

Optimizing the use of poor quality roughages through treatments and supplementation in warm climate countries with particular emphasis on urea treatment

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Introduction

There is no doubt that the main basal feeds for ruminants in warm climate developing countries are essentially crop residues and poor quality grasses from rangelands either grazed or, even manually collected at a very advanced vegetation stage, when mature, during the dry season.

What is less obvious are the ways and means for optimal use of these feed resources at both the nutritional and economical levels.

The objective of this paper is, after rapidly reminding the basic principles for optimizing the digestive use of poor quality roughages, to quickly review the main technologies available for optimizing these roughages and, in the mean time, to try highlighting assets and drawbacks of transferring them at the practical level.

Basic Principles for Optimizing Poor Quality Roughages Digestion

We will not embark here in a detailed course on ruminant nutrition physiology, this has been done quite clearly in previous papers out of which Leng's one. The purpose is more to recall the key basic points related to the digestive utilisation of poor quality roughages

that every one should bear in mind when facing a situation involving the use of such feed resources. The aim is in fact to understand those basic principles so that the solution sorted out be adapted to the practical situation in the best nutritional way as possible.

These key principles are as follows:

(a) To feed the microorganisms of the rumen in such a way that the cellulolytic strains be favoured. Poor quality roughages are fairly and slowly digested in the rumen. The energy required for the synthesis and the fermentation activity of the micro-organisms is that contained in the roughages cell-walls. It is slowly released. But poor quality roughages are low in N, minerals and vitamins. The N requirement for microbial synthesis (roughly 145 g CP per kg Organic Matter Fermented in the rumen - figure still subject to more precision) is not met by the N intake from the basal diet. N, in the form of degradable protein (or, better, NPN) for NH₃ supply to the microbes, is therefore the main supplementation component. Also vital for the microorganisms synthesis and activity are the minerals (out of which S, Mg; Cu and Zn).

(b) To feed the host animal the necessary nutrients (namely amino-acids and glucogenic precursors) that would ensure a satisfactory nutritional and reproductive status for his production. Such supplementation implies feeds that are as rich as possible in by-pass N (protein of alimentary origin) and in digestible cell-walls so that the rumen fermentation of cellulolytic type is not negatively affected (avoid rapid drops of pH consequently to soluble carbohydrates fermentation).

There exist two ways for improving the feed value of poor quality roughages (PQR). One is of nutritional nature, it is the supplementation. The other one is of technological nature, it is the treatments. Since the treated roughages will have often to be supplemented and since the final and same objective will be optimizing the cellulolysis in both cases of untreated and treated roughages, we propose first to consider the treatments and, secondly, the supplementation.

The various treatments

We will not undergo a comprehensive description of all the treatments utilized in the past and available at present time. Let us say, in order to summarize, that the "urea treatment" (which shortens the right expression "urea-generated ammonia treatment") is the treatment best adapted to the small farmer's conditions, both at the individual small scale treatment and at the collective large scale treatment.

As a matter of fact the classical anhydrous ammonia treatment requires, (a) industrial ammonia, either locally produced or imported, (b) a distribution network: roads, lorries and tanks of this ammonia and (c) trained staff for ammonia manipulation from the the master tank down to the stack of straw to be treated. All these conditions are seldom met in developing countries.

Urea treatment: principles and factors of success

The "urea treatment" is the result of two processes which occur simultaneously within the mass of forage to be treated: ureolysis which turns urea into ammonia, and the subsequently generated effect of the ammonia on the cell walls of the forage. As they have already been described and discussed in many review articles out of which Chenost and Besle (1993) we will briefly recall them in order to concentrate more on their practical implications.

Ureolysis

Need for a ureolytic medium

Ureolysis is an enzymatic reaction that requires the presence of the urease enzyme in the treatment medium. Urease is practically absent in straw which is a dead graminaceous material. According to research work (Williams *et al.*, 1984; Hassoun, 1987; Yameogo-Bougouma *et al.*, 1993; ...) and the numerous field experience acquired during the last decade, urease produced by the telluric ureolytic bacteria during the treatment of residues such as straw or maize stalks, is sufficient, at least under conditions where humidity imposes no limits. Only in the specific case of intentional reduction

of water (20 to 25 l added to 100kg straw) for mechanization purpose (Besle *et al*, 1990) will addition of urease be necessary.

