

# Utilization of Fibrous Agricultural Residues in Ruminant Production in China

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## Abstract

Feed deficit is a major constraint on ruminant production in China. With the tremendous increase in the human population and the growing demand for available cereal grains, great efforts have been made in improving the utilization of fibrous agricultural residues as ruminant feeds. It is estimated that 550 million tons of these feed resources are available annually in China. The nutritive characteristics of the resources, their utilization and the main constraints on their production are described briefly in this paper. Chemical ( $\text{HN}_3$ ,  $\text{NaOH}$  or  $\text{Ca}(\text{OH})_2$ ), physical (grinding, high pressure steam or irradiation) and biological (enzyme, ensilage) treatments of fibrous residues have been found to be effective in increasing their nutritive values (mainly digestibility and intake). Feeding ruminants on treated fibrous residue-based diets along with proper nutrient supplementation or with growth-promoter implantation brought about an evident improvement in animal performance. Research on ruminant nutrition and physiology undertaken over the past years has mainly focused on studies on the digestion and metabolism of various nutrients, including energy budget, N, vitamins or minerals of ruminants raised on fibrous residue-based diets. Further research on ruminant nutrition and physiology is necessary, with a need for considerable emphasis on upgrading the nutritive values of fibrous residues, as well as on optimizing rumen fiber digestion.

## Introduction

It is generally recognized that presently the tropical and sub-tropical countries are faced with a shortage of feed supply which is a major constraint on the production of ruminant livestock. The situation is particularly acute in China where there is a large population of ruminants with a rather low productivity.

According to the statistics (Chinese Animal Production Statistics, 1990), the total ruminant population amounted to  $312.4 \times 10^6$  head in China in 1989, which in terms of  $10^6$  head, includes native and improved yellow cattle, 76.8; buffaloes, 21.4; dairy cattle, 2.5; sheep, 113.5 and goats, 98.1. These animals can provide about  $2,034 \times 10^3$  tons of meat,  $4,358 \times 10^3$  tons of milk,  $254 \times 10^3$  tons of sheep wool and 5,000 tons of goat hair. In addition, they can also provide draught power for farmers in most of the rural areas. Over the past decade (1979–1989), there has been a rapid development in ruminant production in the country, as reflected by the growth rate of 22.8% for the total population and 138.4% for the total amount of animal products. Among these growth rates, the highest increases involved the dairy cattle population, the total milk and meat yields. Although ruminant production has experienced a rapid development, the current production level is still rather low in comparison to the average levels in the world. For example, the average milk yield per cow per lactating year

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was only about 1,510 kg throughout the country in 1989, and it generally takes two to three years for sheep and goats, or even 4 to 8 years for native yellow cattle to reach the minimum market weight. The low productivity of ruminants is mainly associated with their inadequate and low level of feeding.

Ruminant livestock are customarily maintained on four main categories of feedstuffs : natural grasslands, green fodder, cereal grain and fibrous agricultural residues. Although the 408.5 million ha of natural grassland should offer a great potential for ruminant feeds, due to desertification, salinization as well as poor management like overgrazing, most parts of the grasslands are losing their plant cover, and presently their actual productivity is rather low : 100 mu (equivalent to about 6.7 ha) can only sustain 5 sheep or 1 head of cattle. Green fodder grown in fields, waysides and river banks offers a great potential for feed supply, but generally its availability is only restricted to the growing seasons. Cereal grain as ruminant feed is mainly included in dairy cattle rations and no or a small amount of grain is available for feeding other ruminants. China is a country with low levels (about 370 kg) of available grain per capita in the world. With the tremendous increase in the human population and the growing demand for available grain, there is an urgent need for reducing the reliance on cereal grain for ruminant production, and for exploiting alternative feed resources, especially those that do not compete with human food. Fibrous agricultural residues (FAR) do represent such feed resources. In this paper the present situation and prospects of the utilization of fibrous agricultural residues in ruminant production in China will be reviewed.

