

SUPPLEMENTATION AND TREATMENT OF STRAW FOR GROWING CATTLE

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SUMMARY

Supplementation of straw based diets and/or treatment of the straw component can considerably enhance the growth rates of cattle fed such diets. The major factors determining the outcome of such dietary manipulations is how conducive the diet is to an optimal **rumen** fermentation and **how well** the nutrients absorbed match the animal's requirements. High growth rates on diets that consist of at least 70% straw are only realised if the straw is treated with ammonia (or with sodium hydroxide and supplemented with urea) and supplemented with small quantities of green fodder and bypass nutrients including protein, starch and long chain fatty acids.

INTRODUCTION

Cereal straw is characterised by a high content of **lignocellulosic** cell wall material, a low digestibility, a low content of protein, fat and storage carbohydrates coupled with a high ash content.

Utilisation of straw by cattle is dependent principally on fermentation by **rumen** microorganisms. This yields acetic, propionic and butyric acid in the approximate molar proportions of **70:20:8** with **iso-butyrate, iso-valerate** and **valerate** making up the last 2 percentage units. From the energy obtained from this fermentation process, new microbial cells are synthesised. Because of the low N-content and low digestibility of straw, the production and ratio of VFA and microbial cells in the **rumen** is low. The nutrients absorbed, relative to those required by growing cattle, are quantitatively deficient and **particularly deficient** in protein and glucogenic precursors. Cattle on a diet of only straw barely maintain their weight and typically eat about 2 kg straw DM per 100 kg live weight.

Appropriate feeding strategies for ruminants consuming fibrous diets depend on an understanding of how modifications of the diet alter the quantities and array of absorbed nutrients, both through their effects on the ratios of the end-products of **rumen** fermentation and by providing nutrients that escape unfermented from the **rumen** but are digested and absorbed **postruminally** (Preston and Leng 1984; Nolan et al. 1986).

Supplementation and treatment of straw potentially stimulate rate and extent of fermentation of cell wall carbohydrates in the **rumen**, enhance voluntary feed intake and balance the absorbed nutrients with the animal's requirements. The nett result is a decreased heat production and a higher efficiency of feed utilisation.

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SUPPLEMENTATION OF STRAW-BASED DIETS

Green fodder supplements

Supplementation of basal diets of untreated or treated straw with a small quantity (10-30% of DMI) of high quality forage such as lucerne hay was reported to stimulate voluntary intake and growth rates by cattle (Verma and Jackson 1984).

The beneficial effects on straw utilisation by ruminants of green fodder supplements, and in particular of lucerne, have been attributed to provision of readily fermentable cell wall carbohydrates and enhanced yields and efficiencies of rumen micro-organisms through increased concentrations in the rumen fluid of ammonia and branched-chain VFA which are essential nutrients for some cellulolytic bacteria (Ndlovu and Buchanan-Smith 1985). An important principle underlying optimisation of straw fermentation in the rumen is the promotion of a large colonising pool of microbes and provision of readily digestible forage ensures a rapid build-up of the population of cellulolytic organisms.

NPN supplementation

A concentration of 50 mg $\text{NH}_3\text{-N/l}$ rumen liquor may be adequate to maximise microbial growth in vitro (see for instance Satter and Slyter 1974). However, to maximise voluntary straw intake and rate of fermentation of straw in the rumen, studies with cattle in this laboratory (H.B. Perdok and R.A. Leng unpublished) suggested a minimal concentration of 200 mg $\text{NH}_3\text{-N/l}$, which is similar to the minimal rumen ammonia concentration of 195 mg $\text{NH}_3\text{-N/l}$ reported by Mehrez et al. (1977) to maximise the rate of rumen fermentation in sheep fed an all grain diet.

A rumen ammonia concentration of 150-250 mg $\text{NH}_3\text{-N/l}$ can be achieved by spraying the straw with a urea solution supplying 15-30 g urea/kg straw or by treating the straw with 30 g $\text{NH}_3\text{-N/kg}$. There is apparently no advantage in terms of liveweight gain by supplementing a basal diet of ammoniated straw with urea (Perdok and Leng 1986).

Bypass protein supplements

According to the Agricultural Research Council (ARC 1980) cattle weighing over 200 kg and gaining less than 0.75 kg per day do not require bypass protein when they are on a diet with a low metabolisable energy density. However, various workers have demonstrated significant increases in daily gain by feeding bypass protein in addition to, or instead of, urea to 200-400 kg cattle fed a basal diet of low-N roughage (see for instance Smith et al. 1980; Mullins et al. 1984; Perdok and Leng 1986; Lee et al. 1987). (See also Figures 1 and 2 and Table 1).

