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POSSIBILITIES OF NON-CONVENTIONAL FEED RESOURCES IN LIVESTOCK FEEDING-A REVIEW

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SUMMARY

Conventional feed sources are an indispensible part in livestock feeding for Indian rural households. Though India possesses huge population of diverse livestock, but the productivity is low. The main constraint in livestock production is unavailability or fluctuating year round feed supply of quality feed. Therefore, for sustainable development of livestock sector, it is pertinent to look into all possibilities to overcome feed shortages. The inclusion of non-conventional feed resources (NCFR) could be a most viable option for bridging the gap between supply and demand for animal feeds, for reducing the competition between human and animals for food and for providing nutritional sufficiency to available feed sources. This would also be an effective way of diversification of traditional agriculture and biodiversity conservation. A variety of feeds from perennial crops, multipurpose trees and shrubs, weeds and agro-industrial byproducts are included in the category of NCFR. They are excellent source of nutrients which keep intestinal microflora active for digesting cellulosic biomasses. However, some of them are low in nutritive quality and contain high concentrations of aversive factors which reduce the nutrient utilization and causes discontinuation of various metabolic processes. An array of processing and feeding methods has been developed to overcome the negative effects of the anti-nutrients from NCFR. The present review emphasizes the integration of NCFR in livestock feeding for achieving improved livestock productivity and the sustenance of rural livelihoods.

Keywords : Anti-nutrients, Fodder scarcity, NCFR, Nutritional composition, Processing, Tree fodder

Agriculture and animal husbandry are two major components interwoven with the intricate fabric of diverse culture, religious beliefs and economic values in the rural community. The efficient utilization of these components is absolute for improving the socioeconomic status of rural households. India is basically an agrarian country, where crop farming and rearing of livestock have economic and socio-cultural roles in wellbeing of the rural households. Although India has the largest population of livestock in the world, but their productivity is comparatively low (Katoch, 2009, Katoch et al., 2017). Studies have revealed that scarcity of year round unavailability of feed, continuous hiking in the prices of commercial feeds; over reliance on low quality feed stuffs and low genetic potential are the key reasons for low livestock productivity in the country. It has been estimated that by the year 2025, Indian livestock has an expected deficit of 68% green fodder, about 25% dry fodder and 64% feeds for meeting the mounting feed requirements (Ayyadurai et al., 2013; Singh et al., 2013). Additionally, the increased human population and their increasing demands for the animal products have further aggravated the situation. The above circumstances necessitate the identification and exploitation of NCFR for feeding millions of animals and safeguarding their food as well as nutritional security. The propagation of alternative fodder sources would lead to diversification of traditional agriculture and conservation of biodiversity through sustainable utilization of natural resources. Till date, the utilization of the non conventional fodder sources in livestock feeding is limited due to meager information on their nutritive potential.

NON-CONVENTIONAL FEED RESOURCES-An Overview

Non conventional feed resources are generally defined as “Shrub fodder, tree fodder, and agro-industrial by products which have not been utilized traditionally and/or commercially in livestock feeding (Amata, 2014). Now a days, the term “new feeds or alternative feeds”, is being increasingly used to describe new feed sources. A number of feed resources have been included in the category of NCFR and their numbers are increasing. Even though many resources of NCFR are available, the farmer perceptions on

NCFR vary from country to country and region to region. Sometimes, it is also difficult to distinguish traditional feeds and NCFR. Therefore, identification of available NCFR is necessary to exploit their potential in order to bring changes in livestock feed improvement programs for enhancing livelihood of the people.

Some salient characteristics of NCFR are:
(1) Low economic value
(2) Alternative source to ensure feed insurance during lean periods *e.g.*, Tree foliage
(3) Non competitive in terms of human consumption
(4) Excellent source of fermentable nutrients
(5) Conservator of biodiversity
(6) Enhances the environmental resilience of farming system
(7) Compatible with existing farming system
(8) End products of various production processes and consumption *e.g.*, Agro-industrial by products.

