Opportunities and Challenges for Straw Fortification for Livestock Feed: Scope for Mechanization

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Abstract

The prime reason for the poor performance of livestock in developing countries like India is the seasonal inadequacy of feed, both in terms of quantity and quality. Livestock production is mainly based on use of agriculture by-products and crop residues (including straws, stovers, husks and other crop by-products make up a major portion of animal feed in many developing countries) as feed resource. These residues are low quality fodder with low nitrogen, high lignin contents, poor digestibility and low intake by the animals. The fortification of straw upgrades the nutritional value of poor quality roughage. There are two types of (viz., loose and baled) straw fortification methods being practice in India. In these methods, the straw fortification will be performed in two different steps and in off-field condition. These reasons are leading to make the above methods more time consuming and labour intensive process. Therefore, there is a need to develop and adopt a suitable fortification application system which perform fortification job while baling the straw in the field itself so that, simultaneous fortification cum baling of straw in in-field condition is possible. So that, in addition to improve the nutritional value of straw, it also helps to reduce the time of fortification and labour expenses which will play an important role in traditional fortification methods.

Keywords

Baling, Fortification methods, Straw fortification, Livestock feed.

Introduction

Feed and fodder scarcity has been one of the limiting factors for improvement of livestock productivity in India (Thakur et al., 2007). Dairy production is mainly based on use of agricultural by-products and crop residues such as cereal straws contributing 45 – 60\% of the feed resource consumed by dairy animals. There is regional variation in the type of cereal straw commonly used for feeding animals. In Northern India, wheat straw is commonly used, while feeding paddy straw is common in Eastern, Southern and most parts of Western region (Roy and Rangnekar, 2006). The fundamental reason for the lower performance of livestock in developing countries is the seasonal inadequacy of feed, both in terms of quantity and quality. These deficiencies have rarely been corrected by conservation and/or supplementation, often for lack of infrastructure, technical know-how, poor management etc. (Makkar, 2000). The agricultural residues are low quality fodder (including straws, stovers, husks and other crop by-products make up a major portion of animal feed in many developing countries).
with low nitrogen and high lignin contents. These two factors are responsible for dairy animal’s poor digestibility and low intake and consequently low productivity of livestock (Maeng and Chung, 1989; Smith, 2001; Thakur et al., 2007). Expensive concentrates and milling by-products are forcing farmers to rely more upon crop residues as source of energy. India contributes nearly 17 % of the world’s human population and has a share of about 10.7 % of total livestock resource. But it has only 2.3 % of the total land area in the world. As per the 19th livestock census, India’s livestock population was 512.05 million during 2012-13. It was estimated that, the shortfall of dry fodder is 163 Mt (million tonnes) and the inadequacy of green fodder is 79 Mt. This shortage of fodder is due to growing importance of food crops and other cash crops to meet the needed of the growing human population (Anon., 2013; Anon., 2015).

Rice straw and other such crop residues including grass (from uncultivated land) have rich in cell wall lignin and provide unbalanced nutrients for the growth of rumen microbes (Sultana et al., 2011). The rice and wheat straws are the main crop residues which farmers usually store and use them as ruminant feed in India, especially during the long dry season whereby natural forages are being in constraint. The rice straw contains protein (2 to 5 %), crude fibre (34 %) and lignin contents (NDF > 50 %) and low digestibility (< 60 %) (Wanapat et al., 2013). Fibre contains high energy but is not available to animals due to its highly indigestible in nature. The primary components of fibre are cellulose, hemicellulose and lignin (Hussein et al., 2010).

**Importance of straw fortification**

Cereal straws are characterized by low crude protein, high lignin and low available energy content resulting in low intakes and utilisation by the livestock. Therefore the mechanical and chemical methods of processing have been proposed for upgrading the nutritional value of poor quality roughages (Hadjipanayiotu et al., 1997).

Physical and/or chemical treatments are necessary to improve the nutrient utilisation as well as to increase the bulk density to minimise the cost of collection, handling, transportation and storage. Since rice, wheat and other straws have low nutritive value, some fortification ingredient are mixed with them to increase the milk production of livestock. Molasses is one such fortification ingredient that increases the palatability of the straws due to its high sugar content. It also acts as a binder for the densification of straw (Garg et al., 2005). Ammonia is another such ingredient, treatment of crop residues with ammonia can increase digestibility of dry matter by 20 to 40 %, crude protein content by 2 to 3 fold and increase voluntary consumption by 20 to 35 % (Maeng and Chung, 1989). Use of a cheap source of nitrogen such as urea to improve the nitrogen and makes it a technically feasible method to improve the nutritive value of straw. But its application in the field has been very limited in India.

