developing countries having surplus biomass can use this technology for production of straw-based pellets for feeding dairy animals. Such pellets could also be used for creation of buffer stock in large quantity because the bulk density of the pellets exceeds 600 kg per cubic meter, very close to concentrate feed pellets. It is very difficult to make densified feed blocks from the highly lignified biomass as such blocks would tend to disintegrate if not packed immediately after pressing.

Major benefits of densified feed pellets are:

- Highly lignified biomass can be enriched and densified in the form of pellets which otherwise is difficult to handle.
- Densified pellets are more palatable than the straws/crop residues.
- Because of high bulk density, storage and transportation costs decrease.
- Wastage (up to 20%) is reduced.
- Fire hazards are reduced.
- Shelf life of the biomass increases.

Usually, the biomass with soft stem is considered to be more suitable for making densified feed blocks, while, the biomass that is more hard and lignified can be handled more effectively through the pellet making technology. Density of the straw-based feed blocks is about 450 kg per cubic meter against 600 kg per cubic meter for pellets. Pellets can be stored in bulk while blocks always need wrappers or high density polyethylene bags to retain their shape. During long storage sometimes blocks tend to swell back. Also, mechanical aeration and fumigation in bulk stored pellets is easier as compared to blocks, when densified biomass is required to be stored as buffer stock for longer duration of time (2–3 years) .

Feed pellet units can be used for production of straw-based feed pellets as well as for production of concentrate feed pellets. Straw-based block production units could be in use only for few months after the crop harvest season.

Conclusions

The commercial production of straw based densified total mixed ration blocks is an innovative technology, which could play an important role in feeding the balanced rations to dairy animals and other livestock in areas that face an acute shortage of green forages and of well managed pastures. As the demand for grains increases in future due to increased human population, and as increased amount of grains get diverted for biofuel production, the role and significance of densified straw based complete feeds is likely to increase. The technology offers attractive options of increasing milk and meat production in the tropics. Other advantages of this technology are: decrease in environmental pollutants, increase in income of farmers and increase in availability of free time with farmers, especially women, for other constructive tasks.

The technology also has the potential to remove regional disparity in feed availability, as the units can be set up to act as 'Feed Banks'. It could also provide complete feed to livestock under emergency situations created by natural calamities and man-made conflicts. The Government of India, realizing the potential of this technology, has thoughtfully decided to provide a furthering environment for propagation of this technology, offering 50% subsidy for setting up feed block units. This is acting as an incentive to attract the feed entrepreneurs, big dairy farmers and livestock cooperatives for the commercial manufacture of densified complete feed blocks on a large scale. However, there is a need to take up further research on energy cost of straw transportation and feed densification and how to reduce it. Research may also be taken up for monitoring the quality of the processed feed to check that the nutrients are not diluted by the addition of more of non-nutritional feed additives.

Densified feed pellet technology enables production of TMR in the form of pellets from biomass such as soybean, mustard and cotton stalks which are harder than rice, maize, and sorghum straws and dried grasses. It is also a useful technology for feed mills running at spare capacity and located in regions where the biomass is available in abundance, but is generally wasted. This would enable a judicious use of such biomass. It is important for the policy makers and feed entrepreneurs in the tropical region to realize the tremendous potential this technology offers, and take appropriate actions to promote the technology.

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Crop residues are valuable resources since they form a bulk of ruminant feed in many tropical countries. Due to lack of effective management of these resources, unfortunately they are being burnt in some countries, causing environmental pollution. The digestibility of crop residues and other low quality forages can be increased through the action of rumen microbes by strategically mixing nitrogen and minerals that are deficient in these feed resources. The increase in digestibility of crop residues and low quality forages, in turn also increases their intake. Both these phenomena enhance the efficiency of nutrient utilization from these feed resources in animal food chains. To achieve this, the present paper discusses a technology based on the formation of a complete diet in the form of densified feed blocks or pellets from straws mixed with minerals, oil seed cakes and other agroindustrial by-products. The methods for preparation of such total mixed rations, their use and impact have been presented. It is hoped that this technology will enhance income of farmers, decrease environmental pollution and help alleviate shortage of good quality feeds in tropical countries. In addition, the feed produced in the densified form as blocks or pellets could also provide complete feed to livestock in emergency situations. Public-private partnership is expected to enhance the application and impact of this technology.

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