SOURCE AND AVAILABILITY OF NCFR

The sources and availability of NCFR could be as follow:

1. From cereal crops, NCFR can be obtained in the form of as straw and hull; from grain crop, stover and husk can be used as NCFR; from beans, straw and pod peel can be used as NCFR and from tuber crops, NCFR can be in the form of stems, tops and vines. The availability of these NCFR depends on the type of crop is in cultivation and applied crop technology.
2. In the estate crop, where shrubs and trees are used as a shade and climber, NCFR is in the form of shrubs, leaves and pod peels. In sugarcane plantation, sugarcane top and bagasse can be used as NCFR. In plantation crops like coconut and palm, NCFR is available in the form leaf fronds and fruit husk.
3. In agroforestry, shrubs and tree leaves can be used as alternative feed source.
4. In natural pastures, weeds can also be a source of feed.

NUTRITIONAL STATUS OF SOME POTENTIAL NCFR

NCFR in Agro-forestry system : Agro-forestry includes both trees and agricultural production on same piece of land (Mellink *et al.*, 1991). It is not only as a way of increasing the timber, energy, feed and food productions but also contributing to environment conservation. NCFR has potential in different variants of agroforestry including:

1. Silvicultural system
2. Silvipastoral system
3. Agrisilvicultural system
4. Agrisilvipastoral system

In silviculture system, NCFR can be obtained in the form of tree foliage and pod peel, while in agri-silvicultural system, where food crops are integrated, straw, stover, and other crop wastes are another form of NCFR. In silvipastoral system, where pasture production is the main objective, NCFR can be obtained in the form of tree fodder, shrub, and weeds for cattle. In agri-silvipastoral system, shrub, tree foliage, and crop waste/residues can be used as NCFR.

Trees are an important component of agroforestry system, and considered as best alternative feed source because they can easily grow, require minimum efforts, maintain soil fertility and are excellent source of nutrients. In order to promote the utilization of tree foliage as a component of ruminant feeding, the information about under given points is essential, which include

- Nutritive value of tree foliage
- Ability to regenerate foliage
- Effect of different environmental conditions on voluntary intake
- Growth pattern
- Adaptability to local environmental conditions
- Easy establishment
- Tolerance to various management practices

FODDER TREES IN LIVESTOCK PRODUCTION

- Fodder trees have long been considered as an alternative source to ensure feed insurance to farmer during pronounced dry periods (Lefroy *et al*., 1992; Tol, 2004; Kamalak *et al*., 2004; Van *et al*., 2005). They remain lush green in seasonal dry conditions due to extensive root system which enable the extraction of water and nutrients from deep soil profile (Lefroy *et al*., 1992; Abel *et al*., 1997; Teferi *et al*., 2008).
- Marginal and sub-marginal farmers rear particularly cattle, goats and sheep to generate income by producing milk, meat, leather, wool and manure. To maintain stable health conditions of the animals, farmer generally fed low quality feeds. Though various commercial feed concentrates are available for supplementation but regular increase in their prices make them uneconomical to be used in livestock feeding. The leaves of fodder trees contain high level of proteins (10 to 30% of dry matter) and can replace the concentrates without any adverse effects on animal health.

- Fodder trees improve the physical and chemical properties of soil by providing green mulch, by fixing the atmospheric nitrogen into readily available form with the help of symbiotic association with rhizobium and by increasing the uptake of minerals such as phosphorus through mycorrhizial association in roots (Topps, 1992). Forage trees also serve as source of shade, wind shelter, live fence, improved fallow, bee forage, human food, fuel wood, timber, fiber, resins, dyes, medicines, wildlife habitat, nutrient cycling and farm diversity (Elevitch and Wilkinson, 2000).