The fortification of straw from lime can also improve the utilization of straw by the livestock and supplement the ration with calcium, which has been found to be in a negative balance in cattle feed like rice straw (Hanafi et al., 2012). The acid detergent and neutral detergent fibre content of high moisture hay will be reduced by treating it with urea and that will increases the digestibility of their fibre components (Alhadhrami, 1991). Crude protein (CP) content of rice straw treated with 3 and 5 % urea will increase from 2.90 to 5.90 and 6.70 % respectively (Saadullah et al., 1981).
Ammoniation of wheat straw with urea significantly improves the mean daily consumption of wheat straw by 46% (Cloete and Kritzinger, 1984). The addition of urea at a rate of 40 g kg\(^{-1}\) of forage and above (weight w.b.) reduces microbial activity and increases the nitrogen content of hay by approximately 14.50 g kg\(^{-1}\) (Belanger et al., 1987). Maeng and Chung (1989) reported the daily gain of 20 and 30% respectively for animals fed by anhydrous and aqueous ammonia treated rice straw.

Addition of anhydrous ammonia into the high-density round bales of rice straw improves palatability to cattle and conditions of straw to withstand for long periods of outside storage (Toenjes et al., 1986). Fertilizer-grade urea treated high moisture alfalfa hay remains free of visible mould and increases the nutritive value of the hay because urea will broke down to ammonia and carbon-dioxide. The released ammonia acts as a preservative (Ghate and Bilanski, 1979). The voluntary feed intake is also significantly higher on urea treated rice straw rations stored either as stack or bale compared to untreated rice straw ration stored either as stack or bale (Prasad et al., 1998). The lactating goats feeding by urea-treated wheat straw would significantly increases the percentage of fat, solid not fat, casein, titrable acidity, ash and decreases pH of milk compared to those feeding with wheat straw alone (Al-Busadah, 2008).

**Straw fortification by various treatment**

Various treatment methods are being used to improve the nutritive value of rice straw those include physical, biological and chemical treatment. Among these methods chemical, physical and/or combination of physical-chemical methods of straw fortification is being widely practiced as a method of improving intake and digestibility.

**Physical treatment methods**

In this method, crop residues can be ground, soaked, pelleted or chopped to reduce particle size or can treated with steam and/ pressure (Hanafi et al., 2012). These methods improve the quality of cellulosic feedstuffs for animals by freeing digestible materials from lignin or silica (Liu et al., 1990). But these treatments are not practical for use on small scale farms because they require machines or industrial processing.

**Biological treatment methods**

The use of fungi and/or their enzymes that metabolize lignocelluloses is a potential biological treatment to improve the nutritional value of straw by selective delignification (Hanafi et al., 2012). The potential of biological treatment would be explained by the ability of certain microbes specifically basidomycetes fungi to disrupt plant cell by partial breakdown of the lignin-carbohydrate complex thus improving their utilisation in the rumen by increasing the availability of fermentable energy to rumen microbes (Mahesh and Mohini, 2013). Nitrogen intake, its digestion and retention in cross breed calves fed by fungal treated wheat straw would higher than urea treated straw fed group (Walli et al., 1988).

**Chemical treatment methods**

In this method, chemicals are used to improve the utilization of crop residues by ruminants by improving their feeding value. The chemicals may be alkaline, acidic or oxidative agents. Among these, alkali agents have been most widely investigated and practically accepted for application on farms. Basically, these alkali agents can be absorbed into the cell wall and chemically break down the ester bonds between lignin and hemicellulose and cellulose and physically make the structural
fibres swollen. The most commonly used alkaline agents are sodium hydroxide (NaOH), ammonia (NH₃), lime and urea (Hanafi et al., 2012).

Among the chemicals being used for straw fortification, NH₃ and urea have a considerable attention because these chemicals make the treated material palatable by solubilizing the hemicellulose fractions, thus improving the DM digestibility and daily DM intake (Mir et al., 1991, Jabbar et al., 2009 and Ali et al., 2012). In India, use of urea for straw fortification is common because of its readily availability, safe and easy to handle as it is soluble in water.

Efforts were made in the past to improve the straw digestibility and protein through chemical treatment. The various fortification chemicals used by several researchers in past studies are given in table 1.

