

FAO ANIMAL PRODUCTION AND HEALTH



# proceedings

## SUCCESSSES AND FAILURES WITH ANIMAL NUTRITION PRACTICES AND TECHNOLOGIES IN DEVELOPING COUNTRIES

FAO Electronic Conference  
1-30 September 2010



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# Contents

Acknowledgements	vi
Introduction	vii
<b>Change in animal nutrition research paradigm needed to benefit resource-poor livestock producers in countries like India</b>	<b>1</b>
<i>D.V. Rangnekar</i>	
<b>Technologies and practices for improving livestock feeding in India</b>	<b>7</b>
<i>M.P.G. Kurup</i>	
<b>Urea treatment of straws</b>	<b>11</b>
<i>T. K. Walli</i>	
<b>Urea treatment of straw: hugely extolled rarely used</b>	<b>15</b>
<i>Mahesh Chander</i>	
<b>Production of urea-molasses-mineral blocks in a process developed by Dairyboard of India</b>	<b>21</b>
<i>M.R. Garg and P.L. Sherasia</i>	
<b>Impact of urea-molasses-multinutrient blocks supplementation on livestock production in Pakistan</b>	<b>25</b>
<i>S.A. Khanum, M. Hussain, H.N. Hussain and M. Ishaq</i>	
<b>On-farm preparation of low-cost feed blocks using mulberry fruit wastes: impact analysis and adoption by farmers</b>	<b>29</b>
<i>Ghulam Habib</i>	
<b>Urea-molasses-multinutrient blocks/licks: a blend of nutrients for ruminants</b>	<b>35</b>
<i>M. Wadhwa and M.P.S. Bakshi</i>	
<b>Straw-based densified complete feed block technology</b>	<b>41</b>
<i>T. K. Walli</i>	
<b>Processed crop residue based complete diets for enhancing ruminant performance</b>	<b>45</b>
<i>Y. Ramana Reddy and G.V.N. Reddy</i>	
<b>Processing and evaluation of poor-quality crop residues as livestock feed</b>	<b>51</b>
<i>M. Wadhwa and M.P.S. Bakshi</i>	

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<b>Biological treatment of straws</b>	<b>57</b>
<i>T. K. Walli</i>	
<b>Rumen by-pass protein technology for enhancing productivity in dairy animals</b>	<b>61</b>
<i>M.R. Garg and P.L. Sherasia</i>	
<b>Rumen by-pass protein technology</b>	<b>65</b>
<i>T. K. Walli</i>	
<b>Food-feed-systems for smallholder livestock farmers</b>	<b>69</b>
<i>M. Wanapat and V. Chanthakhoun</i>	
<b>Silvopastoral system, cerrado and tropical forest biome in Brazil: Case studies</b>	<b>75</b>
<i>Rogério Martins Maurício and Luciano Fernandes Sousa</i>	
<b>Utility of <i>Arachis pintoi</i> to renovate degraded pastures in a cattle producing region of the Amazon of Colombia</b>	<b>79</b>
<i>Carlos E. Lascano</i>	
<b>Integration of forage production with high-yielding rice variety cultivation in Bangladesh</b>	<b>85</b>
<i>A.B.M. Khaleduzzaman, M.A. Akbar and M. Shamsuddin</i>	
<b>Low-cost silage technology increases milk production and farmers income in north-western districts of Bangladesh</b>	<b>91</b>
<i>A.B.M. Khaleduzzaman, M.A. Akbar and M. Shamsuddin</i>	
<b>Improving the utilisation of Napier grass by dairy cows through fractionating the stems into juice and fibrous residue</b>	<b>97</b>
<i>John Moran</i>	
<b>Utilisation of tannin-containing tree leaves in sheep and goat production</b>	<b>101</b>
<i>Raghavendra Bhatta, A.K. Shinde, S. Vaithyanathan, S. K. Sankhyan, O. Enishi and M. Kurihara</i>	
<b>Economic utilisation of saline marginal lands for animal production</b>	<b>107</b>
<i>S.A. Khanum, M. Hussain, H.N. Hussain, A.R. Awan and K. Mehmood</i>	
<b>Spineless cactus (<i>Opuntia</i> spp.) in low-input production systems in dry areas</b>	<b>111</b>
<i>Hichem Ben Salem</i>	
<b>Azolla: a sustainable animal feed?</b>	<b>119</b>
<i>Mahesh Chander</i>	
<b>Area-specific mineral mixtures for sheep and goat</b>	<b>125</b>
<i>A.K. Shinde and S.K. Sankhyan</i>	

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<b>Investing in inorganic fertilisers on tropical dairy farms</b>	<b>129</b>
<i>John Moran</i>	
<b>Chaff cutters and fodder chaffing: A simple technology worth adoption</b>	<b>133</b>
<i>Mahesh Chander</i>	
<b>Synthesis of the FAO E-Conference “Successes and failures with animal nutrition practices and technologies in developing countries”</b>	<b>137</b>
<i>Emyr Owen, Tim Smith and Harinder Makkar</i>	

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# Introduction

Nutrition is the foundation of a livestock production system and proper nutrition is imperative for achieving high and sustained livestock productivity. The success of animal reproduction and health programmes rests on proper nutrition. During the last four decades a number of animal-nutrition-based technologies and practices have been developed and applied both on-station and on-farm in developing countries, with varying degrees of success. Some technologies have produced profound beneficial effects and have been widely used; while others have shown potential on research stations but have not been taken up by farmers. Other nutritional strategies produced benefits to farmers so long as they were supported by a donor-funded project, but their use could not be sustained after the project concluded.

To learn from these experiences, the FAO Animal Production and Health Division organised an E-Conference from 1 to 30 September 2010. This was a stock-taking exercise to describe the current status and analyse the reasons for the success or failure in applying different animal nutrition practices and technologies and to draw conclusions for the future. The conference covered both ruminant and monogastric animals and the focus was on developing countries.

This E-Conference provided an opportunity for researchers and development workers with an interest in livestock development, based in government and non-government organisations and in private sectors, to share their knowledge and experience in the area of animal nutrition.

Before the conference, a background document was prepared that contained an overview on the different animal nutrition technologies and practices for consideration in the E-Conference (can be downloaded from: [http://www.fao.org/ag/againfo/home/documents/2010\\_sept\\_E-Conference.pdf](http://www.fao.org/ag/againfo/home/documents/2010_sept_E-Conference.pdf)). The background document also provided guidance to participants, for example the issues to be addressed in the E-Conference and suggestions on the format for providing inputs. Some salient guidelines were:

- For any one (or combination) of the practices and technologies, identify those that have generated significant impact in your region and those that failed to do so considering its application at the field level in one of the different livestock production systems and in any particular developing country;
- For each identified technology/practice provide an overall assessment of the experience of applying them and state whether it was a success or failure, partially or fully;
- Based on this, describe some of the key features that determined its partial or complete success (or failure). For assessing a practice or technology as success or failure, the impact (economic, environmental, social and/or on food security/biodiversity/natural resources) generated through its application should be considered and presented in your contribution (quantitative information on these impacts would be appreciated by readers). Impact of applying a practice or technology on trade, equity, gender and food safety could also be parameters for defining success or failure.
- What lessons can be learnt from the experience, and how do you see the future of the technology?

Most of the lead contributions followed these guidelines. These contributions were posted on the E-Conference platform as discussion papers and the participants were invited to give comments, views and experiences on the technology(ies) discussed in the paper. Each contribution or a message from the participants was given a number, in the sequence it was posted (message from the Moderator was not given a number). The participants were assumed to be speaking in their personal capacity, unless they explicitly stated that their contribution represented the views of their organization. The messages can be downloaded from [http://www.fao.org/ag/againfo/home/en/events\\_archive/Messages\\_E-conf\\_0910.pdf](http://www.fao.org/ag/againfo/home/en/events_archive/Messages_E-conf_0910.pdf)

After the conference, the participants who submitted the lead contributions were invited to submit their contributions in extended form. These proceedings present the extended papers, giving the current status of animal nutrition practices and technologies being practised in developing countries (with considerable emphasis on South Asia) and an analysis of the reasons for their success or failure. The proceedings also contain a synthesis paper that summarises the major issues discussed by participants and presents conclusion drawn and lessons learnt for the future.

This document is expected to assist developing countries make informed decisions about the adoption of appropriate animal nutrition practices and technologies. In addition, it should also be useful for the development community, including donor agencies, to better understand, prioritise and support appropriate animal nutrition practices and technologies in developing countries.

# Change in animal nutrition research paradigm needed to benefit resource-poor livestock producers in countries like India

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## SUMMARY

A case for change in the animal nutrition research paradigm to extend benefits to the resource-poor livestock producers in countries like India is presented. The characteristics of livestock production which form the basis for the argument and discussion include: a) crop-livestock mixed farming prevails in India, b) resource-poor rural families are major contributors to livestock produce and depend on it for family income, c) low external-input system prevails in livestock production, d) livestock can provide pathway out of poverty provided some constraints are overcome, and e) livestock feeds and feeding is one such constraint and a challenge for the research system. The paper draws attention to the limited benefits of research to resource-poor farmers. The need for change in the research paradigm to meet the challenges is stressed by discussing issues such as, relationship between livestock production and research systems and lack of pro-poor focus; persistence of reductionist approach and low adoption of 'systems and participatory approach' by the research system; reasons for low adoption of animal nutrition research outputs and apathy of the system about it, and need for rethinking of some conventional recommendations on feeding livestock. Approaches are suggested to make research outputs appropriate and beneficial for resource-poor livestock keepers.

**Keywords:** *animal feeding, participatory approach, pro-poor, research paradigm*

## INTRODUCTION

Crop-livestock mixed farming prevails in India and the majority of rural families own livestock. Livestock production in countries like India has characteristic features such as:

- Prevalence of crop-livestock mixed farming system;
- High diversity and multi-functionality;
- Dependence of a large number of rural families on livestock for their livelihood;
- Increasing demand/prices of livestock products provide an opportunity for extra income;
- Ruminants dominate livestock production; and
- Feeding is based on 'Low External-Input System' utilising crop residues and by-products.

Livestock development provides a pathway out of poverty for the underprivileged families, however some constraints have to be overcome (Thomas and Rangnekar, 2004). Feeding of livestock is one such constraint and a challenge for the research system in India since the contribution of research to livestock development and particularly for the resource-poor farmers, is marginal.

Hardly any livestock research project is planned whilst keeping resource-poor farmers in focus (Rangnekar, 2006). The paper is based on a review of literature and observations and experience of more than four decades of livestock development, extension and applied research. The arguments presented highlight the need to change the research paradigm to extend benefits to resource-poor farmers.

### **RELATIONSHIP BETWEEN LIVESTOCK PRODUCTION SYSTEMS OF RESOURCE-POOR FARMERS AND ANIMAL NUTRITION RESEARCH SYSTEM**

Commonly reported observations on feeding of livestock focus mainly on two aspects: the majority of producers follow traditional feeding practices and they resist change/adoption of scientific recommendations and technologies. These observations imply that the fault lies with the livestock producer while the research system has done its job. There is hardly any attempt made to understand the reasons for non-adoption which raises an important question as to why the research system is not sufficiently concerned with the utility of outputs/products of research. This situation indicates that there is probably a mismatch between the prevailing livestock production systems (that are not likely to change in the near future) and research systems (resistant to change). Some characteristics bearing on the relationship between these two systems are discussed below.

*Whole-farm approach of the farmers as against sectoral approach of the research system.* Livelihood and farming systems of the underprivileged are complex and livestock production is a crucial component. Most farmers are concerned about the output of the whole farm and not of livestock alone while animal nutrition research usually focuses only on the animal. As the sub-systems influence each other, changes in any sub-system tend to impact the whole farm.

*Reductionist approach of the research system.* Studies on production of greenhouse gases (GHG) by ruminants is a good example of the reductionist approach. It is only the enteric GHG production that is estimated and no attempt is made to get a total picture based on production as well as savings of GHG due to the feeding systems of ruminants applied. Mishra and Dixit (2004) studied the total picture and reported that GHG produced by ruminants are balanced by savings due to the feeding systems adopted in India. Use of crop residues and agricultural by-products saves GHG that would have been emitted in producing grains and making grain-based livestock feeds. These uses also save the GHG that would have been produced by burning of crop residues. Recommending low fibre/high energy rations to reduce methane production is also inappropriate for Indian conditions.

Methane production by different types of animal is compared on the basis of amount of methane per unit of milk produced, which is not appropriate since the majority of cattle and buffalo, in a country like India, are not dairy type. A different approach that also accounts for other useful services, functions and products for farmers is needed for

comparing GHG production. There is a need to consider farmers' perceived value of these services and products, however, as these are not quantifiable by conventional methods, a social-cost accounting approach may have to be used.

*Livestock production in India is highly internalised.* The system is mainly low external-input oriented and thus tends to optimise the use of available resources (human as well as material). Livestock are mostly grazed and supplemented by farm produce (crop residues, by-products, tree fodders), hence the resistance to adopt new feeding systems or technologies that require purchase of material or hire of labour.

The Indian Council of Agriculture Research (ICAR) led the Indo-Dutch project on Bio-conversion of crop residues which was implemented in the 90s through a network of centres in different regions. This project demonstrated the use of systems and participatory approaches to understand the farming system in general, with in-depth understanding of livestock sub-systems in various agro-ecozones of India. The project showed a way of planning animal nutrition research based on the understanding of systems and the need to define conditions under which each recommendation/technology would work.

*While the role of women in feeding of livestock is well known the research system has not given it due consideration.* Studies on the involvement of women in livestock production show women to have good knowledge of feeding habits of animals and of local feed resources, and that women take decisions related to feeding of animals (Rangnekar, 1994). However, the research system rarely involves women or considers their knowledge and views in planning studies, conducting trials or assessing the research outputs.

*Some of the conventional recommendations for livestock feeding need reconsideration.* Rangnekar, Schiere and Rao (1995) have discussed recommendations e.g. feeding milk or milk replacer to calves and kids at the rate of 10 percent of body weight, and feeding of greens equivalent to 33 percent of total roughage dry matter. Feeding of milk is probably recommended for ideal gain in body weight, however, hardly any small farmer can afford to offer that much milk to calves. Green fodder production is taken up only on small plots and its availability will always be limited. Most recommendations suit high external-input systems, are aimed at maximising production (of a particular commodity) and are not appropriate for smallholders. Moreover, there is variation in systems and resources between and within regions of the country, thus making uniform recommendations inappropriate. Critical assessment of reasons for non-adoption of recommendations would provide useful guidance for the future.

## **FACTORS INFLUENCING DECISIONS BY FARMERS TO ADOPT NEW PRACTICES AND TECHNOLOGIES**

The decision to change from traditional feeding systems and to adopt new practices and technologies is a complex process. Contrary to common belief the decisions are not based on economic benefit considerations alone; several more factors come into play. A good understanding of the decision-making processes is useful in the selection of appropriate research outputs for recommendation.

The factors usually considered by farmers while deciding change of practices or adoption of technology were listed and discussed by Rao *et al.* (1995). These factors range from

relative advantage, observable results, divisibility, simplicity/complexity and initial cost to compatibility of the recommendations with the farming and social systems. Another factor crucial in deciding adoption is the 'relevance to constraints/problems' faced by livestock owners. Hence, only outputs of research (feeding recommendations or technologies) that are technically sound, economically beneficial, socially acceptable, suit the prevailing farming system and solve current problems stand a chance of adoption.

In a study of the role of women in urban livestock production, in western India, it was observed that most of the commercial dairy producers in urban areas continue to make feed mixtures and feed animals in the traditional manner (S.D. Rangnekar, personal communication, 1990) contrary to the reports that educated, commercially-oriented and urban livestock producers are early adopters. Multidisciplinary research may provide better understanding of the reasons for continuing traditional practices of feeding livestock by these urban producers.

Roy and Rangnekar (2006) conducted a participatory study to understand the reasons for adoption of urea treatment of cereal straws (rejected in most parts of India) in the operational area of Vaishali cooperative milk union in the state of Bihar, in eastern India. The farmers reported three main benefits of urea treatment, namely prevention of spoilage of straw due to unseasonal rain (common in that area), more straw could be stored in the bins and marginal increase in milk production. Other factors contributing to adoption of the technology were: initiative of dairy cooperative in demonstration of the technology, availability of straw and water, shortage of legumes in summer and high level of milk production of the cows. According to recent reports, more than 4 000 farmers adopted the technology in 2010. It can be concluded that urea treatment of straws fitted well with the straw handling system in Vaishali area, and benefitted the whole farm operation of the farmers (not milk production alone).

### **SUGGESTED APPROACHES TO MAKE ANIMAL NUTRITION RESEARCH RESOURCE-POOR FRIENDLY**

To be effective, development needs research, and without linkage with development, research remains academic. There is a need to promote pro-poor approaches in livestock research, similar to that done by the FAO, for livestock development. Hazel and Haddad (2001) recommend that public sector research in developing countries should give priority to developing a strategy for pro-poor research through strategic planning. Moreover, to develop pro-poor research there should be good understanding of livelihood systems and adoption of a 'participatory approach involving women'. Developing technologies and prioritising research areas on the basis of agro-ecological and socio-economic conditions, at national as well as regional levels, is recommended.

The participatory research should not be 'scientist led' but all the stakeholders including farmers should be involved from planning to the stage of interpreting the results (Conroy, 2005). The study of traditional feeding practices and perceptions of the livestock owners, especially the women, about feeding of livestock is suggested to 'understand why farmers do what they do'. The large network of Krishi Vigyan Kendras (technology transfer centres in India), universities, research institutes and centres of the ICAR in India should enable adoption of such approaches without much difficulty. However, there would be need to

orient animal nutrition research workers to develop close linkage/interaction with extension system and farmers.

To further explain the nature of change proposed in animal nutrition research, the case of studies on GHGs in ruminants is taken as an example and suggestions are given below:

- Estimate total GHG production by local ruminants under traditional feeding regime;
- Undertake balance study of GHG using the approach and social cost accounting method suggested by Mishra and Dixit (2004) to get a holistic picture under different production systems; and
- Screen various feed materials including tree leaves and pods, in different regions, for effect on GHG production in ruminants. Identify low-cost locally-available materials that reduce GHG and can be used by an average livestock owner. Used by a large number of farmers would have impact, even with a marginal decrease in methane production.

There are two new initiatives developing in India that are worth considering. One is in the crop sector known as "System of Rice Intensification or SRI" and based on participatory research and technology development (C.S. Prasad, personal communication, 2010). It is a joint initiative of farmers, NGOs and scientists and is fast emerging as an alternative to conventional high-input system of rice cultivation and is being tried with other crops (for information visit <http://hib.ximb.ac.in/Hibiscus/Pub/faccvDet.php?client=ximb&facid=XF262>). The other initiative is "Knowledge Swaraj" taken by scientists and a civil society organisation to renew the relevance of traditional knowledge with the objective of guiding the use of science and technology for development of India (for more information visit [www.kicsforum.net](http://www.kicsforum.net)).

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# Technologies and practices for improving livestock feeding in India

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## SUMMARY

Marginal farmers constitute the core of the livestock production sector and own over 80 percent of all livestock in India. Ruminant production is based on grazing and crop residues. Small ruminants subsist entirely on open grazing/browsing. Fodder scientists have developed many superior fodder crops like hybrid Napier varieties CO3 and CO4 yielding over 300–400 tonnes of green fodder per hectare annually and giving net income of Rupees 250 000 per hectare (1 US\$ = ca Rupees 45). In some villages there are several few 'land surplus' farmers with fully-irrigated land to spare for high-yielding fodder crops. The milk collection centres, dairy and farmer cooperative societies in the village can identify 'land surplus' farmers and enter into mutually-benefiting annual contracts with them for cultivation and daily supply of cut-green fodder. Rotary chaff cutters in farmer households can maximise fodder utilisation. In straw-rich states millions of tonnes of straws are burnt as a means of disposal. This straw could be used for making pellets. Enriched straw pellets from Punjab state could take care of the total needs of ruminant feeds/fodder in the adjoining deficit states. The technology for pulverising, chopping and pelletising straw will have industrial-scale application in all regions.

**Keywords:** *enriched straw pellets, fodder on contract, land surplus farmers*

## INTRODUCTION

Marginal farmers constitute the core of the livestock production sector in India (Table 1). Nearly 80 percent of all large ruminants, including the high-yielding crossbred cows, and over 85 percent of all other livestock are owned by marginal farmers. Ruminant production in India is predominantly based on grazing highly-overgrazed common grazing lands and on crop residues like straws and stovers.

Concentrate feeds are used to supplement the dry fodder diets in the case of producing/working large ruminants while small ruminants subsist entirely on open grazing or browsing. Supplementing the dry fodder diets with some green fodder considerably enhances the efficiency of the production system including reducing the emission of greenhouse gases and reducing the dependence on expensive concentrate feeds and lowering production costs. As far as promotion of green fodder production is concerned, India has been trying to persuade the marginal farmers to grow green fodder, but with very limited success.

TABLE 1  
Land and Livestock Holding in India in 2003

Category	RHH (million)	RHH %	AFCB Cattle %	AF Indigenous Cattle %	AF Buffalo %	Sheep/Goat %	Pig %	Poultry %
Landless (no land)	46.09	31.18	0	0	0	0.21	0.15	1.03
Marginal (0.002–1 ha)	70.89	47.89	78.47	77.40	71.86	85.34	94.79	85.07
Small (1–2 ha)	16.59	11.22	4.80	5.39	5.98	3.46	1.91	4.79
Semi-medium (2–4 ha)	9.21	6.23	7.09	8.04	9.34	4.04	1.63	3.68
Medium (4–10 ha)	4.33	2.93	8.77	7.42	10.69	4.45	1.04	4.79
Large (> 10 ha)	0.81	0.55	0.87	1.75	2.12	2.50	0.48	0.63
Total	147.84	100	100	100	100	100	100	100

RHH, rural households; AF, adult female; CB, crossbred

Source: Livestock Census of India (2003); National Sample Survey (2003)

## APPLICATION OF TECHNOLOGY AND PRACTICE BY FARMERS

*Fodder on contract by 'land surplus' farmers.* Access to fodder in every village with a milk collection centre (MCC), dairy cooperative society (DCS) or farmer cooperative (FC), would greatly enhance animal production. There are over 100 000 villages in India with some type of organised milk marketing infrastructure (MCC/DCS/FC). Without such access to quality fodder, livestock production in India will not be in a position to meet its burgeoning demand for livestock products.

Research efforts of fodder scientists in the country have resulted in the development of high-yielding fodder varieties of grasses and legumes. A number of high-yielding perennial (replanting in 5–6 years) tropical grasses like hybrid Napier varieties CO3 and CO4 yield over 300–400 tonnes of greens per hectare annually. Selling green fodder at Rupee 1 per kg, the fodder-producing farmer would receive daily cash income round the year, totaling up to Rupees 300 000 per hectare annually and net income of Rupees 250 000. One hectare of such fodder crops could sustain the fodder requirements of at least 30 cows or buffalo round the year (@ 20 kg/animal daily) or over 300 small ruminants @ 4 kg per head daily.

There are farmers that have surplus, fully-irrigated land to spare for high-yielding, high-income cash crops, in almost every village. Such farmers are keen to obtain a higher income from their irrigated land than that obtained from the cultivation of conventional crops. The MCC/DCS/FC could identify the 'land surplus' farmers in the village with irrigated land to spare for cash crops and enter into mutually-benefiting annual contracts with them to cultivate and supply cut-green fodder daily to collection centres for sale to milk suppliers or other small ruminant-farmers. Milk collection centres and dairy cooperative societies sell branded, balanced cattle-feed daily to milk producer members. Similarly the MCC/DCS/FC in each village can sell the cut-green fodder daily in the collection centre, making marketing of green fodders easier.

Fodder on contract by 'land surplus' farmers in every village needs only promotional efforts and organised marketing by the MCC/DCS/FC, and requires no cash inputs by the Governments or the Cooperatives. This is eminently practical and demand-driven, and can be universally applied in any village in the country where organised milk marketing exists.

Promotion of rotary chaff cutters (manual or electric powered) in farmer households can help chop the green fodder into small bits and avoid wastage. Reasonably-priced manual or power-driven rotary chaff cutters are readily available in the market.

*Enriched Straw Pellets.* India produces some 300 to 400 million tonnes of straws/stovers annually. Farmers all over the country use home-grown dry fodder as the staple diet for their animals. There are straw surplus states that burn millions of tonnes of straws as a means of disposal. Salvaging the straws for animal feed would go a long way in increasing the availability of ruminant feeds.

A survey on the end-use of rice and wheat straws in the state of Punjab showed that less than 10 percent of rice straw and 40 percent of wheat straw produced annually is used as animal feed. The farmers in the states of Haryana, Punjab and Western Uttar Pradesh have largely replaced rice and wheat straws from the diets of dairy animals with high yielding and high quality fodder crops. In Punjab alone nearly 8 million tonnes of rice straw and around 9 million tonnes of wheat straw are burnt annually *in situ* as a means of disposal (Table 2).

Millions of tonnes of wheat straw in Gujarat and rice straw in Madhya Pradesh are also burnt annually as farmers do not feed them to their dairy or work animals. Tamil Nadu is a straw surplus state even though rice straw is the staple diet of dairy cows and work animals in the state.

Wheat and rice straws left behind by harvesters can be pulverised or chopped and pelletised in feed mills, with or without enrichment (urea, molasses, other supplements), which enhances their utility as ruminant feeds, as they can then be easily stored, transported and utilised as feeds in far-away fibre-deficit areas. The technology for pulverising, chopping and pelleting straw will have industrial-scale application in all regions of the country where straw is burned for disposal thus making available millions of tonnes of enriched straw pellets as ruminant feed.

There are over 800 animal-feed milling plants of assorted sizes distributed all over Punjab. These minimise the transport of straw across the state for processing. Enriched rice or wheat straw pellets from Punjab can take care of the total needs of ruminant fodder and

TABLE 2  
Rice and wheat straw production and end-use in Punjab State

Straw type	Quantity ('000 tonnes)	End use (% of total)				
		Fodder	Manure	Burnt	Sold	Miscellaneous
Rice straw	9 852	6.5	0.9	81.4	4.8	5.8
Wheat straw	18 972	42.6	0.2	48.2	8.1	1.0

Source: Sidhu et al. (1998)

feed in the drought-ravaged and fibre-deficit state of Rajasthan. Punjab can also market enriched straw pellets to cattle-feed manufacturing plants in North India, as a low-cost ingredient for balanced cattle-feed. Small straw-pelletising plants, if established in the straw-producing areas in Madhya Pradesh or Gujarat can supplement ruminant feeding in straw-deficit areas of Andhra Pradesh and Orissa; and in Tamil Nadu for use in Kerala.

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# Urea treatment of straws

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## SUMMARY

Straws are the main source of roughage for feeding ruminants in the tropics but do not supply sufficient nutrients even for maintenance of the animals. Efforts have been made in different parts of the world to improve the nutritional quality of straws, using various treatments. Among these, substantial research has been conducted on the urea treatment of straws. While the developed countries used direct ammoniation process for treating straws, urea treatment was suggested as its cheaper version for the tropical countries. Studies were carried out on optimising conditions e.g. the urea level, moisture content, duration of the treatment, shape of the stack and the type of cover/covering material. The treatment increased crude protein (CP) and energy content of straw resulting in increased straw intake, growth rate and the milk yield of the animals. It appeared to be a cost-effective technology and the farmers were satisfied with the results as long as the nutritionists and the extension specialists were involved with the on-farm trials. However when the farmers were left on their own, they stopped treating their straw. Only some farmers with larger herds and a lack of green fodder continued with this technology. The major constraints to use of the technology were the cumbersome and labour-demanding aspects of treatment, marginal returns, requirements of large quantities of clean water and covering material, and spoilage of straw if not properly covered. If the spraying of the urea solution could be mechanised, the adoption of this technology would increase.

**Keywords:** *field trials, straws, technology transfer, urea treatment*

## INTRODUCTION

To improve the nutritive value of fibrous crop residues, urea treatment of straw was developed as an alternative to caustic/corrosive sodium hydroxide treatment, for use mostly in tropical countries. A large number of on-station and on-farm trials conducted in several countries under different conditions have shown that feeding urea-treated straw vis-a-vis untreated straw increases feed intake by 10 to 15 percent, growth rate of calves by 100 to 150 g/day and milk yield by 0.5 to 1.5 litres/day. Urea-treated straw is more palatable and digestible. The dry matter (DM) digestibility increases by approximately 10 percentage units, the total digestible nutrient (TDN) value increases by 10 to 15 percentage units and the CP content increases almost three times. The feedback received from the farmers involved in on-farm trials has been largely positive. In spite of the technology appearing to be quite sound, it was almost entirely rejected by livestock farmers in the tropical region, barring some exceptional situations (Walli *et al.*, 1988; Schiere and Nell, 1993).

## EXPERIENCES OF APPLYING TECHNOLOGY/ PRACTICE IN THE FIELD

During the mid-seventies when it became clear that sodium hydroxide, a strong alkali, is capable of breaking the ligno-hemicellulosic bonds in straw and making it more digestible, scientists started looking for less corrosive alternatives to sodium hydroxide. During the eighties, some developed countries used ammoniation for upgrading straw. However a cheaper version of ammoniation i.e. urea treatment was suggested for the developing countries of the tropical region because urea was easily available, given to farmers at cheaper/subsidised rates and is readily hydrolysed to ammonia under the warmer tropical climate (Saadullah, Haque and Dolberg, 1981). A number of national and international research projects on urea treatment of straw were undertaken in Asian countries, e.g. Bangladesh (DANIDA/IDRC/ ODA/ADAB/USAID), Malaysia (ABAB), Philippines (ADAB), Sri Lanka (ADAB/The Netherlands), Thailand (ADAB/IFS), Indonesia (ADAB) and India (Indo-Dutch) to optimise treatment conditions under their respective situations. The research activities were mainly directed towards optimisation of urea and moisture levels and the duration of the treatment. The other aspects investigated were the method of spraying urea solution and the manner the stack has to be shaped and covered and with what kind of materials. On the basis of these studies, a broad consensus on using 4 percent urea and keeping the moisture level at 40 percent was developed. The duration varied from two to three weeks, depending upon the ambient temperature of the place, the duration being higher for the colder places (Walli *et al.*, 1988).

Several institutions including National Dairy Research Institute (NDRI), Karnal, Southern Regional Station of NDRI, Bangalore, Bharatiya Agro Industries Foundation (BAIF), Pune and Pantnagar University of Agriculture and Technology, Uttarakhand were involved in the Indo-Dutch project in India. The author was a part of the team working on this project at NDRI, Karnal. After conducting research on optimisation of the conditions for the treatment, we moved into the rural areas of Karnal for conducting on-farm trials. This was during the year 1987–88, when India was facing a drought situation and we thought that it was an ideal situation to propagate the technology among the farmers. Normally, the dairy farmers around Karnal grow sufficient green fodder and are not keen to use the urea-treated straw. Demonstration of urea treatment was carried out in 25 villages around Karnal and the farmers were asked to feed the treated straw in place of untreated straw. Feedback on feed consumption and milk yield was collected through personal observations and by interviewing the farmers.

*Positive feed back from farmers.* Out of the 54 observations collected for feed consumption, 76 percent farms reported an increase in straw consumption and reduction of feed wastage. Out of the 32 observations on milk yield, 28 percent farmers reported 0.5 litre, 25 percent reported 0.5–1.0 litre and 25 percent reported 1.0–1.5 litre increases in yield. The farmers could not monitor growth rates, but from visual observations they reported better growth and health condition of animals. The treated paddy straw was easier to chaff than untreated straw. While the untreated straw had to be given along with greens, the treated straw could be given as a sole source of roughage.

*Negative feedback by farmers.* After harvesting the paddy crop, the farmer has to prepare the field for the wheat crop, and there is neither the space available for drying of

straw and nor the time for treating the straw. During the period when paddy straw is available, berseem (*Trifolium alexandrinum*), a leguminous fodder is available in plenty, and thus the effect of feeding treated-straw along with berseem gets masked. Most of the farmers could not afford to purchase polyethylene sheets for covering the stack. The lack of proper cover caused wetness in the stack during rains, leading to fungal growth and spoilage of the straw. This also led to leaching of nutrients. It requires huge quantities of clean and fresh water @ 50 litres/100 kg of straw, which could be a constraint at times. If water from a pond is used, it could result in spoilage of straw due to fungal infestation. For preparation of the urea solution, which involves dissolving 4 kg of urea in 50 litres of fresh water, a drum of 100-litre capacity is required, which may not be available with the poor farmer. Preparing a stack of 2 500 kg of straw, apart from requiring 100 kg of urea and 1 250 litres of water, also needs at least 3 men for at least 3 hours to complete the process. All this appears to be a cumbersome and time consuming exercise and a costly affair for the poor farmer. Some farmers did complain about the sticky dung from animals fed treated straw, which made the cleaning of the floor more time consuming. The pungent smell of ammonia coming from the treated straw was not liked by some farmers. Because of the higher consumption of urea-treated straw, the resource-poor farmers complained of rapid exhaustion of straw stocks and the need to purchase extra straw.

### **STATUS OF APPLICATION OF TECHNOLOGY/PRACTICE BY FARMERS**

Although the technology of urea treatment of straw is beneficial to the farmers, especially in terms of improving the productive performance of the animals, it was only partially successful in China and Vietnam. In these countries, the technology has been applied on a larger scale, as community projects on a cooperative basis.

Despite the beneficial effects observed by farmers themselves during on-farm trials, the discontinued use of urea treatment after initial demonstration has been disappointing. Even the best efforts made by the researchers and extension specialists have not been able to motivate farmers to adopt this technology. Most of the farmers around Karnal keep their dairy animals traditionally, i.e. to meet their milk requirement for home consumption and only the surplus milk is sold in the market. A landless farmer possessing a few animals is not interested in using the technology of urea treatment of straw, as he allows his animals to go out for grazing on fallow lands and roadside grasses and does not want to incur any extra expenditure on the urea treatment. A farmer cultivating cash crops prefers to use urea for fertilising cash crops, rather than to use it for treating the straw. Urea treatment of straws could be adopted if:

- Grasses and other greens are not available;
- Straw is cheap and easily available;
- Concentrates are relatively expensive;
- Water is readily available;
- Labour is cheap;
- Farmer has good dairy farming skills;
- Market for milk is available; and
- Farmer gets good support price for milk.

## LESSONS LEARNT

The most important constraints in the adoption of the urea treatment technology are its cumbersome and labour intensive nature and economic non-viability for the marginal and landless farmers. The returns are also marginal. The technology may prove to be successful if it is operated on a collective basis as a community project, as is done in China and Vietnam. It may be difficult for an individual resource-poor farmer to adopt this technology.

## FUTURE OF THE TECHNOLOGY

The technology needs to be refined further, technically and made simpler for the farmer. If a mechanical process is developed for spraying and mixing of the urea solution during the threshing operation itself, larger farmers may come forward and adopt this technology.

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# Urea treatment of straw: hugely extolled rarely used

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## SUMMARY

Livestock production in developing countries especially in dry land areas, with limited scope for cultivation of fodders, depends to a great extent on low-quality crop residues. Urea treatment improves the nutritive value of cereal straws by increasing crude protein content, palatability and digestibility. This technology is considered a proven technology to improve the nutritive value of roughages. Opinions on its utility and application in the field, however, are varied among animal nutritionists, farmers and extension workers. Notwithstanding the enormous research and technology-transfer efforts, this technology, in many countries including India, has remained a 'hardly used technology' at farmer level. An increasing number of workers believe that this technology, in its present format, does not have a future.

**Keywords:** *adoption, crop residues, farmers, urea treatment*

## INTRODUCTION

Green fodder is one of the best options for feeding livestock, but its availability is very limited in most of the rain-fed and dry regions, especially during summer. Therefore, most of the livestock in rain-fed subsistence systems are raised on crop residues including rice and wheat straws (Singh and Schiere, 1995). In India, for instance, dairy production is mainly based on the use of agricultural by-products and crop residues as feed resources with cereal straws contributing 45–66 percent of the feed consumed by dairy animals (Kelley and Parthasarathy, 1996; Parthasarathy and Hall, 2003). These straws are low in quality, digestibility and nutritive value. To improve the value of such low-quality feedstuffs, the urea treatment technology is considered a potential option (<http://www.fao.org/ag/aga/AGAP/FRG/Aphp135/chap4.PDF>). Accordingly, many countries across the tropical world tried to promote the technology among farmers through various research, development and extension programmes, but sustained use of urea treatment beyond the intervention phase is rarely observed in any country, barring some sporadic success stories.

## EXPERIENCES OF APPLYING TECHNOLOGY/PRACTICE IN THE FIELD (FARMERS' FARM)

A large number of trials involving farmers have been conducted on straw treatment with urea, but very few farmers have adopted the technology on a continuous basis (Dolberg, 1992; O'Donovan *et al.*, 1997; Birthal and Parthasarathy, 2002; Rabbani *et al.*, 2004; Nguyen, 2004). Urea treatment of straws has not become popular amongst the farmers because of inadequate extension efforts, non-availability of sufficient straw and the limited

availability of liquid cash with farmers for purchase of urea (Walli *et al.*, 1995; Badve 1991; Nguyen 2004).

Animal nutritionists working on straw treatment consider it as an excellent technology, worthy of large-scale adoption by farmers, especially in subsistence rain-fed situations. Animal nutritionists believe the technology has not been taken up by farmers due to inadequate efforts made by extension workers. The moisture level of straw during treatment and the duration of treatment need to be precisely understood by extension workers. Initially the duration of the treatment was suggested as three weeks, but it was observed that under Indian conditions seven days of treatment time was sufficient. Farmers found the treatment period (three weeks) long and thus a regular supply of treated straw for feeding became a problem. The workers responsible for dissemination of this technology need to be properly trained before they approach farmers to demonstrate the method. Farmers need to be convinced that in the absence of green fodder, feeding urea-treated straws is an alternative option. This requires a good understanding of the treatment process and location-specific indicators (Photos 1 and 2). Yet, in many instances, even well-trained extension personnel failed to convince the farmers to adopt this technology.

### **STATUS OF APPLICATION OF TECHNOLOGY/PRACTICE BY FARMERS**

Notwithstanding the considerable efforts of various research and development agencies over the last 20–25 years, with significant financial implications, the urea treatment technology is largely considered a failure in India as far as its application in the field is concerned. Nevertheless, effective adoption of the technology by smallholder dairy farmers has been reported in some pockets e.g. Mithila milkshed in the state of Bihar, where a sizeable number of farmers are using it on a regular basis (Roy and Rangnekar, 2006).



**photo 1**  
*Wheat straw being treated with urea mixed with water*



**photo 2**  
*Urea treated straw ready for feeding*

The professionals who visited the villages in the vicinity of a national institute in India where urea treatment had been demonstrated and promoted passionately for over ten years by animal nutritionists involved in developing the technology, found no adoption of the technology by farmers. The extension personnel of KVK (Krishi Vigyan Kendra – a district-level training and extension agency for farmers governed by Indian Council of Agricultural Research) also demonstrated urea treatment in different villages. The technology had not diffused among non-contact farmers even within the village where it was being promoted. Frequently, even if farmers participated in the demonstration of the technology, they did not practise it once the experts left the place. Maybe the impact of the technology was not sufficiently apparent to the farmers to convince them to adopt it. Ironically, non-animal-nutrition scientists were not only ignorant about the technology but also had a negative attitude towards it, including having a belief that urea treatment was a harmful practice. Nevertheless, efforts are still going on to promote the technology in areas where it has not been taken to so far. Such efforts are driven more by the funds available for the extension of potential technologies rather than by applicability of the technology itself.

## LESSONS LEARNT

The major reasons for low adoption of the technology by the farmers are as follows:

- Unorganised and sporadic extension efforts to promote this technology, usually restricted to the periphery of livestock research institutes, agricultural and veterinary universities and dairy cooperatives;
- Usually farmers are not exposed to the advantages of the technology as they do not get to see other farmers practising urea treatment successfully;
- Farmers do not feel comfortable feeding urea to the animals as it is considered toxic by many farmers; and
- The availability of straws is limited in most places which also limits the use of this technology.

Urea treatment is considered superfluous in the areas where farmers grow green fodder. The practice of green fodder cultivation is on the increase with increasing awareness among farmers about its importance. Also the efforts are being made to popularize green fodder cultivation and its use by dairy cooperatives and other development agencies. It is increasingly believed by extension agencies and farmers that efforts should be directed more to augmenting green fodder cultivation, rather than to urea-treatment of straws which farmers find difficult to adopt.

## FUTURE OF THE TECHNOLOGY

No technology is worthwhile if it is not adopted by intended users. Urea treatment is not generally used by the farmers even in villages where it was intensively promoted by researchers and extension workers. Farmers find the treatment too technical and cumbersome to follow. Other major factors reported to hinder adoption are myths associated with the technology being risky (causing allergies, infertility and toxicity) and the non-availability of sufficient straw and the limited availability of cash with farmers to purchase urea. Farmers find cultivation of green fodder more worthwhile as they can mix green fodder with the straws/residues. Urea treatment is perhaps a classic case of mismatch

between the perceived usability and appropriateness at the level of scientists, farmers and extension workers. Furthermore, the various components, i.e. the research system, the extension system and the client/user system work in isolation – independent of each other, without getting to know each other's opinions on the technology. A technology and its dissemination need to be better understood through farmer-scientist-extension-worker interactions and participatory technology appraisal methods.

Based on the experiences so far, it appears that urea treatment of straw, in its present form, has a bleak future. Moreover, in light of increasing interest in organic farming, climate change and sustainable agriculture, the use of this technology is expected to be further restricted in the future, since chemical treatment of feedstuffs has no/limited application under such systems.