NUTRITIONAL COMPOSITION OF SOME IMPORTANT FODDER TREES

Fodder trees have excellent nutrient profile with high feeding value, tolerance of a wide range of management practices, longevity and capacity for alleviating acute feed shortages when all other fodder sources have been exhausted (Katoch, 2009; Katoch *et al.,* 2017). As compared to conventional grasses, tree foliages have good proportions of nutrients which keep intestinal microflora active for digesting cellulosic biomasses (Rana *et al*., 1999; Shelton, 2004; Katoch *et al*., 2012; Singh and Todaria, 2012; Singh *et al*., 2015). The nutrients from fodder trees retain the microbial activity in gastrointestinal tract of ruminants, which increases their efficiency of livestock for better utilization of dry season pastures (Abel *et al*., 1997). The nutritive value of fodder trees is significantly affected by various plant and environmental factors. Sharma *et al*. (1966) reported that crude protein content in tree foliages ranges from 9.13 to 22.08% while calcium and phosphorus content ranges from 0.50 to 6.31mg/100g and 0.12 to 0.27 mg/100g of dry matter, respectively. Sahoo *et al.* (2016) estimated that calcium content ranged from 1.20% to 2.70% in fodder tree leaves. High calcium content in *Ficus palmata* (2.70%) than the critical level (<0.30%) could be useful during the early stages of lactation in animals. *Bauhinia variegata* have excellent nutritive profile, resemble to other leguminous fodder (Negi, 1986).

Khosla *et al*. (1992) also observed high protein content (32%) in immature leaves of *Grewia optiva*, *Celtis australis* and *Robinia pseudoacacia*. Protein form *Grewia oppositifolia* and *Bambusa arundinacea* leaves show similarity in digestibility to other leguminous forages (Sharma *et al*., 1966). Pal *et al*. (1979) reported that average dry matter composition (%) of fodder trees growing varies with respect to crude protein from 10.29% in *Ficus benghalensis* to 20.99% in *Albizzia stipulata,* crude fiber from 14.38% in *Morus alba* to 33.74% in *Atriplex stipulata*, nitrogen free extract (NFE) from 35.41% in *Bambusa nutans* to 60.41% in *Syzygium cumini*, total ash from 7.40% in *Bauhinia variegata* to 17.41% in *Cordia dichotoma*, insoluble ash from 0.35% in *Syzygium cumini* to 8.05% in *Banksia nutans*, calcium from 0.76% in *Dendrocalamus hamiltonii* to 4.79% in *Aegle marmelos* and phosphorus from 0.11% in *Syzygium cumini* and *Quercus incana* to 0.25% in *Callicarpa dichotoma*. The comparative analysis of different fodder trees by Khatta and Katoch (1983) reported that *Bambusa arundinacea* is a nutritionally superior, ecologically resilient, fast growing plant with more palatable foliage.

Mulberry (*Morus alba* var. *multicolis*) is considered as an excellent alternative for low quality forages in Himalayan region owing to excellent nutrient profile with 15.00 to 27.60% crude protein, 2.30 to 8.0% ether extract, 9.10 to 15.30% crude fiber, 48.0 to 49.70% nitrogen free extract, 63.30% total carbohydrates, 14.30 to 22.90% ash, 2.42 to 4.71% calcium, 0.23 to 0.97% phosphorus, 30-50ppm iron, 0.5 to 1.0% potassium, 33.00 to 46.00% NDF, 28.00 to 35.00% ADF, 5.00 to 10.00% hemicelluloses, 19 to 25% cellulose and around 11% lignin content on dry matter basis (Jayal and Kehar, 1962; Singh *et al*., 1984; Lohan *et al*., 1979; Singh *et al*., 1989; Makkar *et al*., 1989). Dhungana *et al*. (2012) reported that protein content in fodder trees varied from 15.00 to 29.00%, of which, *Artocarpus lakoocha* contains highest amount of crude protein, *Ficus lacor* have highest crude content (42.07%), and *Machilus odoratissima* yields highest amount of digestible carbohydrates (21.92%). Sahoo *et al.* (2016) also reported that OM, CP, EE, NDF and ADF contents in fodder trees varies from 90.60 to 97.40%, 9.50 to 21.10%, 3.90 to 5.90%, 38.40 to 69.40% and 40.10 to 70.50%, respectively. Makkar and Becker (1998) reported protein content in fodder trees from 8.0 to 25.90%. The changing nutritive profile of fodder trees with different environmental conditions during growth reveals the significant influence of seasonal variations on nutritional constituents. Cell wall constituents *viz.,* NDF, ADF and hemicellulose content in fodder trees of Himalayan region increases while crude protein, ether extract, ash cell content decreases in advancing months of the year (Katoch *et al.* 2017). Leaves of *Morus alba* retained maximum nutritive value from March to April and September to December. *Grewia oppositifolia* leaves was advocated as excellent feed from May to June, July to August and from January to February which could be a supplementary fodder during lean season of the year (Katoch *et al.* 2017).