About half the amino acids arising from protein digestion are glucogenic and this may explain the growth response of straw-fed cattle to supplementation with bypass protein. Straw based diets have a low glucogenic potential and lack of glucose may limit growth of cattle fed such diets. Glucose is the major energy nutrient for utilisation in the brain and central nervous system (Preston and Leng 1984). Glucose is also needed for foetal growth, red blood cells, synthesis of lactose and milk volume.

In addition, glucose is required for oxidation in the pentose phosphate pathway to generate NADPH which is required for the synthesis from acetate of long chain fatty acids in the adipose tissue and therefore liveweight gain (Oldham 1983; see also section on fat supplements).

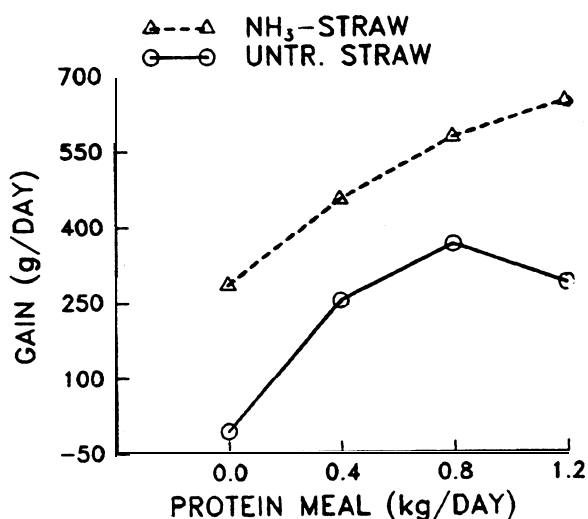


FIG. 1 Daily gains of Friesian heifers (275 kg) fed untreated or ammoniated (NH_3) rice straw with 0.6 kg rice polishings, 0.4 kg molasses-urea blocks (15% urea) and 0.0, 0.4, 0.8 or 1.2 kg bypass protein meal (98 d study; 4 heifers/group) (H.B. Perdok and R.A. Leng, unpublished data).

Carbohydrate supplements

There is some controversy about the merits of supplementing straw based diets with carbohydrate sources which ferment rapidly such as molasses or grain. Benefits are probably restricted to situations where nitrogen and minerals are not limiting microbial protein synthesis and where the supplement of rumen fermentable carbohydrate forms less than 10% of the ration DM. At higher levels of supplementation with soluble carbohydrates, voluntary intake and digestion of cellulose decline rapidly (Henning *et al.* 1980), possibly due to reduced populations and inactivity of cellulolytic bacteria at low pH (Mould and Ørskov 1983).

The energy requirements of cellulolytic bacteria on straw-based diets may be better satisfied by enhancing the digestibility of the straw itself by chemical treatment rather than by supplementation with starch.

When there is a surplus of amino acids in the nutrients absorbed relative to energy-yielding substrates, then it is energetically advantageous if starches are digested intestinally (Leng 1982). Post-ruminal digestion of starch can be most readily encouraged by the selection of supplements such as rice polishings, maize grain and sorghum grain which apparently have a chemical structure which is conducive to them partially escaping rumen fermentation (Elliott *et al.* 1978; Harrison and McAllan 1980). Broken rice probably also partially escapes digestion in the rumen and a small supplement of it was very efficiently converted into growth, especially when combined with bypass protein (Perdok and Leng 1986, see Table 1).

TABLE 1 Synergistic effect of supplementation with 0.5 kg bypass protein meal and 0.5 kg broken rice on gain (g/d) of yearling **Friesian** cattle (200kg) fed a basal diet of ammoniated wheat staw (98d study; 16 head/group) (adapted from Perdok and Leng 1986)

	Protein meal		
	0.0 kg	0.5 kg	Difference
Broken rice 0.0 kg	268	438	170
0.5 kg	373	596	223
Difference	105	159	

Fat supplements

Straw contains only about 1% digestible fat and when cattle are fattened on straw based diets, a considerable proportion of the long chain fatty acids (LCFA) in the adipose tissue may have to be synthesised de novo from acetic acid for which NADPH is needed which arises partially or totally from glucose oxidation (Oldham 1983). Glucose can either be synthesised from propionate or from glucogenic amino acids, the supply of both of which is low on straw based diets.