The physico-chemical conditions of treatment, namely humidity and temperature, and their interactions, must therefore favour the activity of these bacteria and that of their enzyme.

Humidity

The ideal humidity of ureolysis is 100% (water solution), of course impossible to reach in a complex (heterogenous) medium composed of plant material and water.

This is why, nevertheless, water content of the medium is one key factor of success of the "urea treatment". This also why there are so many contradictory statements amongst people practising this treatment.

More than the amount of water to add (which will depend on the water content of the material to be treated), the humidity percentage of the treatment medium to reach will be the best informative criteria. Results of both experimental and practical works achieved until now show that this percentage, should never be less than 30%, and not greater than 60%. Below 30%, ureolysis may be severely reduced and, even, not take place. On top of that it will be more difficult to compress the mass of forage and expell the air when the former is in the loose form (of course less problems with bales since the plant is already pressed). As a result, not enough NH_3 , too much oxygen in, still, a somehow moistened medium, will lead to a bad alcali treatment and to mould development.

Beyond the (arbitrary) upper limit (50 to 60%) the problems encountered will be,

- inadequate compaction of the forage mass,
- leaching of the urea solution downward the bottom layers (urea/ammonia overdosage with its associated toxicity risks),
- insufficient diffusion of the generated NH_3 within the forage mass, in view of its hygroscopic characteristic (ammonia would bind on the water instead of the plant cell-walls),

- development of moulds, because of the moisture and an inadequate ammonia environment (trapped by the excessive water).

Within this recommended range, there are no fixed rules and the amount of water to add will be left to one's own judgement according to the prevailing local conditions, eg, availability and cost of water, hygrometry of the ambient air, watertightness of the enclosure, type of forage to treat (structure/easiness to compact it), etc.

50kg water to add is an easy figure to remind and is generally applied at the practical level. Added to 100 kg of a 90% DM straw it leads to a final moisture content of 30%.

Temperature x duration

The optimal temperature of ureolysis would lie between 30 and 60°C, according to the type of urease. The speed of the reaction is multiplied (or divided) by 2 for any increase (or decrease) in temperature of 10°C. Within the range of temperature of 20 to 45°C the ureolysis can be completed after one week or even 24 hours. The temperature is therefore not a concern in tropical climates. However the activity of urease is either severely reduced or even cancelled out for temperatures below 5 to 10°C. One must therefore be very careful in tropical highlands (eg Tanzania, Madagascar plateaux) where night frosts can take place during the dry season when it is time to treat.

Alkali treatment of the generated ammonia:

The factors ensuring a good alkali treatment are of course the same as with NH₃ treatment. Without going back into the detailed study of the alkali treatment factors (Sundstol and Owen, 1984) we will say that regarding humidity and temperature, and their interaction, the parameters supposed to be already met for a good ureolysis are also favouring the alkali treatment. However, duration, type of forage and, overall, NH₃ (therefore urea) dose and their interactions will have to be taken into consideration with much more attention.

Urea dose (alkali dose) x type of forage x duration

The quantity of alkali to be used is the first factor responsible for the efficiency of the alkali treatment. It is unfortunately still a subject of much controversy. The majority of anhydrous ammonia treatments involve quantities of ammonia of 3 kg per 100kg of DM of treated straw (Sundstol and Owen, 1984). This figure would correspond, if ureolysis is total, to 5.3 kg of urea per 100 kg DM of straw.

Now many authors, e.g. Williams *et al.* (1984), Ibrahim et Schiere (1986), do not observe the increase in digestibility of the treated matter that could have been expected with an increased dosage of applied urea. Some even go so far as to recommend the use, in practise, of threshold dosages of urea of 4kg for 100kg of straw (rice straw), for lack of evidence that higher dosages would improve the treatment.