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# Production of urea-molasses-mineral blocks in a process developed by Dairyboard of India

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## SUMMARY

In most developing countries, ruminant animals usually survive on crop residues and natural herbage, which do not provide adequate nutrients for improving productivity. Low quality crop residues are deficient in fermentable nitrogen, carbohydrates and minerals. Urea-molasses-mineral block (UMMB) is a strategic feed supplement for ruminants which provides a constant source of fermentable nitrogen throughout the day to promote growth of rumen microbes. Supplementation with UMMB licks significantly increase feed intake, milk yield and growth rate and as such is a cost-effective approach to maximise the utilisation of locally-available feed resources for improved productivity. National Dairy Development Board (NDDB) of India developed a modified 'cold process' of manufacturing UMMB and has also designed a plant with automatic pressing device for manufacturing block licks. In addition, a dispenser has also been designed for feeding the block lick, to prevent its biting and over-ingestion by the animal. UMMB manufacturing technology is being provided to dairy cooperatives, private organizations and international agencies for commercial production of block licks.

**Keywords:** *milk production, ruminant, supplementation, urea molasses mineral block*

## INTRODUCTION

The productivity of dairy animals in developing countries is greatly constrained by the lack of green fodder and good quality feed, due mainly to low availability and high cost. Crop residues and dry grasses are the major source of forages for feeding livestock in these countries. These crop residues are low in nitrogen and high in fibre and lignin; characteristics that restrict intake and digestibility in animals. Animal nutritionists, all over the world, have proved that the nutritive value of these crop residues can be enhanced if supplemented with deficient nutrients (Makkar, 2002; Singh and Singh, 2003). UMMB through licking provides fermentable nitrogen, energy and minerals intermittently, necessary for optimum microbial growth. Microbial protein can contribute 30–40 percent of crude protein requirement of an animal. As ruminants can produce microbial protein from non-protein nitrogen, UMMB supplementation in the ration is quite beneficial, especially when fed crop-residue-based diets. The use of UMMB for supplementing crop-residue-based diets for livestock

has the potential to increase livestock production and net daily income (Misra, Reddy and Balakrishna, 2006). UMMBs can be fed throughout the year but are more-beneficially utilised during the dry season or when the animals are grazing low-quality fodder. Considering the benefits of UMMB supplementation of crop-residue-based diets, as demonstrated by several scientific studies, Dairyboard of India initiated efforts to standardise the formulation, production process and equipment for the commercial production of block licks.

## EXPERIENCES OF APPLYING UMMB TECHNOLOGY IN THE FIELD

### The 'hot process'

National Dairy Development Board (NDDB) first introduced UMMB to farmers in 1983, by manufacturing block licks using a 'hot process'. Blocks were produced by steam-heating the molasses and then mixing it with other ingredients in a double-jacketed insulated vessel. Although farmers started using these blocks there were inherent problems in their manufacture, transport, storage and feeding (Garg, Mehta and Singh, 1998). It was difficult to handle the hot material manually at 130 °C and the blocks, being highly hygroscopic, would start melting and de-shaping on storage.

### The 'cold process'

In view of problems faced in manufacturing the block licks by the 'hot process', efforts were made to produce blocks by the 'cold process' using lime as a gelling agent. It was possible to produce reasonably-hard blocks using lime, however these blocks had very low palatability due to their bitter taste, resulting in poor acceptance at the field level.

### The 'cold process' developed by Dairyboard of India

Efforts were made to improve the block lick formulation, to ensure that the blocks were hard enough and also palatable to the animals. To achieve this, lime and magnesium oxide were used in combination, and a buffering agent was added towards the end of the process to reduce the pH which considerably improved palatability of the blocks. In addition to modifying the formulation and the production process, Dairyboard also designed a plant for manufacturing the blocks and a dispenser for feeding blocks (Photos 1 and 2).

## APPLICATION STATUS OF THE UMMB TECHNOLOGY

Supplementation with UMMB increased digestibility of low-quality basal diets leading to improvement in milk production (Garg, Sanyal and Bhandari, 2007; Misra and Reddy, 2004). Use of UMMB supplementation proved economically beneficial. Taking into account the milk production alone, average cost: benefit ratio of feeding UMMB prepared by the 'cold process' was 1:3. Although the benefits of using UMMB are well documented by researchers in developed and developing countries, use of UMMB licks amongst milk producers need to be popularized through extensive extension efforts.

## CONSTRAINTS OBSERVED DURING THE IMPLEMENTATION OF THE TECHNOLOGY

*Imprints of the 'hot process'*. Various problems were encountered in production, storage and feeding when UMMBs produced by the 'hot process' were first introduced, adversely





**photo 1**  
*UMMB plant with pneumatically controlled rotary pressing device for UMMB feeding to animals*



**photo 2**  
*A plastic trough for UMMB feeding to animals*

affecting the large-scale acceptance of the UMMB technology by farmers. Even with all the improvements through the 'cold process', it was very difficult to remove the imprints of the 'hot process' from the minds of people.

*Feeding and management practices.* Feeding and management practices vary from region to region in India. In some regions, animals are let loose (untethered) into the field in the morning and are returned home only in the evening. The tethering place of animals is different in the morning and evening. Milk producers do not move the UMMB dispenser when they move animals from one tethering place to another. At certain tethering places, there is no manger to offer feed to animals. Under such situations, animals do not have regular and free access to UMMB. As a result, the benefits from UMMB feeding are not clearly noticeable to milk producers.

*Cost and availability of molasses.* Being highly palatable and a rich source of calcium, sulphur and B complex vitamins, molasses is an important and economic source of nutrients in the UMMB. In view of large variations in sugarcane production, the cost and availability of molasses fluctuates. The price of molasses varies from as low as Rs 4 000 per tonne to as high as Rupees 15 000 per tonne (1 US\$ = ca Rupees 45). Due to the high cost of molasses and problems of availability, agencies are sometimes discouraged from taking up production of UMMB on a regular basis.

*Lack of extension education.* As well as taking-up the production of good-quality UMMB by various agencies, delivering proper extension-education to milk producers concerning the advantages of regular use of UMMB is considered equally important. Milk producers need to be explained the do's and don'ts of using UMMB so that they are able to derive proper benefits. Some agencies tried to introduce UMMB in their areas of operation without educating milk producers about the benefits and importance of regular use of the licks. These agencies had to discontinue as there was no regular demand for UMMBs after some time.

## LESSONS LEARNT AND FUTURE OF THE UMMB TECHNOLOGY

In view of the above-mentioned constraints, we advise the following to agencies that are willing to popularize the UMMB technology in their areas of operation.

- The UMMB technology is only suitable for areas where dry fodder is the predominant source of roughage for animals.
- Ensure the availability of a manger for feeding UMMB and also ensure its free access for at least 10–12 hours in a day.
- Popularise the use of a specially-designed dispenser for feeding UMMB which prevents the animal biting and over-ingesting the feed block.
- Educate the milk producers about the safe use of UMMB and the benefits accrued from its regular use.
- Ensure regular availability of molasses at a reasonable price.

Some of the agencies are now producing and supplying UMMB on a regular basis, using the equipment, formulations and production process developed by Dairyboard of India. On average, about 300 000 blocks, each weighing 3 kg, are used in India annually.

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# Impact of urea-molasses-multinutrient block supplementation on livestock production in Pakistan

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## SUMMARY

Livestock production is an integral part of agriculture in Pakistan. The ruminant feeding system is based on low-quality roughages. The utilisation of these low-quality feeds can be improved by creating proper conditions in the rumen that maximises fibre digestion. A solidified urea-molasses-multinutrient block (UMMB) prepared with locally-available low-cost ingredients to provide critical nutrients for microbial fermentation was formulated. Supplementation with UMMB improved feed intake and dry matter digestibility, weight gain, milk production and resumption of post-partum oestrus. The use of UMMB is an attractive alternative to other forms of supplementation especially when they are not easily available or are too expensive. The farmers, particularly in arid and semi-arid regions, are fully convinced of the benefits of the UMMB feeding and this technology is fast becoming popular in Pakistan.

**Keywords:** *blocks, livestock, molasses, roughages, supplementation, urea*

## INTRODUCTION

Livestock is an integral part of the agriculture sector in Pakistan. Pakistan has over 66 million buffalo and cows and 80 million goats and sheep. Small farmers have limited feed resources, which are generally low in essential nutrients and thus unable to support efficient rumen fermentation. Low-ammonia concentration in rumen fluid is a major limiting factor for achieving optimum microbial growth and digestibility. A solidified UMMB provides critical nutrients namely nitrogen as urea, readily available energy as molasses, and minerals for efficient microbial fermentation in the rumen. The use of blocks is convenient and can be easily introduced into existing on-farm practices (Sansoucy, 1986; Habib *et al.*, 1991).

In Pakistan, UMMB technology was established with the technical and financial help of FAO/IAEA. The UMMBs were prepared from local, easily-available and low-cost feed ingredients, e.g. sugarcane molasses, cotton seed meal/sunflower meal and wheat bran (Table 1). The high contents of crude protein (18.2 percent) and metabolisable energy (9.0 MJ/kg dry matter) make UMMB an excellent supplement for livestock. The evaluation of UMMBs was conducted on different farms, with buffalo, cattle, calves, goats and sheep

and involved a number of research organisations, e.g. Ayub Agriculture Research Institute, Faisalabad; Livestock Production Research Institute, Okara; and Livestock Experimental Station, Qadirabad. A number of progressive farmers, livestock owners and NGOs were also involved in the evaluation.

### EXPERIENCES OF APPLYING TECHNOLOGY ON FARMS

UMMB supplementation had significant positive effects on various traits of animal production such as digestibility of feed, growth rate, meat production, milk yield and reproductive efficiency. The studies conducted on cows, buffalo, sheep and goats revealed the following positive effects:

- Fodder intake and dry matter digestibility were significantly increased and during the shortage of green fodder, UMMB proved a better and attractive alternative;
- Due to the high cost of feed supplements, balanced rations become expensive making livestock production uneconomical. UMMB was found to be the most economical source of protein as well as of energy, among the supplements evaluated;
- Pica was a common problem in almost all animals of the arid region due to mineral deficiencies; pica was effectively overcome by UMMB supplementation. In some cases animals suffering from haemoglobinuria, due to phosphorus deficiency, recovered when supplemented with UMMB;
- Farmers are fully convinced of the benefits of supplementing with UMMB and are receptive to this technology;

TABLE 1  
Formulation and chemical composition of UMMB

Ingredients	Percent
Molasses	41
Urea	6
Lime	6
Calcium phosphate	2
Wheat bran	26
Cotton seed meal	8
Sunflower meal	6
Calcium sulphate	2
Salt	2.5
Mineral powder	0.5
Chemical composition	Percent
Dry matter	80.2
Ether extract	03.9
Crude fiber	05.8
Crude protein	18.2
Ash	26.9
Nitrogen-free extract	45.3

- UMMB is an appropriate technology for all types of livestock, including sheep and goats where concentrate feeding is not commonly practised;
- After UMMB supplementation the animals looked healthier and were more active in searching feed on ranges with sparse vegetation;
- Due to prolonged mineral deficiency, animals especially lactating and pregnant buffalo and cows suffered from bone disorders manifested by stiff joints, ataxia, and characteristic posture with bulging scapula and stiff neck. When the animals were offered UMMB, containing calcium and other minerals, the symptoms subsided within a week of feeding of the blocks; and
- Cows with delayed oestrus due to inadequate nutrition resumed the oestrous cycle when supplemented with mineral-rich UMMB.

Farmers in arid and semi-arid regions liked the UMMB technology because block feeding fitted well into their feeding practices.

### CONSTRAINTS

- Lack of awareness of the benefits of UMMB supplementation is one of the major constraints to widespread adoption of this technology.
- Inadequate resources and unavailability of molasses in certain parts of the country restrict the scope of this technology. Farmers prefer to buy UMMB rather than prepare the blocks themselves.
- Lack of coordination between farmers and extension workers, and involvement of commercial agencies make the technology more expensive for farmers.

### FUTURE OF THE TECHNOLOGY

The technology has the potential for further dissemination and propagation to all parts of the country. Local government, extension workers, cooperatives and various NGOs need to be involved in the transfer of technology to the farmers on a more extensive scale.

The farmers from the pilot farms should be thoroughly trained in the preparation and proper use of UMMB, to get maximum benefits. The farmers should be motivated to adopt this technology by arranging their visits to the farmers who are using and taking advantage of this technology.

In Pakistan, the prevalence of parasite infestations in ruminant livestock is common. The technology may also be used for the control of parasites in livestock by incorporating traditional herbal medicines and plants with anthelmintic properties into UMMB (Akhtar *et al.*, 2000; Knox, 2003).

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# On-farm preparation of low-cost feed blocks using mulberry fruit wastes: impact analysis and adoption by farmers

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## SUMMARY

Feed blocks were prepared using fresh or dried mulberry fruit for supplementary feeding of livestock during feed-scarcity periods in the northern, hilly region of Pakistan. Molasses is not available in this region and the cost of feed blocks imported from plain areas is very high. Fruit waste of mulberry tree, native to the northern region, was used in place of molasses for making feed blocks. The final formula consisted of 45, 5, 5, 5, 10, 5, 10 and 15 percent of fresh mulberry fruits, urea, lime, clay, mineral mixture, salt, dried lucerne leaves and wheat bran respectively. The farmers in three different village organisations were trained to prepare blocks. The blocks were offered as free-choice licks to lactating cows and goats. An increase in milk production varying from 30 to 50 percent and improved feed intake and health condition were recorded in animals receiving feed blocks. The preparation of feed blocks was followed by the farmers preparing blocks on their own farms. Scope of the on-farm preparation of the feed blocks as income generating activity was also assessed. However, financial support from government or other service providers may be required to provide seed money to the resource-poor farmers, especially female farmers for starting this activity on a sustainable basis. This will not only increase livestock productivity and enhance food security but will also contribute to poverty reduction through encouraging setting up of micro-enterprises based on indigenous resources.

**Keywords:** *adoption of block technology, feed blocks, milk production, mulberry*

## INTRODUCTION

Feeding of multi-nutrient blocks is a relevant supplementation strategy for ruminant livestock during lean periods when they are offered crop residues and other low-quality feeds. Molasses is generally used as the main vehicle for mixing ingredients and moulding feed blocks. In the northern region of Pakistan the long-winter feed-scarcity period of more than 5 months from November to March demands block supplementation for improving the utilization of low-quality feeds and enhance the survivability of farm animals. However being a hilly region, the local availability of molasses is out of the question and import of feed blocks or of molasses from other areas is very expensive due to added transportation cost. Mulberry trees are highly adapted to the agro-climatic conditions of the region. Mulberry leaves are used as forage and fruits are consumed by humans both as fresh and in dried form. A large quantity of fresh and dried mulberry fruits is wasted due to improper

collection and the conventional sun drying method. Certain varieties, such as “lashari”, containing seed, are not used for human consumption and are entirely wasted. Attempts to substitute molasses with fresh mulberry fruit for making feed blocks have proved successful (Habib and Roomi, 2000). Further work was undertaken to modify the formulation to reduce the cost, increase feed value and train farmers in preparing mulberry fruit-based blocks. The impact of feeding mulberry fruit blocks on livestock production and their preparation as an on-farm income generating activity was also assessed.

### PREPARATION OF MULBERRY FRUIT-BASED FEED BLOCKS

Feed blocks were prepared from both fresh mulberry and dried mulberry fruits. Six different combinations of ingredients (Table 1) were tested for making blocks of desired hardness. The blocks were prepared manually with the cold method described by Sansoucy, Aarts and Leng (1988) and Garcia and Restrepo (1995). Fresh mulberry fruits containing more than 85 percent moisture were first hand-crushed to form a paste. Urea was added slowly and thoroughly dissolved in the paste. The moisture content of mulberry fruits was sufficient to dissolve urea and no additional water was required. The other ingredients were added in the order listed in Table 1 and mixed thoroughly. Finally, after adding wheat bran or dried lucerne leaves, the mixture turned into dough, which was transferred to a wooden mould (6 x 6 x 4 inches; length x width x height). After pressing with hands the mould was removed and the block was left in shade and allowed to dry and harden for 48 hours.

Among the six different blocks prepared, Block-2 quickly settled and was reasonably hard after 24 hours. After 48 hours, all the blocks, except Blocks-1 and 4 were hard to almost the same degree. Block-1, with no cement or clay, never solidified and remained very soft at all the times. Block-4 containing 25 percent lucerne leaves in place of wheat bran was brittle with no cohesion and could not be moulded to a shape. The formulae of Blocks 3, 5 and 6 were selected for on-farm adoption. Block-2, although very hard, was

TABLE 1  
Percent ingredient composition of mulberry-fruit-based multi-nutrient blocks

Ingredients	Block-1	Block-2	Block-3	Block-4	Block-5	Block-6
Mulberry fruit (fresh)	48	45	45	45	45	45
Urea	5	5	5	5	5	5
Lime powder	10	10	5	5	5	5
Cement	0	5	5	5	0	0
Clay	0	0	0	0	5	5
Mineral mixture	10	10	10	10	10	10
Salt	5	5	5	5	5	5
Wheat bran	22	20	25	0	15	25
Lucerne leaves (dried)	0	0	0	25	10	0
Hardness after 24 hours	Soft	++	+	--	+	+
Hardness after 48 hours	Soft	+++	+++	--	+++	+++

--, Brittle with no cohesion; see text for block description



not selected because of the high level of lime which makes it less palatable due to a bitter taste. Substitution of cement with clay in Block-3 was effective and reduced the cost of the block. However, clay was not available in all the farms and its inclusion was left to the choice of farmers. Experience in our laboratory has shown that wheat bran is an excellent binding agent in making feed blocks. Partial replacement of wheat bran with lucerne leaves (Block-5) produced equally good blocks and lowered the cost of the block and was selected as the final recipe. It was used for demonstration of the block preparation to farmers and for adoption by the farmers.

Blocks were also prepared from dried mulberry fruits. Dried mulberry fruits were suspended in equivalent quantity of water (w/w) and boiled for about 10 minutes with continuous stirring which turned the mixture into a viscous liquid having consistency almost similar to thick molasses. After cooling to about 60 °C, urea was added and dissolved. The rest of the ingredients were added in the same order as listed for Block-5 in Table 1. The blocks settled quickly and were of the desired hardness after 24 hours. According to experience of the local farmers, if the suspension after boiling is left as such for a day or two, the viscosity of the solution increases, resulting in better-quality blocks.

### **TRAINING OF FARMERS IN PREPARATION OF MULBERRY-FRUIT-BASED BLOCKS**

Groups of 20–30 male and female farmers in five villages were trained in making the feed blocks using fresh or dried mulberry fruits. The farmers were first briefed on the importance of feeding the feed blocks and were informed of the steps in the preparation of blocks. This was followed by weighing and step-wise mixing of the ingredients and finally moulding of the blocks by the farmers using a participatory approach (Photos 1 and 2). All the steps in preparation of the blocks were performed by the farmers, facilitated by the author. Household pots and tools were used for mixing the ingredients and moulding the blocks. Each group prepared 10 to 15 blocks of 3 kg each. The blocks were left for two days to achieve the desired hardness and were then distributed among three interested farmers of the group for feeding to lactating cows or goats.

### **FEEDING AND ECONOMICS OF MULBERRY-FRUIT-BASED FEED BLOCKS**

The blocks were offered free-choice lick and observations were recorded on consumption behaviour and changes in milk production and general body conditions of lactating cows and goats. After one week, the farmers were visited to monitor the animal responses. Despite availability of sufficient green fodder and range grasses at the time of field testing, the animal responses to feed blocks were very encouraging. All the farmers in the five villages consistently reported that the animals readily accepted and licked the blocks and in all cases and that milk production increased by 30 to 50 percent. In goats, milk production increased from 500 ml to 750 ml/day. A positive change in the hair coat of the animals receiving the blocks was also noted. The increase in milk production was apparent on the third day of feeding the blocks in all the animals. Four farmers reported that their cows did not lick the block therefore the blocks were cut into ten pieces and one piece was fed mixed with feed daily. None of the animals bit the blocks indicating that the blocks were of the desired hardness. The blocks were placed in the feed trough or in a shallow pot for



**photo 1 and photo 2**

*Farmers being facilitated in making mulberry-fruit-based feed blocks*

easy access to the animals. Daily intake of the blocks in cows (body weight 150–180 kg) varied from 120 to 200 g and averaged 50 g/day in goats.

The cost of preparing one block weighing 3 kg was Pakistani Rupees (PKR) 21 or PKR 7 per kg (1 US\$ = 86 PKR). This is much below the prevailing price of PKR 12 to 25 per kg of conventional concentrate ingredients in the local market. For a cow consuming 200 g block per day, cost of the block would be PKR 1.40/day. In turn block increases milk production by 250 ml to 500 ml/day/cow, which is valued PKR 10 to 20. Such a benefit: cost ratio is encouraging for adoption of the technology. In addition, there are added advantages of the block feeding in terms of improved body condition, improved fertility and lower disease incidence.

### **SCOPE OF MULBERRY FRUIT FEED BLOCKS AS INCOME GENERATING ACTIVITY**

After experiencing the benefits of the blocks, some farmers prepared blocks in bulk for feeding to their animals and also for sale to other farmers. The sale price of a 3 kg block was fixed by the farmers as PKR 35 with a profit of PKR 14 (almost 67 percent). This price of a 3 kg block was much lower than the market price of over PKR 100. It was estimated that an average village having a total of 200 mulberry trees producing 50 kg fruit per tree would provide 10 tonnes of fruits in a season. Assuming 30 percent wastage, about 3 tonnes of fruits could be made available for making feed blocks in each village, enough for preparing about 2 000 blocks weighing 3 kg each in two months (April–May), which would be enough for feeding all the cows in milk in the village over the winter lean period.

These estimates show the considerable potential of using the technology for income generation as a micro-enterprise. The income generating activity appears to be best suited for women in the area. In the northern region of Pakistan, women are almost solely responsible for rearing livestock. During the field demonstrations, most of the farmers suggested that priority be given to capacity building of female farmers in making the blocks.

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# Urea-molasses-multinutrient blocks/licks: a blend of nutrients for ruminants

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## SUMMARY

There is an acute shortage of feedstuffs for livestock in developing countries. Frequent floods, earthquakes and other natural calamities further aggravate this situation. Low-quality crop residues (low in nitrogen) constitute the bulk of dry matter consumed and hence most of the animals do not get adequate amounts of feed. The uromin lick (UML)/urea-molasses-multinutrient blocks (UMMB) – a blend of energy, protein and minerals can act as an important feed supplement and life saver. The blocks prepared by using alternative, non-conventional feed resources, e.g. waste bread, tomato pomace and spent sugar syrup replacing wheat flour, mustard cake and molasses respectively were as effective as those prepared using conventional energy and protein supplements. The dietary supplementation of UML/UMMB improves the voluntary dry matter intake and nutrient utilisation, checks mineral deficiency, and improves daily live-weight gain of calves and the productive and reproductive performance of lactating animals. The medicated UMMB, besides providing the conventional nutrients, can help in reducing the load of internal parasites and in expulsion of the placenta.

**Keywords:** *crop residues, non conventional feed resources, urea molasses multi-nutrient blocks*

## INTRODUCTION

A comprehensive survey conducted to assess the nutritional status of dairy animals in six different agro-climatic zones of Punjab state of India revealed that animals of all zones, except that of central plain zone (CPZ) and western plain zone (WPZ) were being offered highly-imbalanced diets, deficient in protein and/or energy or minerals. The diets offered were unable to meet the nutrient requirements, as also indicated by low milk urea-N (4.67 to 9.45 mg/dl). The proportion of roughage in the complete feed was highest (86.9 percent) in undulating plain zone (UPZ) and lowest (71.4 percent) in western zone (WZ), indicating that the rations of dairy animals under field condition were roughage based. Only 19.7 percent of farmers offered mineral mixture (MM) in CPZ while only 2.5 percent in sub-mountainous undulating zone (SMUZ). Forty-eight percent of farmers in CPZ and 19.7 percent of farmers in WZ supplemented the diet with common salt. The deficiency in minerals and salt was reflected in the reproductive problems of animals in these areas. The

highest cases of repeat breeding (anoestrus) were recorded in CPZ and WPZ (52.0 and 51.5 percent respectively) and the lowest in WZ and FPBZ (28 and 34 percent respectively). It was clear from the survey that feeding of a balanced diet (with respect to energy, protein and minerals) must be advocated under field conditions (Bakshi and Wadhwa, 2011a). Wheat/ rice/ragi straws, and maize stover/millet stalks constitute the bulk of dry matter (DM) consumed under field conditions (Bakshi and Wadhwa, 2004). Supplementing such diets with UML/UMMB would be beneficial to ruminants.

### DEVELOPMENT OF THE TECHNOLOGY

Several processes have been developed to slow down the release of ammonia from urea in the rumen. Uromol – a Maillard product formed by heating urea and molasses (1:3 ratio w/w; heating for 20–30 minutes) was developed by the Department of Animal Nutrition, Punjab Agricultural University, Ludhiana (Chopra *et al.*, 1974). To avoid solidification of Uromol at room temperature, it was mixed (whilst hot) with four parts of wheat or rice bran. The ensuing mixture was named Urobran. Rate of rumen release of ammonia from uromol/urobran was slow and consistent leading to better nitrogen utilization by rumen microbes compared to urea-molasses fed without heat treatment. Urobran was shown to be suitable as a complete replacer for groundnut or mustard cake in a concentrate mixture (Malik, Langar and Chopra, 1978). Uromol-straw combinations could be safely used as a basal ration for ruminants provided adequate energy was available as digestible organic matter (Langar, Bakshi and Rana, 1985). To reduce fuel costs and make the process more farmer-friendly, the heating was dispensed with and urea-molasses-multi-nutrient blocks (UMMBs) were prepared by the cold process. The heat generated by mixing calcium oxide with urea and molasses helped bind the urea and molasses via the Maillard reaction. Nutrient utilisation in buffalo calves was comparable for UMMBs prepared by hot and cold process (Bakshi and Wadhwa, 2011b).

### UMMB PREPARATION AND PALATABILITY

UMMB is a convenient and inexpensive method of providing a range of nutrients to animals. It can improve the digestion of low-quality roughages by satisfying the requirement of rumen microorganisms, creating a better environment for fermentation and increasing production of microbial protein and volatile fatty acids. Urea, after hydrolysis to ammonia in the rumen, provides a nitrogen source for the rumen microbes, while molasses acts as a source of readily-fermentable energy.

The conventional UMMB weighing 3 kg contains (g): molasses 900, urea 300, mustard cake 300, de-oiled rice bran 300, wheat flour 450, mineral mixture 450, calcium oxide 120, salt 120 and guar gum 60. The required quantity of molasses and urea are weighed and mixed in a 25 kg capacity iron pan. The guar gum is added to the urea-molasses mixture as a binder. A premix of other ingredients is prepared; calcium oxide is the last ingredient to be added to this premix in the iron pan with rapid stirring. Two to eight UMMBs may be prepared at a time, either in a manually operated (for small/marginal/landless dairy farmers) or electrically powered (for commercial production) block-making machine (Photo 1).

On average an animal licks 500–700 g UMMB/day, but some animals may lick as much as 1.25 kg/day without any adverse effect on their health. The hardness of the UMMB

affects its intake; this aspect acquires greater importance when medicated blocks are used for drug delivery, since dosages are based on intake of such blocks. Animals do not seem to like licking very hard blocks, while soft blocks are chewed rather than licked. Blocks that show no finger impression on pressing, are considered to be of desirable hardness.

### UMMB CONTAINING NON-CONVENTIONAL FEED RESOURCES

The blocks may also be prepared by using non-conventional feed resources. Iso-nitrogenous and iso-energetic licks were prepared by replacing: a) wheat flour with waste bread (an excellent source of by-pass starch containing 11–12 percent crude protein) and b) oiled mustard cake with tomato pomace (20–22 percent CP, 10–11 percent ether extract and a 'good' amount of lycopene, an antioxidant and pigment that gives colour to meat). The combination of alternate energy and protein sources improved the utilisation of nutrients. The metabolisable energy (ME) content of UMMBs containing non-conventional feed resources varied from 5.71 to 6.03 MJ/kg DM. *In vitro* gas production studies also revealed similar efficiency of nutrient utilisation from various UMMBs. Adult male Murrah buffalo offered 1 kg concentrate, 5 kg green fodder and 9 kg wheat straw daily, supplemented with ad libitum UMMB consumed 1.08 kg of conventional block compared with 1.32–1.84 kg experimental blocks. The UMMB supplementation improved intake of wheat straw, CP digestibility and N-retention. The use of such wastes can reduce the cost of producing UMMB because tomato pomace is available free, whilst waste bread is available at Rupees 7/kg compared with wheat flour at Rupees 15/kg (Chobey, Wadhwa and Bakshi, 2011).



**photo 1**  
Preparation of urea molasses multinutrient blocks (UMMBs)

The cost of molasses can be reduced by using spent sugar syrup available at nominal charges or free from the 'Muraba' (fruits preserved in sugar syrup) manufacturing industry. Bakshi, Wadhwa and Parmar (unpublished) used spent sugar syrup in place of molasses for manufacturing UMMB. The results were comparable with those recorded for UMMB containing molasses.

### **IMPACT OF UMMB ON PERFORMANCE OF ANIMALS**

Due to mineral deficiencies, pica is a common problem in almost all the animals in arid regions. Pica was effectively reduced by UMMB supplementation. In some cases, animals suffering from haemoglobinuria due to phosphorus deficiency recovered when supplemented with UMMB. Farmers reported animals to be better general body condition, with glossy coats and healthier appearance. Cows that had not shown oestrus signs for a long time (presumably due to inadequate nutrition) resumed cycling when given mineral-rich blocks. Increases in milk production due to UMMB supplementation have generated additional income whilst improving reproductive performance, leading to more calves. These improvements have undoubtedly improved the socio-economic status of farmers.

With UMMB supplementation, first service conception rate was improved (from 41.4 to 56.7 percent), while services per conception declined (from 2.54 to 1.88). UMMB supplementation also reduced culling rate due to infertility (from 8.6 to 3.2 percent). Out of 64 observations on calving intervals, 42.2 percent were below 360 days, compared with 50.0 percent after UMMB supplementation. UMMB supplementary feeding during the pre-partum period improved post-partum reproduction in terms of days to first oestrus (from 48 to 34 days) and conception rates (from 0 to 30 percent).

The response to supplementary feeding with UMMB was more pronounced in buffalo kept in rural areas by marginal farmers than in those kept on organised farms. This was due to the differences in basal diet of the systems. UMMB supplementation of early-calved buffalo induced a higher proportion (71 vs. 14 percent) exhibiting oestrus during the first 50 days post-partum compared to controls. Pre-partum UMMB supplementation improved milk yield, and peak milk yield was maintained longer during the post-partum period. UMMB supplementation for 30 days in delayed-puberty buffalo heifers induced oestrus in 33 percent of cases in summer, and in 93 percent of cases in winter. Similarly in anoestrous buffalo, UMMB supplementation induced ovarian activity in 40 percent of buffalo during the summer season and in 90 percent during the winter season. In addition, UMMB supplementation was shown to increase the effect of pregnant mare serum gonadotropin used to induce oestrus in anoestrous and delayed-puberty buffalo.

### **MEDICATED UMMB**

Supplementary feeding of recently-calved buffalo using UMMB medicated with Replanta (an indigenous herbal preparation) decreased the time for shedding of placenta (5.75 vs. 4.40 hours) and the days to first post-partum oestrus (42.5 vs. 36) for treated and control group, respectively. UMMB containing anthelmintic has been successfully used for controlling nematode parasites (Brar, Nanda and Juyal, 2006).



## ADOPTION OF THE TECHNOLOGY

Mineral mixture prepared as per Bureau of Indian Standards (BIS, 2002) specifications is being used for manufacturing UMMBs by the cold process and also using conventional feed ingredients in an electric block-making machine. Using the machine, eight blocks are made at a time and this is achieved within three to five minutes. Currently, UMMBs are prepared under a Revolving Fund Project and a sum of Rupees 4 million has been provided by our university for the project. UMMBs are sold at Rupees 70 per 3 kg block (1 US\$ = ca 45 Indian Rupees). The UMMBs are sold all year round, from the premises of our department. UMMBs are also sold in the livestock shows organised by the University twice-a-year, and sold too in the zonal as well as regional cattle-judging competitions organised by the State Animal Husbandry Department. In addition, the Krishi Vigyan Kendras (an institution under Indian Council of Agriculture Research, responsible for technology transfer) purchase the UMMBs from our department and sell them to farmers. During the last three years the sale of the UMMBs has increased from 2 660 to 6 530/annum. Farmers are keen to buy the blocks and feed them to animals. Some cattle-feed manufacturers and government agencies, e.g. Markfed and Milkfed have taken up these technologies. The future of these technologies would appear to be very bright.

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# Straw-based densified complete feed block technology

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## SUMMARY

Due to acute shortage of feeds coupled with the poor management of feed resources in India (e.g. burning of straw in states where straw is surplus), improved feed management practices are urgently required. These should include the mechanical collection of residual straw from the field and use of processing technologies for the commercial production of the balanced feed. The technology of straw-based Densified Total Mixed Ration (DTMR), also called Densified Complete Feed Block (DCFB), offers a good opportunity to remove regional disparities in feed availability, because of easier transportation of feed blocks. The technology is a novel approach of supplying balanced feed for ruminants in the tropics. Straw and concentrate (adequately supplemented with minerals and vitamins) are mixed in different proportions (for different levels of production) and then compacted by hydraulic press to form a block. Apart from providing a balanced feed which improves the productive and reproductive performance of animals, DCFB is also an attractive disaster management technology for use in emergency situations that arise due to natural calamities like floods, droughts and conflicts. Feed banks could be set up to overcome the problem of feeding animals during natural calamities which are increasingly common in the tropics.

**Keywords:** *balanced feed, densification, feed blocks, ruminants, straws*

## INTRODUCTION

Most of the countries in the tropical region face an acute feed shortage. Crop residues, especially cereal straws are the staple feed available in this region for ruminant feeding. These fibrous and bulky feeds are of low palatability and digestibility. Also crop residues have low available energy, protein and mineral contents. Apart from feed shortage, India is also facing regional feed disparity, with some states like Punjab, Haryana and Western UP growing sufficient green fodder and being surplus in straws, while other states lack in the supply of greens and dry roughages. The bulky nature of crop residues makes their transportation costly and difficult. Straws worth millions of dollars are therefore burnt in the fields; this not only wastes a feed resource, but also causes environmental pollution and soil degradation. Therefore there is need to improve the management of feed resources in India. One improvement would be using specially designed balers for collecting straw from fields and then subjecting straw to processing technologies for the commercial production of balanced animal feeds (Kundu *et al.*, 2005).

## TECHNOLOGY OF STRAW-BASED DENSIFIED COMPLETE FEED BLOCKS

*A novel concept in nutrient delivery system for ruminants in the tropics.* The technology for making straw-based Densified Total Mixed Ration (DTMR) or Densified Complete Feed Blocks (DCFB) is a novel and revolutionary approach, which provides an excellent opportunity for feed manufacturers and entrepreneurs to remove the regional disparities in feed availability and also to supply balanced feeds on a large scale, to dairy and other livestock farmers. This approach could overcome the problem of feeding animals during natural calamities such as floods and droughts, which are increasingly common in the tropics. The technology has potential for use in other tropical countries where farmers find it difficult to compute balanced feeds. These difficulties result in below-optimum levels of livestock production. Each DCFB is a total ration for a cow or buffalo and supplies all the major and minor nutrients, including micronutrients required by the animal.

The two major components of straw-based DTMR/DCFB are roughage and concentrate, added in different ratios, depending on the level of production, stage of lactation and physiological state of the animal. The roughage part is generally crop residue e.g. straws, stovers and sugar cane tops. Sometimes gram straw, sugar cane bagasse and groundnut haulm are also used as part of the roughage component. In hilly areas, even non-conventional roughage sources like dry forest grasses and tree leaves have been used in place of crop residues. The proportion of straw and concentrate in the block varies with the type of animal to be fed. The ingredients of the concentrate mixture are oilcakes (as protein source), molasses, grains, grain products/by-products (as energy sources) and supplements like by-pass protein/by-pass fat, to enhance the direct supply of amino acids and fatty acids to the host animal. The third component provides strategic and catalytic supplements, e.g. vitamins, minerals, bentonite (toxin-binder), probiotics, antioxidants and herbal extracts. The role of this component in the feed block is to enhance the productive and reproductive efficiency of the animal and to enhance the immuno-protective ability to keep the animal disease-free (Walli, 2008).

*Method of manufacturing feed blocks.* The making of feed blocks requires appropriate processing. Blocks can be manufactured on a large scale in a factory. The concentrate mixture is prepared separately and then mixed with straw (in a specified ratio) in a specially-designed mixer to ensure that the two components, which vary greatly in their densities, are adequately mixed. The mixed feed is compacted in a specially-designed hydraulic press. With the help of a binder, the process of densification results in concentrate particulate-matter becoming physically attached to fibrous straw particles. The whole process brings uniformity to the feed, prevents selection of ingredients by the animal, increases palatability and minimises the feed wastage. A few agencies have taken the initiative of developing and refining the feed-block technology in India. Fuel-efficient and labour-efficient models of machines for feed-block production have been developed in India. Results of on-farm feeding trials with feed blocks, conducted recently on buffalo in rural areas around Karnal, showed a significant increase in milk production (10–15 percent) compared with normal feeding practised by farmers in the villages. Although feed cost increased by 30 percent with block feeding, the profit earned was approximately 20 percent higher (Walli, 2009).

## EXPERIENCES OF APPLYING TECHNOLOGY/PRACTICE BY FARMERS

The DCFB technology offers a variety of benefits, both to the farmer as well as to the feed entrepreneur. The following advantages of this technology have been identified.

*A balanced ration for ruminants.* In India, except at some organised farms, the practice of feeding a balanced ration is almost negligible. The DTMR/DCFB is a complete, balanced feed. By feeding a balanced feed with optimum nutrients, one can expect improved nutrient utilisation, resulting in optimum productive and reproductive performance from the animal.

*An efficient nutrient-delivery system.* The feeding is simple and hassle-free. The animal is not able to select ingredients. In the system where ingredients are fed separately, the animal picks up the more digestible/palatable part first, followed by the less-palatable and lower-quality component of the feed. Feeding of DTMR/DCFB reduces feed wastage and thus lowers feed costs.

*Time and labour saving.* The labour requirement of feeding is reduced by 30–40 percent. Twenty animals can be fed in about 10 minutes as against 2 hours required for feeding the same number of animals in a conventional feeding system. DTMR/DCFB could also be a clear advantage to women, especially in hilly areas, where women generally look after the feeding and management of dairy animals. In these areas, women spend most of their time in drudgery having to cut, collect and transport large loads of grasses and tree forages from the forest areas.

*Cheaper and easier transportation.* Densification of the straw caused a 3-fold reduction in its bulkiness. Accordingly, less space is required to store the feed, especially straws. Because DCFB occupy less space/volume, almost 3 times more feed (by weight) can be accommodated per load, making transport of crop residue-based feeds much easier and cheaper. Blocks are also easier to handle during storage.

*Can check environmental pollution.* The emission of methane gas (a greenhouse gas) from ruminants can be reduced on feeding densified feed blocks. The feeding of a balanced diet reduces the methane emission by 10 to 15 percent. There is also less dust pollution when blocks rather than loose straws are transported in over-loaded trucks. The latter are also a traffic hazard. In north-western parts of India, straws worth millions of dollars are burnt in the field after the harvest. Residual straw converted into feed blocks can be efficiently utilised and environmental pollution can also be reduced. Burning of straw in the field also lowers soil fertility.

*Improved productive and reproductive efficiency.* Feeding DCFB can increase growth rate of calves by 25 to 30 percent and milk yield by 10 to 15 percent. Also the milk yield persists longer, causing an increase in total lactation yield. The absence of dietary fluctuations results in a relatively stable microbial-ecology in the rumen which increases its efficiency. Feeding CFB results in earlier maturing of animals. This not only lowers the cost of rearing, but also reduces age at first calving. It also provides regularity to subsequent calvings and increases life-time production. The optimum supply of nutrients, including micronutrients has a positive effect on health which keeps the animal free from many reproductive problems e.g. late maturity, anoestrus and repeat breeding. Block feeding provides immuno-protection against infectious diseases resulting in significant savings in costs of medicating animals.

*Storage of bulky feeds possible.* With the availability of feed-block technology, it is possible to set up feed/fodder banks in feed-deficit areas, because of the ease of handling, transport and storage blocks. Feed block technology can also be beneficial during natural calamities, e.g. floods and drought. The blocks can be air-lifted to the remotest places to avert disasters.

*Vehicle for feed additives/pharma/nutraceuticals.* DCFB offers a delivery system for specific nutrients, nutraceuticals and medicines e.g. anthelmintics to control parasites in livestock.

### STATUS OF APPLICATION OF TECHNOLOGY/PRACTICE BY FARMER

The technology of straw-based densified feed block is a step towards better feed management in the tropics. Apart from providing a balanced feed to animals, the technology has the potential to remove regional disparity in feed availability. It is now possible to set up fodder banks, which can be used during emergency situations created by natural calamities. The Government of India, realising the potential of this technology in enhancing livestock production, has decided to offer a 50 percent subsidy for setting-up feed-block units. The approach is acting as an incentive to attract feed entrepreneurs and livestock cooperatives to become involved in the commercial manufacture of densified complete feed-blocks on a large scale. It is expected that this technology will be the key feeding technology for ruminants in the tropics.

### LESSONS LEARNT

The straw-based complete feed as densified blocks is a novel feeding technology for ruminants. Its use will increase livestock productivity and at the same time decrease environmental pollution. The technology is expected to produce higher impact in areas of fodder shortages, including hilly regions, where dry grasses and tree leaves can also be incorporated into the blocks.

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# Processed crop residue based complete diets for enhancing ruminant performance

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## SUMMARY

Due to the highly fibrous nature and low nutrient content of crop residues, several physical processing methods were employed to improve their utilisation in ruminants. Among the physical processing methods, grinding and blending crop residues and concentrate (in a given ratio) into mash or pellet was found to be a useful technology for efficient utilisation of crop residues in ruminants. Feeding different crop-residue-based complete feed in mash or pellet form, on average increased milk production by 15.4 percent and supported daily weight-gain up to 108 g in lambs and kids. Feed wastage and cost/kg milk or weight-gain in lactating and meat-producing animals were decreased by 23.3, 23.4 percent and 17.5, 20 percent, respectively, in on-farm trials. However the quality of crop residue used in the complete diet influenced the performance of ruminants. A complete-feed processing unit suitable for rural areas was developed and distributed to research institutions and farmers for transfer of technology to improve nutrient use efficiency in the animal food chains. Cost of machinery, infrastructure required and lack of extension are the main constraints for transfer of this technology. The technology, if transferred for use on a community or on cooperative basis, could play a key role in enhancing livestock-based rural economy in India.