## Present production and utilization of FAR

The bulk of fibrous agricultural residues is represented by crop residues that are by-products of cultivation. Based on the respective yields of major crops in 1989 multiplied by certain residue-grain coefficients, the yields of FAR have been estimated, indicating that about 550 million tons of these residues are available annually in China (Table 1) and this amount is expected to further increase by the year 2000. The significance of FAR as ruminant feeds can be assessed from the amounts, but it is more desirable to determine the proportion eaten by ruminants. Although it is rather difficult to obtain precisely such

**Table 1 Estimated availability of some FAR in China, 1989**

Crop	Grain yield <sup>2</sup> (10 <sup>6</sup> tons)	Residue/grain coefficient	Estimated residue yield (10 <sup>6</sup> tons)
Corn	80.41	2.0	160.8
Wheat	93.86	1.2	112.6
Rice	183.02	1.2	219.6
Sorghum	4.50	2.0	9.0
Millet	3.75	2.0	7.5
Soybean	10.22	1.0	10.2
Peanut	5.36	0.7	3.8
Tuber	27.15	0.1	2.7
Sugarcane	48.80	0.25	12.2
Cotton	3.79	0.25	1.0
Sesame	0.34	2.0	0.7
Rapeseed	5.44	2.0	10.8
Total	—	—	550.9

Source : <sup>2</sup> Chinese Agricultural Yearbook, 1990.

information, relatively constant estimates have been made by some scientists (Xiong Yiqiang, 1987 ; Ji Yilun, 1989), revealing that about 20-22% of the total residues are utilized for feeding ruminants at present. Of these, a large proportion that is untreated, is used as feed for draught and meat ruminants with or without supplements of a small amount of bran or/and cotton seed meal to support minimum levels of growth. With the continuous shortage of conventional feed supply, a considerable amount of FAR has also been incorporated into dairy cattle rations in many farms throughout the country.

The fibrous agricultural residues, apart from feed use by ruminants, are also fed to some equine livestock such as horses, mules and donkeys, and this part is estimated not to exceed 10% of the total amount. In addition, a small proportion, about 5% of the total, is used as bedding for pig and poultry, mulch for vegetable production, substrate for mushroom growth, fiber for paper manufacture and materials for building industry. During the past years, the major part of FAR was often used for cooking and heating in many rural areas. Due to the increase in coal production and other commercial energy sources available economically, the situation has changed. Thus, presently it is commonly observed that the majority of FAR is being simply burned in the field. The burning of residues not only results in a complete loss of their energy and nitrogen, but also leads to an exacerbation of air pollution.

There are many factors responsible for the under-utilization of FAR in ruminant production. In addition to the factors including collection, transport and storage of fibrous residues, the main constraints in relation to nutrition and physiology of ruminants are their low digestibility, low feed intake, low nutrient content and low metabolizable energy (ME) conversion efficiency.

One of the main constraints is the low digestibility of FAR, which is mainly related to the high lignin content in the FAR, and limits the cellulose breakdown by rumen microbes. The dry matter digestibility of various FAR generally ranges from 35% to 50%. Owing to the low digestibility the amount of available nutrients for the ruminants fed FAR is small. Thus, when the fibrous residues are fed alone, they cannot support the maintenance of the ruminants.

Ruminants, when fed fibrous agricultural residues, generally display a low feed intake due to the low bulk density of fibrous residues which can lead to a reduced rumen turnover rate of the digesta, as well as to their high cell wall percentages which can lead to a very slow degradation rate and very low degradation extent in the rumen.

Fibrous agricultural residues are generally deficient in fermentable energy, fermentable N and required micronutrients, like trace minerals and vitamins. On the other hand, almost all the residues contain a large amount of lignocellulose and, particularly of lignin. Due to these nutrition characteristics, when the residues are fed to ruminants they can hardly afford efficient rumen fermentation.

The low ME conversion efficiency is also a main constraint on the utilization of FAR in ruminant production. It is well known that the ME conversion efficiency of feedstuffs is a function of their ME contents (NRC, 1984). Among common fibrous residues, the ME contents often range from 1.3 to 1.9 Mcal/kg dry matter (DM), which indicates that the ME contents of the residues may be rather low. Li Aike (1991) reported that cattle fed a ration entirely composed of fibrous rice straw showed a negative energy retention. The relatively high acetic acid proportion of the total VFA produced from fermentation may be mainly responsible for the low ME conversion efficiency of the fibrous residues.