NCFR FROM FIELD AND PLANTATION CROPS

1. From rice : Rice cultivation represents the most important component of agriculture in more than a hundred countries. In most of these countries, rice milling industry is very much advanced and associated with the important agro-based industries due to the higher production of crop byproducts such as paddy husk and rice bran. Generally, paddy husk is not preferred as animal feed because of its limited nutritional value; however, it is valuable as roughage (White, 1965, Horton and Flynn, 1967). Paddy husk can be milled into a fine powder and used as diluents of other high energy feed stuff (Richardson *et al.*, 1958). Rice bran, an oil rich byproduct of rice, is considered as a good source of energy. It also contains a considerable amount of protein (up to 15%). The amino acid profile of rice bran is well balanced and compares favorably with other cereal bran. Besides providing quality proteins and energy, rice bran also considerable amounts of vitamins B, E and anti-oxidants that are essential for better animal health (Table 1).

2. From sugarcane : Bagasse refers to the remaining residue after the juice extraction from sugarcane. It constitutes approximately 15 to 20% of sugarcane tops. Presently, bagasse has principle use as a fuel but bulky and fibrous nature makes it a valuable feed source for livestock feeding. Roxas *et al.* (1969) determined that digestibility of bagasse based diets supplemented with molasses and copra meal revealed higher dry matter intake in large ruminants. Replacement of maize silage with bagasse have negligible effect on weight gain, feed intake and feed efficiency (Hochstrasser *et al.*,1977).

3. From banana, cassava, coconut and coffee :

(a) Banana wastes and banana stems are two by-products from banana cultivation that are potentially used as feeds (Devendra, 1985). Reject bananas have also been used as a fermentation substrate for the production of single cell protein (Sequido *et al.*, 1979).

(b) The waste products obtainable from cassava roots s used for the feeding of livestock especially ruminants. The other waste product obtained from the root is cassava pulp. This can be used as a replacement to ragi flour in the diets of layers (Pillai *et al.*, 1968).

(c) Coconut meal, a byproduct of coconut or skin of the coconut is obtained after pressing or extracting oil. It is a highly digestible supplement with moderately high protein and energy values.

(d) Coffee pulp and coffee parchment are two important by product of coffee cultivation. Coffee pulp has lower levels of NDF, ADF and lignin and thus has higher OMD (Negesse *et al.*, 2009).

NCFR FROM WEEDS AND OTHER SOURCES

(i) From weeds : Weeds are frequent visitors of crop fields and pastures; therefore, it is necessary to know the potential quality of individual weed species for making their management decisions. It is generally assumed that weeds are of low nutritive quality and could not be used for livestock feeding; however, many weeds have excellent nutritive profile with high IVDMD. In a study conducted by Marten and Andersen in 1975, reported that dandelion (*Taraxacum officinale*), white campion (*Silene alba*), perennial sowthistle (*Sonchus arvensis*), Jerusalem artichoke (*Helianthus tuberosus*), and hoary asylum (*Berteroa incana*) at their vegetative and bud stages have higher/equal IVDMD than alfalfa (*Medicago sativa*) whereas, Redroot pigweed (*Amaranthus retroflexus*) and common ragweed (*Ambrosia artemisiifolia*) shows higher IVDMD than alfalfa, while common lambsquarters (*Chenopodium album*), yellow foxtail (*Setaria glauca*), and barnyard grass (*Echinochloa crusgalli*) has similar IVDMD to alfalfa. The study conducted by Marten and Anderson (1975) revealed higher IVDMD of common ragweed, velvetleaf (*Abutilon theophrasti*), redroot pigweed, and barnyard grass in comparison to oats (*Avena sativa)*. Temme *et al.* (1979) reported that common lambsquarters, Pennsylvania smartweed (*Polygonum pensylvanicum*), redroot pigweed, and common ragweed have similar or slightly lower NDF concentrations than alfalfa.