Supplementation with dietary LCFA would be theoretically attractive because it would spare amino acids and acetic acid for deposition of proteinaceous tissue. This hypothesis assumes that in liveweight gain proteinaceous tissue synthesis must be accompanied by an obligatory fat deposition. Unfortunately, supplementation with dietary fat at levels as low as 4% depresses cellulolysis in the rumen (see for instance Moore et al. 1986). More than 4% fat can be included in straw based diets by feeding fat prills or calcium salts of fatty acids which are relatively unreactive in the rumen but dissociate completely in the acidic environment of the abomasum, permitting absorption of the LCFA in the small intestines (Palmquist, 1984).

On straw based diets, growth responses to supplementation with "bypass fat" only appear to occur when supplementation with bypass protein is done at the same time (Van Houtert and Leng 1987; H.B. Perdok and R.A. Leng, unpublished data, see Fig. 2).

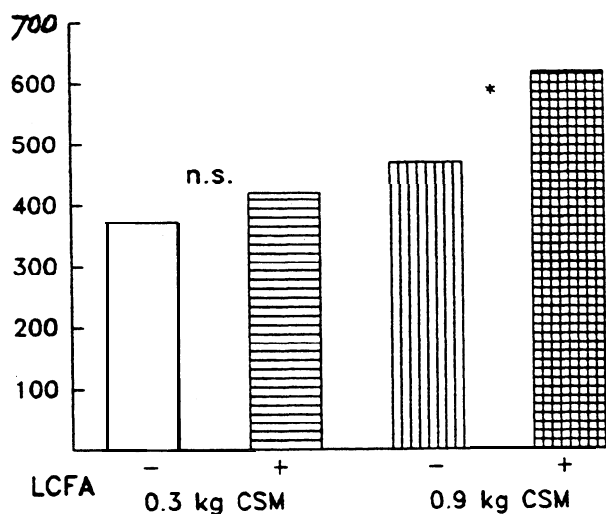


FIG. 2 Daily gain of Friesian heifers (350 kg) fed ammoniated rice straw with 0.6 kg lucerne chaff, 0.3 or 0.9 kg formaldehyde treated cottonseed meal (CSM) and 0 or 0.2 kg calcium salts of long chain fatty acids (LCFA). (84 d study; 4 heifers/group). (H.B. Perdok and R.A. Leng, unpublished data)

TREATMENT OF STRAW

Comprehensive reviews of straw treatment methods including physical, chemical, physico-chemical and biological treatments have been published recently (see Figure 3 [from Ibrahim 1983] and papers in the book edited by Sundstøl and Gwen, 1984) and only the main points will be summarised here.

Physical treatments such as grinding or pelleting increase voluntary intake but frequently depress digestibility because of reduced retention time of the feed in the rumen.

Biological treatment aims at "predigesting" the fibrous residue with microorganisms with a strong lignin-degrading capacity combined with a low utilisation of cellulose and hemicellulose. Different species of white rot fungi have been found capable of breaking the ligno-cellulosic complex, but the recovery of dry matter in such aerobic treatment systems is low. Biological treatment has not found commercial application so far. Genetic engineering of lignin-degrading rumen micro-organisms may offer more scope in the future.

Chemical and physico-chemical treatments all aim at breaking of the linkages between lignin and hemicellulose to make the latter, and also cellulose which is embedded in the lignin/hemicellulose complex, more exposed to microbial degradation in the rumen. It has been observed that the digestibility of straws of the various cereals and of the varieties within each cereal differ considerably and that, although chemical treatments generally improve the least digestible straw the most, the differences between treated straws may still be large enough to be important (Tuah et al. 1986).

There is general agreement that treatment of cereal straws with ammonia is the most effective treatment because it enhances both the digestibility and N content of straw. However, brief attention will also be given to treatment with steam and sodium hydroxide.