## **Possibilities of improving ruminant production**

Considering the various constraints limiting ruminant production of FAR in China, attempts to overcome these constraints have led to development both of suitable treatment methods like chemical, physical and biological treatments and of the use of supplementation,

with the aim of improving ruminant production on fibrous agricultural residues.

### 1 Treatment methods

Sodium hydroxide treatment of FAR has been investigated and used in some areas of the country since the 1950s. The procedure basically followed the "dry method", where NaOH is applied at the rate of 3-5% and the moisture content is 20-30% of the dry residue. The procedure largely contributes to the increase of the digestibility and palatability of the residues, and also to the improvement of the growth rate of steers (Sun Qinghai, 1985) and milk production of dairy cows (Zhao Zhengqi *et al.*, 1986). Due to sodium accumulation in soils as a result of feeding NaOH-treated residues to ruminants, the NaOH treatment is presently hardly used by the famers.

Since 1982, ammoniation of FAR has drawn a great deal of attention in China due to several advantages : effectiveness in improving the digestibility, addition of non-protein nitrogen to the treated residues and absence of sodium accumulation in soils unlike in the NaOH treatment. The ammoniation methods currently used include treatments with anhydrous ammonia, ammonium hydroxide solution, ammonium carbonate and urea at atmospheric temperature and pressure. It is recommended that the level of addition of ammonia should correspond to 3% of dry residue and the moisture level should be 40% (Meng Qingxiang, 1988). Through technology support and policy encouragements, the amount of ammoniated fibrous residues has exceeded 1.8 million tons throughout the country within the last three years. Many feeding trials were conducted to examine the effect of ammoniation of FAR on the animal performance. Xiong Yiqiang (1987) summarized some of the results that are listed in Table 2. Almost consistently, treatments with urea,  $\text{NH}_4\text{HCO}_3$  and  $\text{NH}_3$  both in anhydrous and aqueous forms, led to the improvement. However variations in feed intake, body weight gain and feed conversion efficiency across various breeds and species were observed. Positive responses to ammoniation were also found in milking heifers (Table 3).

Since limestone is available at a very low cost in China, the use of  $\text{Ca}(\text{OH})_2$  to treat FAR has attracted a great deal of interest since the 1950s.  $\text{Ca}(\text{OH})_2$  is generally less effective in treating fibrous residues than other alkaline sources, such as NaOH or  $\text{NH}_3$ . A satisfactory treatment consisting of the use of  $\text{Ca}(\text{OH})_2$  in combination with urea and pelleting, has enabled to solve this problem. Using this method, Mao Huaming (1991) observed that all the treated crop straws showed an increase in the crude protein content and *in vitro* OM digestibility. In the feeding trials, it was found that steers and dairy cows fed such treated

**Table 2 Effect of ammoniation of fibrous residues on ruminant performance**

Residues	Ruminant	Dry matter intake		Body weight gain		Gain/Feed	
		Control	Treated	Control	Treated	Control	Treated
		g/day				%	
Wheat	native	4,420	5,170	266	630	6.02	11.00
Straw	steers	—	—	92	178	—	—
	lambs	500	730	-67	19	-13.48	2.64
	heifers	6,580	7,448	324	613	4.92	7.91
Rice	steers	5,040	5,990	935	1,226	18.55	20.45
Straw	heifers	6,720	7,720	494	728	7.35	9.43
Corn	steers	6,030	6,770	607	830	10.07	12.25
Stover	heifers	8,506	9,380	830	950	9.70	10.13

Source : Xiong Yiqiang, 1987.

**Table 3 Effect of ammoniation of rice straw on milking heifer performance**

	Animal number	Intake (kg/day)		Fat corrected milk (kg/day)	Body weight change (kg/day)
		concentrate	straw		
Treated	10	4.49	8.86	8.69	0.240
Control	10	4.49	6.38	8.28	-0.287

Source : Xiong Yiqiang, 1987.

wheat straw-based diets, showed significant increases in feed intake, body weight gain and milk yield as compared to those either fed the same untreated or basal diets with medium quality pasture grass. If the slightly high processing cost could be reduced, it is considered that this method may enable to treat low-quality fibrous residues.