**Keywords:** *animal performance, complete diet, crop residues, processing, ruminants*

## INTRODUCTION

The efficient utilisation of crop residues and agro-industrial by-products as animal feed has assumed importance in India due to shortages of dry roughages, concentrates and green fodder which were estimated to be 19, 62 and 45 percent respectively (Anonymous, 2008). Due to cultivation of food and commercial crops, enormous quantities of different types of crop residues are produced as a renewable resource every year. Most of them are being wasted or used as fuel in some villages. Crop residues are rich in fibre and low in nitrogen, minerals and vitamins. Hence, their palatability is low and therefore crop residues cannot form a sole ration for livestock. Any processing method that improves the nutrient availability from crop residues will assist in bridging the gap between availability and requirement of roughages.

The concept of complete feeds for ruminants is relatively recent in India. In this system, all feed ingredients inclusive of roughages are proportioned, processed and mixed into a

uniform blend. The product is fed as a sole source of nutrients. This system ensures an adequate supply of balanced nutrients to the animal, controls the ratio of concentrate to roughage, helps in improving utilisation of low-grade fibrous crop residues and reduces feed wastage and feeding cost. The system also promotes feed intake and avoids refusal of the unpalatable portions of feedstuffs. Such rations also reduce eating and rumination time and increase resting time.

An even intake of feed is associated with less fluctuation in rumen-release of ammonia so that non-protein nitrogen may be more efficiently utilised. This system gives good scope for increasing the use of home-grown fibrous crop residues and by-products. The level of inclusion of different crop residues in complete diets of ruminants is shown in Table 1.

The roughage portion varies from 30 to 70 percent depending upon the physiological status of animals to be fed. The roughage content of complete diets is 30–40 percent for high-yielding animals, 40–50 percent for growing animals and 60–70 percent for dry animals, whereas the protein content varies from 11 to 13 percent. The proportion of other ingredients varies accordingly. These diets can be processed into mash or pellets. For pelleting of mash feed, traditional steam pelleting or recently developed expander-extruder technology can be adopted.

### PROCESSING OF COMPLETE DIETS

*Mash.* The different ingredients of the diet are proportioned as per formula into 100 kg batches using appropriate scales. A hammer mill with 8 mm sieve is used for grinding the ingredients. Through screw conveyor and bucket elevator the ground ingredients are discharged into the hopper fixed on top of the mixer. The ingredients that do not require mixing are directly added to the mixer. Molasses is pumped from the storage tank to a heating tank, where it is heated to 70 °C. The heated molasses is sent to the mixer through a dosage tank, as per formula. The micro-ingredients (vitamins and minerals) are made into a premix by mixing them with ground grain or bran and the required quantity of premix is

TABLE 1  
Inclusion levels of different crop residues in complete diets of ruminants

Crop residue	Percent in complete ration
Sugar cane bagasse	20
Sorghum straw	20–46
Dry mixed grass	30–75
Sunflower straw	30–50
Sunflower heads	33–50
Wheat straw	50
Fallen teak leaves	17.5–70
Mango leaves	30–60
Rice straw	40–50
Cotton straw	45



added to the mixer directly. Later, all ingredients are mixed for about 10 minutes and then collected in sacks and stored.

*Pelleting.* For pelleting, the mash from the mixer is dropped into bucket elevator and lifted and conveyed into a hopper over the pellet mill. The feed, in mash form, is conveyed from the hopper into the conditioning chamber of the pellet-mill through a screw conveyor. A wheel-valve controls the rate of flow of the feed into the conditioning chamber.

The steam produced from a boiler attached to the pellet-mill is supplied into the conditioning chamber of the pellet-mill. The required quantity of steam at 97–98 °C is supplied into the conditioning chamber through a control valve. Conditioned mash at 90–92 °C and 16–17 percent moisture is conveyed to the pellet mill and extruded through a ring die with 9 mm holes. The pellets of 9 mm diameter at 83–85 °C and 14–15 percent moisture are dropped from the pellet mill into a vertical cooler, fixed below the pellet mill. The cooled pellets are collected into sacks.

*Expander-extruder processing.* This is a system which combines the features of expanding (application of moisture, pressure and temperature to gelatinise the starch portion) and extruding (pressing the feed through constrictions under pressure). The mash containing 12–13 percent moisture and at room temperature is reconstituted with the required quantity of water to get 17–18 percent moisture in the mixer and then sent to the hopper above the expander-extruder from which it passes through a screw in which it attains 90–95 °C by the time it comes out of the die openings. Otherwise, the mash without reconstitution can be sent to hopper and steam is added to get the required moisture while the feed is passing through the screw of expander-extruder. The pellets coming out of the expander-extruder are cooled and collected into sacks.

## EXPERIENCES OF APPLYING TECHNOLOGY IN THE FIELD

To demonstrate the advantages of the complete diet for economical milk and meat production, three complete diets containing a) cotton stalks (Reddy and Reddy, 2003), b) maize cobs, and c) sunflower heads as sole roughage sources (28.5 percent in dairy ration and 40 percent in sheep and goat ration) were fed to Murrah buffalo/sheep and goats owned by farmers in the state of Andhra Pradesh, India.

*Milk production studies.* The diets maintained 6–8 litres/day of milk yield in lactating Murrah buffalo. Dry matter intake was 28.2, 26.7 and 15.0 percent less on complete diets containing cotton stalks, maize cobs and sunflower heads, respectively, compared with the conventional diet. Average milk yield increased by 11.3, 11.5, 23.5 percent and cost of feed/kg milk yield reduced by 21.5, 23.4 and 25.2 percent on feeding complete diets containing cotton stalks, maize cobs and sunflower heads respectively, compared with the conventional diets. The results indicated that cotton stalks, maize cobs and sunflower heads can be incorporated in complete diets as sole sources of roughage without any adverse effect on milk production in lactating Murrah buffalo. The milk yield was 16.7 and 11.4 litres/day on feed blocks produced from premium and lower-quality sorghum stover, respectively (Anandan *et al.*, 2010) indicating the feasibility of medium levels of milk production on crop-residue-based complete feeds.

*Meat production studies.* The diets supported 87–108 g average daily gains (ADG) in Nellore ram lambs and 71 to 81 g ADG in local male kids in intensive-feeding system. The

ADG was significantly ( $P<0.05$ ) higher on complete diets compared with the respective conventional diet in both species. The dry matter intake/kg gain decreased by about 20 percent in sheep and 15 percent in goats while the cost of feed/kg gain decreased by 13 to 32 percent in lambs and 13–22 percent in kids compared with the conventional diet. Dressing percentage and meat: bone ratio were optimum and almost similar for complete and conventional diets in sheep and goats.

These results indicate that complete diets containing cotton stalks, maize cobs and sunflower heads can sustain optimum growth in lambs and kids under intensive system of feeding without any adverse effect on meat characteristics. In addition, enteric methane production can be reduced considerably by formulating a balanced complete-diet with different concentrate ingredients and crop residues. Gross energy lost as methane reduced ( $P<0.01$ ) from 5.64 to 4.90 percent and from 5.85 to 5.14 percent in buffalo and cows, respectively (Kannan and Garg, 2009). Further, with this system of feeding, migration of sheep and goats during scarcity periods can be avoided.

### **STATUS OF APPLICATION OF TECHNOLOGY/PRACTICE BY FARMERS**

Based on the response of farmers in on-farm evaluations, a small-scale complete-feed processing unit (Photo 1) capable of grinding all crop residues including cotton stalks, was developed under National Agricultural Technology Project (NATP) for use at village level. Twenty four units of small-scale complete-feed processing units were distributed to different research institutions and farmers in India. Two farmers established the same units on their own farms for feeding dairy animals and sheep in the state of Andhra Pradesh, India. This enabled the farmers to utilise their crop residues effectively. However, the technology developed is not being extensively used due to the prevailing smallholder livestock-system, the high cost of the machinery (US\$11 000/unit), the infrastructure required and the lack of extension.

### **LESSONS LEARNT**

Crop residues hitherto wasted can be effectively, efficiently and economically utilised in the form of complete diets. The technology has the potential to create wealth from waste in an environmentally friendly manner – crop residues when fed in the form of complete diets reduce greenhouse gas emission from ruminants whilst at the same time improving milk and meat production.



**photo 1**  
*A small-scale complete-feed processing-unit*

## FUTURE OF THE TECHNOLOGY

Owing to human population-growth, increasing urbanisation and rising incomes, the demand for milk and meat is projected to double by 2020 in India. At the same time there will be increased requirement for food grains (cereals, pulses and oilseeds) which will result in decreased land for cultivation of fodders and in increased availability of crop residues. Ruminant livestock in developing countries, including India, will have to depend increasingly on crop residues to meet their nutrient requirements. To make the ruminant production system efficient, the crop residues will have to be processed. The technology described in this paper will play a key role in enhancing the livestock-dependent rural economy in India in the near future provided the technology is adopted on a community and cooperative basis.

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# Processing and evaluation of poor-quality crop residues as livestock feed

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## SUMMARY

In most developing countries, poor-quality crop residues (PQCRs) constitute the bulk of dry matter consumed by the ruminants under field conditions, but high-lignin, lignocellulose complex and low nitrogen content limit their efficient utilisation. In order to improve the nutritive value of PQCRs, there is need to overcome these limitations. The physical, chemical and biological treatments proved to be effective, but were not applicable under field conditions because of high cost of chemicals, loss of dry matter, depression of digestibility of PQCRs especially after grinding or biological treatments and difficulties in scaling-up the process. The natural fermentation technology (urea:wheat straw in 3.5:96.5 ratio, moistened to 40 percent and stacked for 9 days) involving a combination of physical, chemical and biological treatments seems to be the most suitable and field-applicable technology under present situation, provided the process is appropriately mechanized.

**Keywords:** *crop residues, livestock, processing, solid state fermentation*

## INTRODUCTION

The key to improving the utility of PQCRs (straws, stalks and stovers) for ruminants is to overcome the barriers which limit their microbial fermentation in the rumen. The two major factors limiting microbial digestion in the rumen are high lignin and low-nitrogen contents. A 10 percent increase in cell-wall digestion would result in saving of 2 million tonnes of grain supplements and decrease manure solids by 2.8 million tonnes (Smith, 2001) and increase animal productivity. A number of physical, chemical and biological treatments have been researched and developed worldwide in order to improve the utilization of PQCRs as feed for ruminants. However these technologies could not be sustained because of high cost of chemicals, depression in digestibility of PQCRs or problems in scaling-up or applying the technologies under field conditions. A blend of technologies discussed in this paper is especially suitable under field conditions.

## NATURAL FERMENTATION OF PQCRS WITH UREA

The recommended carbon to nitrogen ratio for the composting process of edible mushroom cultivation was maintained by providing 1.6 percent nitrogen in the substrate (wheat straw) through urea. The urea:wheat straw (3.5:96.5) mixtures, moistened to 70 percent

and fermented by an open stacking method for 9 or 12 days (with or without turning at 3-day intervals) were evaluated on 6 adult buffalo. More than 85 percent of the added urea was hydrolysed by the 9<sup>th</sup> day and the straw that was not turned had the highest nutrient availability and nutritive value (NV). It was concluded that 9-day naturally-fermented urea wheat straw (FWS), daily supplemented with mineral mixture and vitamin A (or carotene) could meet both energy and protein requirements for maintenance of adult buffalo (Bakshi, Gupta and Langar, 1986). The technology was not readily accepted by farmers because of the high moisture content of the treated straw. The technology was therefore modified using different levels of moisture (40, 50, 60 and 70 percent). The NV of straw fermented for 9 days at 40 percent moisture was comparable with the straw fermented at 70 percent moisture (Bakshi, Gupta and Langar, 1987). The fermentation technology so-developed by using 40 percent moisture proved highly applicable under field conditions. The technology has universal application in improving the NV of PQCRs. The treatment can be done all year-round depending upon availability of the substrate e.g. wheat straw in April and paddy straw in November.

The natural fermentation technology involves a combination of treatments (Bakshi and Wadhwa, 1999), i.e. chaffing straw (physical) and hydrolysis of urea and utilisation of ammonia-nitrogen by microbes for their proliferation, thereby enriching straw with microbial protein (biological), as indicated by significantly higher microbial population (bacteria, fungi and actinomycetes) in the stacks (Bakshi, Gupta and Langar, 1986; Gupta, Bakshi and Langar, 1987; Makhdoomi, Bakshi and Langar, 1996). Furthermore the rise in stack temperature to 55 °C (physical) facilitates ammonia from urea hydrolysis to penetrate cell walls and break the alkali-labile lignocellulose bonds (chemical). In the studies, the lignin content of the straw was not affected by natural fermentation because most of the microbes isolated from stacks (except *Aspergillus fumigatus* and *Streptomyces* sp.) were non-lignolytic. Pathogenic microbes such as *Salmonella* or *E. coli* were never detected in any of the stacks. The fermentation process could be hastened by using freshly-prepared fermented wheat straw as a natural crude inoculum (5 percent, DM basis). The 9-day inoculated straw preparation had significantly higher NV than un-inoculated fermented straw. The fermentation of inoculated straw could be terminated by the 6th day without affecting the NV and with minimum nutrient losses (Bakshi and Wadhwa, 2001). Rumen fluid dilution and outflow rates, and the nutrient availability post-rumen in buffalo fed 6–9-day inoculated fermented straw were higher than when untreated or urea treated straw was included in the diets.

The feeding of FWS could sustain the growth of buffalo calves (Bakshi and Langar, 1990), and productive and reproductive performance of lactating buffalo (Lamba, Wadhwa and Bakshi, 2002) even when supplemented with either a lesser quantity of concentrate or concentrate mixture with low-protein content. The incorporation of FWS with concentrate mixture containing non-protein nitrogen supplements (Uromol bran or deep-stacked poultry litter) in the ration of young calves had no adverse effect on productive performance (Bakshi *et al.*, 1996). Use of naturally-fermented rice straw with urea, as livestock feed for calves improved the metabolisable energy content of feed by 15.5 percent and live weight gain by 33 percent. The use of fermented straw in livestock rations could spare about 70 percent of oil seed cakes (Wadhwa, Kaur and Bakshi, 2010).

## TRANSFER OF TECHNOLOGY

In a pilot project, 54 farmers from 21 villages of 4 districts of Punjab state were selected and were given repeated demonstration for upgrading wheat straw by natural fermentation containing urea (urea:wheat straw, 3.5:96.5) at 40 percent moisture by stacking for 9 days. Demonstrations with regards to gradual inclusion of fermented straw in the ration of livestock were also given regularly. Handouts in vernacular language were distributed periodically. Each selected farmstead was monitored for one year. The palatability of fermented straws was higher compared with untreated straws. Calves (above 6 months), heifers and lactating animals showed a remarkable improvement in physical appearance, health and milk production respectively.

## BENEFITS OF THE FERMENTED STRAW TECHNOLOGY

- Serves as a maintenance ration when supplemented with 25 g salt, 50 g mineral mixture and 2 kg green fodder;
- Improves the productive performance of calves above the age of 6 months as well as that of lactating animals, when supplemented with low-protein concentrate mixture;
- Spares oilseed cakes (ca 70 percent) and improves the economics of dairy farming; and
- Controls environmental pollution

## MAJOR CONSTRAINTS

Although the technology is exceedingly effective, it has not been adopted extensively. The main reason for low adoption is the male farmer being very busy in the day-to-day agricultural practices and being unable to spare sufficient time for dairy farming. This is one of the reasons for dairy farming being taken care of by the house lady or farm labourer.

Lack of mechanisation is the major constraint to widespread adoption of this technology at farm level. In northern India especially Punjab and Haryana, dairy farming is not a full-time occupation for the farming community, except commercial dairy farmers. Therefore, the farmer wants ready-made feed to be available at his/her doorsteps. If the technology is mechanised, it will not only save time and labour (availability of labour is declining), but will also make the production of treated straw economic.

## SOLID STATE FERMENTATION

Sixteen different lignolytic fungal strains were evaluated in our laboratory for upgrading the NV of straws with minimum pre-treatment, with or without exogenous nutrients. The proliferation of mycelia enriched the straw with microbial protein. The increase in *in sacco* dry matter (DM) and crude protein (CP) degradabilities of straws after 5–10 days of fermentation was associated with linear increases in DM loss in all the cases. *Heterobasidion annuum*, *Phellinus linteus*, *Phialophora hoffmannii* and *Cyathus stercoreus* (Bakshi *et al.*, 2010) or a blend of *Pycnoporus sanguineus* and *Oideodendron echinula* proved promising, provided fermentation was stopped before the onset of the reproductive phase to avoid high nutrient losses. In order to achieve the optimum DM and CP degradabilities with minimum nutrient losses, fermentation should be stopped within 6–8 days of spawning. Amongst the tested strains, only *Coprinus cinerius* required nitrogen and phosphorus

exogenously, and was found to be highly cellulolytic rather than lignolytic. Some workers have used urea-treated straw as substrate for *Coprinus* cultivation, but that adds to the cost and incurs loss in digestible nutrients.

### SPENT STRAWS

The wheat and rice straws available after harvesting edible mushrooms viz. *Agaricus bisporus*, *Pleurotus ostreatus* or *Volvariella diplacea*, currently used as soil conditioners, can be incorporated in the ration of ruminants. The spent straw usually has low NV compared with the original straw except the *Agaricus bisporus* harvested washed spent straw which has 5.5–6.0 percent digestible CP and 30–55 percent total digestible nutrients. Spent straw can serve as a maintenance ration for an adult ruminant if supplemented with 200 g maize grains daily. *Pleurotus florida* harvested spent straw could be incorporated in the complete feed of kids without any adverse effect on palatability or nutrient utilisation (Kaur, Wadhwa and Bakshi, 2010).

### LIMITATION AND STRENGTHS

The individual-microorganism inoculation experiments were successful in the laboratory under strictly controlled conditions, but failed badly on scaling-up. Industrial treatments which are energy dependent and thus costly should not be recommended for small farmers.

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# Biological treatment of straws

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## SUMMARY

The concept of using biological treatment for improving straw quality was given by the mycologists, who thought that the spent straw after harvesting mushrooms could be used as an animal feed. However the feeding trials conducted on buffalo calves using spent straw resulted in lower feed intakes and growth rates, because of the very high mineral content and the presence of lignin derivatives after lignin-degradation by fungi. Subsequently, mycologists and microbiologists screened a large variety of soft-rot and white-rot fungi and identified highly-lignolytic strains. This was followed by treating straws with lignolytic fungi on a larger scale through solid-state fermentation (SSF), and conducting feeding trials on animals. However the experience of using straw treated with *Coprinus fimatarius*, a lignolytic fungi capable of growing in alkalophilic medium of urea-treated straw, as a feed for calves and goat kids proved disappointing. The treated straw containing 65 percent moisture (necessary for the growth of fungi) was unpalatable to the animals. Even sun-drying the straw did not improve its palatability and digestibility. It may be concluded that the technology of treating straws using lignolytic fungi, is not worth pursuing in its present state. However, cultivating lignolytic fungi for the large-scale production of ligninase is worth pursuing; ligninase could then be used for delignification of straws thus improving their nutritional quality.

**Keywords:** *biological treatment, lignolytic fungi, solid state fermentation, straws*

## INTRODUCTION

The idea of using biologically-treated straws as animal feed originated from mycologists engaged in producing edible mushrooms using straw as the substrate for growing soft-rot and white-rot lignolytic fungi for human consumption. It was presumed that after harvesting the mushrooms, the by-product, i.e. the spent straw containing less lignin, with some added protein as fungal mycelium, would have an improved nutritional quality compared to the original straw. Subsequently, some mycologists screened and identified aerobic fungi with higher lignolytic activity, for the detachment of indigestible lignin from digestible cellulose and hemicellulose in straws. Later, mycologists collaborated with animal nutritionists for treating straw with promising lignolytic fungi on a larger scale for animal feeding purposes. Since straws are important roughage sources in the tropical world, the focus shifted to tropical countries to evaluate the potential for this new, recycling technology for increasing ruminant productivity. Attempts were made to grow lignolytic fungi under field-like conditions, using solid-state fermentation (SSF), for the biological treatment of straw to improve its quality.

## EXPERIENCE OF DEVELOPING/APPLYING TECHNOLOGY/PRACTICE IN THE FIELD

*Lignolytic fungi.* During the lignification of plants, indigestible lignin forms an encrustation over the digestible cellulose/hemicellulose fibres, thus limiting their digestion in the rumen by cellulolytic organisms. In straws, delignification or lignin solubilisation could be achieved by steam treatment or alkali treatment. Delignification in straws could also be achieved by lignolytic fungi. Aerobic lignolytic fungi, which belong to the following three major groups, play a major role in lignin degradation: i) brown-rot fungi preferentially attack cellulose and hemicellulose, leaving behind a brown residue, ii) soft-rot fungi e.g. *Chaetomium cellulolyticum* leaves the attacked lignocellulosic material watery-soft and breaks down cellulose and hemicellulose (Chahal and Moo-Young, 1981), and c) white-rot fungi e.g. *Phanerochaete chrysosporium*, which is capable of degrading lignin without much affecting cellulose and hemicellulose (Zadrazil and Brunnert, 1981; Agosin and Odier, 1985).

*Lignin biodegradation.* Lignin biodegradation is largely an oxidative process. In aerobic environments, lignin peroxidase produced by lignolytic fungi breaks the lignin polymer into products which can finally be converted to CO<sub>2</sub>. The enzyme is H<sub>2</sub>O<sub>2</sub>-dependant which catalyses the oxidation of various lignin model compounds. White-rot fungi *P. chrysosporium* has been shown to have the highest ligninase activity. While several mycologists and microbiologists studied ligninase enzyme systems and identified fungal strains with high lignolytic activity, their experiments on straws remained mostly confined to laboratories. Some of these mycologists and microbiologists collaborated with animal nutritionists and treated large amounts of straws with fungi using SSF and evaluated the nutritional value of the biologically treated straws by feeding to animals.

*Feeding trials with spent straw.* In India the spent straw as animal feed caught the attention of animal nutritionists and the first feeding trial was carried out on growing calves at Punjab Agricultural University, Ludhiana in the mid-eighties. However, animals fed the control diet with normal straw performed better than those fed the diet containing spent straw. Scientific studies revealed that the mineral content of spent straw was 18–20 per cent, since additional minerals had been added to meet the requirement of the lignolytic fungi. The high mineral content also lowered the palatability of the straw. The derivatives of lignin degradation were present and most of the cellulose and hemicellulose had been utilised by fungus for its growth in the treated straws. It was concluded that the spent straw was a very-low- quality animal feed, unfit for feeding ruminants (Langer *et al.*, 1982; Bakshi and Langer, 1985).

*Solid-state fermentation of straw using lignolytic fungi.* In the mid-eighties, an Indo-Dutch project entitled, "Bio-conversion of Crop Residues", was launched in India, involving a few animal nutrition research centres, e.g. NDRI, Karnal, Southern Regional Station of NDRI, Bangalore, Bharatiya Agro Industries Foundation (BAIF), Pune and Pantnagar Agriculture University, Uttarakhand. At NDRI Karnal, Dr Flegel, a mycologist under the project, supplied a non-toxic alkalophilic-cum-lignolytic fungi, *Coprinus fimetarius*, which could grow in the alkaline conditions of urea/ammonia treated straw (Flegel, 1988). Use of the urea-treated straw as a substrate for the growth of this lignolytic fungi provided the dual benefit of keeping contaminants at bay through higher pH and at the same time providing nitrogen for mycelial growth.

Solid-state fermentation was carried out in a 2.0 m x 2.0 m x 0.6 m brick enclosure with sufficient aeration. Moisture content of the straw was maintained at 65 percent and 1 percent calcium oxide and 0.1 percent single super phosphate were also added. A culture of *C. fimetarius* grown on sorghum seeds was added @ 3.5 percent of the straw dry matter. The enclosure was covered with wet gunny bags during fermentation. After a period 7–10 days a white cottony growth of the fungal mycelium was visible at the top. At this point, the fermentation was stopped to minimize the dry matter and organic matter losses.

*Organic matter loss during solid state fermentation.* Lignin biodegradation is an oxidative process, involving the use of peroxidase enzyme and hydrogen peroxide. Lignolytic fungi use cellulose and hemicellulose as energy sources for mycelial growth, produce several enzymes as well as hydrogen peroxide all of which results in a loss of cellulose and hemicellulose present in the straw. Lignolytic fungi found in nature are either cellulose or hemicellulose degrading and many fungi degrade both these substrates.

*Feeding trials with straw subjected to solid-state fermentation.* The wet, fermented straw had a peculiar flavour, because of which calves and goat kids would not eat the treated straw. After sun drying it was offered to animals in a one-month feeding trial, comparing it with urea treated straw. The crude protein content increased from 9 percent in urea-treated straw to 13 percent in fungal-treated straw, but the palatability and digestibility of fungal-treated straw were lower than those of urea-treated straw. Dry matter intake was reduced by 15 percent. Calves and kids fed fungal-treated straw grew 10–16 percent slower than those fed the urea-treated straw. In short, the fungal-treated straw had lower nutritive value compared to urea-treated straw.

### **STATUS OF APPLICATION OF TECHNOLOGY/PRACTICE BY FARMER**

The organic matter loss during solid-state fermentation could be minimised to 10 percent if the fermentation is carried out until mycelia growth only. Losses could go up to 50 percent if fermentation is continued until appearance of fungal fruiting bodies (mushrooms). However loss of a certain amount of biomass during the process of fermentation is unavoidable.

Mineral content even before start of fermentation is higher and loss of organic matter during fermentation concentrates minerals further resulting in a lowering of palatability of treated straw. Palatability is further lowered by the presence of lignin derivatives produced during lignin biodegradation. These derivatives accumulate in the fermented straw and impart a bitter taste. It is likely that these lignin derivatives may even be toxic to rumen microorganisms and thus reduce their activity in the rumen.

In the wet form, the treated straw has an offensive smell. Sun-drying changes the texture of the straw and its colour becomes dark. This may also lower the palatability of the treated straw.

The process of SSF is quite cumbersome and requires appropriate moisture, humidity, temperature and aeration. It may also be difficult to keep pathogenic organisms at bay, though the alkaline medium resulting from the urea treatment of straw does help to some extent.

Conducting SSF of straw under farm conditions is difficult. Industrialisation of this technology is an option but cost of treatment would increase two to three fold and the only benefit would be straw with a higher crude protein content.

## LESSONS LEARNT

The technology has a number of negative attributes. Therefore it would be safe to conclude that the technology has a bleak future. It would be challenging to produce a lignolytic fungus through genetic manipulation which does not degrade cellulose and/or hemicelluloses.

## FUTURE OF THE TECHNOLOGY

Isolating a highly-lignolytic fungus in nature and then cultivating it for the commercial production of ligninase could be considered. However it needs to be ascertained that the products of lignin degradation are not toxic to rumen microbes and that the enzyme-treated straws are palatable to the animal.

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# Rumen by-pass protein technology for enhancing productivity in dairy animals

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## SUMMARY

More than two decades of research involving a number of trials conducted for ruminant production has established the relevance of by-pass protein technology for developing countries, including India. National Dairy Development Board (NDDB) of India has standardized the process of producing rumen by-pass protein supplement by treating the protein meals. Protected proteins were prepared by cross-linking the constituent protein with optimum levels of formaldehyde to enhance the level of constituent amino acids that escape rumen by about 75 percent. By-pass protein technology has emerged as one of the cheapest feeding technologies. It is now a successful commercial feed-technology in India and has led to increases in milk yield of 10 to 15 percent. Feeding by-pass protein protects dietary proteins from excessive degradation to ammonia in the rumen and also supplies more essential amino acids at the intestinal level. With only marginal increase in treatment cost, the efficiency of utilizing scarce protein meals can be increased significantly for growth and milk production in most developing countries. Experiments clearly indicate that farmers feeding by-pass protein can earn about 10 percent more money in case of cows and about 15 percent in case of buffalo.

**Key words:** *by-pass protein, commercialisation, dairying, economics, patented*

## INTRODUCTION

In recent years, several technologies have been developed through intensive animal-nutrition research, one of them being by-pass protein feed technology. By-pass protein refers to dietary protein that escapes rumen degradation. The technology aims at decreasing the wasteful production of ammonia in rumen from highly degradable protein meals, thereby increasing the availability of essential amino acids at the intestinal level. The main aim is to increase the efficiency of protein utilization in ruminants for enhanced milk production. Dairy nutritionists try to enhance nitrogen utilization through dietary manipulation to optimise milk production. Manipulation of protein degradation in the rumen is the most effective strategy to reduce nitrogen losses in dairy animals. Losses of nitrogen can be reduced by balancing the ration to achieve optimum ratio of rumen degradable protein (RDP) to rumen undegradable protein (UDP) and increase nitrogen use by ruminal microorganisms. Optimising RDP:UDP also optimises post-ruminal amino acid supply for productive purposes.

## EXPERIENCES OF APPLYING BY-PASS PROTEIN TECHNOLOGY IN THE FIELD

*Methods evaluated for enhancing by-pass protein value.* Protein meals are normally fed 'as such' to ruminants in India. However the meals have varying degrees of naturally rumen-protected proteins. The fact that solubility of proteins change, when subjected to special treatments, can be exploited to protect good-quality proteins from rumen degradation. A number of treatments to protect proteins have been tried, e.g. alkali, xylose, heat and formaldehyde. Among these formaldehyde treatment has the advantage of being the most cost effective technology for protecting highly-degradable proteins in the rumen and not adversely affecting animal health and milk quality. This method has been extensively used because of the following advantages:

- Desired level of protein protection can be achieved – under- and over-protection of proteins can be avoided;
- The bio-availability of the essential amino acids can be maximized;
- Does not increase contents of acid detergent insoluble nitrogen (ADIN) and neutral detergent insoluble nitrogen (NDIN);
- Less expensive than heat treatment; and
- Helps to control salmonella and reduce mould growth in feedstuffs.

## PATENTED TECHNOLOGY BY THE DAIRYBOARD

By-pass protein technology is a new-generation technology, wherein by-pass protein feed is produced by a special chemical treatment, developed and patented by the Dairyboard of India. Regionally-available protein meals are treated appropriately, so as to reduce degradability of the proteins in the rumen from 60–70 percent to 25–30 percent, in a specially designed airtight plant (Photo 1). By-pass protein feed supplements have been developed by screening protein meals for their amino acid composition and then developing suitable chemical treatment procedures.

Protein meal identified for treatment is first ground, treated chemically at an appropriate level and then stored for 9 days under airtight conditions. After 9 days of incubation period, protein meal is ready for feeding to ruminants and can be stored for more than a year, without any deterioration in the quality.

## APPLICATION STATUS OF THE BY-PASS PROTEIN TECHNOLOGY

*Development of test method.* The test method used by the feed industry in India to measure by-pass content of protein meals was based on nitrogen solubility in buffer solutions. However phosphate-buffer solubility values do not compare favourably with *in vitro* or the



**photo 1**

*By-pass protein supplement production plant*



in sacco protein degradability values. The Dairyboard, in technical collaboration with the Commonwealth Scientific and Industrial Research Organization (CSIRO), Australia and the Australian Centre for International Agricultural Research (ACIAR), has standardised an *in vitro* ammonia release method which gives more accurate values for protein by-passability. In this method, a known quantity of protein meal is incubated under anaerobic conditions at 38 °C for 24 hours in strained rumen liquor (SRL). Protein degradation is measured by analysing ammonia nitrogen level in SRL at the end of the incubation period (Gulati, Ashes and Scott, 1999).

### **FARM AND FIELD TRIALS AND ECONOMIC BENEFIT**

Studies have shown that the feeding by-pass protein to growing animals increased growth rate (25–30 percent), reduced rearing costs and resulted in earlier maturity of calves. Feeding by-pass protein also improved the reproductive efficiency of breeding bulls (Walli, 2009). Numerous feeding trials were conducted at different laboratories using different protein meals in lactating cows and buffalo. In all these trials, daily milk yield in experimental groups increased by 1.0 to 1.5 litres; milk protein increased by 0.3–0.4 percent and milk fat by 0.2 percent. On average, daily net income (per animal) increased by Rupees 10–11 (1 US\$ = ca 45 Indian Rupees) in animals yielding 8–10 litres and Rupees 5–6 in animals yielding 4–5 litres. ACIAR conducted a study to assess the economic benefit of feeding by-pass protein feed in Vadodara district of Gujarat State, India. The study revealed that on feeding by-pass protein, the average increase in net daily income was Rupees 9.20, 6.42 and 12.41 in indigenous cows, crossbred cows and buffalo, respectively. Supplementation with by-pass protein feed was found to be economical in lactating animals yielding on average 5–8 litres of milk daily (Garg *et al.*, 2005; Garg, 2009).

### **COMMERCIALISATION OF TECHNOLOGY**

A commercial by-pass protein production plant was set up in Baroda Milk Union, in Western India, for producing 50 tonnes of by-pass protein feed per day. The demand for the by-pass protein feed produced in this plant has been steadily increasing. Subsequently, the Dairyboard has set up 12 by-pass protein manufacturing plants mainly under the dairy co-operatives network and has thus commercialised the technology.

### **OPERATIONAL HEALTH AND SAFETY MEASURE**

Chemical treatment of protein meal(s) is carried out in a specially-designed airtight plant, so that there is no risk to workers operating the plant. Moreover, workers are advised to wear gloves, masks and safety glasses. The US Food and Drug Administration (FDA) has approved the use of formaldehyde as a feed additive to protect proteins from ruminal degradation, to preserve silages, to maintain animal feeds and feed ingredients free from salmonella and to control fungi. Formaldehyde used in treatment of protein meals is at very low levels and poses no health risk to animals and consumers.

### **LESSONS LEARNT AND FUTURE OF BY-PASS PROTEIN TECHNOLOGY**

Due to the several advantages of by-pass protein technology, including the cost effectiveness of treated meals and increase in milk yield, the technology has been successfully

adopted by the feed industry in India, with NDDB taking the lead in propagating the technology. The Dairyboard is also exploring the possibility for setting up by-pass protein plants in the premises of oil solvent extraction units. The animal nutrition group of Dairyboard is also assessing the amino acid profile of different protein meals available in India, so as to prepare a suitable blend of treated protein meals for improving milk production. The technology could also be employed in other parts of the developing world.

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# Rumen by-pass protein technology

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## SUMMARY

The concept of feeding by-pass protein to ruminants was put forward in the mid-seventies and in developed countries the technology was applied to high-yielding cows to enable them to meet their essential amino acid requirements at high levels of production. It was postulated that feeding by-pass protein may not be of advantage to low- and medium-producing dairy animals, since microbial protein synthesised in the rumen may be sufficient to meet the amino acid requirements. Two reports, one suggesting the optimum level of ammonia for maximum protein synthesis as 5 mg/100 ml of rumen liquor, and the other stating that ruminal ammonia levels of Indian cattle and buffalo are invariably as high as 15–20 mg/100 ml of rumen liquor, inspired animal nutritionists at NDRI, Karnal to test this technology under Indian conditions. Two decades of research in India on cattle, buffalo and goats proved that feeding by-pass protein increased growth rates (20–25 percent) and milk yield (10–15 percent) even in animals yielding only 6–10 litres of milk/day. On feeding by-pass protein there is a net saving of dietary proteins and less excretion of urea and nitrogen. National Dairy Development Board (NDDB), Anand, India demonstrated that by-pass protein feeding is beneficial under rural conditions and have now commercialised this technology.

**Keywords:** *by-pass protein, commercial technology, growth, milk, ruminants*

## INTRODUCTION

In most tropical countries, fibrous crop residues especially the straws are the major roughage feeds, while the concentrate ingredients are mostly agro-industrial by-products. Energy-rich grains are sparingly fed to ruminants and oilcakes, being expensive, are only fed in small quantities. Thus, dairy animals and other ruminant stock in the tropical region generally get insufficient nutrients, resulting in their sub-optimal performance. With the limited availability of feed resources, the best approach would be to increase the efficiency of nutrient utilisation within the animal system, preferably using some feed technological interventions. The rumen by-pass protein technology addresses the problem of inefficient use of dietary proteins by ruminants, increases nutrient use efficiency and optimises the productive and reproductive performances. The wastage of dietary proteins, partly excreted as urea, which pollutes the environment through nitrous oxide emission, is also reduced. After two decades of research in India, the by-pass protein technology has now been commercialised.

## DEVELOPMENT AND METABOLIC ADVANTAGES OF BY-PASS PROTEIN TECHNOLOGY

*The basic thought and the conceptual modification.* Based on the fact that some oilcakes are highly degradable in the rumen and need to be protected from ruminal degradation, the concept of by-pass protein for ruminant feeding was put forth. The rationale behind the concept of feeding rumen by-pass protein (or rumen-protected protein, rumen-escape protein) was to supplement the limiting essential amino acids to high-yielding dairy animals. However western experts at that time held the view that this technology had no relevance in countries where milk yield of cows and buffalo is generally very low and microbial protein synthesised in the rumen from ammonia due to degradation of dietary proteins and non-protein nitrogen should be sufficient to meet the amino acid requirement of the host animal. Most animal nutritionists in India also subscribed to this view.

Generally animals in India, especially those reared under rural conditions, do not get sufficient energy through their diet. Unlike the feeding of energy-rich grains to dairy animals in developed countries, ruminants in India are not fed grains. In the case of insufficient soluble carbohydrates in the ruminant diet, which provide carbon skeletons and ATP for protein synthesis, microbes are unable to trap the available ammonia for amino acid and subsequently protein synthesis.

Satter and Slyter (1975) observed that the optimum ammonia concentration for maximum microbial protein synthesis in rumen was 5 mg/100 ml of rumen liquor. In India, much higher ruminal ammonia levels (10 to 20 mg/100 ml rumen liquor) were reported in cows and buffalo indicating that rumen microbes would be unable to trap excess ruminal ammonia from degradation of dietary proteins for microbial protein synthesis. Excess ammonia is absorbed through the rumen wall and after conversion to urea in the liver is excreted through urine. This excess ammonia amounts to a substantial protein loss. Moreover, converting ammonia to urea, the animal has to spend energy. Feeding by-pass protein reduces the wastage of both protein and energy which could otherwise be used for productive purposes.

*Extra supply of amino acids eventually enhances lactose synthesis.* Feeding by-pass protein generally results in an additional supply of amino acids to the host animal. In growing ruminants, the extra amino acids enhance growth of muscle tissues. In lactating animals receiving insufficient energy from their diet, the extra supply of amino acids compensates for the reduced supply of propionate (a glucogenic precursor). This enhances glucose production in the liver and glucose supply to the mammary gland which triggers more lactose synthesis in the organ. Lactose also regulates the osmotic pressure of milk. The quantity of lactose synthesised in the mammary gland regulates the amount of water uptake by the organ from blood. More lactose production means more uptake of water by the mammary gland, resulting in more milk volume and consequently more milk production. This is the mechanism behind the enhancement in milk yield in bovines and other ruminants on feeding of by-pass protein in tropical countries.

*Method of protein protection.* Cottonseed cake, maize gluten meal and fish meal are the naturally-occurring rumen by-pass proteins while oilseed cakes like groundnut, mustard and rapeseed are highly degradable in the rumen. These highly-degradable oilseed cakes need protection against degradation by rumen proteolytic enzymes. Among the physical

methods, heat treatment is an effective method, but it is not cost effective. Formaldehyde treatment is cheaper and formaldehyde is readily degraded to carbon dioxide and water in the liver, as shown through isotopic studies (Mills *et al.*, 1972). The optimum level of formaldehyde to be used for treating oilseed cakes was found to be 1.0–1.2 g per 100 g of cake protein. Formalin (38–42 percent formaldehyde) is sprayed on ground cake in a closed chamber. The sprayed cake is mixed thoroughly and put into plastic bags which are then, sealed. The treated cake is used as a feed ingredient after 4 days of reaction period. During the reaction period formalin gets adsorbed on the cake particles resulting in reversible and pH dependent protection of proteins against proteolytic enzymes. In the acidic pH of the abomasum, these bonds are loosened and the protein is set free for digestion.

### **EXPERIENCE OF APPLYING TECHNOLOGY – BENEFICIAL ASPECTS**

An increase in milk yield by 10 to 15 percent and in growth rate by 30 to 40 percent have been recorded in several studies conducted during the last two decades. Because of the faster growth rate, calves attain early maturity leading to an early age at first calving. In young bulls, by-pass protein feeding resulted in increased libido and better semen quality, possibly due to enhanced amino acid supply. The lower plasma ammonia levels due to by-pass protein feeding also lessened the interfering effect on embryonic/fetal growth in cows and buffalo, which resulted in better conception rates (Walli, 2005).

Histopathological studies on growing goats were also conducted to prove that the technology is safe and has no adverse effect on the health of animals. In fact, to our utter surprise, it was the untreated mustard seed cake fed to goats that resulted in some cellular damage in various organs, especially liver. This could possibly be due to glucosinolate present in the cake which is converted to isothiocyanate, causing adverse effects. The treatment of cake by formaldehyde also protects glucosinolate from being converted to isothiocyanate. This was demonstrated by the higher plasma thyroxine levels and lower isothiocyanate levels in the milk of goats fed formaldehyde-treated mustard seed cake. Formaldehyde was not detected in the milk of these animals. Also the urea content in milk was reduced following the feeding of by-pass protein, suggesting that the quality of milk is also improved after feeding formaldehyde-treated oilseed cakes (Sahoo, Walli and Sharma, 2006).