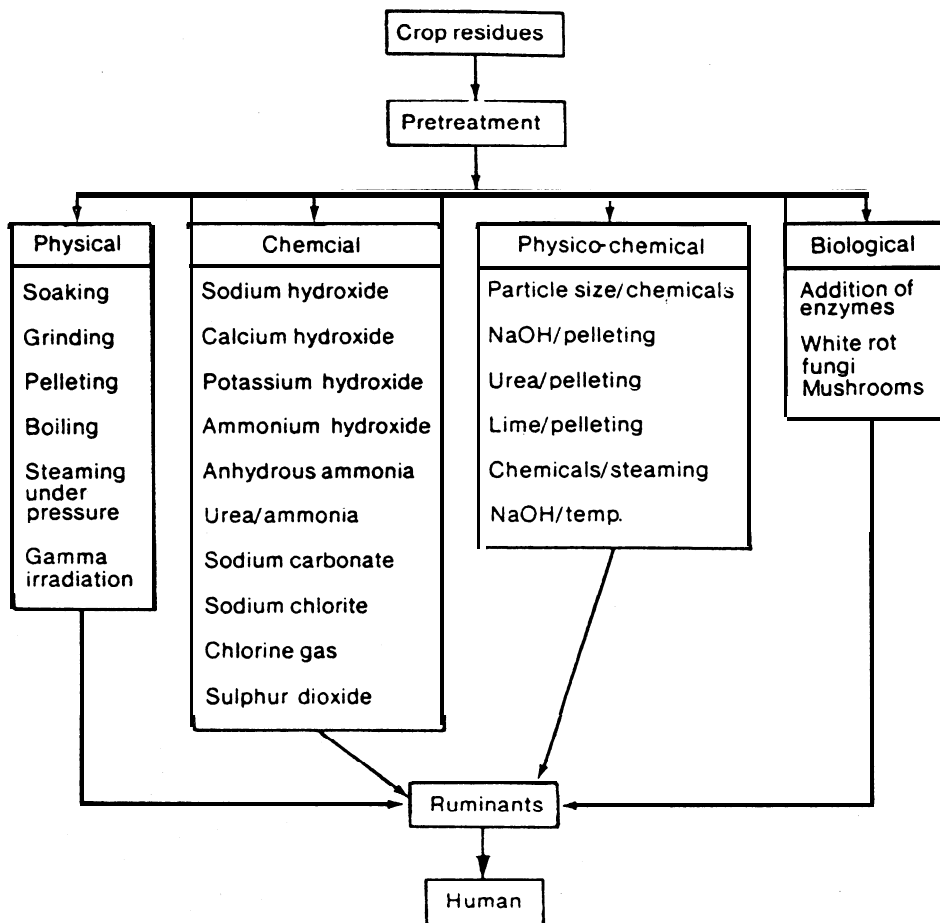


FIG. 3 Methods that have been used to treat crop residues

Treatment with steam

High pressure steam treatment is usually too costly, but it may be economically viable when steam can be obtained cheaply such as in sugar mills. Steam treatment appears to enhance the digestibility of sugar cane bagasse more than that of cereal straws.

Table 2 (from Rangnekar *et al.* 1986) gives an example of the positive effect feeding of steam treated bagasse can have on the growth rate of cattle fed a well balanced diet.

TABLE 2 Performance of **Holstein-Friesian** heifers (190kg) fed diets consisting of (%): untreated or steam treated sugar cane bagasse 40, groundnut cake 20, mango kernel cake 12, molasses 15, wheat 10, minerals and vitamins 2 and urea 1 (165 d study; 10 heifers/group) (from Rangnekar et al. 1986)

Variable	Untreated bagasse	Steam treated bagasse
DMI (kg/100 kg weight)	3.1	3.2
Daily gain (g)	573	775
FCR (kg feed DM/kg gain)	12.7	10.6

Treatment with sodium hydroxide

Treatment of straw with sodium hydroxide (NaOH) has been practised as early as 1900 in Scandinavia and deserves special mention because it is a very rapid treatment method. Basically it involves spraying about 40 kg NaOH dissolved in 100-1000 litres of water (depending on the equipment used) per tonne of straw. Treatment with NaOH increases the digestibility of straw considerably, but supplementation with rumen degradable nitrogen is essential to make the additional potential energy available to the rumen micro-organisms and host animal.

Disadvantages of the use of NaOH as a treatment agent include the corrosive effect on equipment used, the physiological stress sodium imposes on animals fed NaOH-treated straw (Jayasuriya et al. 1982) and the erosive effect of high-sodium animal waste on soil structure.

When the diet is nutritionally balanced, animal performance on high straw diets is usually higher on NaOH treated straw than on NH₃-treated straw (see also Table 3).

TABLE 3 Response of steers (255 kg) to diets containing 72 or 36% rice straw which was untreated or spray-treated with 4% sodium hydroxide (NaOH) or treated in a stack with 5% ammonia (NH₃). The complete diet was ground and consisted of (%): straw 72, lucerne 10, urea 1, minerals 1, molasses 5, barley 3, cottonseed meal 9; or straw 36, lucerne 10, urea 1, minerals 1, molasses 5, barley 45, cottonseed meal 3. (154 d study, 10 steers/group) (from Garrett et al. 1979)

Variable	72% straw			36% straw		
	untr.	NaOH	NH ₃	untr.	NaOH	NH ₃
Gain (g/d)	229 ^a	708 ^c	533 ^b	842	925	926
kg feed/d	8.1 ^a	11.4 ^c	9.3 ^b	9.8	9.7	9.7
kg feed/kg gain	38.4 ^b	16.1 ^a	17.8 ^a	11.7	10.6	10.6
Dressing percentage	52.2 ^a	57.8 ^b	56.6 ^b	60.0	60.7	61.9
Carcass fat (%)	13.8 ^a	22.0 ^b	20.6 ^b	26.2	26.0	26.8

a,b Means in the same row without a common superscript differ (P<0.05).