Redroot pigweed, common lambsquarters, and Pennsylvania smartweed had less ADF than alfalfa (Marten and Anderson, 1975). Temme et al. (1979) obtained similar results for common lambsquarters, Pennsylvania smartweed, redroot pigweed, and common ragweed. Many species of genus Rumex are considered as nuisance weeds, and but some of them have edible quality and are commonly used in soups and salads (such as R. acetosa L., R. sanguineus L., R. patientia L. and R. scutatus L. Rumex acetosa) (Tuazon-Nartea and Savage, 2013). Rumex hastatus, Rumex obtusifolius and Rumex nepalensis are important weeds of this genus. Although, these species are considered as most difficult weeds, but they possess certain characteristics that are important from the forage perspective (Al Haj Khaled et al., 2006; Hameed and Dastagir, 2009; Humaira et al., 2014; Abbasi et al., 2015). The study conducted in our laboratory revealed that crude protein, ash content, reducing sugars and cell content in Rumex hastatus, Rumex obtusifolius and Rumex nepalensis ranged from 22.05 to 31.15%, 7.40 to 18.13%, 18.62 to 31.51%, and 56.46 to 59.00%, respectively. Different cell wall constituent's viz., NDF, ADF, ADL, hemicellulose, and cellulose varied from 41.00 to 43.53%, 27.33 to 33.00%, 9.33 to 11.40%, 10.53 to 13.62% and 16.80 to 23.66%, respectively. The polyphenolic compounds i.e., total phenols, simple phenols and total tannins were in the range of 3.43 to 7.46%, 1.40 to 3.35% and 2.03 to 4.11% respectively. Oxalate content, known for the toxicity of Rumex species, was considerably low (3.60 to 5.50%) in comparison oxalate rich feeds like forage grasses. The digestibility of organic matter (OMD), and dry matter (DMD), metabolizable energy (ME) and dry matter intake (DMI) for Rumex species varied from 55.04 to 59.80%, 63.25 to 66.96%, 8.78 to 9.38 MJ/kg DM, and 2.75 to 2.92 % BW), respectively (Unpublished data). The results of the study indicated that Rumex species could also be considered as potential non-conventional feed source in future.

(iii) From aquatic plants : Aquatic plants also have potential to be used as feed source due to high protein content and low lignin content. Immature plants of aquatic fern contains considerable amount of CP (10.45%) but low dry matter (20.35%), ether extract (1.37%), crude fiber (26.96%) and ash (6.96%) than matured aquatic fern. Duckweed **(***Lemna minor*) also contains high crude protein content ranges from 6.8 to 45% and has the potential to be used for supplementing low quality roughages. It is also rich in carbohydrate (14.10% to 43.60%) and has higher concentration of essential amino acids, trace minerals and pigments such as xanthophylls and carotenes (Fasakin et al., 1999; Negesse *et al.,* 2009). Azolla also holds the promise of providing a sustainable feed for livestock. Gouri *et al.* (2012) reported that floating fern contain 90.10% dry matter; 79.70 % organic matter; 15.40% crude protein; 14.10% crude fiber; 2.70% ether extract; 47.40% nitrogen free extract; 20.40% ash content; 15.60% hemicelluloses; 6.80% celluloses and 17.50% lignin which are required for all classes of livestock including poultry and fish.

(iv) From cactus : Spineless cactus (*Opuntia ficus-indica*) also has the potential as alternative source of fodder in arid and semi arid regions particularly of central parts of India. They can grow well in severely degraded soils and have great capacity to withstand severe dry conditions. The plants retain high water content (up to 95 %) and could reduce the water requirements in animals. It has also been reported that cactus nutrients are degraded and absorbed in the rumen between 6 to 24hr (Firew *et al.*, 2006; Maltsberger, 1996; Shoop *et al.*, 1977; Nefzaoui and Salem, 2001). The pads of cacti are the rich source of soluble carbohydrates, calcium, potassium and vitamin A. Ben Salem *et al.*, (1996) reported that supplementation of poor roughages with cactus, increased feed intake, diet digestibility and improves the microbial activity in gastrointestinal tract of animal.

(v) From Sisal (*Agave sisalana*) : Sisal leaf waste has been used profitably as cattle and rabbit feed. The succulency of fresh sisal waste makes it a useful feed during dry periods. It contains high concentrations of crude protein (76g/kg DM) and metabolizable energy (6.6 MJ/kg DM), but excessive feeding induces haemolysis due to high saponin content (Butler and Baiyley, 1973; Negesse *et al.,* 2009). Soaking of the leaf waste in water before feeding has been recommended to reduce the saponin content.