### **STATUS OF APPLICATION OF TECHNOLOGY IN FIELD CONDITIONS**

An acid test of the success of any technology is its commercial feasibility and economic viability. Two collaborative projects between NDRI, Karnal and NDDB Anand were undertaken to test the viability and the economic feasibility of this technology under field conditions. The positive results in the field trials conducted by NDDB were more encouraging than those from the on-station trials conducted at NDRI. Farmers in Gujarat reported their animals producing 20 percent more milk when fed by-pass protein (Garg *et al.*, 2003)

On the basis of encouraging results in these field trials, NDDB took the bold initiative of propagating the by-pass protein technology as a commercial technology in the country. The Board has set up three manufacturing plants in Gujarat and is in the process of setting up by-pass protein manufacturing plants in other parts of the country. The most distinctive feature of this technology is its cost effectiveness – the cost of the treatment is less than a

rupee (1 US\$ = ca 45 Rupees) per kg of oilcake but the results have far reaching implications in boosting milk production. This technology has the potential to increase the income of resource-poor farmers. Even goat keepers can enhance meat production by feeding by-pass protein.

### LESSONS LEARNT

The success of by-pass protein technology in India could be attributed to the perseverance of scientists to study and show the relevance of this technology for livestock production under Indian conditions.

### THE FUTURE OF THIS TECHNOLOGY

The by-pass protein technology has already been commercialised in India for ruminant feeding. This technology should now be considered for dissemination to other countries of the tropics and for the benefit of farmers in these countries.

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# Food-feed-systems for smallholder livestock farmers

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## SUMMARY

A wide feed-resource base and sufficient year-round feed availability are of prime importance to livestock raised by smallholder farmers. A range of forage legumes (e.g. *Phaseolus calcaratus*, *Vigna unguiculata*, *Leucaena leucocephala*), adapted to the tropical climate of Thailand, have been identified as potential feed resources. Leguminous crops such as cowpea (*V. unguiculata*), *Stylosanthes ssp.*, *L. leucocephala*, and Tua-man (*P. calcaratus*) provide pods and seeds for human consumption and crop residues and leaves for feeding to livestock. Data on agronomic performance and phenological characteristics of these crops have been obtained through trials lasting several growing seasons in Thailand. Cassava (*Manihot esculenta*, Crantz) intercropped with leguminous crops has resulted in the availability of good-quality cassava hay (25 percent crude protein) throughout the year. With successful introduction of the food-feed system (FFS) based on cassava and leguminous forages into farm systems, the legumes increase soil fertility and reduce soil erosion and simultaneously increase livestock and cereal production. The FFS has been evaluated for smallholder dairy, beef and buffalo farms, and has resulted in the improvement of livestock productivity as well as farmers' livelihood. In addition, secondary compounds, especially saponins and tannins contained in the leguminous forages have the potential to reduce rumen methane production.

**Keywords:** *feed resources, food-feed-system, ruminants, smallholders*

## INTRODUCTION

Crop residues, agro-industrial by-products and native grasses, which support only low levels of production, are the main feed resources for large ruminants in the tropics. In areas where rice is the main produce, buffalo and cattle are raised as an integral part of crop production system (Chantalakhana, 2001). The ruminants fed crop residues, such as straws, stovers and stalks release a large quantity of methane (Zhu *et al.*, 2008). Methane production per unit weight gain was reduced significantly when animals were shifted from low-digestible to high-digestible pastures (Hegarty, 1999).

Plant extracts have been shown to be effective in inhibiting rumen methanogenesis (Kamra, Agrawal and Chaudhary, 2006; Newbold and Rode, 2006). In the tropics, many plants contain secondary compounds such as saponins, tannins and essential oils. Tannin-containing forages have been reported to increase protein availability post-rumen in ruminants (Niezen *et al.*, 1996). Cassava and legumes usually contain secondary compounds which could affect rumen fermentation and productivity.

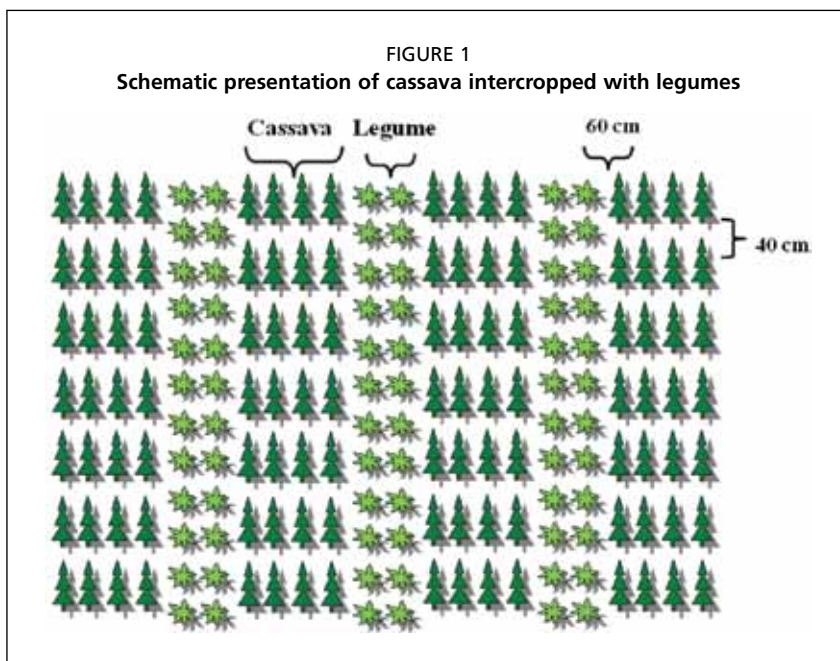
The rapid increases in intensity of cultivation and grazing within the smallholder farming systems have resulted in severe depletion of soil fertility and extensive soil erosion. The FFSs help in improving ruminant production through supply of better-quality fodder and positive effects on rumen fermentation. The expansion and intensification of these systems is a realistic proposition and the system is fast becoming popular with smallholder farmers.

### PATTERN OF FOOD-FEED-SYSTEM (FFS)

Food-feed-system has been shown to produce both foods for human and feeds for animal production (Figure 1). Moreover, intercropping with legumes improves the nitrogen status of the soil. Some examples of the interventions are as follows:

**Cassava hay.** Recently, cassava hay (*Manihot esculenta*, Crantz) has been used as a protein supplement in ruminant feeding especially for dairy cattle, beef and buffalo production (Wanapat, 2000a; Wanapat, 2003). Cassava hay consists of foliage of whole cassava crop harvested after 2–4 months of growth. The stems with leaves are chopped into 3–5 cm long pieces and then sun-dried for 2–3 days to attain a dry matter (DM) of about 85 percent (Wanapat *et al.*, 1997). Cassava hay contains a high level of protein (25 percent in DM) and a strategic amount of condensed tannins (4 percent in DM) (Wanapat *et al.*, 1997). Moreover, cassava hay fed at 1–2 kg/head daily could reduce the number of parasitic eggs in buffalo and cattle (Kiyothong, 2004).

Planting cassava for hay is aimed at increasing the whole-crop digestible biomass, with the tuber root as a by-product. Earlier work (Wanapat *et al.*, 1997) demonstrated that planting cassava at 60 x 40 cm between rows and inter-cropped with *P. calcaratus* (Figure 2) or *Leucaena* could enrich soil fertility and the legumes could be used as food and feed for humans and livestock, respectively. The initial cutting was at 3 months, followed by subsequent cuttings every two months by breaking the stem about 10 cm above the ground.



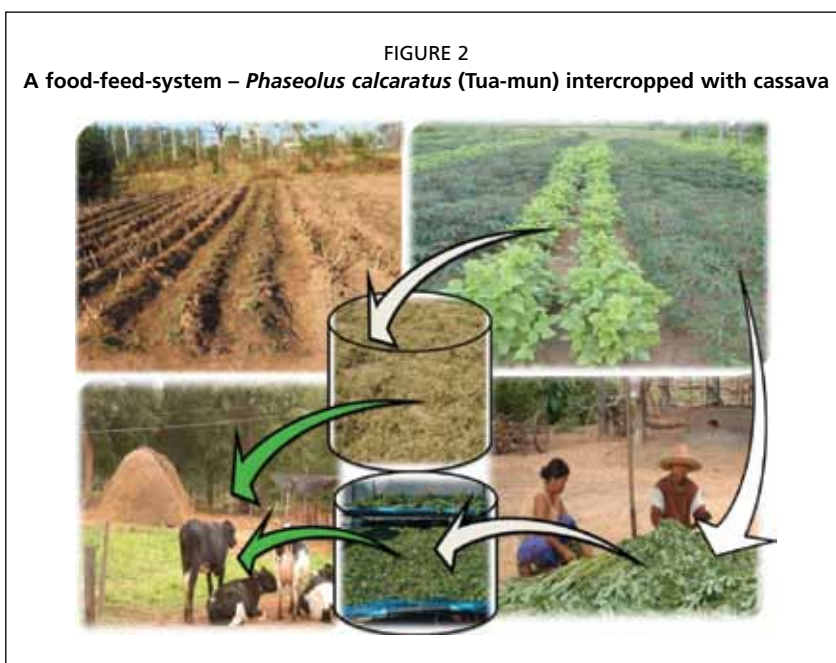


The fresh, whole or chopped crop was sun-dried to obtain a DM of 80–90 percent. This might take 2–3 days but chopping shortens this period. Sun-drying also removed more than 90 percent of the hydrocyanic acid (HCN) and enhanced the palatability and shelf life. Feeding trials with cattle revealed high levels of DM intake (3.2 percent of body weight) and high DM digestibility (71 percent). The hay contains condensed tannins which increase the rumen by-pass protein for digestion in the small intestine (Reed, 1995). Therefore, supplementation with cassava hay at 1–2 kg/head daily to dairy cattle could markedly reduce concentrate requirements, and increase milk yield by 1 to 2 kg/head daily and milk fat from 4.0 to 4.6 percent.

Cassava hay has been used successfully as a source of high-protein roughage in lactating dairy cows (Wanapat *et al.*, 2000a; 2000b). Increasing the levels of cassava hay in the diet from 0.56 to 1.70 kg/head daily reduced concentrate level in the diet from 1.6 to 0.1 kg/head daily without affecting milk yield. Condensed tannins in cassava hay have also been shown to reduce gastrointestinal nematodes (Wanapat, 2000b).

Cassava can be harvested at 2–4 months of growth to produce high-quality hay. Intercropping cassava with food or feed crops could further increase biomass yield and improve soil fertility. Condensed tannins in cassava hay could play an important role in forming a tannin-protein complex thereby increasing rumen by-pass protein and availability of feed protein for the host animal. On-farm trials with smallholder farmers showed good-quality cassava hay production. Harvesting of whole crop at an earlier stage and subsequent pruning to produce hay resulted in an increased protein: energy ratio in the hay. Cassava hay and cassava chips could contribute to more-sustainable crop-livestock production systems in the tropics (Wanapat *et al.*, 1997).

More than 300 smallholder dairy farmers in 6 milk collection centres are practising the FFS, through the support of Dairy Promotion and Farming Organization of Northeast



Thailand (DPO-NE), by planting cassava intercropped with *P. calcaratus* to produce hay for livestock feeding and *P. calcaratus* seeds for human consumption. As a result, milk yield has significantly increased by about 2 kg/head daily and the net income of farmers by 36 Baht/head daily (US\$1.20/head daily).

*Cassava (Manihot esculenta, Crantz) and cowpea (Vigna unguiculata)*. Wanapat *et al.* (2007) observed that intercropping of cassava with cowpea produced 5.96 tonnes/ha of green cowpea pods, 6.83 tonnes DM/ha cassava foliage, and 0.89 tonne DM/ha of cowpea residue (initial cutting at 4 months and thereafter 4 cuttings at 2 months interval). The practice of cassava-legume intercropping also improves farm productivity. However some farmers encountered problems with hay-making in the rainy season, therefore, alternative strategies such as constructing sheds for solar-drying using simple materials such as plastic sheets and bamboo were recommended to farmers. As a result of FFS, green cowpea pods were used for household consumption, as a gift to neighbours and sold for generating higher incomes, while residues and *Stylosanthes* were used as animal feeds (Wanapat *et al.*, 2007).

*Cassava and Stylosanthes guyanensis (stylo)*. A perennial legume, *S. guyanensis* was introduced in the lower midland three (LM3) agro-ecological zone as a fodder legume. It can be continuously or rotationally grazed. Kiyothong (2004) reported that sole feeding of cassava hay or in combination with stylo (*Stylosanthes guyanensis* CIAT 184) hay could be a valuable and potential strategy for use in smallholder dairy farming systems in the tropics. This strategic supplementation significantly increased economic returns through increased productivity and increased ratios of concentrate to milk yield (from 1:2 to 1:3).

*Cassava and Phaseolus calcaratus (Tua-mun)*. *Phaseolus calcaratus* has been found to be a potential crop to improve foliage biomass and crude protein (CP) yield (Chanthakhoun, Wanapat and Wanapat, 2008). It can grow well in poor soil and dry areas. *P. calcaratus* foliage has high protein content (17–20.4 percent in DM), and a biomass yield of 1.9 tonnes DM/ha has been obtained. A preliminary study revealed that after two months, *P. calcaratus* can grow up to a height of about 60 cm (canopy) and produce pods at 3–4 months. The whole crop can be sun-dried as hay. Supplementation of *P. calcaratus* hay for swamp buffalo enhanced the number of cellulolytic bacteria namely *Ruminococcus flavefaciens*, *R. albus* and *Fibrobacter succinogenes* (Chanthakhoun and Wanapat, 2010). Inter-cropping of leguminous fodder as food-feed between rows of cassava or *P. calcaratus*, enriches soil fertility and provides additional fodder. Feeding trials with buffalo revealed high levels of DM intake (2.4 percent of body weight) and high DM digestibility (71 percent). The condensed tannins (2–3 percent) were generally found in lower concentrations in mature *P. calcaratus* leaves and higher in younger leaves.

In a recent trial with various legumes, it was found that CP content of Ruzi grass, *P. calcaratus* and their mixture was 10.7, 20.4 and 14.0 percent respectively (Chanthakhoun, Wanapat and Wanapat, 2008). *P. calcaratus* should be planted as an intercrop with cassava in the FFS because this gives the best improvement in soil enrichment and increase in crop biomass and protein value.

## CONCLUSIONS AND RECOMMENDATIONS

Food-feed-system (FFS) using cassava and various legumes has been demonstrated as a potential system for smallholder farmers. It could provide year-round feed resources. Dissemination of the FFS is recommended as it would increase livestock productivity and profitability to farmers and ensure the sustainability of livestock production for smallholder farmers in developing countries. It would also enhance food production in a sustainable manner.

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# Silvopastoral system, cerrado and tropical forest biome in Brazil: Case studies

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## SUMMARY

Brazil is one of the largest cattle producers in the world. However, the negative impact of cattle production on the environment is increasing and causing pasture degradation. Silvopastoral practices are one of the options to recover degraded land and to combine animal production and landscape conservation. Two case-studies are presented. The first one, deals with a silvopastoral system in the Brazilian cerrado (Savanna), showing the positive impact of trees on soil quality, forage quantity and quality and milk production when compared with a monoculture system (only pasture). The second study, in the tropical forest biome, shows the positive results obtained by a farmer who adopted the silvopastoral system together with electric fencing, water and no-fire practice to recover degraded pastures. The impact has been increase in beef production and reduction of spittlebug. The system is being adopted by other farmers. However environmental legislation should be reviewed so that farmers applying the system get higher benefits, resulting in increased adoption of the silvopastoral practice.

**Keywords:** *biome, ruminants, silvopastoral systems, trees*

## INTRODUCTION

Brazil is currently the largest meat exporter in the world. Its share to the total meat and milk production in South America is 60 and 50 percent respectively. Such a production is aided by the low cost of producing soybean and maize and the abundance of land used for pasture production (Steinfeld *et al.*, 2006). However, deforestation to establish forage monocultures for cattle production has occurred in large areas of Brazil. This practice is producing a negative impact on the environment e.g. loss of biodiversity due to changes in the original ecosystem, high green-house gas (CO<sub>2</sub>) emission due to forest burning and reduction in water availability as a consequence of the decline in water vapour due to conversion of forests into pastures (Rockström *et al.*, 2009). Furthermore, according to Carvalho, Alvin and Carneiro (2001) approximately 50 percent of the 105 million hectares of cultivated pastures in Brazil are currently degraded or are in the process of degradation. Silvopastoral Systems (SPS) – a combination of trees, forages and animals have been adopted as an alternative for sustainable animal production, consequently reducing deforestation and also promoting recovery of the Brazilian cerrado (Savanna). Two case studies are presented.

## EXPERIENCES OF APPLYING THE TECHNOLOGY/PRACTICE TO THE FIELD

### Case study one

*Overall assessment.* A dairy farmer with 80 hectares of land in Lagoa Santa city, Minas Gerais State, Brazil, decided to change from the traditional system i.e. total elimination of all weed species and retaining only the main graminaceous forages (*Brachiaria brizantha* and *Hyparrhenia ruffa*), to a new system based on yearly systematic elimination of weeds. This new system consists of scything all weed species at short intervals (soon after they appear), but keeping the native trees and fodders (graminaceous forages). The seeds spread by the few old native trees are responsible for the propagation of new trees in the area. The growing of these new trees is also promoted by the systematic elimination of weeds. This system is defined as natural regeneration (Photos 1 and 2). The advantages of the natural regeneration system are: cost reduction because cleaning of the area is no longer required every year and increase in forage production and quality and increase in wood production.

### STATUS OF APPLICATION OF THE PRACTICE BY FARMERS

The new system (SPS) increased the amount and quality of grass, increased milk production and also enhanced soil fertility (Table 1).

The Brazilian forest legislation does not allow the cutting of the cerrado native trees. Therefore the income from wood production cannot be obtained until appropriate changes are made in the legislation.

### LESSONS LEARNT

Discussion with the owners of farms and farm workers is vital to make them aware of different tree species which need to be selected during the cutting process. It is important to select tree species (especially legumes) with open canopy which allow enough light for opti-



**photo 1**

*Pasture with no trees, Minas Gerais State, Brazil*



**photo 2**

*Silvopastoral system (natural regeneration), Minas Gerais State, Brazil*

**TABLE 1**  
**Soil fertility, grass quality and milk production in the Silvopastoral and monoculture systems**

Parameters	Silvopastoral system	Monoculture
	<i>Soil fertility</i>	
Potassium (ppm)	180	80
Base saturation (%)	43.0	25.4
	<i>Grass quality</i>	
Crude protein (%)	8.5	6.2
kg CP/ha/cutting interval	101	69
	<i>Milk production</i>	
Litre milk /animal unit /day	8.2	7.4

mum growth of grass (C4) and have a straight stem required for the wood industry. Forest policies need to be changed or adapted for farms following SPS (e.g. allow cutting of native trees in SPS). There is a need to involve policy makers for further promotion of the SPS.

### Case study two

*Overall assessment.* During the last ten years a beef farmer owning 3000 hectares of land in Maranhao state (Tropical Forest biome) has been attempting to reforest the pasture land with native trees species. The practice adopted by him is natural regeneration SPS (Photos 3 and 4). In addition, ground native legume forage (e.g. native name: Mulungu, not botanically identified yet) was selected and maintained. Instead of barbed wire fence, electric



**photo 3**

*Degraded pasture land in Maranhao State, Brazil Status of application of the practice by farmers*



**photo 4**

*Silvopastoral system in Maranhao State, Brazil Status of application of the practice by farmers*

fence powered by solar energy was used to divide paddocks. Clean water was made available to animals and no-fire practice was applied to clean or re-grow the pasture.

The results demonstrated an increase of 20 percent in beef production per year and also a reduction of spittlebugs, *Deois incompleta* and *Deois flavopicta* (Hemiptera cercopidae), which usually devastate most of the pasture lands. The benefits of the SPS (e.g. saving of the high labour cost for the selective cleaning of the area and increase in livestock production) have been discussed with farmers and disseminated to other farmers. This has promoted adoption of the SPS in large areas in Brazil. In addition, deforestation restrictions imposed by the Brazilian environmental legislation is also putting pressure on farmers to recover the degraded areas and stop deforestation. This legislation is acting as a catalyst to promoting the SPS. The adoption of the SPS is resulting in increased production of animal products and in conservation of the environment.

### LESSONS LEARNT

It is important to know which tree species are suitable under the SPS. Leguminous trees with open canopy and straight stem should be preferred. Electric fencing reduces investment compared with fencing using barbed wire. Convincing farmers not to use fire for pasture cleaning and to accept trees on pasture lands is a challenging task. However visits of farmers to farms practising SPS are a tremendous help to achieving large-scale adoption of the practice. Inclusion of SPS in the policies for *payment for environmental services* would further enhance adoption of this practice.

### FUTURE OF THE SPS

The conflict between increasing production and environmental conservation could be minimised by implementation of the SPS. Several farms (12 including medium and large farms) are currently applying this technology. However appropriate government policies, including payment for environmental services, are necessary to further promote this practice. Unfortunately the use of fire is still practised for pasture cleaning, and this could be minimised with education and a punitive legislation.

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# Utility of *Arachis pintoi* to restore degraded pastures in a cattle producing region of the Amazon of Colombia

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## SUMMARY

A case study involving a public-private alliance to promote the diffusion and adoption of legumes to restore degraded pastures in dual-purpose cattle production system in an Amazon region of Colombia is described in this paper. The research and development project carried out by the alliance contributed to identifying ways of facilitating adoption of a legume-based technology to recuperate degraded pastures in dual-purpose cattle farms in forest margins. Through implementation of this project a number of lessons were learnt. Firstly, there is a need to avoid absentee owners since they do not provide the necessary feedback to the process of technology development and do not act as true promoters of the technology. Secondly, model farms and on-farm research using participatory methods do not by themselves accomplish the ultimate goal of diffusion/adoption of improved pasture technology. An alternative diffusion strategy put in place during the course of the project involving credit, seed supply and machinery resulted in over 100 farmers planting *Arachis*-based pastures as an alternative to recuperate degraded pastures and improve milk production.

**Keywords:** *humid forest, milk production, pasture degradation, public-private alliance, tropical legumes*

## INTRODUCTION

The piedmont region of the Colombian department of Caquetá produces about 57 million litres of milk per annum, representing 2 percent of the total production of Colombia. Caquetá is characterised by high rainfall (3200 mm per year), altitudes mostly below 1000 masl and acid soils. In the prevalent dual purpose (milk and meat) systems animal production is low with 3–4 litres of milk/cow. This is mainly due to the low quality of pastures based on unproductive natural grasses such as *Homolepsis aturensis* and *Paspalum* spp. and degraded *Brachiaria* pastures. Therefore forage-technology options to overcome degradation and improve productivity of pastures were urgently needed. Over the period 1987–1990, CIAT's (Centro Internacional de Agricultura Tropical) forage researchers collaborated with several institutions in the piedmont region of the Amazon basin in Caqueta, Colombia in selecting forage germplasm adapted to acid soils and with potential for

reclaiming degraded pastures in cattle farms of the region. The most successful pasture was the legume/grass association of *Arachis pintoii* cv. Mani Forrajero, grown with several *Brachiaria* species. Limited on-farm evaluation of *Arachis*-based pastures had indicated that it was persistent under farmer management. However livestock owners in the region did not adopt the *Arachis* technology mainly because of lack of promotion, little knowledge on benefits and high cost of the seed.

A 4-year project was launched with the general objective of increasing the farmers' income and milk to consumers using appropriate forage legume-based technologies while conserving the natural resource-base (Lascano *et al.*, 1999). To accomplish this, the project focused on introducing *Arachis pintoii* to reclaim degraded pastures, keeping in view its proven value in improving forage quality and enhancing soil fertility (Lascano, 1994). The specific objectives of the project were to: 1) document the on-farm benefits of *Arachis*-based pastures; 2) train personnel of different institutions on establishment and utilisation of *Arachis*-based pastures using participatory methods; and 3) initiate and catalyse an active transfer-mechanism of the *Arachis* technology in the region. A summary of the interventions, experiences in applying the legume technology and lessons learnt are presented. For more details the reader is referred to the CIAT Publication No. 311 (Lascano *et al.*, 1999).

## INTERVENTIONS

Two types of pastures were established on the farms participating in the project: grass alone and grass associated with commercial *Arachis pintoii* cv. Mani Forrajero (Rincon *et al.*, 1992). Newly-established pastures were grazed mainly by the milking herd of participating farms and formed part of the normal paddock-rotation practised on the farm, using the methodology proposed by Lascano, Avila and Ramirez (1997). Pasture measurements including forage on offer and botanical composition were done three or four times a year on each farm. Milk yield of individual cows was recorded on each farm at least four times a year. Other observations such as physical structure, fertility and biological activity of the soil were recorded once a year on the representative farms.

It was hypothesised from the beginning, that success of the project would depend on ensuring that a major area of improved pastures were planted in 10 to 15 model farms of the region, so that they would act as promoters of the *Arachis* technology to surrounding farmers. This in turn would ensure that a minimum of 100 farmers would be exposed and become adopters of the new pasture technology during the project duration. The project also relied on participatory methods for adapting and transferring the new technology in the region.

However this strategy proved unsuccessful because of limited availability of credit to implement the technology, inadequate supply of high-quality *Arachis* seeds in the market and lack of machinery on the farms for preparation of land for planting *Arachis* in association with grasses. Consequently an alternative diffusion approach of the *Arachis* technology had to be put in place for the extension-phase of the project. The new strategy included:

1. Creating a technology-transfer fund managed by a milk company that purchased most of the milk produced in the region;
2. Conducting a survey among all milk producers that sold milk to the company to define interest in restoring degraded pastures using *Arachis*;

3. The multiplication and purchase of commercial seed of *Arachis* on a contract basis among interested producers;
4. Contracting tractors for timely land preparation; and
5. Allowing interest-free repayment for the partial cost of pasture establishment with milk sold to the milk company by the farmers.

## EXPERIENCES IN APPLYING THE TECHNOLOGY

With the new diffusion strategy in place, a total of 2 000 ha of degraded pastures in over 100 farms were recuperated with *Arachis* by the end of the 4-year project. The main driving forces behind the adoption by farmers of the *Arachis* technology were: a) increased milk yield (0.5 to 1.0 litre/cow daily; b) increased carrying capacity of the pastures; c) improvement in biological activity of the soil; and d) high rate of returns on investment (Table 1).

## SUCCESSSES AND FAILURES

A number of lessons were learnt from the successes and failures recorded during and after implementation of the project. These could be of use for future R&D projects in other tropical regions.

## SUCCESSSES

Most of the participating and non-participating farmers in the project became interested due mainly to the large and reliable market for fresh milk in the region and considered investing in reclamation of degraded pastures. The promotion of legumes by the project also generated interest among the livestock owners to learn more about *Arachis* and its role in increasing milk yield and improving soil fertility.

The project also contributed to creating awareness for adopting *Arachis*-based technology in the region by demonstrating the economic benefits of the *Arachis* technology relative to the technology used by farmers and the on-farm results for milk yield with and without *Arachis*.

TABLE 1  
Sensitivity of the Internal Rate of Return (IRR) of production parameters associated with the *Arachis*-based pasture technology (Rivas and Holmann, 2000)

Change in production parameters (%)	IRR (%)		
	[Stocking Rate (AU**/ha)]*	[Milk Yield(litres/cow/day)]*	[Calving Rate (%)]*
+ 10	20.6 [1.65]	21.0 [3.86]	22.5 [66]
+ 20	21.6 [1.80]	22.7 [4.20]	25.8 [72]
+ 30	22.9 [1.95]	24.4 [4.55]	29.1 [78]
+ 40	23.9 [2.10]	26.1 [4.90]	32.6 [84]
+ 50	24.8 [2.25]	27.8 [5.25]	36.1 [90]
0	19.3 [1.50]	19.3 [3.50]	19.3 [60]

\*Figures in square parentheses correspond to absolute values of each variable;

\*\*AU (adult unit), 400 kg LW

## **FAILURES**

A major failure of the project was related to the selection of farmers that directly participated in the project, since most of them were absentee owners. The day-to-day contact of the Technical Assistants of the project was with Farm Managers who in most cases had little decision making power and in other cases felt no need to change as per the objectives of the project. As a consequence, there was lack of feedback to the Technical Assistants of the project, which defeated one of the objectives of the project.

Other failures that became evident as the project progressed were related to technical issues and included:

1. Poor germination of the grass seeds purchased by farm owners resulting in re-planting of many pastures;
2. Failure to carry-out a correct cow-rotation system across the grass and grass/legume pastures on some farms. This resulted in limiting the time for adjustment of animals to the legume and consequently in low legume-intake and as a consequence biased milk-yield estimates; and
3. Low grazing-pressure in some grass/legume pastures due to a small number of animals in the milking herd and/or absence of fencing around the pasture. As a result, the effect of the legume on milk yield may have been underestimated due to selective grazing of the grass.

## **LESSONS LEARNT**

- On-farm adaptive research on livestock production systems cannot be rigid in design or experimental methods. Research protocols have to be adjusted to each individual farm, since there is considerable variation among farms in number and type of animals, type and area of paddock, and grazing management.
- The chances of success in pasture/livestock research are very much dependant on the attitude of farmers for wanting change and on true participation in the research/validation process of new technologies. Thus there is need to devote time to selecting farmers through interviews and farm visits, and to clearly define criteria for the selection of farmers. Absentee owners (small, medium or large) should be avoided as much as possible in on-farm pasture/livestock research work, since they do not provide the necessary feedback to the process of technology development and do not act as true promoters of the technology.
- The concept of model farm and on-farm research using participatory methods allows refinement of new pasture technologies and provides feedback to researchers, but by itself does not accomplish the ultimate goal of diffusion/adoption of the technology. The diffusion strategy should include the timely availability of seeds, fertilisers, herbicides, agriculture machinery and credit.
- Most farmers, regardless of size of farm, are willing to invest in improved pasture technologies as long as they have a reliable market for the farm outputs (fresh milk, cheese, meat). Therefore, pasture development projects should be implemented in the regions where there is an existing market for beef or milk or where there is potential demand that needs to be satisfied.

- Prior to the initiation of a forage/livestock project there should be good baseline information on demand for pasture technologies through rapid rural-appraisal methods. Possible bottlenecks for adoption of the technologies should also be identified through resource-optimisation simulation models. Ultimate determinants of adoption of improved pasture technologies will be acceptability and profitability of the new pastures to the farmer. The potential profitability of the pasture technology being promoted should be investigated using ex-ante economic analysis. To assist in the promotion of the new pasture technology, input and output data recorded on the farms should be used for detailed economic analysis at the end of the project.

One of the objectives of the project was to train Technical Assistants of agricultural institutions in the region to make them aware of the technology being promoted and to provide the basis of participatory approaches for technology transfer. Unfortunately, the multiplier effect that was expected through training was not fully accomplished. One overriding reason for the failure was that institutions being represented by the trainees were not committed to transferring technology for pasture reclamation. Thus future projects should define the research and development plans of relevant institutions in a given region before committing resources to training of their Technical staff.

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# Integration of forage production with high-yielding rice variety cultivation in Bangladesh

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## SUMMARY

The acute shortage of feeds and fodder is one of the major obstacles to dairy development in Bangladesh. The integrated high-yielding variety (HYV) rice-forage production techniques were demonstrated by the Community-based Dairy Veterinary Foundation (CDVF) in the north-western part of the country. The highest net economic return (NER) of US\$832/ha was obtained for Maize (*Zea mays*) and Napier (*Pennisetum purpureum*) mixed crops cultivated in-between two HYV (Aman and Boro) rice-cropping system. The NER for Khesari (*Lathyrus sativus*) forage cultivated as a relay crop with HYV Aman rice was US\$553/ha. The crude protein content of forage was 21.2 percent. In Bogra district, NER of US\$2 550/ha and in Sirajgonj district NER of US\$2 665/ha were obtained for HYV Aman rice + Khesari (relay) + Maize and Napier (2 harvests) mixed-forage cropping. NER for Aman rice + mixed forage (Maize + Napier) + Boro rice cropping was US\$2 525/ha, indicating the potential of integrated-forage cropping in-between two HYV rice crops. Integrated rice-forage production not only increased NER but also improved subsequent HYV rice production. Legume-forage production as a relay crop or intercrop helps in increasing forage yield. Therefore the integrated forage-based cropping systems are becoming increasingly widespread, especially in densely-populated areas of Bangladesh where land is scarce due to cropping intensity.

**Keywords:** forage, high-yielding rice variety, integrated cropping, net economic return

## INTRODUCTION

Dairy cattle production in Bangladesh depends on crop residues and agricultural by-products. Although rice straw is abundant only 25 percent of its metabolisable energy (ME) is utilised by the cattle population of the country (Akbar and Khaleduzzaman, 2009) resulting in low animal productivity. Therefore there is an urgent need to increase production of higher-quality forages. However, due to intensive crop production land is scarce in Bangladesh. Intercropping and relay cropping could be potential options to increase forage supply. Legumes are the crops of choice because they are rich in protein and fix atmospheric nitrogen in the soil.

Traditionally legumes, e.g. Khesari (*Lathyrus sativus*), used to be cultivated with local rice varieties as a relay crop in parts of Bangladesh where pulses were used for human consumption. The legume crops were sown when the local, Aman rice crop, was at the

flowering stage. Aman used to be harvested by December and the legume crop was allowed to grow until early March. The land was then free for cultivation of Aush (a rice crop) or jute by April. This practice has now changed because the local variety Aman is replaced by the HYV Aman, and the Aush is replaced by HYV irrigated Boro, the latter being transplanted by mid-February. In this system, the pulses are not allowed to grow to maturity but are harvested as forage by January, thus allowing the same land to be used for cultivating HYV irrigated Boro rice. However, it was not known whether the pulse seeds would germinate and grow along with the thick vegetation of the HYV Aman rice. Therefore the studies were undertaken to develop a technique of integrated HYV rice-forage production.

### FIELD TRIALS

A total of 10 farmers from 2 districts (Bogra and Sirajgonj) in the north-western part of Bangladesh were selected for integrated HYV rice-forage production. Based on the farmers' preferences two non-legume fodders; Maize (*Zea mays*) and Napier (*Pennisetum purpureum*) and two legume fodders; Khesari (*Lathyrus sativus*) and Cowpea (*Vigna unguiculata*) were selected for integrated-forage production. Khesari seeds were sown in HYV Aman rice fields, as a relay crop, 15 days before harvesting the Aman rice. Khesari seeds were also sown as an intercrop in-between Aman and Boro rice cropping. Legume and non-legume fodders were cultivated as mixed crops after harvesting HYV Aman rice. The recommended fertiliser dose (100 kg N/ha) was applied to non-legume fodders; no fertiliser was applied to the legume fodders. Both legume and non-legume fodders were harvested at 70 days of maturity and total yield was recorded (Photos 1 and 2). Data on forage biomass yield (tonnes/ha) of different cropping systems and production cost per unit area were calculated. The nutritional quality of different forage samples and the NER from the intercrop, relay crop and mixed crop were determined.

### MAJOR FINDINGS

The highest forage yield was 65 tonnes/ha for Maize + Cowpea + Napier mixed-cropping in-between two HYV (Aman and Boro) rice crops, with a NER of US\$761/ha. However, the highest NER (US\$832/ha) was recorded for Maize + Napier mixed-cropping with forage yield of 62 tonnes/ha (Table 1) while the Khesari yield was 27.3 tonnes/ha. The NER for Khesari fodder was US\$553/ha as relay crop with HYV Aman rice which was slightly higher than that (US\$526/ha) of Khesari as intercrop in-between Aman and Boro rice-cropping. The yield of forages was inversely related to crude protein (CP) content of forages (Table 1).



**photo 1 and photo 2**  
*Harvesting and weighing of forages*



The highest average CP (21.2 percent) was obtained for Khesari fodder in relay cropping. The CP of Maize + Napier mixed-cropping (7.8 percent) was not as high as Khesari fodder, either from relay cropping or from intercropping. The average ME (MJ/kg DM) content was highest (9.6) for Maize + Cowpea mixed-cropping in-between two rice (Aman + Boro) crops. However the ME content was relatively lower for leguminous fodder than for non-leguminous fodders.

The NER also increased by different forage-based cropping systems (Figure 1). In the Bogra district, the highest NER (US\$2 550/ha) was obtained for HYV Aman rice + Khesari (relay) + mixed-forage cropping of Maize + Napier (2 harvests). While the NER for HYV Aman + mixed-forage (Maize + Napier) + HYV Boro was US\$2 525/ha, indicating that forage cropping with HYV rice cropping has the potential for achieving higher economic returns. Similarly, in the Sirajgonj district, the highest NER (US\$2 665/ha) was obtained for HYV Aman + Khesari (relay) + mixed-forage (Maize + Napier) cropping. Khesari seeds sown two weeks before harvesting Aman rice produced 2.6 tonnes/ha (85 percent DM) hay 2.5 months later (Akbar *et al.*, 2005). During the subsequent Boro cropping, rice yield also increased by 6.5 percent, providing a higher NER to the farmers. Socio-economic benefits of growing *L. stivus* as a relay crop with HYV Aman were substantial. The extra yield of rice increased the gross margin/ha of the rice crop by 34 percent (Islam *et al.*, 1999).

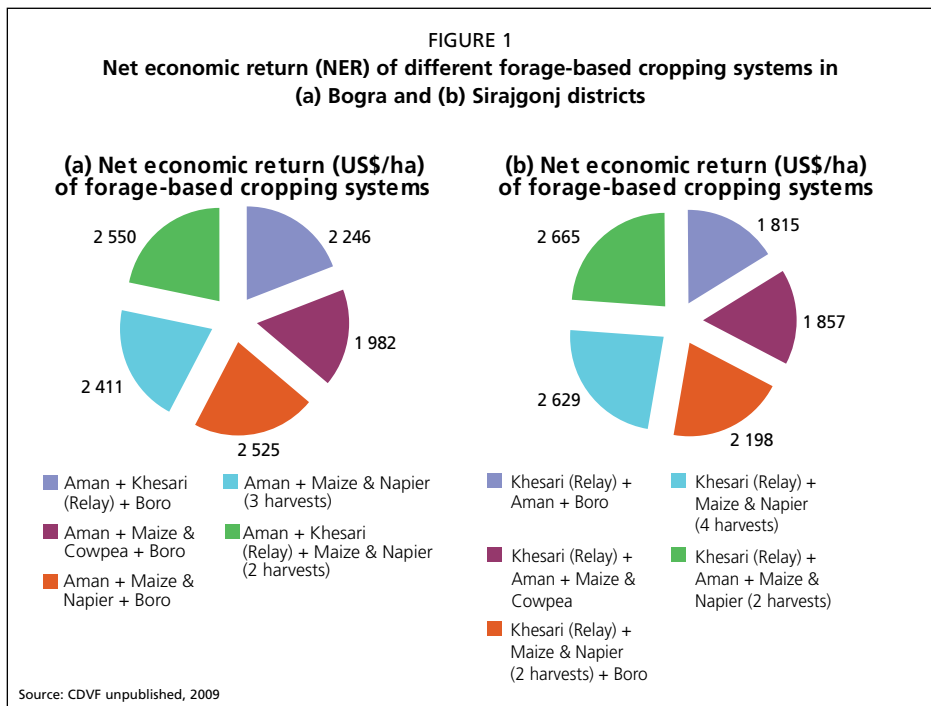
## LESSONS LEARNT

Due to increasing human population of the country there is an increasing demand for food grains. The intensive cultivation of food crops, particularly of HYV rice is undertaken by farmers to obtain higher yields. Urbanisation and industrialisation in the country has shrunk the land available for fodder production. Therefore, integrated HYV rice-forage production technique is the only option for increasing fodder production. The integrated rice-forage production not only increased NER from forages but also increased daily income from sale of milk and rice.

TABLE 1.  
Cost of production, net economic return (NER), crude protein and metabolisable energy content of forages under different cropping systems

Cropping systems	Fodder production (tonnes/ha)	Cost of fodder production (US\$/ha)	NER (US\$/ha)	Average CP (%)	Average ME (MJ/kg DM)
Intercropping (Khesari)	27.3	253.0	526.0	19.7	7.6
Relay cropping (Khesari)	25.0	161.0	553.0	21.2	7.7
Mixed cropping (Maize+Cowpea)	27.0	289.0	289.0	13.0	9.6
Mixed cropping (Maize+Napier)	62.0	496.0	832.0	7.8	8.6
Mixed cropping (Maize+Cowpea+Napier)	65.0	631.0	761.0	11.4	8.9

CP, crude protein; ME, metabolisable energy  
Source: CDVF unpublished (2009)



Dairying has become a preferred livelihood option for many smallholder dairy farmers in rural and peri-urban areas of Bangladesh. The farmers have started realising that feeding of forages must be ensured for maintaining a satisfactory level of milk production throughout the year. Reasons for the growing interest in integrated rice-forage production technology include i) potential for increasing farm profitability; ii) lower fixed costs for land and machinery as a result of the production of a second crop at the same time; iii) better utilisation of farm labour, time and equipment; iv) secure forage production for livestock feeding; and v) possibility of preserving excess forage for animal feeding during the periods of scarcity.

### EXTENT OF USE OF THE TECHNOLOGY

The smallholder farmers of Bogra and Sirajgonj districts are now showing increasing interest in the use of HYV rice-forage production technique. A total of 250 farmers (CARE, Bangladesh, personal communication, 2010) cultivated Khesari fodder with HYV Aman rice as a relay crop. In addition, smallholder farmers of these two districts cultivated Maize + Napier as a mixed crop in-between HYV Aman and Boro rice cropping. The rice-forage production technology was applied to other parts of the country. In the Pabna district, the NER from Aman + Napier and Khesari + Boro cropping were US\$1 505 and 912 per hectare, respectively (Chowdhury *et al.*, 2009). Similarly, in the Madaripur district, the NER from Khesari + Boro and Matikalai (a variety of legume fodder) + Boro cropping were US\$674 and 740 per hectare, respectively. Fodder-based rice cultivation resulted in a better NER than rice cultivation alone.

## FUTURE OF THE TECHNOLOGY

The integrated forage-based cropping systems are becoming increasingly popular, especially in densely-populated areas in Bangladesh where the land for cultivation is scarce. A combination of food, cash and fodder crop production aimed at meeting both livestock and human needs makes it an attractive technology which has proved effective in encouraging rural farmers to grow fodders for their animals. The HYV rice-forage production system is obviously an appropriate technology under the prevailing situation of many smallholder dairy farmers in Bangladesh. The technology not only provides additional income opportunities for smallholder farmers through increased production, but also contributes to addressing the deficits in dairy production at the national level. Effective and realistic means of promoting the technology further, are urgently required. The government and non-government extension agencies could make valuable contributions in this direction.