Fig.1 Schematic flow chart of loose straw fortification method

Fig.2 Schematic flow chart of baled straw fortification method

![Flowchart Diagrams](image-url)
Fig. 3 Various loose straw fortification methods (a indicates straw chopped to small pieces for fortification, b and c shows non chopped loose straw fortification and d represents fortification by spraying and stacking of bundled straw layer by layer)

Fig. 4 Fortification of baled straw in treatment plant (a and c and b and d represents the straw bales in batch type treatment plant before and after fortification respectively)
Table 1. Chemical/material used for fortification by various researchers

<table>
<thead>
<tr>
<th>Name of the straw/stover</th>
<th>MC of straw at fortification time in % (w.b)</th>
<th>Chemical/material used for fortification</th>
<th>MC added during fortification in % WRTSW</th>
<th>Proportion of fortification material used in % WRTSW</th>
<th>Author</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paddy</td>
<td>10.76</td>
<td>Ammonia solution (urea)</td>
<td>40</td>
<td>9.50 on DM basis</td>
<td>Kumar et al., (2010)</td>
</tr>
<tr>
<td>Paddy</td>
<td>-</td>
<td>Urea</td>
<td>50</td>
<td>4</td>
<td>Prasad et al., (1998)</td>
</tr>
<tr>
<td>Wheat</td>
<td>-</td>
<td>Urea</td>
<td>40</td>
<td>4</td>
<td>Meena et al., (2011)</td>
</tr>
<tr>
<td>Wheat</td>
<td>-</td>
<td>Urea Ammoniation</td>
<td>-</td>
<td>4</td>
<td>Pachauri et al., (2010)</td>
</tr>
<tr>
<td>Sorghum</td>
<td>-</td>
<td>Molasses and urea</td>
<td>-</td>
<td>10 &amp; 2 respectively</td>
<td>Nagalakshmi and Reddy (2012)</td>
</tr>
<tr>
<td>Wheat</td>
<td>-</td>
<td>Fertilizer grade urea</td>
<td>50</td>
<td>4</td>
<td>Jabbar et al., (2009)</td>
</tr>
<tr>
<td>Barley</td>
<td>-</td>
<td>NaOH, (NH₄)₂SO₃, NH₄OH, NaHSO₃</td>
<td>40 on DM basis</td>
<td>1, 2.5, 5 &amp; 7.50 (NaOH&amp; (NH₄)₂SO₃), 2.6 NH₄OH &amp; 1.6 NaHSO₃ on DM basis</td>
<td>Kudo et al., (1994)</td>
</tr>
<tr>
<td>Wheat &amp; paddy</td>
<td>-</td>
<td>Urea</td>
<td>50 &amp; 40</td>
<td>4</td>
<td>Roy and Rangnekar (2006)</td>
</tr>
<tr>
<td>Wheat</td>
<td>-</td>
<td>Urea</td>
<td>-</td>
<td>4</td>
<td>AL-Busadah (2008)</td>
</tr>
<tr>
<td>Paddy</td>
<td>-</td>
<td>Urea</td>
<td>55</td>
<td>3 to 5</td>
<td>Saadullah et al., (1981)</td>
</tr>
<tr>
<td>Barley</td>
<td>-</td>
<td>Urea</td>
<td>40</td>
<td>4</td>
<td>Hadjipanayiotou et al., (1997)</td>
</tr>
<tr>
<td>Wheat &amp; rice</td>
<td>-</td>
<td>Fertilizer grade urea</td>
<td>50</td>
<td>8 of water applied</td>
<td>Sharma et al., (2004)</td>
</tr>
<tr>
<td>Cassava peel</td>
<td>-</td>
<td>Fertilizer grade urea</td>
<td>20</td>
<td>4, 6 &amp; 8</td>
<td>Uzaet et al., (2005)</td>
</tr>
<tr>
<td>Wheat</td>
<td>-</td>
<td>Urea &amp; molasses</td>
<td>60</td>
<td>3 &amp; 10 respectively on DM basis</td>
<td>Saeed and Latif (2008)</td>
</tr>
<tr>
<td>Sorghum</td>
<td>3.55</td>
<td>Urea &amp; molasses</td>
<td>10 on DM basis</td>
<td>2 &amp; 20 respectively on DM basis</td>
<td>Nianogo et al., (1993)</td>
</tr>
<tr>
<td>Paddy</td>
<td>-</td>
<td>Urea &amp; urea-calcium hydroxide</td>
<td>100</td>
<td>3 &amp; 5</td>
<td>Wanapat et al., (2013)</td>
</tr>
<tr>
<td>Maize</td>
<td>-</td>
<td>Urea</td>
<td>100</td>
<td>4</td>
<td>Yahaya and Kibon (2013)</td>
</tr>
<tr>
<td>Paddy</td>
<td>-</td>
<td>Urea + Ca(OH)₂&amp; ammonium hydroxide</td>
<td>100</td>
<td>2 + 0.50, 3 respectively on DM basis</td>
<td>Elseed et al., (2002)</td>
</tr>
<tr>
<td>Wheat</td>
<td>-</td>
<td>Feed grade urea</td>
<td>40</td>
<td>5</td>
<td>Cloete and Kritzinger (1984)</td>
</tr>
<tr>
<td>Paddy</td>
<td>-</td>
<td>Lime, urea &amp; lime + urea</td>
<td>-</td>
<td>3, 4 &amp; 3 + 4 respectively</td>
<td>Trach et al., (2001)</td>
</tr>
<tr>
<td>Wheat</td>
<td>-</td>
<td>Urea &amp; commercial lime powder</td>
<td>50</td>
<td>2, 3, 4 &amp; 5 and 2, 4 &amp; 6 respectively</td>
<td>Sirohi and Rai (1999)</td>
</tr>
<tr>
<td>Paddy</td>
<td>-</td>
<td>Anhydrous ammonia &amp; aqueous ammonia</td>
<td>-</td>
<td>3 &amp; 3 on DM basis</td>
<td>Maengand Chung (1989)</td>
</tr>
<tr>
<td>Paddy</td>
<td>22 – 30</td>
<td>Ammonia</td>
<td>29.5-29.7 (retained in the bales after fortification)</td>
<td>5 on DM basis</td>
<td>Toenjes et al., (1986)</td>
</tr>
<tr>
<td>Paddy</td>
<td>-</td>
<td>Fertilizer grade granulated urea</td>
<td>-</td>
<td>3.50 on DM basis</td>
<td>Hossain et al., (2010)</td>
</tr>
</tbody>
</table>