(vi) From agro-industrial byproducts : The mounting demands of teeming human population for food have increased the total cropping area the under food crops which leads to increased availability of agro-industrial by-products. However, they are not fully utilized for feeding purposes due to difficulties in handling, storage and lack of efficient ways for their integration in feeding regimes (Chadhokar, 1984). For example, the residues generated from the tomato processing industries contain high crude protein and metabolizable energy but high moisture content and difficulties in transportation and storage limits their use as a livestock feed.

CONSTRAINTS IN USING NCFR AS A LIVESTOCK FEED

A number of factors are associated with the limited use of non-conventional feed resources. These are :

(1) Low nutritive value
(2) Seasonal availability
(3) High cost of handling and transportation
(4) Meager information on nutritive value and their efficient integration in livestock feeding
(5) Presence of anti-nutritional factors
(6) High toxicity due to fungal and bacterial growth
(7) High moisture content in some feed resources

DELETERIOUS PRINCIPLES IN NCFR

The high nutritive value of NCFR encourage their wide spread use as an economical feed resource to increase feed intake and nutrient digestibility. However, animals refuse to eat certain feeds due to high level of anti-nutritional factors (Table-2). These anti-nutritional factors interfere with nutrient intake, their digestion, absorption and utilization. These factors in NCFR have been categorized under two classes :

(i) Non-proteinaceous and
(ii) Proteinaceous antinutrients

TABLE 1
Nutrient content of some non-conventional feed resources (Alimon, 2009)

Feedstuffs	Dry matter (%)	Crude protein (%)	Crude fiber (%)	Crude fat (%)	ME poultry (MJ/kg)	ME ruminants (MJ/kg)
Root crops : Cassava meal, sweet potato	20-27	3-4	4-6	2-4	10.50	11.00
Copra meal	91.00	20.00	26.00	4.00	-	8.00
Rice bran	90.00	15.00	13.00	15.00	10.50	11.00
Paddy husks	91.00	5.00	45.00	1.00	4.00	6.00
Legume leaves, peas, winged bean, grams	20-25	15-25	15-25	5-12	10.50	11.00
Oilseed meal : linseed, cottonseed meal, sunflower seed,	88-91	35-40	12.00	1.70	10.50	10.00
Poultry by products	94.00	60.00	2.10	17.10	10.50	10.50

The first class of anti-nutrients mainly includes alkaloids, phytic acid, polyphenolic compounds (tannins, lignins), nitrates, oxalates, cyanogenic glucosides and saponins while latter includes protease inhibitors, ?-amylase inhibitors and lectins. Anti-nutritional factors due to their unpleasant taste, poor palatability, toxicity and indigestibility are disliked by animals. The toxicity and indigestibility of anti-nutrients depends on chemical nature and rate of degradation by ruminal microbes. The anti-nutrients factors can also be further classified into different groups on the basis of their effects on nutritional value of the feedstuffs, and on the basis of biological responses to them in animals. Using this criterion, different anti-nutritional factors have been classified into following subgroups (Huisman and Tolman, 2001).

I. Factors having reductive effects on protein digestion and mobilization *e.g.*, protease inhibitors, tannins and saponins.
II. Factors depressing the mineral utilization *e.g.*, phytates.
III. Factors associated with immunostimulatory effects *e.g.*, lectins, antigenic proteins.

Factors with negative effect on digestion and utilization of carbohydrates *e.g.*, polyphenolic compounds, ?-amylase inhibitors.

STRATEGIES FOR IMPROVING NUTRITIONAL QUALITY AND DIGESTIBILITY OF NCFR

Different processing technologies for improving the nutritive value of low quality feed sources are discussed below:

(i) Supplementation : It is the simplest approach to improve the nutritive value of low quality feeds. Supplementation of NCFR with concentrate feeds is the effective way to provide a balanced feed. However the use of concentrate feeds could lead to significant increases in the cost of feeding. The supplementation of NCFR with browse foliage could partially or totally replace concentrate feeds as a feed supplement without causing any negative effects on livestock performance. Ben salem *et al.* (2002) reported that cactus pads high in soluble carbohydrates make better use of the high amount of soluble nitrogen in *Atriplex* foliage. Abundant water in cactus pads facilitates excretion of the excessive salt in *Atriplex* foliage. On the other hand, *Atriplex* may overcome nitrogen and fiber deficiency in cactus pads.