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# Low-cost silage technology increases milk production and farmers income in north-western districts of Bangladesh

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## SUMMARY

Seasonal variation and acute scarcity of forages are major obstacles for increasing milk production of dairy animals in Bangladesh. Maize (*Zea mays*), Napier (*Pennisetum purpureum*) and jumbo (*Sorghum bicolor* x *Sorghum sudanese*) forages were preserved as silage in bamboo-mat-fenced chambers (BFC) in Baghabarighat milk-pocket area. The BFC was made from 4 bamboo mats (local name 'chatai') with a volume of 150 cubic feet, costing US\$21.23. Silage prepared in BFC significantly ( $P<0.01$ ) increased milk yield in a study on 32 cross-bred dairy cows (Local x Holstein Friesian). Farmers' income increased by US\$19.81, 11.94 and 7.66 per cow per month by feeding maize, Napier and jumbo silages respectively. The techniques of making BFC and maize-stover silage were extended to other north-west districts of the country. In 15 cross-bred dairy cows (Local x Holstein Friesian), milk yield increased ( $P<0.01$ ) from 6.25 to 7.22 kg per cow per day when maize-stover silage was fed with rice straw. The net income from milk increased ( $P<0.01$ ) from US\$32.91 to 40.06 per cow per month. BFC can be used as a low-cost silage-making technique to increase milk production and income of smallholder dairy farmers.

**Keywords:** *bamboo-mat fenced chambers, income, low-cost silo, milk production, silage*

## INTRODUCTION

The acute shortage of feeds and fodder is one of the major obstacles to dairy development in Bangladesh. The availability of straw, green fodder and concentrate is 20.51, 23.58 and 2.79 million tonnes as against requirements of 16.27, 70.42 and 27.73 million tonnes respectively (Alam, 2002). The most severe feed shortage period is from July to October when most of the fields are under rice cultivation and all low-lying areas are flooded. Bangladesh produces 1.25 million tonnes of wheat straw and 5.90 million tonnes of maize stover but these are not used as cattle feed because of lack of appropriate technologies (Khaleduzzaman and Khandaker, 2009). The most-widely ensiled fodder is maize due to its high contents of non-fibre carbohydrates (NFC). In addition to maize fodder, dairy

farmers of Baghabarighat (Sirajgonj) milk-pocket are increasingly producing Napier (*Penisetum purpureum*) and jumbo (*Sorghum bicolor* x *Sorghum sudanese*) forages. Napier has been introduced both in Bathan (basin-like pasture land along river side) and in arable land together with boro rice (a high-yielding variety). The proportion of Napier cultivation is 24.32 percent among different cultivated fodders in Bangladesh (Chowdhury, 2009).

There is need to develop a silage-making technology that is suitable for use under local conditions and which is also affordable to smallholder farmers in Bangladesh. The need for silage making is even more important for dairy animals, where high-quality feed is required on a regular basis. The daily harvesting of green forage from the traditional "cut and carry" system is also posing problems, particularly when family labour is insufficient. Lane (1999) worked on "Little Bag Silage (LBS)" in northern Pakistan and Nepal using strong, high-density plastic bags with a capacity of 5 kg green fodder. Making LBS was labour-intensive and protection from the rodents was the major drawback for forage preservation. Otieno, Onim and Mathuva (1999) demonstrated the feasibility of ensiling maize stover, sugarcane tops and sorghum stover in synthetic gunny bags in Kenya. However, until recently, little attention has been paid in Bangladesh to conserve forages as silage using different low-cost methods. Keeping this in mind, Community-based Dairy Veterinary Foundation (CDVF) has taken initiatives to develop a low-cost forage preservation technique that may prove useful to smallholder farmers for increasing milk production and income.

### LOW-COST SILAGE MAKING

Low-cost bamboo-mat-fenced chambers (BFC) were made from the available inputs found in local markets (Table 1).

Bamboo-mat-fenced chamber was made from 4 bamboo mats (local name is 'chatai') with a volume of 150 cubic feet (height x length x width; 5' x 5' x 6'). The outer-surface of the BFC was plastered by a mixture of mud, rice husk and cow dung in order to make it compact and airtight. The floor of the BFC was prepared with bricks and sand. The inner-surface of the BFC was lined with polythene sheet to make the BFC completely airtight (Photo 1). Maize, Napier, jumbo and maize stover were chopped (2–3 cm) using a locally-

**TABLE 1**  
**Cost of making low-cost silo pit**

Items	US\$
Bamboo-mat (prepared from bamboo slices)	4.35
Polythene sheet	6.52
Bamboo pieces	4.93
Brick/sand for floor space	2.54
Making charges	2.89
Total cost/silo	21.23
Total volume, cubic feet (cft)	150.00
Cost in US\$/cft	0.12



**photo 1**  
*Bamboo-mat fenced chamber*

manufactured grass chopper. The chopped forage was compacted thoroughly in the chamber to ensure removal of air. The wilted fodders were placed in the chambers separately, and molasses at 2 percent of fresh-weight of fodder was added. When green fodder was used, individual chambers were covered with a 10 cm-thick layer of rice straw, followed by a polythene sheet plastered with a blend of straw which was then compacted with bricks to make the silo airtight. Maize stover was similarly preserved in BFC in the north-western part of the country. When required for feeding, the polythene sheet was removed and silage was withdrawn starting from the upper layer and working downwards to the lower ones. After removing the required amount of silage for the day's feeding, the polythene sheet was put back to keep the chamber sealed.

### **MILK PRODUCTION AND INCOME GENERATION STUDIES**

In a study, 32 cross-bred cows (Local x Holstein Friesian) were randomly allocated to four dietary treatments. Animals in control group ( $T_0$ ) were supplied 65 percent dry matter (DM) from straw and 35 percent DM from concentrate mixture. Animals in  $T_1$  had 50 percent straw DM replaced with maize silage,, those in  $T_2$  had 50 percent straw replaced with Napier silage and those in  $T_3$  had 50 percent straw DM replaced with jumbo silage. In another experiment, cross-bred cows (Local x Holstein Friesian) in the control group were offered rice straw and concentrate mixture at a ratio of 65:35 on DM basis and in the experimental diet, the rice straw was replaced with maize stover silage. Data on milk yield and composition and income generated from selling of milk were recorded during 90 days trial. Community based Dairy Veterinary Foundation provided a data sheet to each farmer after entering the identifying marks of each cows.

On replacing 50 percent rice straw on DM basis with maize, jumbo or Napier silage, milk production increased ( $P < 0.01$ ) from 8.24 kg in control to 10.25, 9.37 and 8.96 kg per cow per day for maize, jumbo and Napier silages respectively. The increase in income was US\$19.81, 11.94 and 7.66 per cow per month, while the decrease in feed cost was US\$1.86, 1.50 and 1.16 per 100 kg milk production by feeding maize, jumbo and Napier silages, respectively (Table 2).

The smallholder dairy farmers were interested in low cost silage making particularly in north and north-western districts of the country. In the second experiment, the silage mak-

TABLE 2  
Effects of partial replacement of straw with silage on milk production and income generation

Parameters	Diets <sup>#</sup>				Level of Significance
	T <sub>0</sub>	T <sub>1</sub>	T <sub>2</sub>	T <sub>3</sub>	
<i>Milk yield and composition</i>					
Milk yield, 4% FCM <sup>1</sup> (kg/cow/day)	8.24 <sup>c</sup>	10.25 <sup>a</sup>	9.37 <sup>ab</sup>	8.96 <sup>bc</sup>	*
Milk fat (%)	4.08 <sup>b</sup>	4.11 <sup>b</sup>	4.46 <sup>a</sup>	4.24 <sup>ab</sup>	**
Milk fat, kg/day	0.34 <sup>b</sup>	0.40 <sup>a</sup>	0.41 <sup>a</sup>	0.38 <sup>a</sup>	*
<i>Feed cost, US\$/cow/month</i>					
Cost of straw	7.32 <sup>a</sup>	3.03 <sup>c</sup>	3.93 <sup>b</sup>	3.80 <sup>b</sup>	**
Cost of silage	-	7.40 <sup>a</sup>	6.12 <sup>b</sup>	6.42 <sup>b</sup>	**
Cost of concentrate	30.45	30.46	29.52	28.21	NS
Total cost	37.78	41.19	38.94	38.43	NS
Total milk price, US\$/cow/month <sup>2</sup>	95.42	118.65	108.53	103.74	NS
Total income US\$ from milk <sup>2</sup>	57.64	77.45	69.58	65.30	NS
Increase in income (US\$/cow/month)	-	19.81	11.94	7.66	-
Feed cost US\$/100 kg milk production	15.53	13.67	14.03	14.37	NS
Decrease in feed cost US\$/100 kg milk production	-	1.86	1.50	1.16	-

<sup>1</sup> FCM, Fat corrected milk; <sup>2</sup> Milk price was calculated at a rate of US\$0.40 per kg; <sup>NS</sup> Not significant; <sup>#</sup>, see text for diets

\*\* P<0.01, \* P<0.05; <sup>abc</sup> Mean values of different superscripts differ significantly

ing activities were jointly organised by CDVF and CARE (Cooperation for American Relief Everywhere) Bangladesh. The project did not give any financial support to the farmers for making chambers, however a grass chopper was provided from the project for chopping maize stover. The project staff trained the farmers in silage-making techniques. The cost for producing maize stover silage was higher (US\$5.71/100 kg) than maize forage (US\$1.77/100 kg) due to maize stover processing and labour cost involved in the processing. The average daily milk yield per cow increased (P<0.01) from 6.25 to 7.22 kg with the addition of maize stover silage in the feed. The milk fat percentage also increased (P<0.01) from 4.18 to 4.30 (Table 3). The monthly income from milk, after deduction of feed cost, increased (P<0.01) from US\$32.91 to 40.06.

### FEASIBILITY OF THE BFC

A key feature of the BFC is that it allows conservation of fodder in quantities required for feeding 3 to 20 cows for 3 to 4 months. These quantities of silage could be obtained from one or two chambers during scarcity periods. Bangladesh has a long rainy season, therefore silage making in earthen pits is not practised particularly in low-lying areas. On



**TABLE 3**  
**Effects of feeding maize stover silage on milk production and income generation**

Parameters	Control (n=15)	Experimental (n=15)	Level of Significance
<i>Milk yield and composition</i>			
Total milk yield, kg/cow/day	6.25 <sup>b</sup>	7.22 <sup>a</sup>	**
Milk fat (%)	4.18 <sup>b</sup>	4.30 <sup>a</sup>	**
<i>Feed cost, US\$/cow/month</i>			
- Cost of straw	5.62	5.19	NS
- Cost of silage	-	14.78	-
- Cost of concentrate	36.47 <sup>a</sup>	26.61 <sup>b</sup>	*
Total feed cost, US\$/cow/month	42.09	46.58	NS
Total milk price, US\$/cow/month <sup>1</sup>	75.00 <sup>b</sup>	86.64 <sup>a</sup>	**
Income from milk, US\$/cow/month	32.91 <sup>b</sup>	40.06 <sup>a</sup>	**

<sup>1</sup> Milk price calculated at a rate of US\$0.40 per kg; NS Not significant, \*\* P<0.01, \* P<0.05

<sup>abc</sup> Mean values of different superscripts differ significantly

the other hand, the initial cost of traditional concrete silos is too high (about US\$1 000) for smallholder farmers. The cost for making a BFC is low and the inputs are readily available to the farmers.

## LESSONS LEARNT

Silage feeding is a better feeding strategy as it improves nutrient supply and productive performance of animals especially during periods of feed scarcity. Silage making by the farmers, particularly in milk-producing areas is gaining popularity. The silage was better in nutritive value compared with urea molasses straw (UMS) and untreated straw.

Demonstration of low-cost silage making and dissemination of benefits of feeding silage have been made by the CDVF to create awareness among the farmers. Smallholder farmers showed greater interest in the BFC due to its low-cost and use of locally-available materials. The farmers continued making silage even after the end of the project. Maize stover should be introduced as cattle feed in the form of silage made in the BFC and extended in other parts of northern districts of Bangladesh where maize cultivation is fast increasing.

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# Improving the utilisation of Napier grass by dairy cows through fractionating the stems into juice and fibrous residue

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## SUMMARY

Tropical grasses are normally of low nutritive value when compared with temperate grasses because of higher structural fibre content. Napier grass is popular on smallholder dairy farms because of its high yield and ease of harvest. However low dry matter and high fibre contents and the physical nature of the crop are factors reducing the utilisation of freshly harvested Napier grass. Nutrition researchers are continually seeking feeding techniques for tropical dairy systems that can improve both the voluntary intake of tropical forages and the utilisation of more expensive concentrate supplements. The utilisation of Napier grass can be improved through fractionating the stems into juice and fibrous residue by squeezing them through a simple roller mill. Forage intake in milking cows would increase because of higher rate of rumen digestion of the fibrous residue through a greater surface area available for digestion by rumen microbes. Increased forage intakes will reduce total feed costs and improve feed efficiency hence farm profits.

**Keywords:** *fractionation, juice, Napier grass, residue*

## INTRODUCTION

Napier (or Elephant) grass is the major improved forage species fed to dairy cows in the humid tropics (Moran, 2005). Because of its tropical ancestry, its nutritive value is reduced through high levels of intra-cell water and structural fibre, consequently forage intake and hence milk yields are below those attainable with temperate forages. However its potential for high dry matter (DM) yields, which surpasses that of virtually all other tropical forages, is the major reason for its popularity on smallholder dairy farms. In addition, because its cell wall content does not increase with age as fast as in other tropical forages (such as Kikuyu and Pangola grasses) it retains a given level of digestibility for a longer period (Orodho, 2006).

Napier grass is an ideal crop for smallholder dairying, which is essentially zero grazing (or cut and carry) because it can be easily harvested by hand for feeding to the stalled animals. Being an erect grass species, Napier has a tall, highly-fibrous stem with leaves growing from several nodes along the stem. Total crop DM contents can fall below as low as 12 percent, with leaves containing 16 percent DM and stems only nine percent DM.

(Moran and Mickan, 2004). Depending on stage of maturity, neutral detergent fibre levels vary from 55 to 75 percent. As a sole feed or when supplemented only with *Leucaena*, Napier grass will only support milk yields of 7 to 8 litres/cow/day (Muia *et al.*, 2000). Low DM and high-fibre contents and the physical nature of the crop are all factors reducing the utilisation of freshly harvested Napier grass.

In addition to restricting forage intakes, the high-fibre content and lengthy rumen-retention time are likely to reduce the digestion of concentrate supplements, usually fed to milking cows (P.T. Doyle, personal communication, 2010). Such a phenomenon is called associate effects, because the rumen microbial population created by the highly-fibrous tropical forages reduces the numbers of starch-digesting microbes, required for optimum utilisation of concentrate. Nutrition researchers are continually seeking feeding techniques for tropical dairy systems that can improve both the voluntary intake of tropical forages and the utilisation of more expensive concentrate supplements.

### **MECHANICAL PROCESSING TO IMPROVE FORAGE UTILISATION**

There are several ways that mechanical processing can improve the utilisation of Napier grass. Following harvest, it can be chopped, either by hand or mechanically, prior to feeding. Chopping improves forage utilisation by reducing selection of leaves and stems by the animal. Secondly, the stems can be conditioned, through damaging the cuticle on the stems, after which the unchopped forage is wilted in the sun for several hours. This process improves forage utilisation through reduced total crop moisture levels which stimulates appetite through smaller rumen volumes of intra-cell water and improved rumination of the chewed forage (McDowell, 1994). In addition, the higher forage intake produces a denser mat of pre-digested forage in the upper rumen, making it easier for this material to be regurgitated during rumination. A faster rate of forage breakdown (particle size reduction) in the rumen increases the rate of passage of feed through the animal's digestive tract, thus increasing its appetite for more. Increased forage intakes will reduce total feed costs and improve feed efficiency, hence farm profits (Moran, 2005).

Another way in which mechanical processing could improve forage utilisation is through fractionating the stems into juice and fibrous residue by squeezing them through a simple motorised, draught powered or human operated roller mill. Many food markets in South-East Asia sell freshly-squeezed sugar cane juice using a small 3-roller mill (driven by a 3 HP motor) to extract the juice from sugar cane stalks; these machines would adequately serve this purpose.

Fractionation of forages into juice and fibrous residues has been commercially practised to produce protein-rich liquid from which the high-value protein can be easily extracted for inclusion in pig and poultry diets, with the fibrous residue fed to ruminants (Dumont and Boyce, 1976) and in sugar cane to produce soluble sugar-rich liquid for intensive dairy and beef cattle or pig production, with the fibrous residue fed to ruminants (Preston, 1988).

Processing sugar cane stalks was developed to overcome the extremely low fermentability of sugar cane fibre and the negative effect this had on voluntary intake of the overall diet. Fractionation allowed the juice and residual fibre in the pressed stalk to be treated as separate entities (Preston, 1988). A similar argument holds true for Napier grass stems.

## FRACTIONATING NAPIER GRASS STEMS

Fractionation of Napier grass stems is one way of improving total forage intake in milking cows by allowing them to drink much of the intra-cell liquid and to increase their rate of rumen digestion of the fibrous residue through a greater surface area available for digestion by rumen microbes. Physical fractionation is similar as pre-chewing the forage except the juice is drunk separate to the “masticated/squeezed” forage stalks.

Cows could be initially fed the Napier grass leaves, which would be readily consumed, followed by the residual stem, with the juice offered in a drinking trough. Concentrate supplements, required by milking cows, should be fed prior to the juice. As has been found with sugar cane juice, juice consumption can be regulated through varying free water intake.

Increased labour requirements are not an issue because all grass is harvested, and in many cases, chopped by hand in smallholder dairy systems. Larger dairy operations generally mechanically chop the forage using a chaff cutter or forage chopper. Fractionating sugar cane stems has been shown to greatly increase animal performance. Because of the high concentration of soluble sugars, the addition of urea (0.5 percent of the juice volume) provides a cheap source of dietary nitrogen. Fattening beef cattle can grow at 0.8 kg/day on a diet solely of cane juice (with urea) plus residual stem, and at 1.3 kg/day with additional sunflower meal (Sanchez and Preston, 1980).

## RESEARCH TO BE UNDERTAKEN

There are several unknown factors to investigate before a procedure can be developed for Napier grass. Napier grass stems contain considerably less soluble sugars than sugar cane, hence the resultant juice would be lower in nutritive value. Much is known about the benefits of fractionating sugar cane stalks, and this can be used as a basis of any new research to ascertain:

- The extraction rate of Napier grass juice. As a percentage of stalk weight, 45 to 55 percent of juice from sugar cane can be extracted using a simple 3-roller press;
- Nutritive value (chemical composition) of grass juice. Sugar cane juice contains about 15 percent DM with a very high content of soluble sugars, resulting in high levels of animal performance;
- Intake of grass juice and how it changes with amount of free water offered. Growing 130 kg bulls can consume 25 to 30 kg/day of freshly extracted sugar cane juice;
- Shelf life of grass juice. Because of its high soluble-sugar content, sugar cane juice ferments within 10 to 12 hours of extraction;
- Voluntary intake of pressed grass stems. There may be little production benefit by feeding all the residual pressed Napier grass stalks to milking cows;
- Total forage intake and milk response. The ultimate measure of potential success would be the additional milk produced on a diet based on ad libitum forage components (leaves, pressed stems and juice) with additional protein and energy supplements to formulate an ideal ration for tropical smallholder dairy systems. Current recommendations for Napier grass are to offer 50 kg fresh forage per day (that is 6 to 8 kg DM/day); and

- Costs and benefits from Napier grass fractionation. Unless there were economic benefits in this process, it is unlikely to be adopted, except possibly by farmers with high-yielding dairy herds who would benefit more from the improved voluntary intakes of processed forage. The economic benefits would obviously have to take into account the investment of a roller mill, and motor if required.

Only after answering most, if not all, of these questions can feeding systems incorporating physical fractionation of Napier grass stems, be developed and adopted by smallholder farmers trying to produce more milk from their limited areas of forage.

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# Utilisation of tannin-containing tree leaves in sheep and goat production

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## SUMMARY

The productivity of small ruminant livestock in arid and semi-arid regions of India is constrained by the low quality of native grasses and straws and the shortage of good quality feed, especially during the long dry season. These regions are inhabited by various fodder trees such as *Prosopis cineraria*, *Acacia nilotica*, *Albizia lebbek*, *Ailanthus excelsa*, *Azadirachta indica* and *Bauhinia racemosa*. Leaves of *Prosopis cineraria* are one of the most important feeding resources in these regions, especially during the dry season, since the leaves remain green during summer. These leaves are highly nutritious (contain 165 g crude protein/kg DM) and palatable, despite containing about 90 g condensed tannins/kg DM and 3.5 g hydrolysable tannins/kg DM with a protein precipitating capacity of 112 g bovine serum albumin precipitated/kg DM. The supplementation of tree leaves in sheep and goats increased milk yield by 58 to 61 percent. Dried leaves of *Zizyphus nummularia* and *Prosopis cineraria* fed with concentrate at 50:50 ratio to lambs and kids increased growth, feed efficiency and meat production. The supplementary feeding of *Prosopis cineraria* leaves and pods induced oestrus in 73 percent of goats and increased twinning to 33 percent as compared with 3–4 percent recorded under routine management without supplementation of tree leaves or pods.

**Keywords:** goat, methane, sheep, tannins, tree leaves

## INTRODUCTION

Sheep and goats play a pivotal role in sustenance of the economically- and socially-weaker section of population in arid and semi-arid regions of India. About 90 percent of small ruminants are maintained under extensive range management on native ranges, fallow land, wasteland and forest. The rangeland supports a full spectrum of production systems from secondary to traditional nomadic and semi-nomadic. Top feed constitutes an important component of feed for small ruminants in arid and semi-arid tropics. Tree leaves and pods are rich sources of protein and their supplementary feeding in sheep and goats improve growth, production and reproduction.

## BIOMASS YIELD AND CARRYING CAPACITY

In India, 80–90 percent of community grazing-land is in poor to very poor condition due mainly to over-stocking and year-round grazing without resting the pasture, all of which does not allow vegetation to grow and attain peak yield (Shinde *et al.*, 1998a). In general, sheep and goats on pastures start gaining weight after the monsoon and attain maximum weight during winter. Subsequently, these animals lose weight with the onset of summer in the semi-arid region (Shinde *et al.*, 1998b). The lush vegetation of the post-monsoon season cannot be effectively harvested and conserved due to the prevailing wet season. Further, the growth cycle of vegetation in arid and semi-arid environments is completed in less than 90 days and hence livestock survive on sparse vegetation for most of the year.

The biomass yield of semi-arid community grazing-land is recorded to be 1.5, 1.6 and 0.09 tonnes/ha during the monsoon, winter and summer seasons, respectively. The *Cenchrus ciliaris*-dominated cultivated pasture in semi-arid environments has average biomass yield of 2.0 tonnes/ha which can maintain five sheep or one Adult Cattle Unit (ACU) round the year (Table 1). Establishment of silvopasture with various tree combinations has biomass yield ranging from 2.0–2.5 tonnes/ha, adequate to maintain 6 sheep or 1.2 ACU round the year.

Lambs reared on a multi-tier silvopasture at a stocking density of 12 lambs/ha for a period of 3–6 months attain body weight of 18.0 kg at 6 months with an average daily gain (ADG) of 53 g. Kids, born during September to October, grazing protected range occupied by a sufficient number of fodder trees and shrubs attain 18–20 kg body weight with ADG of 75–80 g from 3–6 months of age. Kids born during the spring season and grazing on protected ranges often remain under-nourished during their major growth phase and hardly attain 14–15 kg weight at 6 months of age. Kids raised on *Cenchrus* pasture attain body weights of 15.4 kg at 3 months and 26.0 kg at 6 months of age, under grazing with concentrate supplementation at 1.5 percent of body weight.

Silvopasture systems are considered to be most ideal for rearing kids because the latter show preference for browse species. Kids attained 22 kg finishing weight at 6 months with 101 g ADG. Carcass yields of kids were 40.6 and 50.2 percent on live weight and empty live weight bases respectively.

Avivastra (a wool breed evolved at Central Sheep and Wool Research Institute, Avikanagr, India) lambs on semi-intensive feeding system grazing *Cenchrus* pasture and supplemented with concentrate at 1.5 percent of body weight yield 1.30 kg wool in the first 6-monthly clip.

## USE OF TANNIN-CONTAINING TREE LEAVES FED WITH POLYETHYLENE GLYCOL (PEG) UNDER EXTENSIVE SYSTEM OF REARING

Browse species constitute over 60 percent of the intake of range goats. However, the use of browse by goats is restricted in many cases, due to the presence of a high concentration of tannins. Tannins restrict feed-protein utilisation in animals, due to their binding to exogenous as well as endogenous proteins. Polyethylene glycol (PEG), a non-nutritive synthetic polymer with high affinity for tannins renders them inert by forming PEG-tannin complex. Treatment of tannin-rich tree/shrub leaves with binders such as PEG offers a means of enhancing their nutritive value and improving animal productivity. However in the majority of the cases cost is a limiting factor.



## USE OF TREE LEAVES UNDER INTENSIVE SYSTEM OF REARING/ COMPLETE FEED BLOCK

The prime objective of economic mutton/chevon production is to reduce feed costs without compromising growth. Under an intensive system of small ruminant production in India, the weaners (usually after 3 months of age) are housed indoors and are offered a diet of ad libitum concentrate mixture and roughage. The animals tend to consume more concentrate, leaving the roughage portion. This often defeats the concept of economic meat production. One way of overcoming this problem is by feeding the animals with complete feed block (CFB). In CFB, the roughage portion can be straw or tree leaves. We have demonstrated the effective utilisation of tree leaves containing tannins in CFB with the addition of PEG.

## SUCCESS OF FEEDING TREE LEAVES TO SHEEP AND GOATS UNDER EXTENSIVE, SEMI-INTENSIVE AND INTENSIVE SYSTEMS OF MANAGEMENT

By feeding ruminants with tree leaves containing tannins, there is a shift in the nitrogen excretion from urine to faeces, which is beneficial in terms of preventing environmental pollution and better utilisation of nitrogen through application of manure.

Feeding of as little as 5 g PEG-6000 per day alleviated the negative effects of *Prosopis* tannins on protein digestion in kids and also improved voluntary intake of foliage and

TABLE 1  
Biomass yield, carrying capacity and production performance of sheep on different types of pastures

Pastures	Biomass yield (tonne/ha)	Carrying capacity (sheep/ha)	Growth rate (g/day)	Carcass yield (%)	Annual fleece (g/head)
Degraded rangeland	0.4–0.45	1	35–45	35–37	800–900
Protected rangeland	0.8.0–1.0	2	50–60	40	950–1050
<i>Cenchrus</i> /Sewan pastures	1.6–2.0	4	70–80	42.5	1200–1300
Grass-Legume pastures	2.2–2.5	6	90–100	45	1500
Two-tier silvopastures	2.2–2.5	6	90–100	45	1500
Three-tier silvopastures	3.0–3.5	7–8	100–120	47.5	1500–1600
<i>Cenchrus</i> /Sewan pasture + concentrate supplementation	Grazing		66	40	620
	25% of ad libitum		90	43	800
	50% of ad libitum		100	48	900
	75% of ad libitum		110	49	1200
	ad libitum		125	51	1250

growth performance (Bhatta *et al.*, 2002). Instead of providing a supplement with a high-protein concentrate feed mixture (CFM) (CP 210 g/kg DM) to kids browsing tannin-rich foliage, a low-protein CFM (140 g/kg DM) supplement with a small quantity of PEG (5 per cent) can be used. The conventional protein source (say groundnut protein) can be spared for human consumption and the *Prosopis* leaf protein can be utilised efficiently for animal feeding (Bhatta *et al.*, 2005a). If PEG is commercially available at a cheaper cost, then these findings could greatly improve the productivity of grazing small ruminants.

*Albizia lebbbeck* appears to be nutritionally better than *Prosopis cineraria* and *Acacia nilotica* leaves (Table 2); however supplementation with *Prosopis* leaves has an edge over the other two because of the better rumen-fermentation pattern obtained, resulting in lower loss of nitrogen. Maximum nutritional and economic benefits could be achieved if fodder trees were used as a supplement rather than as a sole feed (Bhatta *et al.*, 2005a; 2005b). Supplementation with tree leaves containing low levels of tannins has an additional advantage because these improve overall nitrogen use in the whole system.

During lean seasons supplements of concentrate mixture (containing about 130 g CP/kg) could be safely replaced with leaves of *Ailanthus excelsa*, *Bauhinia racemosa* and *Azadirachta indica* to maintain body weight of animals. The performance of lambs and kids fed on a total-mixed-ration containing 50 percent *Prosopis* leaves was the best in terms of feed efficiency ratio. The effect of *Prosopis* tannins was different in lambs and kids. A high intake of *Prosopis* tannins had a detrimental effect on digestibility of nutrients and growth performance in both species. However the performance of kids was better than lambs, indicating greater tolerance of goats to *Prosopis* tannins (Bhatta *et al.*, 2007).

## TANNINS AS METHANE SUPPRESSANTS

*In vitro* and *in vivo* studies have confirmed that tannins suppress methanogenesis directly through their antimethanogenic activity, and indirectly through their antiprotozoal activity. Samples containing both hydrolysable tannins and condensed tannins were more potent in reducing methanogenesis than those containing hydrolysable tannins only (Bhatta *et al.*, 2009).

TABLE 2  
Nutritional composition of major tree leaves and their tannin concentration

(g/kg DM)	<i>Prosopis cineraria</i>	<i>Acacia nilotica</i>	<i>Albizia lebbbeck</i>	<i>Ailanthus excelsa</i>	<i>Azadirachta indica</i>	<i>Bauhinia racemosa</i>
CP	118.6	139.6	194.1	197.1	128.0	132.0
NDF	519.0	262.8	369.8	240.9	363.4	477.6
ADF	404.2	126.7	250.4	181.9	265.5	327.8
CT	90	-	-	-	123.2	211.2
HT	3.5	18.9	-	-	-	-

CP, crude protein; NDF, neutral detergent fibre; ADF, acid detergent fibre; CT, condensed tannins as leucocyanidine equivalent; HT, hydrolysable tannins as gallotannins

Tannins at low levels suppress CH<sub>4</sub> emission without adversely affecting the digestibility of nutrients. However at higher levels of tannins intake, CH<sub>4</sub> suppression was also attributed to reduced organic-matter fermentation. These results suggest that tannins have the potential to minimise CH<sub>4</sub> emission by ruminants and tree leaves containing tannins could be used for this purpose.

### TECHNOLOGY ADOPTION AND THEIR IMPACT

Feeding *Ailanthes indica*, *Prosopis cineraria* and *Bauhinia racemosa* leaves to goats increased milk yield (by 58 percent) and increased protein and solids-not-fat (SNF) content of milk. Lambs and kids given supplements of *Ailanthes excelsa* and *Dicrostachys nutans* leaves whilst grazing *Cenchrus ciliaris* grass attained 20–22 kg body weight at 6 months of age.

The pods of *Acacia nilotica*, *Acacia tortolis* and *Prosopis cineraria* are also fed to goats and sheep in these regions. These pods are rich in protein (13–15 percent) and contain a lower level of rumen-degradable protein and a higher proportion of branched-chain amino acids. Supplementation with *Acacia* pods induced oestrus in 74 percent of goats. Supplementary feeding with *Prosopis cineraria* leaves and pods increased twinning rate to 33 percent as against 3–4 percent recorded under a routine management system in the Kutchi breed of goats.

### ADOPTION OF TECHNOLOGIES AT FARMERS' END AND FUTURE OF THESE TECHNOLOGIES

Farmers utilise the top feeds either by feeding fresh tree foliage/pods to sheep and goats or by feeding dried/conserved tree leaves during scarcity periods. Fresh tree leaves of *Azadirachta indica*, *Prosopis cineraria* and *Zizyphus nummularia* are lopped and fed to small ruminants by farmers during the winter season. Leaves are offered up to 30–40 percent of the total feed intake to avoid any deleterious effects of tannins on animal performance. It is a general practice to offer top feeds after grazing (6–8 hours/day) so as to prevent any negative effect of leaves on grazing. Moreover, tree leaves are fed when they are highly-palatable and relished by the animals e.g. *Azadirachta indica* leaves are fed only during the winter season. In certain areas, fresh loppings are transported for feeding to stall-fed animals.

Under field conditions, *Acacia nilotica* and *Prosopis cineraria* pods are used as a protein and energy supplements in the diets of sheep and goats to induce oestrus. Feeding pods synchronises oestrus and improves overall reproductive performance by increasing prolificacy (higher birth rate) and improving the birth weight of lambs and kids. *Prosopis cineraria* and *Zizyphus nummularia* leaves are often conserved as dried leaves and fed as a supplement to growing, lactating and pregnant sheep and goats.

The complete feed block (Bhatta *et al.*, 2005c), incorporating tannin-containing tree leaves has a great potential in small ruminant production. A combination of 50:50 tree leaves and concentrate mixture has shown promising results under intensive system. This feeding strategy is very useful because the grazing lands are being rapidly depleted due to increasing urbanisation in many parts of India.

There is need to evaluate cost: benefit ratio of PEG inclusion. It may be noted that inclusion of a small amount of PEG in tannin-containing diets increases animal performance substantially. Certainly making available PEG at a reduced cost would provide impetus to this technology.

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# Economic utilisation of saline marginal lands for animal production

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## SUMMARY

Salinity is one of the major agricultural problems in Pakistan. About 6.2 million hectares of land in Pakistan is affected by salinity. Nuclear Institute for Agriculture and Biology (NIAB) has developed a biological approach to overcome this problem. Plants suitable for saline soils were identified through extensive studies and the biomass produced from these plants was evaluated as a novel feed resource for livestock. Various studies were conducted on goats and sheep to evaluate the potential of salt-tolerant plants such as *Acacia ampliceps*, *Brachiaria mutica*, *Cynodon dactylon*, *Desmostachya bipinnata*, *Echinochloa colona*, *Eleusine flagellifera*, *Kochia indica*, *Sesbania aculeata*, *Sorghum vulgare*, *Sporobolus arabicus* and *Suaeda fruticosa*. The use of salt-tolerant plants proved successful under saline conditions and could be used for poverty alleviation by improving the income of poor small farmers on saline lands. A net profit of approximately US\$1 038 per ha was recorded on one goat farm using this technology. Moreover, the technology provides a continuous and long-term income to farmers on the waste, saline lands.

**Keywords:** rearing of livestock, saline lands, salt-tolerant plants

## INTRODUCTION

Salinity is threatening sustainable agriculture worldwide. Twenty percent of the world's irrigated lands are saline or irrigated with saline water. Through appropriate crop-based management and viable biological systems, economic opportunities could be generated from salt-affected lands and from lands that use saline water (Qadir *et al.*, 2008). In Pakistan out of 23 million ha, 6.2 million ha are affected by salinity. Among the saline lands 0.2 million ha are slightly saline, 2.3 million ha moderately saline, 1.5 million ha highly saline and 2.0 million ha very-highly saline (Agriculture Statistics of Pakistan, 2004; Khan, 2007).

In Pakistan ruminants are mostly fed on low-quality roughages, which are low in protein, energy, minerals and vitamins. Addition of foliage from tree species to ruminant diets can improve the utilisation of low-quality roughages, mainly through supplying nitrogen to rumen microbes. Ruminants can make efficient use of non-conventional feeds such as salt-tolerant plants (containing tannins and oxalate) because of microbial interventions in the rumen. The feed shortage for livestock has prompted rearing livestock on saline lands.

Additionally, the cash crops are not salt-tolerant and may not be cultivated on highly-saline lands especially where subsurface water for irrigation is also salty.

Because environmental conditions on salt-affected lands generally remain too harsh, raising dairy buffalo and cows is not practical on these lands. Small ruminants (sheep and goat) are better adapted to such areas and have an edge over large animals (Khanum *et al.*, 2001). Small ruminants have the ability to utilise low-quality salt-rich fibrous feeds and can also tolerate vagaries of the physical environment in degraded/eroded areas (Khanum *et al.*, 2007; Khanum, Hussain and Hussain, 2010).

### **EXPERIENCES OF APPLYING THE TECHNOLOGY IN THE FIELD (FARMERS' FARMS):**

The NIAB's mandate is to demonstrate developed technologies to farmers. Most times, this was achieved by providing information on the outcome of saline livestock production technology in the form of brochures of "Package of practices" and by demonstrations of the technology to farmers. Farmers were also given technical know-how about the practical aspects of rearing sheep and goats on their saline lands. Farmers were also trained on nutrition and management aspects of animals, including approaches to combat the anti-nutritional factors in feeds grown/available on saline lands. In order to satisfy the nutritional requirements of livestock during feed-scarcity periods and under saline-stress conditions, farmers were provided urea-molasses-multi-nutrient blocks (UMMB) or alternatively, given know how on the block-making technique.

The NIAB, under a Government of Pakistan funded project entitled, "Saline Agriculture Farmer Participatory Development Project (SAFPDP)", aimed to reclaim saline lands with the participation of farmers, investigated the utilisation of green biomass raised on saline lands for livestock rearing. The technology-transfer activities were carried out at farmers' farms at four locations in the country. The farmers were given necessary demonstrations and training on the utilisation of salt-tolerant plants for animal feeding. Learning from these experiences, a package of technology on *Livestock farming for economic utilisation of saline waste lands* was produced and disseminated to the farmers.

With the increased forage-base the number of animals increased substantially on poor saline lands. The economics of rearing 100 goats at Shorkot site under SAFDPDP project on 4.04 ha saline land containing *Acacia ampliceps* and 0.8 ha of other grasses (Para grass and Kallar grass) is presented in Table 1. The annual net returns from the enterprise show a net return of US\$1 038.20 per hectare, which is similar to that obtained with cash crop production on normal lands.

### **STATUS OF APPLICATION OF TECHNOLOGY BY FARMERS**

The technology has only been partially adopted. This could be attributed to multiple factors including lack of extension networks in the areas far from the rural countryside, lack of infrastructure for starting livestock rearing on saline lands, and the financial and social constraints. Low farmer-adoption of the livestock-based saline-land reclamation programmes was because farmers usually take a long time to get convinced about the advantages of a technology. The benefits from livestock rearing are generated after about three to four years, unlike cash crops where returns are much quicker, normally after five to six months

TABLE 1  
Economics of a herd of 100 goats raised on saline lands during 2009–2010

Item	Value (Rupees)	Value (US\$)
Cost of feeding	200 000	2 352.9
Cost of vaccines and treatment	10 000	117.7
Water and electricity charges	6 000	70.6
Depreciation/Maintenance	20 000	235.3
Land rent	36 000	423.5
Total annual expenses	2 72 000	3 200.0
Annual sales	700 000	8 235.3
Net returns per year	428 000	5 035.3
Returns/acre	35 666.7	419.6

1 US\$ = ca 85 Rupees

or one year. Another reason for partial and lower technology-transfer rates is the scattered and isolated location of the farmer units. At times it is difficult to contact the majority of farmers. It is also challenging to follow-up the programme and assess the success or failure of the technology transfer under conditions of poor literacy-rates and sub-level extension services.

### CONSTRAINTS OF THE TECHNOLOGY

Despite the competitive edge of small ruminants on marginal and waste saline lands, certain constraints have been recognised during the course of the technology transfer. These include

- Developing pastures on barren saline lands is time-consuming for resource-poor farmers; and
- Diseases/infections and cold stress could take a heavy toll under saline conditions. Due to poor nutrition, relatively uncomplicated disease conditions may become severe.

### LESSONS LEARNT

- The technology for livestock production under saline lands offers a practical option for reclamation of saline waste lands and the use of biomass produced for livestock feeding.
- Rearing of livestock on saline lands offers a long-term and continuous source of income to farmers. A part of the herd can be sold to meet the day-to-day expenses, while keeping the breeding stock.
- The refusals of feed by the livestock can be used as fuel by the farmers in agroforestry-based agricultural system on saline lands, which is of advantage to the farmers.
- The manure added to the field improves soil fertility and mitigates the negative effects of salinity more efficiently compared with that of a "crop only based system".

## FUTURE OF TECHNOLOGY

There is a growing interest among the farmers in establishing their own pasture on saline lands. The increasing mutton price as well as the high demand for mutton in the country is expected to result in faster adoption of the technology.

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# Spineless cactus (*Opuntia* spp.) in low-input production systems in dry areas

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## SUMMARY

Inadequate year-round supply of feed resources is one of the most important factors contributing to low animal production in arid and semi-arid regions. The continuous and rapid degradation of range vegetation coupled with the irregular availability of roughages and the frequent leaps in the price of concentrate feeds are threatening the productivity and sustainability of the livestock-based production systems in these regions. Alternative technologies have been developed to address some of these challenges. Described as “bank of life” and “dromedary of the plant world”, cactus is a drought-tolerant species which can grow in harsh environments. The multi-purpose uses of cactus empower the rural population to better face the challenges of living in low-rainfall areas. Cladodes, fruits, seeds and flowers of cactus have a number of applications, and their use has been shown to increase income of farmers. Characterisation of cactus and the advantages of its use in livestock-based production systems are discussed in this article. The extent of adoption of cactus cultivation and feeding to livestock by farmers is also presented.

**Keywords:** *benefits, cactus, dry areas, livestock, production systems*

## INTRODUCTION

The dynamic changes in production systems over the last few decades, driven mainly by high demand for animal products, competition between food and feed, continuous and rapid degradation of rangelands, and imbalance between nutrient provision and livestock requirements, are threatening the sustainability of livestock-based production systems (Ben Salem and Smith, 2008). Feed scarcity and high cost of feed coupled with the instability of their prices in the international market have rendered the use of alternative and local feed-resources a priority in many countries. The use of multi-purpose plants in dry areas is an attractive option. However the range of plants that can grow under drought conditions and on low-quality soils is restricted to only few, prickly pear cactus (*Opuntia* spp.) being one of them. Brazil, Italy, Mexico, South Africa and Tunisia have introduced cactus and are using them as forage or for fruit production, while India, Mauritania and Pakistan have introduced them recently. The importance of spineless cactus for boosting productivity and sustainability of livestock-based production systems in dry areas and for improving livelihoods of rural populations is presented.