Biological treatment consists of ensilage of corn stover and enzyme treatments of fibrous residues. Ensilage which has been found to be a better method for the preservation of the nutritive value of corn stover is being adopted by an increasingly larger number of farmers for feeding ruminants, especially for dairy cattle. In order to improve the silage quality, agronomists have made a great contribution to the selection of suitable corn varieties in which plants remain green and succulent when the crop is harvested, and animal scientists have made efforts to study the use of various additives such as urea, poultry manure for balancing silage nutrition (Yu Shunin, 1988 ; Chao Kunxian *et al.*, 1988). The use of enzymes attacking the lignocellulose structure to improve the nutritive values of FAR has been noticed. Some researchers (Fang Guoxi *et al.*, 1985 ; Chen Xiapu *et al.*, 1988) have treated crop residues with cellulolytic enzymes from fungi to improve their digestibility. Although the *in vitro* digestibility was improved, since the cost of the treatment is high this method is only applied in the laboratory.

Among the physical treatments, fine grinding, steaming under high pressure (heat extrusion) and irradiation for the treatment of FAR have been found to be very effective in improving the nutritive value and animal performance (Fu Chunjiang, 1990 ; He Jian *et al.*, 1987 ; Meng Qingxiang *et al.*, 1991). Due to the high cost of the treatment as in the case of the enzyme treatment, these treatments have not yet been applied on a large scale.

## 2 Use of supplementation

Low-quality fibrous agricultural residues could be improved by proper supplementation of energy, N, minerals and vitamins. In an experiment on beef cattle fed a combination of treated rice straw-based diets, it was found that the supplementation of diets with by-pass starch and by-pass soybean meal enabled to improve the energy retention compared with the use of degradable starch and protein (Li Aike, 1990). Another study carried out by Lu Dexun *et al.* (1990) indicated that supplementation of fish meal and green forage to heat-extruded straw basal diets of sheep resulted in the improvement of the rumen micro-ecological environment, and subsequently of feed intake, body weight gain as well as whole growth rate.

Supplementation of urea, urea phosphate and nicotinic acids to the FAR-based diets of ruminants was also found to be effective in improving the animal performance.

## 3 Introduction of techniques into ruminant production systems

The introduction of practical and effective techniques into the ruminant production systems for improving ruminant feeding on fibrous residues has been given priority in China. In the beef cattle feeding system prevailing in the Beijing area, farmers purchase young cattle from grassland areas and feed them on ammoniated crop straws and/or corn silage along with proper nutrient supplementation, including the use of a small amount of concentrate, urea or even poultry manure, and/or with growth-promoter implantation. The results

showed that under this feeding system, the cattle generally could reach or exceed 400 kg body weight at the age of 18 months, which is a great improvement over the conventional grazing system (Jiang Hongmao, 1990).

## Research achievements in ruminant nutrition and physiology

Most of the studies on ruminant nutrition and physiology undertaken over the past years have focused on the digestion and metabolism of various nutrients, such as energy, N, vitamins and minerals and a large number of reports have been published. On the basis of the research results that covered the nutrient digestion and metabolism as well as the analytical chemical contents of various feedstuffs, three feeding standards for ruminant livestock including dairy cattle, beef cattle and *Huyang* sheep, have been proposed and subsequently approved by the Chinese governments as state professional standards. These feeding standards can provide useful guidelines for the farmers for feeding ruminants, especially for feeding nutrient-balanced rations to the ruminants raised on fibrous residues in order to maximize the production.