(ii) Chemical treatment : An alternative to the use of supplementary feeds is to treat the cereal crop residues by chemicals in order to improve its quality. Among chemical pretreatments, alkali pretreatment has been reported to have significant impact on the nutritive value of NCFR. However, the use of NaOH on small farms is uneconomical and dangerous. The use of ammonium hydroxide attracted the researchers because it breaks the bond between cell wall constituents and resulting in swelling and flexibility of fiber content that ultimately increases the crude protein content, feed intake and digestibility of feed resource. Another cheap alkali that can be used is calcium hydroxide. For improving the feeding quality of various crop residues *via* increasing the non protein nitrogen content with feed grade urea has been widely employed. The positive effects of urea application on nutritive value of crop residues are produced by two processes: a) conversion of urea into ammonia by urease and b) effect of ammonia on the cell wall of residues. Various studies have reported the positive effect of urea on nutritional quality of stover, straw and baggase (Woyengo *et al.*, 2004; Aregherore, 2005; Oji *et al.*, 2007; Ramirez *et al.*, 2007; Elias and Fulpagare, 2015). The non protein nitrogen in urea destabilizes the protein complexes and increases the crude protein level.

(iii) Ensiling : Although a number of agro-

TABLE 2
Deleterious principles in NCFR

S. No	Anti nutritional compounds	NCFR
1	**Polyphenolic compounds**	All vascular plants
	(A) Tannins	All vascular plants
	(B) Lignins	
2	**Non protein amino acids**	
	(A) Mimosine	*Leucaena leucocephala*
	(B) Cannavaine	*Canavalia ensiformis*
3	**Glycosides**	
	(A) Cyanogens	*Acacia giraffae, A. cunninghamii, A. sieberiana*
		Bambusa bambos, Cassava leaves
	(B) Saponins	*Albizia stipulate, Bassia latifolia, Sesbania sesban, Agave sisalana,* Duck weed,
4	**Phytohemagglutinins**	
	(A) Robin	*Bauhinia purpurea, Robinia pseudoacacia*
5	**Alkaloids**	
	(A) *N*-methyl-β-phenethylamine	*Acacia berlandieri*
	(B) Sesabine	*Sesbania vesicaria*
		S. drummondii
		S. punicea
6	**Oxalates**	*Acacia aneura, Rumex species*

industrial by-products are available, but most of them are not widely used for livestock feeding. For example, due to high moisture content of olive cake and tomato pulp, tends to become more rancid and moldy. Ensiling techniques can be safely used to extend the storage period of these byproducts separately or combined with other by-products such as molasses or wheat bran. Hadjipanayiotou (1999) reported that ensiling of olive cake increases the storage period.

(iv) Feed block technology : Agro-industrial byproducts having high moisture content can be efficiently used through feed block technology (Ben Salem and Nefzaoui, 2003). Feed block technology exploit the potential of NCFR in a better way that make livestock production system more economically viable. The ingredients of feed block can be divided as major and minor components. Major component are feed source and and minor component include micronutrients and feed additives. This technology provides flexibility to add cheap and easily available ingredients. The inclusion of agro-industrial by products and tree leaves partially or totally replace expensive concentrate feeds thereby reducing feeding costs. Feed blocks may also be used to provide antihelminthic medicines to control gastrointestinal parasites in browsing animals (Anindo *et al.*, 1998).

(**v) Biological treatment :** The nutritive value of NCFR can be enhanced by performing some chemical and physical treatments. However, these treatments are constraint by their high cost, safety and potentially their negative effect on environment and animal health (Chen *et al.*, 1995). Treatment of crop residues with microorganisms (fungi, bacteria) is an effective alternative to physical and chemical treatments. Biological processing of crop residues is more efficient in increasing the nutritive value and digestibility of feeds without any negative effect on environment and animal health. Biological treatments increase the accessibility of hydrolytic enzymes on cellulosic polysaccharides by disrupting the lignocelluloses complex (Ramirez Bribiesca *et al.*, 2010).