## CHARACTERISTICS OF CACTUS

Cactus is a succulent plant well-adapted to extreme climatological and edaphic conditions. Its high water-use efficiency enables it to withstand severe drought conditions. Cactus can grow in areas having 200 mm/year of rainfall and high temperatures, and thrives where common forage species cannot grow. The establishment of cactus is easy and ploughing, fertilising, irrigating and treatment with pesticides being unnecessary. Simple cladodes or preferably double cladodes are placed in furrows, and then about one-third length of the cladode or double cladode is covered with soil. The planting density (number of cladodes per ha) depends on the farmer's objectives. Cactus cladodes and fruits can be harvested after three years of establishment.

*Uses of cactus.* All parts of cactus (roots, flowers, fruits, seeds and cladodes) have been used for various applications. The juicy, ripe fruits are consumed fresh and the younger, tender cladodes are utilised fresh or cooked in a variety of dishes. A number of research programmes evaluating the positive effects of different parts of cactus have been initiated during the last decade. Positive effects of cactus on human health include anticancer, anti-diabetic (Type II), anti-inflammatory, antiviral, antihyperlipidemic, antihypercholesterolemic and antioxidant effects. Cactus fruit and cladode yield high-valued, important nutrients, such as betalains, amino compounds, minerals, vitamins and antioxidants. The chemical composition of cactus fruits and cladodes and their nutritional values have also been widely studied.

*Biomass production.* Biomass yield of cactus (cladodes and fruits) depends upon several factors including planting density, rainfall, soil texture and fertilisation. Overall, the yields vary between 30 and 100 tonnes of fresh cladodes and 2 and 20 tonnes of fruits per hectare per year. Interestingly, higher cladode yields (>160 tonnes fresh cladodes/ha) were achieved in northern Brazil where intensive plantation (density 5 000–40 000 cladodes/ha) and appropriate fertilisers (organic and/or chemical) were applied (Dubeux and Santos, 2005). Felker (1995) reported a yield of 400 tonnes/ha/2 years of cactus cladodes when fields were fertilised with 100 tonnes bovine manure/ha and 200 kg N/ha. Based on these data, one hectare would produce a consumable biomass yield that exceeds those of many common forage species when cultivated in semi-arid and arid regions. The moisture content of cactus is around 90 percent and animals consuming cactus cladodes will reduce and even stop drinking water (Ben Salem and Abidi, 2009). This is certainly an advantage for raising livestock in dry areas or during drought periods.

*Cactus in alley-cropping.* Alley-cropping consists of cultivating herbaceous vegetation between rows of shrub species. This technique improves soil, increases crop yield, reduces weeds and improves animal performances. Compared to barley alone, the total biomass (straw and grain) of barley cultivated between the rows of spineless cactus increased from 4.24 to 6.65 tonnes/ha and the grain yield from 0.82 to 2.32 tonnes/ha (Alary *et al.*, 2006). The barley crop stimulated an increase in the number of cactus cladodes and fruits, while the cactus increased the amount of root material contributing to the soil organic matter.

*Nutritive value of cladodes.* Nutrient contents of cactus cladodes vary with age, cultivar, species and fertilisation. The cladodes are high in carbohydrates (*ca* 600 g/kg dry matter, DM), starch (*ca* 75 g/kg DM), calcium (40–80 g/kg DM),  $\beta$ -carotene (*ca* 0.65 mg/100 g DM) and oxalates (60–120 g/kg DM) (Ayadi *et al.*, 2009; Ben Salem and Abidi, 2009). The

oxalates are present in insoluble form, thus have no direct effect on animal health but they form insoluble complexes with calcium. The cladodes are low in fibre (neutral detergent fibre, NDF, 170–300 g/kg DM) and crude protein (30–70 g/kg DM) (Santos *et al.*, 2005; Stintzing *et al.*, 2005). Therefore, association of a fibrous feedstuff and a nitrogen source should be emphasised when cactus is fed to ruminants. Attempts have been made to increase nitrogen content of cactus cladodes through fertilisation (Gonzalez, 1989), breeding (Felker and Inglese, 2003) and solid-state fermentation (Araújo *et al.*, 2005). It is worth noting that cladodes are high in malic acid (a hydrogen acceptor in the rumen), therefore, the introduction of cactus in livestock feeding could also reduce methanogenesis, thus contributing to decreasing greenhouse gas emission.

*Cactus in livestock feeding.* Cladodes are often fed to ruminants with fibrous feedstuffs (e.g. straws and hays) to avoid disturbances in rumen functioning. When mixed with cereal straws, cactus can maintain a sheep herd until water and better feeds become available. Cladodes are a low-cost source of energy, and sheep fed with large amounts of cactus for long periods are able to survive without water. Some data showing responses of different ruminant species to cactus cladodes in the diet are presented in Table 1. Replacing barley with cactus cladodes had no adverse effect on digestion and growth in lambs (Ben Salem and Abidi, 2009) and on performance of late pregnancy-early suckling ewes (Rekik *et al.*, 2010). Total replacement of maize and barley with cactus could be achieved without any adverse effects. However with forages such as hay, straw and silage the replacement level should not exceed 50 percent, otherwise DM digestibility, daily gain and milk production are impaired (Ben Salem and Abidi, 2009).

Cactus can be used in ruminant feeding as fresh, dried or ensiled forms. Cactus cladodes are mostly fed fresh to cows, sheep, goats and dromedaries. In order to avoid material loss, it is recommended to cut cladodes into small slices before offering to animals. Tegegne *et al.* (2005) showed that compared to a control diet (without cactus) sheep performed better when part of grass hay was replaced by fresh cactus. Total replacement of barley (300 g) by fresh cactus (ca 3.5 kg) had no effect on hay intake, *in vivo* organic matter (OM) digestibility and nitrogen balance in male lambs and kids (Abidi *et al.*, 2009).

Cactus cladodes can be dried, and then ground. The meal obtained can be used as a supplement feed for animals. Veras *et al.* (2002) reported lambs on elephant grass hay supplemented with maize or cactus meal had similar OM intakes and OM and NDF digestibility.

Çürek and Özen (2004) evaluated the nutritive value of chopped cactus cladodes (1–2 cm), wilted (DM content 35 percent) which were then ensiled. Based on pH and organic acid contents, the quality of the silage was acceptable but its nutritive value was low. It might be advantageous to ensile cactus mixed with other ingredients. Abidi (2010) ensiled fresh cladodes with olive cake and wheat bran. Replacing oaten hay with this silage had no effect on digestible nutrient intakes but decreased the average daily gain of concentrate-supplemented lambs from 50 to 37 g. However, scarcity and high price of oaten hay during drought periods would fully justify the use of cactus-containing silage.

*Impact of cactus feeding on meat and milk quality.* Data on the effect of cactus feeding on meat and milk quality in ruminants are scarce. Abidi *et al.* (2009) concluded that cactus cladodes could replace barley in the oaten hay-based diet of lambs and kids without detrimental effect on meat quality. The substitution of maize and Tifton hay with increasing

TABLE 1  
Responses of different ruminant species to cactus containing diets

Animal	Feed replaced by cactus	Replacement levels (%)	Animal responses
Cattle <sup>a</sup>	Maize	0, 100	No effect on milk production
Cattle <sup>b</sup>	Sorghum silage	0, 12, 24, 36	No effect on DM intake, milk production
Dairy goat <sup>c</sup>	Maize meal	0, 7, 14, 21, 28	No effect on milk production (1.5–1.6 kg/day) Substantial decrease of drinking water (5.2 vs. 0.1 kg/day)
Lamb <sup>d</sup>	Maize meal	0, 25, 50, 75	No effect on nutrient intake and DM digestibility
Lamb <sup>e</sup>	Grains	0, 20, 30, 40	No effect on average daily gain
Lamb <sup>f</sup>	Barley	0, 100	Lambs given cactus and soyabean meal (SBM) performed better (120 vs. 110 g body weight gain/day) than those supplemented with barley and SBM
Lamb <sup>g</sup>	Grass hay	0, 20, 40, 60, 80	Cactus could replace up to 60% of hay Highest daily body weight gain (33 g) obtained when cactus replaced 20% of hay Decrease of water intake with 40% level of cactus
Lamb <sup>h</sup>	Teff straw	0, 25, 50, 75	Highest daily weight gain when cactus replaced 50% of teff straw (23 vs. 53 g) CP and NDF digestibility decreased with increasing level of cactus
Kids <sup>i</sup>	Barley	0, 100	No effect on intake, DM digestibility, microbial-N supply and average daily gain

<sup>a</sup> Lima *et al.*, 2003; <sup>b</sup> Wanderley *et al.*, 2002; <sup>c</sup> Costa *et al.*, 2009; <sup>d</sup> Veras *et al.*, 2002; <sup>e</sup> Veras *et al.*, 2002; <sup>f</sup> Ben Salem *et al.*, 2004; <sup>g</sup> Tegegne *et al.*, 2005; <sup>h</sup> Gebremariam *et al.*, 2006; <sup>i</sup> Abidi *et al.*, 2009.

levels of cladodes (0, 12.5, 25, 37.5 and 50 percent) had no effect on milk production and milk fat content in dairy cattle. However the profile of medium and long-chain fatty acids in milk was altered. In goats, Costa *et al.* (2010) concluded that cactus could replace up to 50 percent of maize meal without significant effect on milk composition. However at higher substitution rates, milk fat and total solids decreased. A diet containing up to 50 percent of cactus cladodes would not adversely affect meat and milk quality in cattle, sheep and goats.

### EXTENT OF ADOPTION OF CACTUS CULTIVATION AND FEEDING TO LIVESTOCK BY FARMERS

In Tunisia, farmers consider cactus cultivation as a profitable venture because of its multi-purpose nature and low establishment and maintenance costs. Once established on either natural rangelands or marginal cereal cropping lands, cactus becomes a good source of income for the farmers. The high internal rate of returns (IRR) obtained with cactus plantation in Algeria (99 percent, Redjal, 2005) and Tunisia (80 percent, Elloumi *et al.*, 2005) is demonstrative of the high profitability that could be achieved on adoption of

this technology, even on marginal lands. The highest IRR was obtained with cactus-barley alley cropping. Cactus planting on marginal lands was highly profitable. In Tunisia 700 000 ha are cropped with cactus, and within this are approximately 500 000 ha are cropped with spineless cactus (*Opuntia ficus indica* f. *inermis*). The national strategy of rangeland improvement which started in 1990 has played an important role in the expansion of spineless cactus plantations in Tunisia. Cactus is a highly-subsidised crop in Tunisia. It is subsidised by the government through the Pasture and Livestock Agency (OEP). Under this, a contract is established between the state and the farmer owning livestock. The contribution of the farmer is about 25 percent of the total cost of cactus plantation, which is in the form of ploughing the soil, planting cactus cladodes, and maintaining the planted area during the first three years. The OEP offers cladodes (US\$0.03–0.04/double cladode) and reimburses a part of the farmer's expenses (soil preparation. US\$10.71/ha, planting US\$28.57/ha). The OEP also allocates a compensation of US\$28.57, 39.28 17.86 per hectare annually in the north, centre or south respectively for the first three years for not allowing the animals to graze in the planted plots during this period. These compensation fees are determined on the basis that one hectare of native rangeland before cactus plantation produce 160, 120 or 80 kg barley in the north, centre and south of Tunisia, respectively. This participatory and integrated approach was the key to boosting the adoption of the cactus technology by Tunisian farmers. The total number of beneficiaries during the period 1990–2009 was about 6400 farmers and the area planted with spineless cactus with the intervention of OEP was 135 340 ha. On the other hand, less than 4 000 ha were planted with fodder shrubs during the same decade under the framework of this strategy, suggesting that the adoption of the cactus technology has been highly favoured by farmers.

## FUTURE OF THE TECHNOLOGY

The use of cactus could reduce the amount of concentrate feeds, decrease feeding cost, secure animals raised under severe harsh conditions and decrease water consumption by animals. Besides, farmers could increase their income by selling cladodes and fruits. These features of cactus make it an attractive technology/practice to mitigate the adverse effects of drought and harsh environmental conditions on animal performance and to combat desertification. Moreover, the increasing demand of pharmaceutical and food-industry companies for cactus products (e.g. seed oil and cladode meal) would give further impetus to the development of cactus in low-input production systems. The promotion of cactus would boost the productivity, ensure sustainability of livestock-based production systems in the dry areas and enhance farmers' income.

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# Azolla: a sustainable animal feed?

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## SUMMARY

*Azolla*, commonly known as duck weed fern, is a waterborne blue green algae mainly used as a biofertiliser in rice fields in many parts of the world. It is also being promoted as a feed supplement for livestock in many countries including India. Available reports indicate that *Azolla* is an economic and efficient feed supplement for livestock, containing substantial amounts of protein, vitamins and minerals. When used in feed for lactating cattle, *Azolla* increased milk production by 15 to 20 percent, yet it has not become popular as a sustainable feed. *Azolla* use is in its infancy in India, nevertheless it is being promoted by non-government organisations, cooperatives and government agencies and interest in its use is catching up, although sporadic.

**Keywords:** *animal feed, azolla, supplement*

## INTRODUCTION

*Azolla* is a free-floating fresh water fern belonging to the family *Azollaceae* and order Pteridophyta. Six species of *Azolla* are commonly found in the tropics and sub-tropics. It grows naturally in stagnant water in drains, canals, ponds, rivers and water bodies including marshy lands (Photo 1). The plant is highly productive with the ability to double its weight in seven days. It can produce 9 tonnes of protein per hectare of pond per year. *Azolla* is cultivated widely in China, Vietnam, Philippines, Thailand, Brazil and many other countries, mostly along rice fields. It is rich in crude protein (18–20 percent in dry matter), minerals, chlorophyll, carotinoids and vitamins, and is a potential feed ingredient for livestock (Lumpkin, 1984) and broilers (Singh and Subudhi, 1978).

The potential use of *Azolla*, as a biofertiliser and animal feed makes it an attractive and effective input for both the vital components of integrated farming: crops and animals. It has a good nutrient profile (Table 1) though its low dry matter content is a negative attribute (Huggins, 2007).



**photo 1**

*Azolla* growing naturally in stagnant water

TABLE 1  
Comparison of *Azolla* feed with some common feeds

Product name	Dry matter (%)	Metabolisable energy (MJ/kg DM)	Crude protein (% in DM)	Neutral detergent fibre (% in DM)
<i>Azolla</i>	5.7	9.0	18.4	46.0
Quality pasture	15.0	11.0	22.0	39.0
Summer pasture	20.0	10.5	17.0	44.0
Lucerne hay	88.0	10.0	23.0	44.0
Wheat grain	90.0	12.7	12.0	12.0
Canola meal	90.0	12.0	38.0	20.0

### EXPERIENCES OF APPLYING TECHNOLOGY/PRACTICE IN THE FIELD

*Azolla* is used as a feed for pigs and ducks in South-East Asia, for cattle, fish and poultry in Vietnam and for pigs in Singapore and Taiwan. It is an excellent substitute for green forage for cattle and may replace up to 50 percent of the rice bran used as feed for pigs in Vietnam. The amino acid composition of *Azolla* also compares favourably with the FAO reference protein sources. Methionine content is low, as in many leaf proteins, but lysine content is more than twice that of maize. In growing pigs supplementation of *Azolla* reduced the performance compared with the control, however the animals compensated and grew faster in the period from 24–89 kg. *Azolla* has been used as a sole feed for lactating sows which have a higher intake to compensate for the low DM content. Ducks (650–1 800 g live weight) consumed 350 g *Azolla* when given free-choice with sugarcane juice and soya (about 5 percent of the diet). It is also used for grazing ducks and geese in paddy fields where *Azolla* is used as a fertiliser (<http://www.fao.org/ag/AGa/agap/FRG/afris/Data/558.htm>). In the Philippines, *Azolla* was propagated for fertilising rice and for feeding animals, nevertheless has not become a very popular source of protein feed for animals (<http://www.fao.org/docrep/004/AC153E/AC153E12.htm>).

*Azolla* feeding has been practised on a number of farms in Colombia with satisfactory results, both from the biological and economic standpoints. These on-farm activities have generated invaluable information about the practice of growing and utilising *Azolla* under varying environmental conditions (Becerra *et al.*, 1990). Despite favourable experimental findings and farmer trials, concrete evidence regarding the success of *Azolla* as an animal feed at the field level is lacking. In Australia, *Azolla* cannot be fed to ruminants of any class because it contains traces of aquatic life, like fresh water shrimp, that reside in the floating plant structure (Huggins, 2007).

In China, *Azolla* when fed to pigs increased their body weight significantly (Zhuang-Ta *et al.*, 1987). Growing pigs fed *Azolla* gained 26.2 g/day more and starter pigs gained 28.4 g/day more than those fed only concentrate. On an average, 97.4 kg *Azolla* (fresh basis) produced 1 kg live weight in pigs. The daily weight gain of geese fed *Azolla* was close to those fed vegetables. The weight of grass carp fed *Azolla* was 22.8 percent higher than that of fish fed only concentrate feed. Every 31.5 kg of *Azolla* (fresh basis) increased the

weight of grass carp by 1 kg, equal to the forage coefficient of common fish fed green forage. Preliminary tests in the Philippines showed that *Azolla* meal can be used up to 10 percent in pig starter rations, 20 percent in pig grower rations, and 15 percent in broiler rations, without significantly affecting the performance of the test animals (Alcantara and Querbin, 1985). In mallard ducks, egg production and egg size were not significantly affected when fresh *Azolla* was fed up to 20 percent of the feed. Replacement of groundnut cake with *Azolla* at 50 percent level for 90 days improved the digestibility of major nutrients and resulted in higher weight gain in buffalo calves (Indira *et al.*, 2009).

*Azolla* has the potential to replace expensive concentrates in cattle and poultry diets. Feeding of *Azolla* saved 20–25 percent of cost towards the purchase of commercial feeds (Gowda *et al.*, 2010). The cost of producing *Azolla* is 0.60–0.65 Indian Rupee (US\$0.015) per kg as per the trials conducted during 2008–2009 at a Krishi Vigyan Kendra (KVK, an agricultural training cum extension centre in India). Up to 5 percent *Azolla* meal on DM basis in a broiler ration has been reported to improve performance. This inclusion rate in broiler diets was also established as safe. *Azolla* meal had no deleterious effects on palatability of broiler diets (Basak *et al.*, 2002). It improved weight of the broilers and also increased egg production in layers.

### STATUS OF APPLICATION OF TECHNOLOGY/PRACTICE BY FARMERS

In India, KVKs, cooperatives, Non-Government Organizations (NGOs), agricultural universities and other development departments have found *Azolla* to be a very promising feed option, and is being promoted by them. The feeding of *Azolla* to different animal species has also been standardised in India (Table 2). Some NGOs (e.g. Agriculture Man Ecology Foundation, Bangalore) have reported that *Azolla* as cattle feed is receiving a very good response from farmers in Kolar area of Karnataka state. Dairy cooperatives have also shown interest in providing financial support to farmers for constructing pits for *Azolla* cultivation. Tamil Nadu Agricultural University, among several other universities and KVKs, has been trying to popularise *Azolla*. These KVKs have developed demonstration units (Photo 2) on their campuses to illustrate its benefits. Dairy farmers in South Kerala and Kanyakumari, in India, have started adopting this low-cost production technology and it is believed the technology will be taken-up more widely by dairy farmers, in particular those with insufficient land for fodder production (Pillai *et al.*, 2005).

TABLE 2  
Species-wise feeding regime of *Azolla* (on fresh weight basis)

Animal	Amount/day
Adult cow, buffalo, bullock	1.5–2.0 kg
Goat	300–500 g
Pig	1.5–2.0 kg
Layer/broiler	20–30 g
Rabbit	100 g



**photo 2**  
***Azolla demonstration unit established by  
 Krishi Vigyan Kendra***

Recently, the Government of India has launched a nationwide programme “Assistance for Demonstration of *Azolla* Cultivation and Production Units” to popularise it. Under this programme, demonstrations of *Azolla* cultivation are being held to encourage production of *Azolla* as an alternate source of green fodder. In addition, training of farmers in the production of *Azolla* and materials to establish *Azolla* production units are being provided on subsidy basis. Farmers, members of milk cooperatives, KVKs, Agricultural Technology Management Agency (ATMA) are the implementing agencies for this government project.

### **LESSONS LEARNT**

The technology has not gained popularity in India even among the progressive farmers who are generally quick to accept new technologies. One possible reason for the reluctance to adopt could be unavailability of water. The growth of *Azolla* is also adversely affected under elevated or low temperatures. Hence, adoption of this technology in dry zones where the temperature exceeds 40 °C or in cold regions will be difficult.

While promoting *Azolla* for almost four years through a KVK, the following observations were made (T.N. Krishnamurthy, personal communication, 2010):

- The anticipated horizontal spread of *Azolla* as a potential feed among farmers in areas beyond the farmers on whose farms this technology was demonstrated, was not observed. The situation did not improve even after sustained extension efforts, including training programmes;
- Only the large farmers, possessing more than ten cows and generating a major part of their income from dairying, showed some interest in the technology. The small farmers practising dairying as a subsidiary to crop agriculture showed no interest;
- Even after applying the full package of practices
  - good yield was observed for the initial 2–3 months only;
  - *Azolla* turned brownish/pink and started drying off after 3 months;
  - the required removal of water and soil every 5 months was found to be difficult by farmers; and
  - even after changing water and soil, farmers did not achieve good yields.
- The animals do not accept *Azolla* as a sole feed and it needs to be mixed with concentrates or jaggery water; and

Due to high moisture content and short shelf-life, the transportation and storage of *Azolla* are difficult.

## FUTURE OF TECHNOLOGY

The empirical results from on-station trials have been encouraging. These have shown that *Azolla* is a promising feed supplement for different livestock species. However adoption of *Azolla* by the farmers has been low. Extensive extension efforts and addressing the constraints mentioned above could enhance its adoption.

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# Area-specific mineral mixture for sheep and goats

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## SUMMARY

Mineral deficiency or excess in animals are area-specific problems and influenced to a great extent by contents of minerals and their bioavailability from feeds and fodders. Sheep and goats maintained in tropical rangeland systems are normally deficient in minerals. Supplementation with area-specific mineral mixtures meets animal requirements for minerals and avoids deficiency. Mineral mixtures sold in powder form in the market have little utility in sheep flocks maintained on pastures without any kind of concentrate feed supplementation. Therefore, an alternative form of mineral mixture, i.e. a pellet form was developed for easy and effective delivery. Daily supplementation of sheep with the pelleted mineral mixture at the rate of 5 g for 5 months increased wool yield by 8 to 9 percent and for 3 months in early lactation increased milk yield by 10 to 15 percent. Supplementation also brought 60 percent of anoestrous sheep into oestrus within 15–21 days and the remaining 40 percent after 42 days. Area-specific mineral mixture improved overall productivity of sheep flocks on pasture in dry regions.

**Keywords:** *mineral mixture, performance, sheep*

## INTRODUCTION

Minerals play an important role in improving health, reproduction and production of animals (Prasad and Gowda, 2005). Mineral deficiency in animals is an area-specific problem and is related to water, soil, feed, fodder and topography. Low productivity regarding reproduction, body weight gain and milk yield are associated with mineral deficiency in sheep and goats on degraded pastures. Deficiencies of Ca, P, Zn and Cu are commonly noticed in sheep and goats in dry zones of India (Shinde *et al.*, 2006). One of the main reasons for mineral deficiency in sheep and goats is low mineral content of native grasses which constitute the major portion of their diet. Mineral mapping of soil, water, feeds and fodder helps to identify specific deficiency and assists formulating and supplying deficient minerals through production and use of area-specific mineral mixtures. To overcome mineral deficiency in sheep and goats during pregnancy and lactation, supplementation in the form of a concentrate feed and/or mineral mixture, in addition to grazing, may be adopted.

## AREA-SPECIFIC MINERAL MIXTURE

At present, commercial mineral mixtures are prepared and marketed without considering the actual deficiency or excess of minerals in animals of the region. An excess of minerals is taxing to the animal system because of the stress on organs and the extra energy animals

spend in their excretion. Also the use of excess minerals adds to the cost of feed. On the other hand, supplementation of minerals deficient in the diet assists efficient utilization of absorbed nutrients, resulting in improved growth, milk production and reproductive efficiency. Mineral mapping of soil, water, feeds and fodders, and animal serum was done to identify specific deficiencies and formulate area-specific mineral mixture. Deficiencies of Ca, P, Cu, Zn and Co were recorded in sheep flocks maintained on degraded pastures of the semi-arid region (Shinde, Sankhyan and Karim, 2009). The area-specific mineral mixture in powder form, incorporating minerals in the required concentrations, was prepared using calcium carbonate, di-calcium phosphate, cobalt sulphate, zinc sulphate, copper sulphate and common salt. The mineral mixture contained 35.31 g Ca, 13.64 g P, 318 mg Cu, 144 mg Zn, 76 mg Co and 39.0 mg Na.

### **MINERAL MIXTURE IN PELLET VERSUS POWDER FORM**

Initially, the mineral mixture was developed in powder form and tried in sheep flocks. However, the mineral mixture powder was difficult to feed because the sheep flocks were maintained on pastures without any grain supplementation. Accordingly the mineral mixture was changed from powder to pellet form for easy delivery (Photo 1). Mineral mixture pellets of 5 g, incorporating minerals in the required concentration, were prepared using molasses (1 percent) as a binder. Pellets were dried at room temperature to achieve the desired hardness so that they could be transported and used without breakage losses. The average size of pellets was 2.5 cm in length and 6 mm in diameter (ICAR News, 2008).

### **SALIENT FINDINGS**

The area-specific mineral mixture was tested and demonstrated in six villages involving 12 flocks of 50–60 sheep each (Anonymous, 2008). The daily supplementation of pelleted mineral mixture at the rate of 5 g resulted in significant beneficial effects (Table 1).

Due to deficiency of minerals, wool shedding in sheep is a common problem when grazed on degraded pastures. Sheep suffer from skin keratinisation with lesions around the eyes, legs and head. They are also debilitated and weak and have poor intake. Area-specific mineral mixture can be supplemented to overcome skin keratinisation and wool shedding.

At organised farms, ad libitum concentrate feeding of lambs from 3 month of age causes rickets due to the high consumption of concentrate and low intake of roughage, resulting in imbalances of minerals, specially Ca:P ratio. Such cases can be reduced by restricting the concentrate to 40 percent of the total feed intake and supplementing with an area-specific mineral mixture.



**photo 1**  
*Mineral mixture in pellet form*



**TABLE 1**  
**Effect of mineral supplementation on sheep productivity**

	Unsupplemented group	Mineral supplemented group
Wool yield (g) after 5 months supplementation		
Dry sheep	440	481
Pregnant sheep	412	432
Daily milk yield (g) during early lactation of 3 month	350	395
Anoestrous condition	-	Brought 60% of sheep into oestrus within 15–21 days and the remaining 40% after 42 days of supplementation.
Skin keratinisation	-	Skin hardness reduced and healing was faster
Wool shedding		Increased wool growth
Urinary calculi cases in organised farms	4–5% in weaner lambs	Decreased to < 2%

High-concentrate feeding also increases the incidence of urinary calculi due to mineral imbalances, and area-specific mineral mixture at the rate of 2 percent in the concentrates can reduce such cases.

Inorganic mineral mixtures are poorly absorbed and retained in the animal system. Chelated minerals (Cu- and Zn-methionine) in the diet increase mineral absorption and retention and improve growth, reproduction and health. Organic forms of Cu and Zn are commercially available and may be used for formulating area-specific mineral mixtures for improving yield and quality of wool (through increasing the concentrations of Cu and Zn) including, improving crimp, tensile strength and elastic properties. Use of Cu and Zn-methionine in farmer flocks resulted in higher Cu and Zn concentration in wool (4.30 and 172.9 ppm) as compared with inorganic salts (3.50 and 167.2 ppm) and an additional wool yield of 60–80 g.

### **ADOPTION OF THE TECHNOLOGY BY FARMERS AND FUTURE OF THE TECHNOLOGY**

Sheep and goats in semi-arid and arid regions of the country are maintained on poor quality pastures. Low mineral contents of pasture grasses in dry zones cause mineral deficiencies, ranging from acute to mild, which result in loss of production and reproduction. Supplementation with area-specific mineral mixtures can meet animal requirement for minerals and improve the overall productivity of sheep and goats.

The mineral mixture was made available to farmers of five villages in four districts of Rajasthan. After continuous persuasion the technology was adopted by 60 percent of the farmers leading to a four-fold increase in demand for area-specific mineral mixture. The use of this mineral mixture reduced the cases of reproductive disorders, e.g. anoestrus by 40–44 percent, decreased skin keratinisation by 55 to 60 percent and improved wool and

milk yield by 8 to 10 percent and 10 to 12 percent respectively in farmers' flocks. In addition, cases of bone chewing in sheep grazing on the degraded pastures also decreased after supplementation.

Some constraints to popularising area-specific mineral mixture in the region are inadequate extension networks for disseminating the technology to poor farmers. Also the farmers have inadequate market access to the mineral mixture. As the beneficial effects of supplementing diets with the mineral mixture are not immediate, this may also discourage farmers adopting the technology.

Initially the technology could be disseminated through Government support and once adopted by farmers, support should be gradually withdrawn. The cost of the mineral mixture is very low (0.12–0.13 Rupee per sheep daily or 3.75 Rupees per month; 1 US\$ = ca 45 Rupees) and therefore can easily be adopted, even by poor farmers. Many farmers are ready to adopt the technology provided they have easy access to the mineral mixture. The mineral mixture can be made available to farmers, at their doorsteps, through dairy cooperative societies in villages. State extension departments, NGOs, State agricultural universities, Indian Council of Agricultural Research institutions and agriculture extension centres should also be involved in dissemination of the technology.

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# Investing in inorganic fertilisers on tropical dairy farms

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## SUMMARY

The use of cattle manure to fertilise grasses is a common practice in most dairying areas in Asia. The manure supplies organic matter to the forage area but insufficient nitrogen for optimum forage yield and quality. Application of fertilisers improves yield and quality of fodders. Most farmers are not even aware of the economic gains through using inorganic fertilisers. Investing in urea fertiliser is a good business decision with cost:benefit ratios of 1:4–1:5.

**Keywords:** *cattle manure, fodder yield, fertilisers, nitrogen, urea*

## INTRODUCTION

Fertilisers cost money but they return more through improved yields and quality of forage, hence more milk. Provided other soil nutrients are not limiting plant growth, urea fertiliser can produce an extra 9 kg forage DM/kg urea or 18 kg DM/kg nitrogen applied. When harvested and fed to milking cows, this extra forage can yield an additional 9 litres milk/kg urea nitrogen (STOAS, 1999).

Higher-quality forages mean that less concentrates need to be fed to produce the same amount of milk (Moran, 2005). For example, in Thailand, the usual recommendation is to feed 1 kg concentrate per 2 litres milk. Dairy farmers in Latin America feeding well fertilised Napier grass need only feed 1 kg concentrate per 4 litres milk produced, which is half the rate of many South-East Asian smallholder farmers. Furthermore, they can feed 14 milking cows/ha of Napier grass, each producing 15 litres milk/day supplemented with 4 kg/cow/day of concentrates.

An economic analysis of marginal responses to fertiliser applications in Thailand and Malaysia, based on urea and milk prices in these countries is presented in Table 1.

Clearly, in both countries investing in urea fertiliser is a good business decision with benefit:cost ratios of 4:1 or 5:1. This extra income can arise from more milk per cow and/or milking more cows per hectare (Moran, 2009).

## CAN COW MANURE SUPPLY SUFFICIENT NUTRIENTS TO THE SOIL?

One major limitation of forage production on most smallholder dairies in Asia is the low adoption of inorganic fertilisers. Use of cow manure only to fertilise grasses is common practice in most dairying areas, with most farmers not even aware of the economic gains through using inorganic fertilisers. Cow manure supplies organic matter to the soil, but insufficient nitrogen to maximise forage yields and quality. The following nutrient audit

TABLE 1  
**Economic benefits of using urea to fertilise forages for milking cows in Thailand and Malaysia, assuming the response to urea is 9 litres milk/kg urea nitrogen (N)**

Country (currency)	Urea cost per		Milk return per		Benefit:cost ratio
	kg	kg N	litre	kg N	
Thailand (Bt)	16	35	15	135	3.9
Malaysia (MR)	1.50	1.85	1.85	16.6	5.0

shows that smallholder dairy farmers, in addition to the manure, need to apply at least 100 kg urea/ha/year to their forage production area,

It is assumed that the case-study smallholder farmer has 4 milking cows, with a calving interval of 15 months, and uses all the manure to fertilise forage supplies. Each milking cow produces 3 000 litres milk per lactation and consumes 1 500 kg of purchased concentrates. Milk contains 0.5 percent nitrogen (N) and 0.1 percent phosphorus (P) while concentrates contain 16 percent protein (2.6 percent N) and 1 percent phosphorus.

Choi *et al.* (2004) found that each 450 kg lactating cow produced 46 kg/day of manure (32 kg faeces + 14 kg urine) containing 12.9 percent DM and excreting a total of 0.15 kg N, 0.04 kg P and 0.08 kg potassium (K) each day. The ratio of total nutrients output in faeces:urine are 62:38 for N, 99:1 for P and 50:50 for K. These data allow the calculation of nutrient audits. The N in manure can be lost through volatilisation, nitrification, leaching and surface run-off. The P in manure can be lost through leaching, surface run-off and soil erosion.

The nutrients leaving the farm through milk are 15 kg N and 3 kg P/cow/lactation and those entering the farm through purchased concentrates are 39 kg N and 15 kg P/cow/lactation. By recycling all the manure onto the forage production area, the farm then has a positive balance of 24 kg N and 12 kg P/cow/lactation which is available to grow forage, produce replacement stock (pregnancy and rearing) and grow out the milking cows.

Assuming each milking cow consumes 3 tonnes forage DM/lactation containing 1.3 percent N and 0.3 percent P, each cow then consumes 39 kg N and 9 kg P/lactation from forages. Therefore in each lactation, a cow will remove 15 kg more N than is returned via manure, while there is an excess of 3 kg P from the recycled manure. This does not take into account the loss of N and P through sale of calves and culled cows.

In this case-study smallholder farmer then has a positive P audit of 36 kg/lactation (or 29 kg P/year), which is available to provide P for the non-milk farm products. However for each lactation there is a negative N audit of at least 60 kg N/lactation, equivalent to 48 kg N/year, which must be imported onto the farm in the form of N fertilisers. Assuming a yield of 12 tonnes DM/ha from forage, the forage crop would require at least an additional 100 kg urea/ha/year in addition to the manure.

### **SIMPLE ON-FARM FERTILISER DEMONSTRATIONS**

The above calculations are based on a series of assumptions, which will vary depending on the efficiency of manure recycling, particularly the quantity of urine actually reaching the

forage area. It is one thing to calculate the N deficit and another to convince farmers to actually purchase fertiliser for their forage areas.

Many Western dairy farmers base their fertiliser decisions on the nutrient status of the soils, but this is not possible for most Asian smallholder farmers because of the lack of soil testing laboratories and/or the cost of such analyses. However such advice may be available from local agronomists who service cash crops such as rice, wheat or cassava.

A visual and very simple method of assessing the likely response to fertiliser applications is to demonstrate it to the farmers through test strips, whereby they apply different fertiliser regimes to small sections of their forage area, such as rows 2 or 3 plants wide, to visually assess any response. Tropical forages such as Napier grass respond rapidly to improved N status by producing dark green coloured foliage plus a more rapid-growing, hence taller, plant. By trying-out different fertiliser regimes after each harvesting, say nil urea, 50 kg urea/ha, 100 kg urea/ha, urea plus phosphorus fertiliser, with and without cow manure, farmers can assess whether they should apply P as well as N. Because the farmers can associate higher yield and darker green forage with improved milk yield, in most cases they would respond accordingly by changing their fertiliser management.

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# Chaff cutters and fodder chaffing: A simple technology worth adoption

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## SUMMARY

To achieve higher livestock production, sufficient feed and fodder supply to the livestock is essential. In developing countries, especially in drylands, availability of feeds and fodder is often very limited. In India for instance, green fodder availability is short to the tune of 34 percent, with only 5 percent of the total cultivated area under fodder cultivation. The situation is not likely to change because of increasing pressure on land for cultivation of cash crops. In such a scenario, it becomes important to reduce wastage and make efficient use of the available fodder. One of the ways to achieve this is to cut fodder into small pieces – called chaffing. Chaffing fodder and straws is considered to be good practice and is very popular in parts of India, Pakistan and Nepal, with regional variations in intensity of its use. Being a proven technology chaffing needs to be popularised, especially in those countries where it is not yet practised.

**Keywords:** *chaffing, feed utilisation, fodder*

## INTRODUCTION

Chaffing fodders and straws to small pieces and then feeding to animals improves the digestibility and conserves energy that they have to use in mastication. In addition, chaffing reduces wastage of feed resources, and is considered an ideal technology worth adopting by farmers. For chaffing fodder, a machine is available in the market that cuts fodder into small pieces. Chaff cutters can be operated manually (Photo 1). Electric and diesel operated chaff cutters are also used. Since electricity supply is often erratic and undependable in rural areas of many developing countries, diesel operated chaff cutters have become more popular in recent times, for example in India (Photo 2).

Chaff cutters of the flywheel type are widely used in Pakistan and India for both greens and thick-stemmed stovers and contribute to the efficiency of fodder use by reducing selective feeding by the animal. Chaffing also enables thick-stemmed stovers to be easily eaten. Flywheel cutters consist of a metal frame in which a flywheel, with two knives mounted on it, spins and the forage is pushed through the wheel by hand. The knives are adjustable for angle and must be regularly sharpened with a file or stone. The knives can be easily taken out and are also replaceable. The chaff-cutters are sturdy machines, manufactured in large numbers, and are simple to maintain and repair by local technicians. Chaff cutters are used throughout the northern irrigated tracts of India and Pakistan, and

**photo 1**

*A farmer couple chaffing fodder with a hand-operated chaff cutter*

**photo 2**

*A diesel operated chaff cutter being used for chaffing sugar cane tops*

are also common in urban areas. In towns, fodder-chaffing is a specialised occupation and is associated with the local fodder market. Straw in these areas is chaffed during thrashing. Stovers are coarse and usually thick-stemmed. In India and Pakistan, chaffed stovers and straws are mixed with greens and usually fed in troughs (FAO, 2000).

### **EXPERIENCES OF APPLYING TECHNOLOGY IN THE FIELD**

The practice of chaffing fodder was complemented by researchers designing and making-available modified chaff cutters to farmers. Chaffing fodder is a familiar sight in the mornings and evenings in rural areas of Indian and Pakistan. In southern states of India, chaffing fodder is not practised by the farmers and therefore use of chaff cutters is not as common as in North India (Rao *et al.*, 1995). In southern states, long unchopped stovers and straws are placed on the floor in front of animals. The animals eat only the leafy portion and leave dry stems which ultimately end up as mulch. This practice appears wasteful, but reflects an age-old tradition (Misra, Rao and Ravishankar, 2010). When fodder cultivation was promoted and chaff cutters were introduced in Mahboobnagar district of Andhra Pradesh (a southern state of India), fodder wastage was reduced by up to 30 percent (Misra *et al.*, 2007). Chaff cutters are very well accepted even by resource-poor dairy farmers in Haryana, Punjab, Uttar Pradesh and Gujarat states of India.

### **STATUS OF APPLICATION OF TECHNOLOGY/PRACTICE BY FARMERS**

In North India, chaff cutters are easily available in the market and are used in irrigated areas, where dairying, coupled with fodder cultivation, is an important activity. The use of chaff cutters is not popular in states of southern India. This could be due to their unavailability for local purchase, because chaff cutters are even unavailable at district headquarters.



Manufacturers of chaff cutters and shops selling them are rarely seen in any of the states of southern India. Out of 45 chaff cutter manufacturers listed in the Directory of Indian Industry and Suppliers of Agricultural Machinery, 21 (42 percent) were located in the North Indian states, whereas, only five (10 percent) existed in the South Indian states. Goraya, Jalandhar and Ludhiana in Punjab (a northern state of India) are the major centres of chaff cutter manufacturers. Coimbatore, Hyderabad and Trivandrum are the major centres of production of chaff cutters in South India. The maximum concentration of chaff cutter manufacturers in North India may be due to greater demand in this region. Enhancing awareness of the advantages of this technology and demonstrating use of chaff cutters together with making them available, at least at district-level town markets, are all necessary in order to increase adoption. It appears that extension efforts to highlight the importance of chaff cutting have not been made in the southern part of India. It could be that South Indian farmers do not consider dairying an important activity and cultivation of green fodders is not as widespread as in North India. However the situation is gradually changing because of the increasing emphasis on dairying and cultivation of green fodders by dairy cooperatives and a growing number of private dairy industries. Accordingly the use of chaff cutters has also grown in these areas. It appears that use of chaff cutters and chaffing has positive associations with green fodder cultivation (Misra *et al.*, 2007).

## LESSONS LEARNT

Any farmer who is serious in practising dairying and maintaining high-yielding cattle should consider having a chaff cutter as a priority. In order to enhance livestock productivity it is important that fodder cultivation and chaffing are encouraged. Government intervention is needed in the form of incentives to promote the manufacturing of chaff cutters and subsidise their distribution to farmers through livestock development departments and dairy cooperatives who have resources for providing training and inputs. Farmer to farmer extension, which is often quite effective, should be promoted. Exposure visits of farmers from southern states to northern states of India i.e. Punjab and Haryana should be encouraged. Promotion of chaff cutters needs to be done in a concerted manner so that this simple, but vital technology is popularised at a fast pace.

Recognising the importance of chaff cutters, the Government of India in its current five year plan has introduced a scheme entitled "Assistance for introduction of hand- and power-driven chaff cutters". In this scheme the government contributes 75 percent and the farmer 25 percent of the cost of the chaff cutter. An assistance to the tune of five hundred million Indian rupees (US\$11 044 840) is expected to be given to farmers. Preference is given to women farmers, marginal farmers and members of milk cooperatives, therefore leading to further spread of this simple technology.