A great deal of progress has been achieved in the research work in ruminal protein degradation and optimization of rumen fiber digestion. Feng Yanglian *et al.* (1984) using the nylon bag method measured the ruminal protein degradation of some common feedstuffs and then put forward a proposal for a new protein requirement system for dairy cattle feeding, in which many parameters used for calculating the animal protein requirements were included (Feng Yanglian *et al.*, 1985). A new simple and rapid *in vitro* method based on the measurements of 6-hour free  $\text{NH}_3$  concentration and gas production of feedstuffs incubated with rumen liquor has been successfully developed for the estimation of ruminal protein degradation (Meng Qingxiang, 1984). Using this method, Meng Qingxiang *et al.* (1991) estimated the *in vitro* ruminal protein degradation of ammoniated wheat straw and concluded that there was no difference in the protein degradation between the ammoniated and untreated straw. A clear understanding of protein degradation in the rumen has induced animal scientists to consider the use of undegradable protein or by-pass protein sources as supplements to the diets of the ruminants raised on fibrous residues to increase the nutrient supply post-ruminally, as mentioned early in this paper. The work on optimization of rumen fiber digestion has received considerable attention. In a digestion kinetics study, Huang Beiyang (1988) found that the ruminal fiber digestion rate and extent decreased when the dietary concentrate level increased to a certain level, and were enhanced when concentrates were replaced partially by beet pulp. Subsequently, Xiong Yiqiang *et al.* (1991) reported that when the dietary concentrate which accounted for 40% of the sheep diet was replaced by 2/3 beet pulp and 1/3 pelleted legume fodder (*sadawang*) at 50% rate of the total concentrate, the fiber digestion rate in the rumen significantly increased ( $0.050\text{h}^{-1}$  versus  $0.034\text{h}^{-1}$ ) with the increase in the proportion of fiber digested (70.3% versus 61.4%).

## Prospects for research on nutrition and physiology of ruminants

To meet the challenge of feeding 22% of the world population based on 7% of the world arable land in China, the utilization of fibrous agricultural residues as ruminant feeds to provide 1.1 billion people with as much as possible meat, milk, wool and other animal products deserves particular attention. The effective utilization of the residues requires intensive research on ruminant nutrition and physiology. Recognizing this important issue, Chinese animal scientists will step up research activities in the coming five or ten years and place considerable emphasis on the following two aspects :

## 1 Relationship between the physical and chemical characters of FAR and the rumen digestive physiology of ruminants

Although the chemical characteristics of FAR such as high lignocellulose content of the cell wall and low nutrient levels limiting their digestion, intake and ME conversion efficiency have been comparatively well documented, the extent to which the physical properties such as cellulose crystallinity and bulk density influence the rumen digestion rate and degree, passage rate, etc. has not been elucidated. Research on these areas is expected to help develop even more effective methods of treatment for further improving the feeding value of fibrous agricultural residues.

## 2 Rumen digestion and physiology

Research may involve the investigation of digestion, absorption and metabolism of nutrients (such as carbohydrates, especially lignocellulose, N, minerals, etc.), their interaction and manipulation in the rumen of ruminants fed fibrous residues.

Considerable attention will be given to the study of rumen microbiology. Several laboratories dealing with such studies have been set up throughout the country. Besides rumen protozoa and bacteria, rumen anaerobic fungi will be mainly included in the research programs, due to currently available research results revealing that rumen fungi show a superior lignocellulose degradation capacity to other microbes.

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## Discussion

**Pradhan, K. (India)** : What is the extent of ammonia loss during straw stacking ?

**Answer** : The loss of ammonia in the ammoniation process of FAR is the major problem as it amounts to 2/3 in the first stacking. To overcome this problem, free ammonium should be adsorbed through the combination of ammonia treatment with corn silage.

**Ku Vera, J. C. (Mexico)** : How much can the animal intake of feed be increased by the pelleting (calcium hydroxide) treatment of the straw? Is this method cost-effective?

**Answer** : Feed intake by animals through pelletized straw can be increased by 40 to 100%. The feed intake also depends on the feed level of the treated straw in the ruminant diet.

**Haryanto, B. (Indonesia)** : Are the treatments of FAR by irradiation applicable at the farmer level?

**Answer** : Irradiation treatment of FAR is not being applied in China and remains at the laboratory level. By increasing the moisture level of treated straw and combining chemical treatment with irradiation, the irradiation dose can be reduced.