(vi) Deactivation of secondary compounds : A number of physical methods from chopping to storage, alone or in combination, and with varying effect found effective for detannification of leguminous fodder. Chopping and grinding increases the surface area that facilitates the interaction of between tannin content and polyphenolic oxidases. Dilution of antinutrients by supplementing antinutrient rich leaves with other feeds also reduces the risk of toxicity from antinutrients. It has also been reported that repeated soaking/washing effectively remove bitterness associated with saponins (Joshi *et al.*, 1989). A number of workers reported that storage conditions also influence the antinutrient concentrations in animal feeds. In particular, storage of chopped fresh leaves at 37^{o}C increases the rate of inactivation of total phenols and condensed tannins in feeds (Bhat *et al.*, 2013). Simple heating or drying also improves the protein quality by inactivating heat labile anti-physiological factors and by unfolding the complex protein structure and make them more susceptible to attack by digestive enzymes. Vitti *et al.* (2005) reported that drying of *Leucaena* leaves at 90°C for 24 hrs reduces the tannin content. Akbar and Gupta (1985) observed that moist heat at 70 to 100°C causes 50% reduction in mimosine content. Mali *et al.* (1990) reported 17 to 19 % reduction by dry heating at 100°C and 19 to 23% reduction by autoclaving in mimosine content.

The application of various chemicals has also been used for increasing the feeding value of NCFR. Supplementation of tannin rich leaves with polyethylene glycol-4000 (PEG-4000) is an effective method to reduce or to neutralize tannin content (Ben Salem *et al.*, 2000; Salem *et al.*, 2007). PEG-4000 prevents the formation of tannin-protein complexes and assists the breakdown of already formed complexes (Reddy, 2001). Makkar and Singh (1992) reported that potassium permanganate (0.03 M) and potassium dichromate (0.02 M) causes 95% reduction in tannin content in feeds. These oxidizing agents convert tannins to quinones, which are not capable of forming complexes with proteins and can be used for large scale removal of tannins. The alkalis like sodium hydroxide, sodium carbonate and sodium bicarbonate act by oxidation of phenolics at higher pH (Makkar and Singh, 1991; Makkar and Singh, 1992). Ferrous sulphate is a tannin-complexing agent and at 0.015M it causes 85% detannification. D'Mello and Acamovic (1982) observed that ferrous sulphate at 0.5% level is effective in increasing the mimosine excretion through faeces. Tawata *et al.* (1986) reported that treatment of leucaena leaves with sodium acetate (0.05 N) removes 95% mimosine without loss of any important nutrients. Fermentation of feed stuff also improves the sensory characteristics, such as flavor and taste by increasing the activity of endogenous enzymes and microbiota present in animal feeds.

FUTURE DIRECTIONS

For inclusion of NCFR in livestock feeding, the suggested future directions are :

- Assessment of availability, nutritive value and utilization of NCFR in the country.
- On-farm trials for assessing the potential of NCFR for commercial production.
- Integration of NCFR in existing farming system.
- Use of biotechnological approaches for producing high quality NCFR.

CONCLUSION

To achieve the goal of improved livestock productivity in the country, sufficient quantity of nutritive fodder has to be provided, therefore, it is desirable that adequate feed resources should build up. Every year considerable amount of crop residues and other agro-industrial byproducts is produced but low nutritive value, uneconomical handling and lack of the knowledge in farmers regarding NCFR are the major roadblocks in their utilization as a livestock feed. Hence it is essential to put adequate efforts for increasing the number of alternative feed sources and improving their nutritive value. Browse foliage particularly tree fodder are becoming popular among farmers as an alternative to conventional feed sources. Hence, the special attention should be drawn on the integration of multipurpose fodder trees and shrubs as a fodder bank in existing farming system. The current study greatly emphasize the inclusion of NCFR in livestock feeding programmes for achieving maximum livestock productivity and that will be reflected in improved socioeconomic status of rural households. The successful integration of the NCFR in farming system requires facilitation of knowledge intensive practices like farmer to farmer extension, different training sessions and field trial demonstrations by local and government extension agencies.

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