## FUTURE OF TECHNOLOGY

Chaffing of fodder is increasingly being recognised as a very beneficial practice in India and is gradually spreading to areas where it was traditionally not practised. It is likely to become more popular with increasing emphasis on dairying and fodder cultivation. Incentives from the government agencies and cooperatives will give impetus to its adoption. Chaffing has a good future in developing countries like India and other countries with similar agricultural production systems.

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# Synthesis of the FAO E-Conference “Successes and failures with animal nutrition practices and technologies in developing countries”

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## EXECUTIVE SUMMARY

This document summarises the major issues discussed by participants of a moderated E-Conference hosted by the FAO Livestock Production Systems Branch of the Animal Production and Health Division from 01 September to 30 September 2010, entitled “Successes and failures with animal nutrition practices and technologies in developing countries”. The aim was to take stock of the current status and analyse the reasons for success or failure in applying different animal nutrition practices and draw conclusions for the future. *Throughout this Document, readers are reminded that ‘failure’ and ‘successes’ refer to application/adoption of technologies.*

A total of 239 e-mail messages were posted by 121 participants from 45 countries. There was a large contribution from Southern Asia and South-Eastern Asia (53 percent of messages). Participants (88 percent from developing countries) were all scientists apart from eight advisers/consultants and two extensionists.

A Background Document ([http://www.fao.org/ag/againfo/home/documents/2010\\_sept\\_E-Conference.pdf](http://www.fao.org/ag/againfo/home/documents/2010_sept_E-Conference.pdf)) was prepared before the conference.

A total of 15 technologies/practices were considered in a sequence based on calls from the Moderator and receipt of mes-

## ABBREVIATIONS

Ca	Calcium
Cu	Copper
FAO	Food and Agriculture Organization of the United Nations
HYV	High-Yielding Variety
IAEA	International Atomic Energy Agency
Mn	Manganese
N	Nitrogen
P	Phosphorus
PEG	Polyethylene glycol
R & D	Research and Development
SSF	Solid-state fermentation
TMR	Total mixed ration
UMMB	Urea-molasses-multinutrient feed block

sages. The technologies/practices were: urea-ammonia treatment of straw (81 messages); stall-grazing of crop residues/self-selection (3 messages); reducing particle size of crop residues (22 messages); enzyme treatment or solid-state fermentation [SSF] of crop residues (5 messages); food-feed crop systems (6 messages); urea as a supplement (4 messages); urea-molasses-multinutrient feed block [UMMB] (19 messages); mineral supplementation, fertilisers and mycotoxins (16 messages); pasture improvement and reclamation (7 messages); silvopastoral and agroforestry systems (10 messages); forage production (24 messages); forage conservation (15 messages); forage fractionation (3 messages); non-conventional feeds (2 messages); and organic farming (2 messages).

For each technology considered, nearly all contributors commented on shortcomings of extension methods, but the evidence presented was largely anecdotal, with only one impact study being cited.

The technologies considered involved feeding ruminants, with the emphasis being on animals kept by small-scale (smallholder) farmers. There was a near absence of messages on feeding poultry and pigs, and those posted being mainly concerned with minerals and the amelioration of mycotoxins.

Urea-ammonia treatment of straw, despite improving digestibility and intake, was considered a failure in that it was not adopted by farmers, except in China and (very little) India. Messages reported many constraints to adoption, particularly the high costs of labour and urea. However there were numerous suggestions on how to overcome constraints, e.g. recent adoption by dairy farmers in Bihar, India was attributed to training and involving para-extension workers.

UMMB was also considered a successful technology that failed to achieve widespread adoption due to constraints in common with those of urea-ammonia treatment. A common constraint was unreliable supply and high cost of molasses. There were examples of successful adoption by dairy farmers in India for feeding cows and buffalo. UMMB had also proved a success during emergencies in Pakistan due to earthquake and floods. UMMB was acknowledged a safe and simple route for supplementing low quality diets with nitrogen and minerals. There was also agreement that supplementation was essential to sustain yields and reproductive performance in dairy cows and buffalo. Use of area-specific mineral mixes as supplements was increasing in India. Examples of successful mineral supplementation in other countries were also reported.

Reducing particle size of crop residues was much practised and therefore perceived a success. However the particle size reduction achieved by different chaffing/shredding/grinding machines varied widely, and there was no discussion of the consequential variation in benefit-cost ratios regarding money and energy.

A technology involving making straw-based, densified, total-mixed-ration (TMR) blocks was making promising progress and attracting Government of India support. The likely energy and monetary costs of processing and transporting straw to and from processing plants, and the implications for benefit-cost ratios were not discussed.

To date, despite considerable research and development, enzyme treatment and SSF of crop residues were considered unsuccessful and in need of further research.

Many technology-initiatives were underway, especially in Latin American Countries, to reclaim pastures and develop silvopastoral and agroforestry systems, with livestock produc-

tion as a sustainable component. To achieve adoption, incentive schemes were considered necessary (e.g. public-private alliances, assistance with credit, government support, payment to farmers for 'environmental services'). Positive aspects concerning environmental protection were featured throughout. Environmental protection was also implied in a brief discussion on organic farming as a technology.

A positive note was the introduction of spineless Cactus as a potential forage source in arid and semi-arid areas. Also in India and South-East Asia there was increasing interest in using Azolla as forage for cattle, pigs, poultry and fish; the traditional use of Azolla being to fertilise rice paddies. There were also positive notes concerning production and utilisation of forage from trees, particularly in Africa and Southern Asia. Research had shown how to reduce the adverse effects of high tannin in some leaves (e.g. Calliandra) by adding polyethylene glycol at feeding. However, more research on the latter and also on the wider role of trees in support of the poor in fragile environments was called for.

Conservation of forages via ensiling was generally not an adopted technique on small-scale farms, but low-cost silos made with bamboo mats and mud were proving successful in Bangladesh. One message reported success with a simple hay-making technique in Tanzania and Malawi.

The question of reducing methane emissions from ruminants was raised in several messages. One message made the important point that methane emission should be expressed as litres per unit output of product (meat or milk), thus emphasising the positive aspect of any technology that improved rate of growth or milk yield.

Discussion of food-feed crop systems emphasised the current and future importance of crop-animal integration on small-scale farms and the need for breeding higher-quality crop residues.

The cross-cutting issue throughout, was the (perceived) constraint to adoption due to inadequate technology transfer/extension methods. Suggestions for improving these were many, including the application of a holistic approach and undertaking situation analysis before introducing new technologies.

Another (perceived) constraint to adoption was small-scale farmers being insufficiently convinced of the benefit-cost ratio of a given technology. The need to include time in costs was suggested. Allied to economics were issues of lack of credit, land tenure and marketing. Some evidence was presented that overcoming these constraints enhance adoption of a number of nutritional strategies and practices discussed; access to market being the main driver. *There is a need to look beyond technological solutions and create conditions for the emergence of institutions/markets/leaders who can take on the challenges of transfer of technology holistically. The idea is not to discount the role of technology but to bring forth the organisational issues in dealing with the challenges. It is as important to invest in processes and people as it is to invest in technologies.*

Surprisingly, a subject not directly raised was the question of future food and water security although one message alluded to this in relation to future use of urea-ammonia treatment of straw. *It is suggested that this report is read in conjunction with those on: a) global food and farming futures between now and 2050 ([www.bis.gov.uk/foresight/our-work/projects/current-projects/globalfood-and-farming-futures](http://www.bis.gov.uk/foresight/our-work/projects/current-projects/globalfood-and-farming-futures)) (24th January 2011), and b) World Livestock 2011: Livestock and Food Security (FAO, 2011).*

## INTRODUCTION

The title of this e-mail conference, which took place from 01 to 30 September 2010, was "Successes and failures with animal nutrition practices and technologies in developing countries". In organising the e-mail conference, the Animal Production Systems Branch of the Animal Production and Health Division of FAO acknowledged correct nutrition to be fundamental to livestock productivity. Also acknowledged, was that during the last four decades a number of nutrition-based technologies and practices have been developed and applied on-station and on-farm in developing countries. The aim of this E-Conference was to take stock of the current status and analyse the reasons for success or failure in applying different animal nutrition practices and draw conclusions for the future.

A Background Document ([http://www.fao.org/ag/againfo/home/documents/2010\\_sept\\_E-Conference.pdf](http://www.fao.org/ag/againfo/home/documents/2010_sept_E-Conference.pdf)) was prepared before the conference. This document provided a description and overview of the main kinds of technologies that have been developed globally over the past 40 years (e.g. feeding standards, systems of feeding and precision feeding, minerals and vitamins, removal of mycotoxins from feeds, site of digestion [rumen by-pass protein, control of biohydrogenation/protected fats, ionophores, probiotics], intake strategies, multi-nutrient blocks, crop residue utilisation [production and nutritive value, grazing *in situ*, stall grazing/self-selection, box baling, leaf stripping, physical treatment, chemical 'urea-ammonia' treatment, enzyme and fungal treatment, plant breeding, supplementation], silvopastoral and agroforestry techniques, forage production and conservation, novel feeds, feed enzyme additives [exogenous enzymes for ruminant feeds, use of phytase and non-starch polysaccharides degrading enzymes for monogastric feeds], methane mitigation, alleviating adverse effects of anti-nutritional factors [tannins, other anti-nutrients] and essential amino acid supplements).

This document presents an account of the technologies and issues discussed in the 239 messages posted by 121 participants from 45 countries. Table 1 shows the large contribution from developing countries, especially from Southern Asia and South-Eastern Asia (53 percent of messages). All but 10 of the participants were scientists at research institutes or universities. Declarations by 'non-scientist' participants indicated they were advisers/consultants; two indicated they were extensionists.

The conference was moderated by Harinder Makkar, from the FAO Livestock Production Systems Branch of the Animal Production and Health Division. The approach taken by the Moderator, at appropriate intervals during the E-Conference, was to call for discussion on a given technology; contributors then responded by posting messages which frequently led to informative dialogue. The style of moderation was not over-prescriptive thus allowing the conference to evolve naturally. This culminated in a discussion of the only true cross-cutting issue, namely improving technology transfer/extension and achieving adoption.

In Sections 2.1 to 2.15 of this document an account is given of the technologies discussed. These are listed in Table 2, along with information on the origin and number of messages relating to a given technology. The order of listing technologies in Table 2 approximates that of their discussion during the conference. On Day 1, the Moderator's call for discussion of urea-ammonia treatment of straw resulted in a large response, with 81 messages posted by Day 6. Therefore in Section 2.1, successes, failures and issues discussed in relation to urea-ammonia treatment of straw are summarised by table (Tables 3

and 4). Section 3 gives an account of the cross-cutting issues. Section 4 lists technologies in the Background Document that were not addressed in the conference. Section 5 summarises the conclusions drawn and lessons learnt for the future. Section 6 lists the names and countries of participants, together with the identification number of the message(s) contributed. Citations in the document are made by author surname followed by message identification number.

## TECHNOLOGIES/PRACTICES DISCUSSED

### Urea-ammonia treatment of straw

A third of all the conference messages related to urea-ammonia treatment of straw (Table 2), with over half the contributions being from Southern and South-Eastern Asia. In general, messages dealt with reasons for success and/or (more often) failure (Table 3). Many

TABLE 1  
Region and country sources of messages and contributors

Region	Country [number of messages]	Total messages	Country [number of contributors]	Total contributors
Africa	Benin [2], Burkina Faso [1], Cameroon [1], Egypt [1], Ethiopia [2], Ghana [2], Kenya [9], Malawi [1], Mali [1], Nigeria [1], Rwanda [8], Senegal [6], South Africa [3], Tanzania [1], Tunisia [4], Uganda [3]	46	Benin [2], Burkina Faso [1], Cameroon [1], Egypt [1], Ethiopia [2], Ghana [2], Kenya [3], Malawi [2], Mali [1], Nigeria [1], Rwanda [2], Senegal [3], South Africa [3], Tanzania [2], Tunisia [1], Uganda [1]	30
Caribbean	Dominica Republic [1]	1	Dominica Republic [1]	1
Central America	El Salvador [2], Mexico [2]	4	El Salvador [1], Mexico [1]	2
South America	Argentina [1], Brazil [9], Chile [3], Colombia [13], Venezuela [2]	28	Argentina [1], Brazil [3], Chile [2], Colombia [2], Venezuela [4]	12
Northern America	United States of America [5]	5	United States of America [3]	3
Eastern Asia	China [1], Mongolia [2]	3	China [1], Mongolia [3]	4
Southern Asia	Bangladesh [4], India [82], Pakistan [22], Sri Lanka [6]	114	Bangladesh [3], India [32], Pakistan [6], Sri Lanka [3]	44
South-Eastern Asia	Indonesia [9], Myanmar [1], Philippines [2], Thailand [1]	13	Indonesia [6], Myanmar [1], Philippines [2], Thailand [1]	10
Western Asia	Turkey [1]	1	Turkey [1]	1
Northern Europe	Denmark [2], Norway [1], United Kingdom [5]	8	Denmark [2], Norway [2], United Kingdom [3]	7
Southern Europe	Italy [3]	3	Italy [2]	2
Western Europe	Belgium [4], France [1], Germany [1]	6	Belgium [1], France [1], Germany [1]	3
Oceania	Australia [6], New Zealand [1]	7	Australia [1], New Zealand [1]	2
<b>TOTAL</b>		<b>239</b>		<b>121</b>

messages included suggesting solutions to adoption constraints and some dealt with issues that may have bearing on adoption in the future (Table 4). Several contributors presented detailed analyses of their experiences involving the technology (Ben Salem, 28; Cabarles, 39; Chander, 2; Habib, 88a; Jayasuriya, 10; Khanum, 68; Krishnamoorthy, 80; Kumar, 74; Ørskov, 1; Rangnekar, 95; Sangare, 79; Suhubdy, 19; Walli, 3).

Table 3 classifies the aspects discussed into five categories, although there is some overlap: A (adopting/non-adopting countries), B (economics), C (technical/practical constraints), D (other factors inhibiting adoption) and E (technology transfer/extension). To provide authentication, the table footnotes list message identification numbers.

There was consensus that the technology had not been adopted in developing countries, particularly at small-scale-farmer level. Messages relating to 20 developing countries specifically mentioned failure of adoption. However, there were exceptions with evidence of adoption in China and a little in some locations in India. There was also consensus that there had been much R & D and that the technology 'worked' when implemented properly – straw treatment increased its digestibility, intake, keeping quality (inhibiting mould) and nitrogen content, with a result that animal productivity (growth and milk) increased.

Ørskov (1) recalled China's request to FAO in 1986 for assistance to increase meat production from cattle by feeding more straw. The FAO team, including Ørskov (1) demonstrated treatment of straw with gaseous ammonia or urea-ammonia in Hubei and Henan provinces respectively. Gaseous ammonia treatment failed due to infrastructure and scale limitations. Urea-ammonia was adopted eventually in both provinces, with an estimated 9 million farmers using the technology in 1994. However Bedard (26) wondered whether there was more recent evidence concerning the number of adopters. Liu (21) reported both successes and failures in China. Urea-ammonia is used in Northern China to treat wheat straw and maize stover. In Southern China ammonium carbonate as a source of ammonia is used for treating rice straw because it is cheaper and more effective than urea, especially for preventing mould in humid, warm conditions.

In India, Wadhwa (84b) reported that some larger farmers in Punjab treat wheat or rice straw at the time of harvesting. Rangnekar (95) also reported successful adoption in 2010 by 3000 small dairy farmers in Bihar. Uniquely, Rangnekar (95) reported an impact study undertaken to identify the reasons for adoption (reduced spoilage of straw after unseasonal rainfall, fitted in with the straw handling system, increased straw storage-bin capacity, reduced mid-summer milk depression). Rangnekar (95) also suggested a plausible reason for lack of adoption in many situations was the introduction of the technology without understanding the needs and production systems through situation analysis.

Economic aspects were referred to in many messages (Table 3) and there was consensus that the technology was generally uneconomic due to benefits being less than costs, particularly on small-scale farms. The high costs of inputs, especially urea, straw and labour were highlighted.

Reported constraints to adoption due to technical and practical aspects of treating straw, especially on small-scale farms, were numerous (Class C, Table 3). The facts that the treatment process was laborious and that small-scale farmers (especially women) had little spare time, were frequently mentioned. Straw availability was also a constraint frequently mentioned. Not only was the quantity of straw produced on small-scale farms limited, but



TABLE 2  
Technologies/practices discussed: origin and number of messages

Technology/practice	Africa	Caribbean	Central America	South America	Northern America	Eastern Asia	Southern Asia	South-Eastern Asia	Western Asia	Northern Europe	Southern Europe	Western Europe	Oceania	TOTAL
Urea-ammonia treatment of straw	14	0	2	7	4	3	35	9	1	3	1	2	0	81
Stall-grazing crop residues/self-selection	1						2							3
Reducing particle size of crop residues	5						16	1						22
Enzyme treatment or solid-state fermentation (SSF) of crop residues							4			1				5
Food-feed crop systems	1						4	1						6
Urea as a supplement				2			2							4
Urea-molasses-multinutrient feed block	3		1	1			13	1						19
Mineral supplementation, fertilisers and mycotoxins				1			12	2				1		16
Pasture improvement and reclamation	2			4			1							7
Silvopastoral and agroforestry systems	1			5			4							10
Forage production	10			3			11							24
Forage conservation	2			2			5	4		2				15
Forage fractionation		1		1									1	3
Non-conventional feeds							1	1						2
Organic farming	1						1							2

TABLE 3  
Urea-ammonia treatment of straw: analysis of messages

Aspect	Implementation aspects	
A. Adopting/ non-adopting countries	Adoption: reported in China <sup>A1</sup> Adoption: isolated instances in India <sup>A2</sup>	Non-adoption: reported in 20 countries <sup>A3</sup> Consensus: not adopted by small-scale farmers <sup>A3</sup>
B. Economics	Consensus: benefits < costs <sup>B1</sup> Expensive: urea <sup>B2</sup> Expensive: straw <sup>B3</sup> Expensive: plastic <sup>B4</sup> Expensive: labour <sup>B5/C1</sup>	Low value: milk <sup>B6</sup> Treated-straw colour – reduced sale value <sup>B7</sup> Difficulty of obtaining credit <sup>B8</sup>
C. Adoption constraints related to technical/ practical aspects of treatment	Labour demanding <sup>C1</sup> Labour unavailability: small-scale farms <sup>C2</sup> Insufficient straw: small-scale farms <sup>C3</sup> Insufficient straw: arid/semi-arid zones <sup>C4</sup> Other uses of straw <sup>C5</sup> Insufficient space at (landless) homesteads <sup>C6</sup> Water shortage <sup>C7</sup>	Perceived health risk to animals of urea use <sup>C8</sup> Perceived health risk to humans of urea use <sup>C9</sup> Vessel for preparing urea solution unavailable <sup>C10</sup> Duration of urea treatment too long <sup>C11</sup> Low retention of N applied to straw <sup>C12</sup> Ammonia (from straw) pollution of air <sup>C12</sup> Freezing of treated straw at low temperature <sup>C13</sup> Not enough urease in some crop residues <sup>C14</sup>
D. Other factors inhibiting adoption (excluding extension)	Small-scale of farms <sup>D1</sup> Livestock a secondary enterprise <sup>D2</sup> Higher-quality forages available <sup>D3</sup>	Systems not market-oriented <sup>D4</sup> No co-operative plants for treating straw <sup>D5</sup>
E. Technology transfer and extension	Project-driven ('artificial' adoption) <sup>E1</sup> Advantage of strong extension service <sup>E2</sup>	Disadvantage of weak extension service <sup>E3</sup> Para-extension workers successful in India <sup>E4</sup>

Note: Numerical figures refer to message identification numbers.

<sup>A1</sup> 1, 21.

<sup>A2</sup> 84b, 91, 95.

<sup>A3</sup> 2, 3, 5, 7, 9, 10, 12, 14, 17, 18, 19, 20, 23, 28, 30, 33, 36, 37, 38, 39, 40, 44, 46, 49, 50, 55, 61, 63, 66, 67, 68, 74, 79, 80, 83, 84a, 84b, 87, 88a, 89b, 91, 92, 93, 95.

<sup>B1</sup> 6, 9, 10, 12, 14, 29, 33, 37, 39, 40, 46, 55, 58, 61, 63, 89b, 93.

<sup>B2</sup> 7, 10, 12, 20, 28, 38, 79, 84a, 87, 88a.

<sup>B3</sup> 10, 28, 63.

<sup>B4</sup> 4, 29, 76.

<sup>B5/C1</sup> 6, 18, 19, 37.

<sup>B6</sup> 63.

<sup>B7</sup> 68.

<sup>B8</sup> 2, 33.

<sup>C2</sup> 19, 67, 89b, 30, 55, 74, 91.

<sup>C3</sup> 3, 9, 10, 20, 89b, 30, 68, 36.

<sup>C4</sup> 1, 88a, 89b.

<sup>C5</sup> 19, 46.

<sup>C6</sup> 3, 30, 88a, 92.

<sup>C7</sup> 3, 9, 10, 31, 32, 79.

<sup>C8</sup> 2, 9, 17, 28, 33, 40, 46, 48, 58, 92, 88a.

<sup>C9</sup> 9, 31, 80.

<sup>C10</sup> 3.

<sup>C11</sup> 2, 58, 80.

<sup>C12</sup> 42, 83.

<sup>C13</sup> 46.

<sup>C14</sup> 88a.

<sup>D1</sup> 10.

<sup>D2</sup> 8, 74, 67.

<sup>D3</sup> 7, 10, 39, 68, 88a, 19.

<sup>D4</sup> 93.

<sup>D5</sup> 7.

<sup>E1</sup> 2, 10, 19, 25, 38, 39, 79, 88a, 95.

<sup>E2</sup> 1, 21.

<sup>E3</sup> 2, 17, 23, 32, 40, 41, 61, 68, 93.

<sup>E4</sup> 95.

the higher intake resulting from treating straw exaggerated the scarcity. The latter was particularly so in semi-arid regions with long dry-seasons. The requirement for large quantities of (clean) water was particularly constraining in drier areas, with the added risk of toxicity in animals consuming straw treated with urea solutions prepared with inadequate

amounts of water (Habib, 88a). For landless and peri-urban farmers in India and Pakistan, the lack of sufficient space for treating straw at the homestead was identified as an adoption constraint.

Concerning other factors inhibiting adoption (Class D, Table 3), Jayasuriya (10) and many other contributors pointed to smallness of scale of farms as being a major reason. Lack of scale also featured in the technical/practical constraints of Class C, Table 3). Regarding 'livestock keeping being a secondary enterprise' on small-scale farms as another inhibiting factor, Kumar (74) cited a very recent ILRI survey indicating that nearly 80 percent of income of such holdings in India came from wages earned off-farm. In these cases livestock were cared for by family labour and were a means of converting fibrous waste into milk or meat and manure.

Many messages mentioned deficiencies in technology transfer and extension services as factors contributing to the non-adoption of the technology (Class E, Table 3). Successful adoption in China was considered to be due to the strength of the country's extension services. Rangnekar (95) attributed the successful adoption by dairy farmers in Bihar to the innovative extension method of training and involving para-extension workers. There was much reference to the 'artificial' successes of project-driven extension, with farmers being enthusiastic and adopting whilst the project was active and then discontinuing when the project ended. Some of the success was due to farmers receiving incentives such as free urea during the project (Habib, 88a; Prasad, 38).

Table 4 lists the many message-suggestions for alleviating adoption constraints particularly regarding labour requirements (20 messages) and extension approaches (24 messages). For small-scale farms, farmer co-operatives for urea-ammonia treatment were suggested. Other contributors suggested industrialising the technology and establishing 'shops' selling treated-straw-based total mixed ration (TMR). Rao (8) suggested incorporating treated straw into feed blocks, but Walli (29) considered this too expensive. He (47) mentioned that straw-based blocks (detailed in message 185) could be useful for distribution during emergencies. *Surprisingly none of the messages concerning co-operative/industrial treatment made any mention of the large costs which would be incurred in transporting straw to treatment plants and then back again to farms.* There was a range of approaches suggested for improving technology transfer and extension (Table 4). Messages from Africa suggested that extension should target market-oriented systems. Peri-urban farmers were considered more receptive and better able to respond to new technologies than rural, small-scale farmers. The need to improve extension tools to include practical manuals and videos was raised by several contributors. Other contributors suggested improving the training of extensionists, with more emphasis on their practical skills. All alternative technologies to urea-ammonia treatment for improving the nutritive value of straws that were suggested (Table 4) were topics for discussion elsewhere in the conference.

Although it is concluded that urea-ammonia treatment of straw was a failure (except possibly in China), the messages submitted identified the many constraints to adoption and ways of overcoming these, as summarised in Tables 3 and 4. Also, as noted in Table 4, the technology may assume economic viability and adoption in the future because of climate changes and other 'food insecurity' factors such as population growth and limiting resources (oil, water, minerals).

### **Stall-grazing crop residues/self-selection**

As an alternative to urea-treatment, Jayasuriya (50) commented on the practice on small-scale farms in Malawi of allowing animals to select the more digestible fractions of maize stover and using the rejected stems as mulch or for increasing soil organic matter. Osafo (223) reported research in Ethiopia showing higher intakes of sorghum stover by cattle and small ruminants when allowed to eat selectively. According to Misra (151), this approach was also practised by small-scale dairy farmers (especially women) in south India, for feeding sorghum and maize stover, pearl millet and paddy straw, with the trampled refusals being composted. However, Walli (79) cautioned against technologies that increased intake where the feed supply was limited, a situation likely in arid and semi-arid areas.

### **Reducing particle size of crop residues**

Twenty-two messages dealing with this topic were posted and there was informative dialogue between Lukuyu in Kenya (4 messages) and contributors in Southern Asia (12 messages, from India) reflecting variation in terminology (chaffing, chopping, shredding, pulverising, grinding). Previous research had shown fine grinding reduced rumen retention-time, thus increasing intake, and digestibility by increasing the surface area open to microbial attack, provided the diet contained adequate amounts of N. Although fine grinding of crop residues was expensive, the resulting material was easily combined with concentrates into TMR or pellets, as suggested by Mirzaei (77). Reddy (228) described a small, complete-feed manufacturing unit which included grinding of residues; the unit was found economical for community use for small-scale dairying. Khanum (162) reported that chaffing by manual machines was the preferred technology for Pakistan, on cost and technical grounds. Khanum (162), Walli (170) and Sharma (173) were concerned that pulverising (interpreted as fine grinding) would reduce digestibility. Lukuyu (158) explained that in the Kenyan project pulverising referred to shredding. In relation to the unit described by Reddy (228), Khanum and Hussain (232) found that similar enterprises in Pakistan were taken over by middle-men, resulting in lack of quality control and the possibility of farmers being sold adulterated feed. Walli (185) reported promising progress with straw-based densified TMR blocks as complete feeds, a technology attracting Government of India support. Sharma (173) was concerned about the number of accidents involving chaffers with inadequate knife guards. Somers (51) found that in Vietnam the whole maize plant was used as feed and that chopping increased intake and reduced selection. Addition of molasses improved palatability. Lukuyu (82, 146, 149) reported on the promotion of 'pulveriser technology' of crop residues, the latter being a key forage resource in Kenya. The programme was part of the East African Dairy Development project that helped with the supply of credit, development of markets and clustering of input services. Chander (141) found that chaffing was more popular in Northern India than in the Southern States and asked if this was due to less dairying in the South coupled with less extension of the technology. This opinion was confirmed by Subrahmanyeswari (163) who also felt that farmers needed more information and help in adopting the technology. In reply, Misra (151) explained that women in the Southern States allowed animals to select the more nutritious fractions and the trampled refusals were valued as they mixed well with dung cakes to use as fuel; trampled refusals also decomposed readily when soiled with dung and urine. There was also more grazing in

**TABLE 4**  
**Urea-ammonia treatment of straw: Suggestions for alleviating adoption constraints and messages on future issues**

Aspect	Aspect details
A. Reduce reliance on external inputs	Use cattle urine as a cheaper source of urea <sup>A1</sup> Reduce plastic requirement by treating straw in mud-wall enclosures <sup>A2</sup> .
B. Reduce labour requirements	Spray straw mechanically as part of harvesting process, to reduce labour requirement <sup>B1</sup> . Treat straw co-operatively (small-scale farmers) <sup>B2</sup> . Industrialise co-op treatment and incorporate supplements to produce TMR for sale in 'shops' <sup>B3</sup> .
C. Improve technology transfer and extension methods	Increase PRA (farmer-scientist-extensionist interaction) to refine and disseminate technology <sup>C1</sup> . Use technology incubation platforms <sup>C2</sup> . Adopt holistic instead of reductionist approach (include social context, farmer receptivity, undertake situation analysis) <sup>C3</sup> . Target market-oriented farming systems <sup>C4</sup> . Promote technology by greater involvement of media, government officers and politicians <sup>C5</sup> . Use farmer to farmer extension <sup>C6</sup> . Improve extension literature and aids (practical treatment protocols, specify conditions for response, videos) <sup>C7</sup> . Improve training of extensionists (practical rather than 'pen and paper' extensionists) <sup>C8</sup> . Develop para-extension workers (PEWs) <sup>C9</sup> .
D. Use alternatives to urea-ammonia treatment of straw	Straw: supplementation (UMMB, urea-molasses liquid licks/sprays) <sup>D1</sup> , chopping <sup>D2</sup> , self-selection (grazing/stall feeding) <sup>D3</sup> , improve straws by plant breeding <sup>D4</sup> , microbial treatment <sup>D5</sup> . Grow better forages <sup>D6</sup> .
<i>Future issues</i>	<i>Issue details</i>
E. Climate change	Urea-ammonia technology may become economic because of scarcities of feed and food <sup>E1</sup> . Urea-ammonia technology may be promoted to reduce environmental pollution due to burning straw <sup>E2</sup> , but pollution from release of ammonia to atmosphere from treated straw will need to be reduced <sup>E3</sup> .
F. Research strategies	More emphasis on research being linked to development <sup>F1</sup> . More emphasis on pro-poor research <sup>F2</sup> .

Note: Numerical figures refer to message identification number.

A<sup>1</sup>46.

A<sup>2</sup>88a.

B<sup>1</sup>44, 49.

B<sup>2</sup>3, 34, 38, 55, 66, 84b, 91, 95.

B<sup>3</sup>8, 17, 19 28, 47, 57, 92, 94.

C<sup>1</sup>2, 16, 28, 95.

C<sup>2</sup>4.

C<sup>3</sup>27, 41, 95.

C<sup>4</sup>4, 32, 43, 52, 79, 93.

C<sup>5</sup>19.

C<sup>6</sup>31.

C<sup>7</sup>19, 53, 88a, 95,.

C<sup>8</sup>2, 33, 68, 88a.

C<sup>9</sup> 95.

D<sup>1</sup>28, 39, 56, 58, 74, 80, 84a, 88a.

D<sup>2</sup>31, 56, 74.

D<sup>3</sup>50, 79.

D<sup>4</sup>59.

D<sup>5</sup>37, 60.

D<sup>6</sup>45.

E<sup>1</sup>12, 66.

E<sup>2</sup>19.

E<sup>3</sup>42, 83.

F<sup>1</sup>95.

F<sup>2</sup>95.

the South, although chaff cutters were becoming popular with dairy producers. Reporting research on chopping rice straw, Chander (143) suggested a particle size of 1.00-1.18 mm ideal for digestion and increasing intake in cattle. In Pakistan chaffers were widely used and there were many manufacturers (Khanum, 150). Farmers preferred to feed a mix of forages, thereby being able to balance the diet. Constraints incurred were the extra costs

of labour and the unreliability of the electricity supply. Manual and animal driven machines were available but demanded labour. In a second message, Khanum (162) stressed the adverse economics of grinding together with the lack of reliable power in Pakistan. Rao (153) was also concerned regarding lack of electricity in rural India and also the effects of particle size on digestibility. Mathur (156) described a system in arid Rajasthan in which chaffed cereal straw was stored after blending with legume straw and local grasses. Lukuyu (158) reported that the 'pulverisers' used in Kenya were diesel driven, the engines being mounted on either mobile or stationary frames, and the forage was shredded rather than finely ground. In Senegal and Chad getting tools to harvest straw had been a problem and more information on the Kenyan pulverisers was requested (Missohou, 168). On a positive note, Kundu (202) supported chaffing as it increased intake and reduced methane production. In Bangladesh straw chopping was established in some areas and with increasing interest in maize it was hoped the feed industry would promote the stover and examine its role in a TMR for cattle (Shamsuddin, 165).

In summary there was support for the concept of chaffing, or shredding (in Kenya 'pulverising'), where machinery and labour were available, and costs could be recovered. Fine grinding was seen as having a role in TMR.

### **Enzymes in feed supplements or solid-state fermentation (SSF) of crop residues**

Five messages on this topic reported R & D in India, the objective being to improve fibre digestibility of crop residues. Sridhar (196) reviewed the complexity of feed enzyme additives (xylanases, cellulases and ligninases offered alone or in combination) and reported their efficacy for improving productivity in monogastrics, but not in ruminants where effects were inconsistent. As enzyme additives were likely to have a pivotal role in advancing livestock nutrition in the future, Sridhar concluded further research was necessary to understand their mode of action, particularly in the rumen. The alternative approach to feeding supplements was to upgrade crop residues before feeding, using SSF with white rot fungi (*Phanerochaete chrysosporium* and *Pleurotus ostreatus*), where improvements in straw digestibility had been reported. Sridhar considered SSF to be low cost and suitable for small-scale farmers. However, Walli (197) disagreed, citing the failure of the mid-eighties Indo-Dutch project (Bio-conversion of Crop Residues) which yielded unpalatable straw of lower digestibility after fungal treatment with *Coprinus fimetarius*; loss of organic matter and increase in ash content also occurred. Walli considered the process more suited for industrial development to produce ligninase. Walli also considered more research was needed on the effects of the products of lignin degradation on rumen microbes. In reply Sridhar (198) reported lignin-degradation products were unlikely to be harmful to rumen microbes because ligninases produced by white rot fungi had given promising results in *in vitro* trials, but conceded that consortia of fungi would be preferable for SSF. Wadhwa (199) agreed and suggested that 6-8 days should be the maximum time of fermentation so that dry matter loss was not excessive. Wadhwa also agreed with Walli that SSF was cumbersome, but, like Sridhar (198) was unconcerned regarding damage to the rumen microbes because of the low level of release of phenolics that could be expected. Walli (197), Wadhwa (199) and Ørskov (200) all commented on the low nutritive value of spent

straw from (SSF) mushroom production. Wadhwa felt the material could be incorporated into complete feeds, thus helping reduce pollution from burning straw. Ørskov (200) reported work on steam treatment of straw to release lignin and also the hemicellulose and cellulose fractions, all of which could have specific uses in paint manufacture (lignin), ruminant feed (hemicellulose) and paper (cellulose). Ørskov estimated from preliminary experiments that sufficient steam would be produced by burning 10 percent of the straw.

It is concluded that despite considerable R & D, enzyme treatment and SSF of crop residues, were unsuccessful and require further research.

### Food-feed crop systems

The six messages posted acknowledged that on most small-scale farms, crops and livestock were an integrated system. Tarawali (78) reviewed the multi-dimensional crop improvement programme of ILRI and highlighted the responsibility of plant breeders to meet the dual need of high yields of grains or tubers with the need for improved residues for livestock feeding. Websites dealing with food-feed issues were given. Walli (81) requested that ILRI's work in India on breeding for improved nutritive value of sorghum and pearl millet stovers be extended to rice and wheat straws. In Bangladesh, Khaleduzzaman *et al.* (104) reported that integrated rice/forage production had become popular with dairy farmers due to increased milk yields, higher profit margins and greater output from the scarce land resource. From India, Rangnekar (118) called for research on innovations by small-scale farmers to integrate human food and animal feed production; examples included: 1) planting maize at a high seed rate and using the thinnings for forage; 2) integrating sugarcane and leguminous forage crops for milk production (reference given); 3) feeding cover crops as forage for milk production; and 4) collecting and feeding weeds. In Bangladesh there was a shortage of protein for animal feed that could be partly met by growing legume forage as a relay crop to high-yielding variety (HYV) rice (Shamsuddin, 165). Wanapat (277), in Thailand, gave examples of food-feed crops that provided nutrients for humans and livestock, including cassava, cowpeas and other legumes (a reference list was provided).

It is concluded that food-feed systems with the emphasis on crop-animal integration and breeding higher-quality crop residues will become increasingly important in the future.

### Urea as a supplement

Four messages from South America and India considered the use of urea to alleviate the deficiency of protein in low-quality grasses and sugarcane stalks. Krishnamoorthy (101) reported good growth (200-300 g/d) in heifers and calves fed chaffed green grass mixed with 0.5 percent urea. In contrast to urea-ammonia treatment the technology did not involve waiting-time, use of water or smell of ammonia. There was also the opportunity to add minerals with urea. From Colombia, Ceballos-Marquez (102) advocated urea as a supplement for cattle on protein deficient diets, but stressed the need for a complementary source of fermentable energy and control of urea to avoid toxicity. For supplementing sugarcane, Morgulis (99) reported the Brazilian Enterprise for Agricultural Research recommending a mixture of 90 percent urea and 10 percent ammonium sulphate (added to freshly 'minced' sugarcane at a rate of 1 percent). In the dry season it was estimated that 13 million head of cattle were fed on sugarcane. Morgulis also suggested adding

mono-ammonium phosphate to the mixture if phosphorus was deficient. Reddy (100) commented that the technology reported by Morgulis would fail with crop residues on account of their deficiency of readily-fermentable carbohydrate. Overcoming the latter is an integral component of the urea-molasses multinutrient block technology.

### **Urea-molasses-multinutrient block (UMMB)**

This technology attracted 19 messages, mostly from South and South-East Asia (Table 2). Many of the messages reported both successes and failures when using UMMB for supplementing crop residues and dry-season pastures for ruminants. Ruminants unlike other livestock species can digest fibre and synthesise 'non-protein nitrogen' (urea) into protein, thus reducing dependence on traditional feeds such as oilseed cakes. However, for efficient use urea needs readily fermentable energy in the rumen. The urea-molasses-multinutrient block (UMMB) is a practical solution, to which minerals and medication can be added.

The UMMB technology, as used in India was summarised by Garg (174). The equipment for commercial production and delivery in the field was described. Advantages were in supplying fermentable energy and nitrogen, minerals and when necessary anthelmintics, which improved intake, milk yield and reproductive performance and helped in reducing methane output. Constraints included: encouraging use of dispensers to ensure block consumption by licking (not biting) and to be accessible daily for 10-12 h (including grazing animals); cost and availability of molasses; and lack of extension of the technology to farmers. Some agencies were now supplying blocks and uptake had been encouraging in Rajasthan, Karnataka and Maharashtra states of India, states where crop residues were a major feed, a point also made by Walli (211, 185) In Panjab state of India UMMB improved milk yield and reproductive efficiency in buffalo, although its use was seasonal, particularly by small-scale farmers, as summer feed when green forage was unavailable (Brar, 175). Brar (175) also found that UMMB had to compete with commercially-produced feeds on price, although on-farm production had not taken off. Jayasuriya (176) divided the functions of UMMB into a survival feed based on molasses and urea, and as a production supplement for low-quality forages. Jayasuriya was concerned at the lack of widespread uptake of this proven technology and asked why? Was it 1) cost and availability of urea and molasses; 2) the manufacturing process; or 3) a low return from the investment? This was confirmed by Weerasinghe (178) from Sri Lanka who also noted that molasses needed storing correctly. Corea (180) reported storage problems of UMMB during the wet season, again associated with the molasses, a constraint confirmed by Harberd (182). In Pakistan (Khanum *et al.*, 177) farmers in arid and semi-arid areas appreciated the technology, established with the help of FAO and International Atomic Energy Agency (IAEA). Constraints included lack of awareness, limited resources and unavailability of molasses in some areas. Farmers found it easier to buy blocks rather than manufacture them. The contribution of UMMB, provided by various agencies, to ruminant survival after the recent floods and the 2005 earthquake in Pakistan was reported by Habib (183) and Khanum (191). The preference for buying blocks was confirmed by Bangani (179) from South Africa, where the message was "Rather than having 10 starving unproductive animals, it is better to sell one and use the money to improve the condition of the others and hence their productivity". In El Salvador and with IAEA support, Corea (180) developed a hydraulic press to produce UMMB. However, farm-



ers found block-making difficult, suggesting that communal factories for production would be more appropriate. More extension initiatives were also needed. Wet-season storage of blocks was difficult, although corn stover dust reduced the problem (see also Bedard, 182). Moran (181) also recommended that UMMB manufacture was more suited to co-operative/group activity. Moran also urged that economic analyses and impact studies be undertaken. In Afghanistan selling blocks through veterinary field units gave them the status of a treatment, which inflated the price beyond that of grain or oilseed cake (Thieme, 184). Difficulties were encountered in preparing blocks of the right hardness and ensuring quality control. Often blocks did not meet nutritional specifications (a point also made by Habib, 186), with the result that farmers would only use them if they were free or subsidised. Replacing cement with dolomite as a binder had proved successful (Weerasinghe, 178).

Possible alternatives for molasses were suggested. Habib (186) reported farmers using raw sugar before it became too expensive. Mulberry fruit was also satisfactory. Ben Salem (206) reviewed the history of UMMB in Tunisia; blocks containing cactus fruits, olive cake, tomato pulp and wheat bran were successful. Ben Salem (206) suggested that the composition of UMMB could be specific to meet needs, including adding polyethylene glycol (PEG) where large quantities of tanniferous forage was on offer. The low adoption rate in Tunisia was thought to be due to high labour costs and difficulties in obtaining urea. Habib (186) reported the successful inclusion of anthelmintics, but was concerned about controlling intake of the drug. Herrera *et al.* (194) from Venezuela stressed the need to consider the local ecosystem, both for suitable components and nutritional characteristics quoting success from increasing levels of P in blocks for use in well-drained savannah regions. Similar approaches were advocated by Bakhi and Wadhwa (203, Khanum and Hussain (212b) and Walli (215).