Treatment with ammonia or urea

Ammonia is now by far the most widely used treatment agent for low digestibility fodders. It can be applied as a gas (anhydrous ammonia), as a solution of about 25% NH_3 in water (aqueous ammonia), or as a solution of about 6% urea in water. In the latter case, ammonia is generated from the urea.

Application rates under field conditions are 25-35 kg NH_3 or 40-50 kg urea per tonne of straw. It should be emphasised that ammonia is a toxic chemical and care should be exercised, especially when handling pressurised anhydrous ammonia.

Highest improvements in intake, digestibility and nitrogen content are obtained when the moisture content of the straw is raised to 15-20% when NH_3 or NH_4OH is used and to 35-50% when urea is used.

Minimum treatment times are temperature dependent and vary from eight weeks at ambient temperatures of 10°C , to one week at ambient temperatures above 30°C .

For best results, and to reduce ammonia losses, it is important to treat the straw under gaslight conditions. This is done by placing the baled straw in plastic-covered stacks, in purpose built plywood containers or in converted buildings. The use of purpose built ovens in which the straw is heated to over 70°C is advised against because of the danger of toxin formation from ammonia and reducing sugars which are present in immaturely cut forages but also in straw of failed cereal crops (Perdok and Leng 1987).

GROWTH OF CATTLE ON BASAL DIETS OF UNTREATED OR TREATED STRAWS

The additional production due to feeding treated compared with untreated straw depends largely upon the composition of the diet of which the straw is part and on the proportion of the diet consisting of straw. At low proportions of straw in the diet and high proportions of starchy supplements (grains), the effect of treatment is usually small or absent (see also Table 3).

When straw comprises 50% or more of the diet, a higher production can be attained by treatment and supplementation together, than with supplementation alone (see also Table 3, and Fig. 1). Higher growth rates on fibrous residues are usually associated with higher voluntary intakes of feed (see also Table 4) and always with a higher efficiency of conversion of feed into gain (see also Tables 2, 3, and 4).

Laboratory and growth studies suggest that the major treatments of straw from highest to lowest efficiency rank as follows: NaOH treatment, $\text{NH}_3/\text{NH}_4\text{OH}$ treatment, urea treatment, urea supplementation, untreated (Wanapat et al. 1985; Tables 3 and II),

Treatment of straw enhances its potential digestibility and intake by ruminants. However, the increased quantity of potentially available nutrients will only be converted efficiently into microbial mass if the rumen micro-organisms are supplied a substrate with adequate quantities and ratios of essential nutrients including fermentable cell wall carbohydrates, N, branched-chain VFA, minerals (including S) and vitamins. Increased amounts of usable end-products of fermentative digestion (microbial protein and VFA), in turn, will only serve as nutrients for the host animal and increase animal productivity if they are balanced by dietary nutrients absorbed from the small intestines.

Highest growth rates on straw-based diets are realised if the straw is treated with ammonia (or with NaOH and supplemented with urea) and supplemented with green fodder (supplying "slow release" NH₃ and VFA to the rumen), bypass protein (supplying "slow release" NH₃ and VFA to the rumen and essential and glucogenic amino acids post-ruminally), bypass starch (generating glucogenic propionate in the rumen and supplying alpha-linked glucose post-ruminally) and bypass fat (supplying LCFA post-ruminally and sparing amino acids and acetate for proteinaceous tissue deposition).

Examples of separate and combined effects on growth rates of cattle of treatment of straw and/or use of different supplements are given in all Tables and Figures in this paper.

TABLE 4 Response of yearling *Bos indicus* bulls (115kg) to basal diets of rice straw which was untreated, supplemented with 2% urea at the time of feeding or ensiled for four weeks with 4% urea. Each bull also received 1.2kg rice bran, 1kg fresh grass and 100g minerals, incl. 30g Na₂SO₄ (98 d study, 10 bulls/group) (from Perdok et al. 1984)

	Untreated straw	2% urea- supplemented	4% urea- ensiled
Daily gain (g)	103	213	310
kg DMI/100kg lwt	3.2	3.4	3.8
kg feed DM/kg gain	36	20	16

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