MC: moisture content; WRTSW: with respect to straw weight
Chemical treatment method for straw fortification

The two types of chemical treatment methods are being practice in India for straw fortification. One among these is fortification of loose straw near to dairy barn or cowshed and other one fortification of baled straw in treatment plant. The loose straw fortification method (shown through schematic flow chart in Fig. 1) involves collection of straw from the field manually and transporting the collected straw near to the cowshed (Roy and Rangnekar, 2006). The straw will be chopped (if straw is not obtained from combine harvested field) and spread on the clean and hygienic floor near to cowshed or dairy barn. The required amount of fortification chemical will be weighed based on the dry matter (DM) content of the straw, mixing it with desired amount water and spraying the fortification solution on to the spread straw layer by layer by using garden sprayer as shown in figure 3. The sprayed straw will be mixed thoroughly in order to ensure uniformity of spraying (Saadullah et al., 1981, Sharma et al., 2004, Ali et al., 2009 and Hossain et al., 2010). The fortified straw will be incubated for some specified days under the cover of plastic sheet or mud plaster (Jabbar et al., 2009). In this fortification method, the steps involved are collection of straw from the field, transporting the collected straw near to the cowshed or barn, preparation of urea solution, sprinkling of solution on straw and pressing the straw during treatment process. Thus requires more number of labours and also more time to fortify per unit weight of straw.

The second method of straw fortification involves baling of straw in the field, carrying the bales from field to treatment plant (as shown in figure 2 through a schematic flow chart). In treatment plant, the bales will be placed in the form of stacking one above the other up to a three to four bale height as shown in figure 4. The pre calculated amount (on straw DM basis) of fortification chemical will dissolve with the known quantity of water to form a solution. Then the fortification solution is sprayed or dripped on the stack of bales in plant with the help of sprayer or dripper (Cloete and Kritzinger, 1984, Belanger et al., 1987, Kumar et al., 2010 and Ali et al., 2012). After fortification, the fortified bales may remained on the treatment plant for an hour in order to drain the excess flow of fortification solution from the bales before it get shifted to incubating place (Kumar et al., 2010). This method fortification is well suited for large scale whereas loose straw fortification method is suited for small scale requirements. This method is better as compare to first method in terms of saving time and labour expenses. But still it requires considerable number of labour for loading and unloading bales to and from the plant, aligning the dripping or spraying system to the stacks of bales in plant and covering the treated bales off-side the plant (Kumar et al., 2010). Because of these reasons, the total cost of fortification per unit weight of straw will increase.

Limitations for adoption of straw fortification methods

Various factors contributed to the lack of impact, most notably the difficulty by farmers to carry out the technical job unaided and the extra work of treatment. The lack of demonstration of satisfactory cost-benefit ratio of using urea treated straw during the entire production cycle of the animals also the reason for the unpopularity of straw fortification (Sharma et al., 2004). In the traditional fortification methods, the fortification of straw will be done in number of steps. Because of this, the traditional fortification methods become more time consuming and labour intensive process.
In India, at present, the practice of straw fortification is done in two different methods. One of these methods is spraying of fortification solution (water + fortification chemicals with recommended proportion) on to the sun dried chopped straw, layer by layer. Another method is spraying of fortification solution on to an each layer of stack of straw bales. It clearly tells that the baling and fortification operation are being done separately and non-homogeneity of fortification within the bales. To reduce the number of operation i.e., baling operation and later fortification process, a simultaneous fortification cum baling operation in in-field condition is needed. So that the separate process of bales or straw fortification can be eliminated and which results in saving of time and labor expenses leading to cost for fortification.

References


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