In summary UMMB is considered a successful technology that has failed to achieve widespread adoption due to constraints in common with those of urea-ammonia treatment of straw. It is also acknowledged that UMMB is a safe and simple route for supplementing low quality diets with N and minerals.

### **Mineral supplementation, fertilisers and mycotoxins**

Messages from India accounted for 10 of the 16 posted. Gowda (122) raised the problem of low reproductive efficiency in cattle and buffalo through area-specific mineral deficiencies, as defined by analysis of soil, water, forage and blood of cross-bred dairy cows. Information from 10 sites in Karnataka state was used to formulate supplements containing common salt and sources of Ca, P, Cu and Zn. As subsequent field-testing showed better conception rates and improved profitability, the mineral supplement had been made available to farmers through the Karnataka Milk Federation. Walli (142) supported the Area Specific Mineral Mixtures (ASMM) approach and envisaged its extension across India. However Shinde (125), supported by Sharma (130), claimed that reproductive failure was mainly a disease, worsened by improper diagnosis and treatment, furthermore, transport of feeds between states negated the value of ASMM. Gowda (128) acknowledged the need for accurate veterinary diagnosis but pointed out that ASMM was being used in eight Indian States. Gowda also cited iodine for reducing goitre problems in humans. In Rajasthan state pelleted mineral supplements containing Ca, P, Cu, Zn and Mn were given

to sheep (Shinde, 125; Sankhyan, 145). Initially, government support to promote mineral supplementation was necessary to overcome lack of information and availability of the pellets, at farm level. The cost of minerals was a constraint for resource-poor farmers in Pakistan and also the presence of chelating agents reduced the efficiency of some mineral mixes (Shanaz, 144).

In Brazil specific mineral supplements, tailored for region, season and class of stock were offered free-choice to cattle at pasture (Morgulis, 134). Phosphorus accounted for about 75 percent of mineral expenditure, but supplements were overfed during the dry season as farmers often viewed them as additional feed. Gowra (139) pointed to the risks in feeding minerals free-choice because of antagonistic effects, especially when composition of the feed was unknown. Reddy (140) disagreed, arguing that the animal's physiological system regulated intake. In Pakistan, Ghulam (148) reported that imbalance of minerals was the problem rather than deficiency, e.g. overfeeding of P without adequate Ca. Ghulam highlighted the influence of irrigation water on forage mineral content, and the possibility of toxic elements in sewage water transmitting disease via forage. Gowda (164), from India, agreed that mineral imbalance was sometimes a problem, but could be resolved by ration formulation, e.g. TMR. This approach was also favoured by Mathur (172) working on reproductive problems of cattle in arid Rajasthan. Moran (124) reported the reliance in many parts of Asia on shed manure for fertilising pastures for small-scale dairying as a major constraint to forage production. Moran presented convincing benefit-cost ratios in favour of using inorganic N fertilisers such as urea to grow more forage and called for more effective methods of technology transfer, such as using 'fertiliser strips' to achieve adoption. Avila (84a) had also noted farmers in Chile being more likely to use urea for fertilising crops than treat straw by urea-ammonia.

Because of advances in pig breeding and management, especially in China, an update of their mineral requirements was requested by Mendoza Huaitalla (231). From the Philippines, De Castro (229) described problems of mycotoxins caused by moulds in pig and poultry feeds. Measures to reduce contamination using clay-based binders containing a range of compounds were partially successful. Supplements containing vitamins, minerals, antioxidants, plant extracts and essential oils were also thought to lessen the impact of the mycotoxins.

The messages received generally favoured supplementing productive livestock with minerals. To be cost effective mineral supplementation should take into consideration the minerals available in the feed and water together with an estimate of animal requirements.

### **Pasture improvement and reclamation**

Degraded pastures due to deforestation, overstocking and inappropriate grazing-management were acknowledged to be common in developing countries. In the Amazon Region of Colombia *Arachis pintoii* was identified as the best legume option to improve Brachiaria-based pastures (Lascano, 69), but for successful adoption a public-private alliance was necessary to develop with farmers the best methods of applying the technology, and to assist with credit, seeds and machinery. Demonstration farms and field days as the only extension pathways had proved inadequate. Mauricio (85) asked how long *Arachis* survived together with *Brachiaria*, as in Brazil the largest problem was the short life-span of grasses (C4) and

legumes (C3). Lascano (86) replied that *Arachis* could survive up to 10 years under heavy grazing as it tolerated low fertility and acid soils, and seeds were produced underground. However its adoption in Latin America Continent (LAC), as in Colombia, was low due to the constraints mentioned. Lascano (90) invited experiences from other contributors in Africa and Asia regarding: 1) use of legumes (herbaceous and woody) as feed; 2) adoption rates of using legumes and 3) use of public-private alliances to promote new technology. In response, Lukuyu (97) indicated low uptake of establishing herbaceous legumes in East Africa because of competition between food and feed crops for land, unavailability and/or high cost of inputs, farmers' lack of technical knowledge and low market returns. However, the East African Dairy Development (EADD) project and the Kenya Tree Seed and Nursery Operators Association (KATRESNO) were working to address these constraints. From Senegal, Niyonsenga (108) advocated 'Horti-pasture' systems, involving grasses, fruits and vegetables to obtain maximum production from minimum land. Khanum (192) reported that in Pakistan 6 million hectares of land was degraded due to salinity. A large government scheme, Saline Agriculture Farmer Participatory Development Project (SADPDP), to promote the use of salt-tolerant plants was underway and appeared successful.

### **Silvopastoral and agroforestry systems**

The multi-functional value of trees was acknowledged by all contributors (Rwanda: 117; Brazil: 70, 72, 126; Colombia: 116, 119, 120; India: 71, 73, 76, 110). Emphasis was turning to developing sustainable methods of livestock production within silvopastoral and agroforestry systems. In Brazil promotion of forage systems had resulted in environmental degradation and low stocking rates, but research demonstrated this could be redressed by establishing silvopastoral systems combining trees, grass and cattle (Mauricio and Fernandes, 70). The system required changes in management, e.g. burning as a tool was inappropriate, and government support would be needed for transferring the technology to large numbers of farmers. Sankhyan (71) agreed with the principles applied in Brazil but felt they were inappropriate in India because gross overstocking and the need for human food would prevent establishment of a system based on trees. Mauricio and Fernandes (72) replied that ultimately higher levels of production would compensate for the establishment period, even in India. Chander (76) drew attention to forest areas of India, where ruminants were totally dependent on tree products, and suggested that development of the forests should be on a silvopastoral basis. Mathur (110) quoted research in Rajasthan state of India that showed the advantages of a system based on agroforestry and silvopastoral practices in an arid area and asked why arid zone farmers were not adopting it. Shinde (73) also advocated a silvopastoral system for areas with a pronounced dry season based on three tiers, a ground crop, shrubs and trees. Attention was drawn to the feeding value of some tree pods as well as the leaves and tree litter. Lascano (116, 120) stressed that lack of appropriate research limited adoption of tree-based systems. He highlighted the limited understanding of interactions between shade and soil fertility and grass productivity. Concern was also expressed regarding claims made on shade and animal comfort without considering breed and level of shade. Lascano suggested that field trials with livestock in tree-based systems should include detailed measurement of air and body temperature to estimate heat stress. While agreeing that further research was required, Ebong (117) reported that remote sens-

ing in Uganda and Tanzania indicated that weed invasion increased as wooded areas and wetlands decreased. In Central America (Costa Rica, Nicaragua and Colombia) silvopastoral techniques had been introduced together with payments to farmers for 'environmental services' for biodiversity, conservation and carbon capture through a Global Environment Fund project and support by FAO and World Bank (Murgueitio, 119). There was improvement in all environmental indicators measured and in milk production. The approach would now be extended to dry Colombian Caribbean regions where extensive livestock production was practised. In Brazil and elsewhere, Mauricio (126) emphasised that some progress had been made in changing from traditional forage production systems to more sustainable ones with more regard for a stable environment. However, he accepted that further work was needed on silvopastoral systems.

In summary, pasture degradation resulting from grass production decline could be redressed by the introduction of trees. However to promote adoption of tree-based systems there was need to conduct research to better understand interaction of trees with soil fertility, grass productivity and animal performance. Payment for environmental services associated with trees could be a way to promote adoption of silvopastoral systems

### Forage production

Of the 24 posted, 14 messages concerned tree forage; the others discussed Azolla and Cactus. The waterborne algae or fern, Azolla, hitherto widely-used as a fertiliser for rice, was gaining interest in India and South-East Asia as a feed for fish, poultry, pigs and cattle (Chander, 103). Being rich in minerals, vitamins and crude protein Azolla was seen as a substitute for green forage but adoption by farmers was limited, possibly due to a number of factors such as scarcity of water in dry-land regions, high temperatures and inadequate extension. However Misra (105) reported increasing interest in feeding Azolla in Orissa State of India, as a substitute for expensive groundnut cake. Feeding Azolla as a green supplement to dairy cows had also increased in Bangalore in India (Gowda, 107).

Djenontin (106) reported uptake of forage production initiatives in North Benin to be constrained by traditional herding systems and access to land and finance. Ben Salem (111), in Tunisia, reported spineless Cactus (*Opuntia* spp.) to be valuable, dry-land forage that was being adopted elsewhere as a component of ruminant diets. Cactus also provided fruit for human consumption and was used in the pharmaceutical, cosmetic and food industries in Tunisia (Ben Salem, 111) and India (Mathur, 159). Walli (112) reported spineless Cactus of particular benefit for improving milk and meat production. Requests for information on establishing spineless cactus were made by Harberd (113) for Somalia, Missohou (123) for Senegal and Rangnekar (118) for Central Asia. Mauricio (136) cited a website (in Portuguese) to obtain this information (<http://www.cpatsa.embrapa.br/imprensa/noticias/comeca-a-producao-de-mudas-depalma-resistente-a-cochonilha-do-carmim-pela-embrapa-semiarido/>).

The contribution of forage trees was raised by Kitalyi (109) from Tanzania where leaves of *Leucaena* and *Calliandra* spp. were being fed by small-scale farmers to ruminants and monogastrics in home-produced diets in the North-East of the country. The potential contribution of leaves containing tannins and related polyphenols to reducing methane emissions from ruminants, and their possible value in carbon credit markets was raised by

Ebong (114). Missohou (123) reported moringa being used in poultry diets in Senegal and that the legumes *Leucephana leucocephala* and *Cassia tora* were being tested. In Pakistan 18 species of native trees were either browsed or cut-and-carried to livestock (Habib, 115), and were valued in hilly areas and during the cold season. Acacia pods were also collected and stored to be fed as protein supplements (Habib, 115). In Uganda dairy farmers used *Calliandra calothyrsus* and *Gliciridia sepium* to supply protein to dairy cows and Calliandra hay was a tradable commodity (Kabirizi, 121). Calliandra leaf hay was also being included in UMMB but a simple moulding technique to make the blocks was sought. Kabirizi (121, 131) also raised the problem of 'die-back' in Calliandra. In view of the importance of Calliandra in South-Eastern Asia and East Africa, Lascano (127) enquired whether the 'die-back' pathogen involved in Uganda had been identified and whether screening for resistance had been undertaken. Lascano also commented on the high content of condensed tannins in Calliandra and asked whether its use as a supplement depressed milk yield. Karbo (129) reported cut-and-carry feeding of browse to be important in the interior savanna of Ghana in the cropping season, when sheep and goats were confined. However, some indigenous tree forage species were becoming scarce and their propagation would prove challenging. Rangnekar (147) noted from farmer observations that the role of trees, including shrubs and forbes, extended beyond the technical aspects of conventional research. Trees had a multipurpose role that was embedded in local culture, with some trees being protected by communities. Rangnekar (147) provided references and websites, and called for more research to examine the wider role of trees in support of the poor in fragile environments. Rangnekar (118) also called for research on the use of xerophytic and halophytic plants.

Two aspects of feeding tannin-rich leaves were addressed by Bhatta (132). The protein-binding effect of tannins was reduced by feeding sheep and goats small amounts of polyethylene glycol (PEG), and a reduction in methane output was achieved when leaves were included in UMMB. Habib (132) asked if a supplement of tanniferous leaves would reduce rumen degradability of dietary protein, thus improving its potential by-pass quality. Ben Salem (135) observed such an effect when tanniferous leaves were fed an hour before feeding the protein source in order to synchronise rumen digestion. In response to Ben Salem (135), Habib (138) called for further investigation of this response from the production perspective and from the environmental aspect of reducing N wastage. Lascano (137) reported that cows grazing low quality forage supplemented with Calliandra performed best when also offered tannin-free *Vigna unguiculata*. In Bhutan, the government had promoted the planting of trees as live fences thus providing a source of edible leaves for livestock (Khurana, 209).

To summarise: Tree forage from introduced species dominated this discussion, with the exceptions of evaluating indigenous species in Pakistan, evaluating the wider role of trees, shrubs and forbes in rural communities in India, and concern regarding diminishing forage available from indigenous species in parts of Ghana because of over-cropping for cut-and-carry. The tannin content of Calliandra was of concern although the use of PEG, synchronisation of feeding, legume mixtures and diet composition were reported as alleviating the problem. On a positive note the inclusion of tanniferous leaves in UMMB was suggested as a way of reducing methane production. 'Die back' in Calliandra was of concern in Uganda. In Benin forage production initiatives were restricted by traditional grazing

systems and lack of land and finance. Tree leaves are being included in home-mixed feeds for monogastrics and ruminants. However, two initiatives were reported, firstly the use of spineless Cactus as a forage source suited to arid conditions and of interest in several countries. The second was harvesting of Azolla as a feed for monogastrics and ruminants, rather than, as in the past, for fertiliser. Azolla has the advantage that it is water-borne, thereby not taking up agricultural land.

### Forage conservation

Two of the 15 messages referred to drying as the means of conserving grass, the other postings discussed ensiling of various forages. Acknowledged was that most grazing systems were characterised by periods of growth and dormancy, caused either by low temperatures or a dry period. Conservation of forage was necessary to ensure continuity of supply when grazing was unavailable.

Moran (96) reported increased consumption by dairy cows in Indonesia when Napier grass was wilted for eight hours. Some progressive dairy farmers adopted the technology in Thailand and Vietnam but small-scale farmers did not. Sundstøl *et al.* (213) reported a project in Tanzania and Malawi involving cutting grass at an early stage of growth, followed by drying on bamboo fences. As well as producing high quality hay, the technology also increased the yield of grass per unit of land. Such haymaking, Jani (216) considered, could be applied in the transhumance system in Cameroon where concentrates were expensive and milk yields were low. The latter was supported by Sundstøl *et al.* who queried, on environmental grounds, the justification for keeping ruminants at maintenance. Chaudhry (218) asked for larger and sustainable improvements in livestock output as being necessary if the livelihoods and social status of smallholders in developing countries were to be improved.

In Bangladesh, low-cost silos made with bamboo mats were successful. Ensiled maize and Napier grass increased milk yields and overcame seasonal shortages of forage (Khaleduzzaman *et al.*, 155). Low-cost, above-ground silos also overcame the expense of concrete bunkers and problems of water entering earthen pits (Shamsuddin, 165). Lascano (157) reported disappointing uptake of ensiling using small plastic bags in Central America. For small-scale farmers, constraints included cost of bags, lack of suitable choppers and inappropriate storage resulting in losses of ensiled material by rodents. Ensiling using large plastic bags (placed horizontally) was used on medium and large farms in Brazil, but small-scale farmers had not yet adopted the technology (Mauricio, 160). Large plastic bags (placed vertically to facilitate consolidating by trampling) were favoured in Vietnam and were considered the most successful of innovations given to dairy farmers (Somers, 169). Iskander (167) reported that in Indonesia, probably because of availability, fresh, chopped Napier grass was preferred by farmers and researchers. Moran (204) also questioned the suitability of silage-making for small-scale dairy farmers in the wet tropics, throughout Asia. Drawing on experience of conducting many workshops for small-scale dairy farmers, particularly in Indonesia, Moran commented that many farmers did not have excess forage to ensile as stocking rates were geared to wet-season supplies and they relied on purchased forages during the dry season. Furthermore, farmers did not like double handling their forage. Khanum (171) from Pakistan also noted a preference for freshly-cut forage, and

a lack of extension activities to encourage silage making. Habib (166) promoted silage making for conserving sugar beet pulp or catch crops such as maize grown where it could not reach maturity in marginal zones or on land available for only short-time intervals. Habib also advocated bag silage for peri-urban dairy producers. Khurana (209) reported that willow leaves, important forage in Bhutan, were being ensiled. Government had provided assistance during the introduction stages, but farmers were continuing after help was withdrawn. In Kenya ensiling in plastic tanks was being promoted for small-scale farmers. Such tanks could also function as multi-purpose stores (Lukuyu, 193).

Ensiling on small-scale farms has not been widely adopted, possibly because of cost and labour constraints together with an unsatisfactory benefit-cost ratio.

### Forage fractionation

Extracting the juice from thick-stemmed forages could result in a highly nutritious product for both ruminants and monogastrics. Moran (152) pointed to the thick stems and low dry-matter content of tropical forages (e.g. Napier grass) being factors contributing to low intakes due to bulk effect in the rumen. As with sugarcane, Moran proposed that stems of Napier grass, when pressed, would yield juice suitable for feeding ruminants or monogastrics or for use in the biofuel industry. The leaves would be fed whole, possibly to dairy cattle. In an attached paper Moran described the mechanics of producing juice and outlined the experimental programme necessary to evaluate the product. In support of Moran, Sanchez (161) recalled his research in 1979 (with T. R. Preston) showing sugar cane juice with urea promoting excellent growth in beef cattle but disappointing milk yields in dairy cows. Sanchez suggested further research was necessary on use of juice for dairy cows. As an alternative to fractionating Napier grass, Lascano (154) suggested using dwarf elephant grass as reported by Wen Shillin *et al.* (2007) in China (Australian Journal of Experimental Agriculture 47: 942-948). Dwarf elephant grass cv. Mott gave similar leaf yields to Napier but produced half the stem yield, with time of cutting not being critical.

### Non-conventional feeds

For ruminants non-conventional feeds were covered by those with area-specific characteristics, e.g. those providing forage or as ingredients in UMMB.

Gunaratne (187) summarised the use of non-conventional feeds for monogastrics in Sri Lanka, where evidence suggested that less than 20 percent of compounded feed was from this source. The situation with farm-mixed diets had not been assessed (references for pigs and poultry were cited). From Indonesia Iskandar (189) found that local feedstuffs for monogastrics had been researched but there was very little transfer of this information to farmers. Iskander also reported that some shops sold poultry feeds prepared by large feed mills from ingredients sold to them by contracted farmers.

### Organic farming

Within technologically-advanced agricultural systems there is an expanding school of thought that supports the principles of organic farming. Chander (234) raised the issue of increasing production of organic produce including livestock products and drew attention to the Codex Commission internationally-agreed standards ([www.codexalimentarius.net/](http://www.codexalimentarius.net/)



download/standards/360/cxg\_032e.pdf) (other references were also given). The extent of field testing of standards was raised and whether niche markets could be supplied. Chander also questioned whether organic sources of essential chemicals such as amino acids would be available. In reply, Abu (236) thought that most developing-country agriculture was basically organic, although commercial poultry production had become dependent on chemicals, and the use of inorganic fertilisers for cropping had also increased.

### **CROSS-CUTTING ISSUES**

Technology transfer/extension and adoption generated 24 messages sent towards the end of the conference, although nearly all earlier postings included comments on these aspects. Moran (188) proposed demonstration/model farms. In the case of dairying such farms could be established, for example, near milk collection centres. The farms would need to be 'typical' and run according to good agricultural practice. Field trials and testing could be incorporated. Chander (190) reported that integrated farming systems models (demonstration farms) were being encouraged in India, but reflecting the local situation was essential, as most small-scale farmers were not specialist producers. However, in Colombia (Lascano, 195, 69) pilot/model farms used to demonstrate the benefits of forage *Arachis* to renovate degraded pastures was not a successful strategy to promote adoption of legume-based pastures. Failure of adoption of *Arachis* was related to lack of capital, seeds and machinery rather than lack of knowledge of the technology (Lascano, 195, 69). In Central America pilot studies to demonstrate pasture/management technologies to intensify milk production resulted in farmers only adopting components of the technology (i.e. the grass variety but not the fertilisation and grazing regime recommended) and as a result there were large areas of degraded pastures in the region (Lascano, 195). According to Khanum (210), in Pakistan model farms had only benefited progressive farmers. Most farmers were either small-scale or landless, and widely-dispersed making it difficult for them to benefit from model farms. Habib (212a) was concerned that demonstration farms would not sufficiently reflect farmers' constraints to adopting technologies. Habib advocated Farmer Field Schools, which had been started in some rural areas of Pakistan. Tebug (235) from Malawi, referring to encouraging pastoralists to adopt zero grazing systems, emphasised the need for practical demonstrations tailored to local conditions, in contrast to the normal approach that concentrated on expected results of a new technology rather than the process of change.

In response to the many postings concerning urea-ammonia treatment of straw, Tarawali (78) commented there was a need to link what did and did not work with farmer's resources and the specific demand for commodities. Tarawali (78) continued "Here it is important to note that there cannot be 'one size fits all' approaches, and that feed based solutions need to be considered in relation to other technological aspects (such as breed and health) as well as policy, institutional and social dimensions required to facilitate small-holder market participation. An 'innovation' approach that encompasses farmers with service providers, input and output markets etc. and empowers all actors to be able to engage and respond may be part of the solution, which is different than addressing feed and technology solutions only (see for example [www.fodderinnovation.org](http://www.fodderinnovation.org) and <http://fodder-adoption-project.wikispaces.com>). It's important to recognise diversity of farming/livestock



systems, especially given the significant changes anticipated for many who are today small-holder crop-livestock farmers (and will be) over the coming decades. The place of animal feed in this bigger context is important". Dicko (230) supported the innovation approach of Tarawali (78) quoting examples from Zambia, Mali and Niger. Rangnekar (95) stressed that the technology selected must be relevant to the problem needing addressing, a view much supported by Dolberg (98). Dolberg (98) described his experiences in Bangladesh, ostensibly aimed at addressing farmer needs. His work progressed from advocating urea-ammonia straw treatment (which was not adopted) and fish culture (which was adopted) to poultry projects for resource-poor, landless women (which were adopted). Kumar (205) was concerned for an approach, aimed at small-scale farmers that covered all aspects of livestock production, including credit facilities and pricing. He accepted that the numbers of farmers who benefited would be relatively small. Monitoring uptake was difficult and researchers were not responsible for non-technical aspects of technology transfer, although ILRI were now promoting 'Research for development' using participatory 'Value chain' and 'Innovation system' approaches. Gunaratne (187) noted lack of farmer involvement in research, lack of farmer-orientated publications and a dearth of impact studies. Uwizeye (207), from Rwanda, considered technology adoption in Rwanda was unsuccessful for many reasons, e.g. farmers lacked ownership of land, cropping land was limited, farmers fed legumes before they matured and concentrates (including UMMB) were too expensive. Farmers also demanded payment for extension activities. Morand-Fehr (208) commented that the lack of standard experimental protocols in nutritional studies that took account of tropical influences on responses in ruminants, had led to difficulty in assessing results that could be adapted for developing-country farmers. Walli (215) stressed the role of agencies in spreading technology such as UMMB and the need to fit the technology to the problem faced by specific farmers. The need to fit new technology to a successful business plan, giving the example of the smallholder dairy farmer, was advocated by Henriksen (214), who pointed out that it was income, not environmental issues that drove change. Jayasuriya (221) supported this approach with a proviso that target farmers should be dependent on making an income from their livestock and have a wish to expand their business. Corea (222) recommended transferring not only technology but also addressing farmer motivation and decision making. Roets (217) suggested using 'transaction costs' as a yardstick of the likelihood of technology being adopted. If cost (including time) was higher than benefit derived the technology would unlikely be used. However, Lascano (225) argued that economics was not the only factor influencing adoption. In project work in South-East Asia the key advantage to planting forages around the homestead had been the reduction in labour for cutting-and-carrying. In Benin, Houndonougbo (219) found lack of knowledge and training throughout the livestock industry regarding nutrition and feed formulation. This extended to economic appraisal of planned interventions. Using dairying as an example, Lukuyu (220) urged that each stage of the whole process, from farmer through to consumer be considered and that extension messages be prepared for each audience. In New Zealand, Margerison (224) reported that the value of a premium payment, e.g. for milk quality, was not correlated with feed cost and response to feed. She also noted reluctance to invest in a long-term goal, e.g. in the rearing of dairy heifer replacements. Walli (210) alluded to the role of commercial organisations in technology transfer and gave the example of research

findings on by-pass protein technology being applied to feed compounding in India by the National Dairy Development Board in Gujarat. By-pass protein produced at the National Dairy Research Institute, Karnal, by treating groundnut cake, mustard cake and rapeseed cake with formaldehyde at 1 percent of protein present in the cake, was found to increase milk yield by 10 to 15 percent in cross-bred cows and buffalo. The National Dairy Development Board and other Indian feed manufacturers were now producing by-pass protein commercially (Walli, 210). Rafique (226) in Pakistan, suggested a need for simple tools (e.g. for chopping and mixing feeds) to facilitate adoption of new technologies and that planting of trees on marginal land, roadsides, field boundaries and water channels be encouraged. Suggested species included mulberry, moringa and acacia. Rangnekar (233) suggested discarding the old system of centrally-generated technologies that often did not sufficiently understand the farming system. Rangnekar favoured moving to a 'participatory and systems approach' that would encompass the socio-cultural links between livestock and humans; such links were absent in cropping systems. This approach was also favoured by Ebong (52).

### **TECHNOLOGIES IN BACKGROUND DOCUMENT NOT ADDRESSED**

Technologies in the Background Document (section number) not specifically addressed were precision feeding (2.3.2), biohydrogenation/protected fats (2.6.2), ionophores (2.6.3), probiotics and live microorganisms (2.6.4), box baling (2.9.4), leaf stripping (2.9.5), and essential amino acids and supplementation (2.17).

Regarding feeding standards (2.2) only one message, concerning mineral standards for pigs, was posted (Mendoza Huaitilla, 231). Amino acid supplementation (2.17) was also only alluded to in one message, concerning organic farming (Abu, 236).

### **CONCLUSIONS DRAWN AND LESSONS LEARNT FOR THE FUTURE**

This E-Conference was very successful, enabling participants to make international contacts and gain valuable information through lively dialogue. The messages posted were almost entirely by individual scientists in developing countries who shared their experiences of undertaking research and development, on-station and on-farm. Nearly all the contributors commented on technology transfer/extension and adoption, but the evidence presented was largely anecdotal, with only one impact study being cited. There was almost no contribution from large, international NGOs concerned with extension.

The technologies considered involved feeding ruminants (particularly cows and buffalo), with the emphasis, understandably, on animals kept by small-scale (smallholder) farmers. There was a near absence of messages on feeding poultry and pigs, and those posted being mainly concerned with minerals and the amelioration of mycotoxins.

Urea-ammonia treatment of straw attracted a third of the conference messages reflecting the large R & D effort on this. The technology was considered a failure in that it was not adopted, except in China and (very little) India. Chander (2) commented "Urea treatment is perhaps a classic case of mismatch between the perceived usability and appropriateness at the level of scientists; while farmers and extension agencies find it difficult to convince either of these as both find themselves correct. If the technology is really good as most of the scientists consider, the farmers in tropical countries should adopt it". Messages reported the numerous constraints to adoption (Table 3), but also made many suggestions

on overcoming them (Table 4). For example, in 2010, successful adoption of urea-ammonia treatment by dairy farmers in Bihar, India, was attributed to training and involving para-extension workers (Rangnekar, 95).

Urea molasses multinutrient blocks (UMMB) was considered a successful technology, but on the whole, failed to achieve widespread adoption due to constraints in common with those for urea-ammonia treatment (Table 3). The unavailability of regular supplies of molasses and its high cost were frequently cited constraints, although in some cases locally-available alternatives proved satisfactory. However, there were examples in India of successful adoption by milk producers, for supplementing cows in Rajasthan, Karnataka and Maharashtra States (Garg, 174) and for supplementing buffaloes in Punjab State (Brar, 175). Use of UMMB in emergencies, e.g. Pakistan floods (Habib, 183) and earthquake (Khanum, 191), was also noted. UMMB was acknowledged a safe and simple route for supplementing low quality diets with nitrogen and minerals. There was also agreement that supplementation (much discussed, especially area-specific mineral mixes in India) was essential to sustain yields and reproductive performance in dairy cows and buffalo.

Reducing particle size of crop residues was much practised and therefore perceived a success. However the particle size reduction achieved by different chaffing/shredding/grinding machines varied widely, and there was no discussion of the consequential variation in benefit-cost ratios regarding money and energy.

A technology involving making straw-based densified total mixed ration blocks (weighing 14 kg) was reported to be making promising progress and attracting Government of India support (Walli, 165). However the energy and monetary costs of processing and transporting straw to and from processing plants, and the implications for benefit-cost ratios were not discussed.

To date, despite considerable R & D, particularly in India, enzyme treatment and solid-state fermentation of crop residues were considered unsuccessful and in need of further research.

There were many technology-initiatives underway, particularly in Latin American Countries, to reclaim pastures and develop silvopastoral and agroforestry systems, with livestock production as a sustainable component. However, to achieve adoption of technologies, incentive schemes were considered necessary (e.g. public-private alliances, assistance with credit, seeds and machinery, government support with technology transfer, payment to farmers for "environmental services"). Positive aspects concerning environmental protection were a feature throughout discussions on pasture improvement and reclamation, silvopastoral and agroforestry systems, and also organic farming.

A positive note was the introduction of spineless Cactus (Ben Salem, 111) as a potential forage source in arid and semi-arid areas. Three contributors sought advice on establishment of this forage source (Mauricio contributed a Portuguese website giving this information [see above]). Also in India and South-East Asia there was increasing interest in using *Azolla* as a forage for cattle, pigs, poultry and fish; the traditional use of *Azolla* being as fertiliser for rice paddies (Chander, 103; Misra, 105; Gowda, 107). *Azolla, being waterborne, has appeal in that cultivation is on water rather than land surfaces.* There were also positive notes concerning production and utilisation of forage from trees, particularly in Africa and Southern Asia. Research had shown how to reduce the adverse effects of high

tannin in some leaves (e.g. Calliandra) by adding polyethylene glycol at feeding. However, more research on the latter, especially in regard to reducing N wastage was called for (Habib, 138). Also called for was more research on the wider role of trees in support of the poor in fragile environments (Rangnekar, 118).

Conservation of forages via ensiling was generally not an adopted technique on small-scale farms. However low-cost silos made with bamboo mats and mud were proving successful in Bangladesh (Khaleduzzaman *et al.*, 155). One message (Sundstøl *et al.*, 213) reported success with a simple hay-making technique in Tanzania and Malawi.

The question of reducing methane emissions from ruminants was raised in several messages. Sundstøl *et al.* (213) made the important point that methane emission should be expressed as litres per unit output of product (meat or milk), thus emphasising the positive aspect of any technology that improved rate of growth or milk yield.

Discussion of food-feed crop systems emphasised the current and future importance of crop-animal integration on small-scale farms. Also stressed was the need for crop breeding to provide higher-quality crop residues in the future

The cross-cutting issue throughout, was the (perceived) constraint to adoption due to inadequate technology transfer/extension methods. Suggestions for improving these (Table 4 and Section 3) were many. *As the conference participants were mostly scientists, identifying extension as the weakest link may have been an exaggeration. Nevertheless there would appear to be institutional shortcomings within the R & D system regarding extension. Also surprising was the dearth of messages suggesting that 'baskets of technologies' be offered to small-scale farmers by extensionists. Farmer involvement in developing R & D programmes appeared minimal.*

Another (perceived) constraint to adoption was small-scale farmers being insufficiently convinced of the benefit-cost ratio of a given technology. The need to include time in costs was suggested. Allied to economics were issues of lack of credit, land tenure and marketing. Some evidence was presented that overcoming these constraints enhance adoption of a number of nutritional strategies and practices discussed; access to market being the main driver. *There is a need to look beyond technological solutions and create conditions for the emergence of institutions/markets/leaders who can take on the challenges of transfer of technology holistically. The idea is not to discount the role of technology but to bring forth the organisational issues in dealing with the challenges. It is as important to invest in processes and people as it is to invest in technologies.*

Surprisingly, a subject not directly raised was the question of future food and water security although one message alluded to this in relation to future use of urea-ammonia treatment of straw. *It is suggested that this report is read in conjunction with those on: a) global food and farming futures between now and 2050 ([www.bis.gov.uk/foresight/our-work/projects/current-projects/globalfood-and-farming-futures](http://www.bis.gov.uk/foresight/our-work/projects/current-projects/globalfood-and-farming-futures)) (24th January 2011), and b) World Livestock 2011: Livestock and Food Security (FAO, 2011).*

## NAME OF PARTICIPANTS WITH COUNTRY IN WHICH THEY ARE LIVING AND REFERENCED MESSAGES

(indented messages are co-authors) [Individual messages are available at: [http://www.fao.org/ag/againfo/home/en/events\\_archive/Messages\\_E-conf\\_0910.pdf](http://www.fao.org/ag/againfo/home/en/events_archive/Messages_E-conf_0910.pdf)]

ABO-DONIA, Fawzy, (Egypt), (87)  
 ABU, Okhiomah, A., (Nigeria), (236)  
 AGUS, Ali, (Indonesia), (37)  
     AKBAR, M.A., (Bangladesh), (104), (155)  
 AHMAD, Tanveer, (Pakistan), (30)  
 ANANDAN, S., (India), (6)  
 AVILA, Jorge, (Chile), (84a)  
 BAKHI, M.P.S., (India), (203)  
 BANGANI, Noluvuyo, (South Africa), (179)  
 BEDARD, Brian G., (USA), (25), (35), (56)  
 BEN SALEM, Hichem, (Tunisia), (28), (111), (135), (206)  
 BHATTA, Raghavendra, (India), (132), (143)  
     BIRBE, Beatriz, (Venezuela), (194)  
 BRAR, P.S., (India), (175)  
 CABARLES, Jaime C., (Philippines), (39)  
 CAPPER, Jude, (USA), (24)  
 CEBALLOS-MARQUEZ, Alejandro, (Colombia), (102)  
 CHANDER, Mahesh, (India), (2), (26), (76), (103), (141), (190), (234)  
 CHAUDHRY, Abdul, S., (UK), (53), (218)  
     CILERA, F., (Malawi), (213)  
 COREA, Elmer E., (El Salvador), (180), (222)  
 DE CASTRO, Ronilo, (Philippines), (229)  
 DICKO, Maimouna S., (Mali), (230)  
 DIRBABA, Dugasa, (Ethiopia), (11)  
 DJENONTIN, Andre J., (Benin), (106)  
 DOLBERG, Frands, (Denmark), (98)  
 DOMINGUES, Carlos, (Venezuela), (17)  
     DOMINGUEZ, Carlos, (Venezuela), (194)  
     DRESCHER, Karin, (Venezuela), (194)  
 EBONG, Cyprian, (Rwanda), (4), (22), (34), (52), (114), (117)  
     EIK, L.O., (Norway), (213)  
 ELANGO VAN, A.V., (India), (42)  
     FERNANDES SOUSA, Luciano, (Brazil), (70), (72)  
 FERNANDEZ, F., (Chile), (54), (62)  
 GARG, M.R., (India), (174)  
 GOMEZ, Sergio, (Mexico), (66), (94)  
 GORGULU, Murat, (Turkey), (9)  
 GOWDA, N.K.S., (India), (31), (107), (122), (128), (164)  
 GOWRA, N.K.S., (India), (139) India

- GRIGERA NAON, Juan, J., (Argentina), (7)  
GUNARATNE, S.P., (Sri Lanka), (187)  
HABIB, Ghulam, (Pakistan), (88a), (115), (133), (138), (148), (166), (183), (186), (212a)  
HARBERD, Andrew, (Belgium), (113), (182)  
HARYANTO, Budi, (Indonesia), (48)  
HASSEN, Abubeker, (South Africa), (43)  
HENRIKSEN, Jorgen, (Denmark), (214)  
HERRERA, Pablo, (Venezuela), (194)  
HOUNDONUGBO, Frederic, (Benin), (219)  
    HUSSAIN, H.N., (Pakistan), (177), (212b), (232)  
    HUSSAIN, M., (Pakistan), (177)  
ISKANDAR, Sofjan, (Indonesia), (5), (89b), (167), (189)  
JANI, Raj, (Cameroon), (216)  
JAYASURIYA, M.C. Noble, (Sri Lanka), (10), (50), (176), (221)  
KABIRIZI, Jolly, (Uganda), (41), (121), (131)  
KAMRA, D.N., (India), (18)  
KARBO, Naaminong, (Ghana), (129)  
KHALEDUZZAMAN, A.B.M., (Bangladesh), (36), (104), (155)  
KHANUM, Shahnaz, A., (Pakistan), (68), (144), (150), (162), (171), (177), (191), (192), (201), (212b), (232)  
KITALYI, Aichi, (Tanzania), (109)  
KHURANA, Ruchita, (Bhutan), (209)  
KRISHNAMOORTHY, U., (India), (80), (101)  
KUMAR, Padma, (India), (74), (205)  
KUNDU, S.S., (India), (44), (202)  
KUSMARTONO, (Indonesia), (67)  
LASCANO, Carlos E., (Colombia), (59), (69), (86), (90), (116), (120), (127), (137), (154), (157), (195), (225)  
LIU, Jian-Xin, (China), (21)  
LUKUYU, Ben, (Kenya), (82), (97), (146), (149), (158), (193)  
LUKUYU, Margaret, (Kenya), (220)  
MARGERISON, Jean, (New Zealand), (224)  
    MARTINEZ, Nelson, (Venezuela), (194)  
MATHUR, B.K., (India), (110), (156), (159), (172)  
MAURICIO, Rogerio, M., (Brazil), (12), (70), (72), (85), (126), (136), (160)  
MENDOZA HUAITALLA, Roxana, (Peru), (231)  
MIRZAEI, Farhad, (Iran), (15), (77)  
MISRA, A.K., (India), (105), (151)  
MISSOHOU, Ayao, (Senegal), (93), (123), (168)  
MOHANTA, Ranjan K., (India), (33)  
MORAN, John, (Australia), (96), (124), (152), (181), (188), (204)  
MORAND-FEHR, Pierre, (France), (208)  
MORGULIS, Sergio, C. (Brazil), (99), (134)  
    MTENGETI, E., (Tanzania), (213)

MURGUEITIO, Enrique, (Colombia), (119)  
MYAGMARSUREN, Soronzonjaviin, (Mongolia), (46)  
NIYONSENGA, Seraphin, (Senegal), (23), (108)  
NYIRANSENGIMANA, Eugenie, (Rwanda), (61)  
ØRSKOV, E.R (Bob)., (UK), (1), (200)  
OSAFO, Emmanuel, (Ghana), (223)  
OTGONJARGAL, Ayushjaviin, (Mongolia), (46)  
PRASAD, K.S., (India), (38)  
RAO, S.B. Nageswara, (India), (8), (153)  
RAFIQUE, Shahid, (Pakistan), (226)  
RANGNEKAR, Datta, (India), (95), (118), (147), (233)  
REDDY, Y. Ramana, (India), (100), (140), (228)  
ROBINSON, Ian, (UK), (64)  
ROETS, Merida, (South Africa), (217)  
SANCHEZ-HERMOSILLO, M.D., (Dominican Republic), (161)  
SANGARE, Mamadou, (Burkina Faso), (79)  
SANKHYAN, Surendra, K., (India), (71)  
SANKHYAN, S.K., (India) (145)  
SENANI, Swaraj, (India), (58)  
SHAMSUDDIN, Mohammed, (Bangladesh), (165)  
SHAMSUDDIN, Mohammed, (Bangladesh), (104), (155)  
SHARMA, Sanjita, (India), (92)  
SHARMA, Vishnu, (India), (55), (91), (130), (173)  
SHINDE, A.K., (India) (73), (145)  
SHINDE, Prashant, (India), (125)  
SOETANTO, Hendrawan, (Indonesia), (20)  
SOMERS, Raf, (Belgium), (40), (45), (51), (169)  
SRIDHAR, Manpal, (India), (196), (198)  
SUBRAHMANYESWARI, B., (India), (163)  
SUHUBDY, Ir., (Indonesia), (19)  
SUNDSTØL, Frik, (Norway), (213)  
TARAWALI, Shirley, (Ethiopia), (78)  
TEBUG, Stanley, (Malawi), (235)  
THIDARMYINT, Hnin, (Myanmar), (63)  
THIEME, Olaf, (Italy), (184)  
TOGTOKHBAYAR, Norovsambuugiin, (Mongolia), (46), (65)  
TRAORE, E.I. Hadjii, (Senegal), (13), (32)  
URIO, N.A., (Tanzania), (213)  
UWIZEYE MUCYO, Aimable, (Rwanda), (14), (207)  
WADHWA, Manju, (India), (75), (84b), (199), (203)  
WADHWA, Manju, (India), (203)  
WALLI, Tej, K., (India), (3), (16), (27), (29), (47), (49), (57), (60), (81), (83), (89b), (112), (142), (170), (185), (197), (210), (211), (215)  
WANAPAT, M., (Thailand), (227)  
WEERASINGHE, W.M.P.B., (Sri Lanka), (178)

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During the last four decades a number of animal-nutrition-based technologies and practices have been developed and used in developing countries, with varying degrees of success. Some technologies have produced profound beneficial effects and have been widely used; while others have shown potential on research stations but have not been taken up by farmers. To learn from these experiences, the FAO Animal Production and Health Division organised an e-conference from 1 to 30 September 2010.

This document presents the current status of animal nutrition practices and technologies being practiced in developing countries and an analysis of the reasons for their success or failure. It also contains a synthesis paper that summarises the major issues discussed by participants and presents conclusion drawn and lessons learnt for the future.

This document is expected to assist developing countries make informed decisions about the adoption of appropriate animal nutrition practices and technologies. In addition, it should also be useful for the development community, including donor agencies, to better understand, prioritize and support appropriate animal nutrition practices and technologies in developing countries.

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