This point deserves some examination in order to avoid any false interpretation, as several phenomena are obviously involved and it is very difficult to dissociate them from one another:

a. Ammonia treatment via alkaline resulting from ureolysis takes place in a more humid environment than anhydrous ammonia treatment. Therefore at a given NH_3 dose, the urea treatment is most probably more efficient and the tendency is to reduce the quantity of urea.

b. If it is more efficient than ammonia treatment, the urea treatment is slower. As a matter of fact and as suggested by Sahnoune (1990), ureolysis generates intermediary products (ammonium carbamate and bicarbonate) which make the fixation of nitrogen and, above all, the alkaline hydrolysis of the plant cell walls, slower than in the case of anhydrous ammonia treatment. It is therefore possible that some authors, working on treatments of a very short duration, as often happens in tropical areas, do not observe the expected reaction to an increase in urea dosage. However the duration parameter has a significant effect on the effectiveness of alkaline treatment (Chenost and Besle, 1993).

c. Finally, and above all, the capacity of the forage to react to alkaline treatment depends upon the botanical family, the species and the

variety to which it belongs. This capacity can essentially be linked to the nature of the phenolic acid/lignin linkages: more or less ether or ester-linked forms, therefore more or less potentially broken down. The fact that legumes contain fewer phenolic acids and that their lignins are less alkali soluble may explain, for instance, their weaker susceptibility to alkali treatment than grasses. There are great variabilities within grasses, little known and therefore difficult to quantify, in the nature and the structure of the lignins from one species and one variety to another. This question still needs more fundamental research work in order to improve our understanding of the degradability of plant cell walls.

As a result of the latter point (c) there would therefore be not one but several optimal dosages of alkali, differing according to the species and the variety to which the straw or forage belong. It is for instance quite probable that dosages which are sufficient for certain rice straws, would not be for others, or even more probably, would not be sufficient for wheat straws.

Unfortunately, we are still grossly lacking necessary information to predict these differences.

Dias da Silva and Guedes (1990) link the capacity of a straw to respond to alkaline treatment to its buffering capacity (phosphate), to the optical density at 280 nm of buffering extract (Besle *et al.*, 1990), and to the saponifiable ester linkages of this extract (24 straws comprising 6 cultivars of wheat, rye and triticale were cultivated in 4 different agro-ecologic environments. Colucci *et al.* (1992), in agreement with Tuah *et al.* (1986) and Givens *et al.* (1988), observe that this capacity is as large as the initial digestibility of the straw is low, and that the links between initial digestibility and response to treatment are specific to the botanic species.

In practice, the majority of both experimental and field work has led to recommend the dose of 5kg urea per 100kg (as such) of straw. This dose ensured good results in many field Projects developed in Africa, Madagascar and Asia (Chenost and Kayouli, 1996).

Attempts are being made, essentially in China and Vietnam, to reduce the amount of urea without losing alkali treatment efficient

through association of lime ($\text{Ca}(\text{OH})_2$) with urea. A recent trial in Vietnam indicates that treating with 2.5% urea plus 0.5% lime and 0.5% salt gives the same increase of the rice straw feeding value compared to a 5% urea treatment. (Bui Van Chinh *et al.*, 1993)

Duration x ambient temperature

The duration of the alkali treatment *per se* is longer than the ureolysis process. The recommended treatment time ranges from more than 8 weeks for temperatures around 5°C to less than 1 week for temperatures above 30 °C (Sundstol and Owen, 1984).

In classical tropical climates the alkali treatment can thus be achieved after 1 week. However, in view of what has been said earlier, the duration to be recommended in practice should never be below one week. As treatment efficiency improves with time it is any how better to wait two weeks before opening the treatment provided the forage and farmer's time availabilities allow such a time table. In tropical highlands (eg Tanzania, Madagascar plateaux, ...) where night frosts can take place during the dry season it is better to recommend at least 3 weeks. We were even compelled to advise 5 weeks at the practical level in the case of the Madagascar Merina Highlands (Chenost, 1993) in view of the very cold nights (periodical slowing down of the ureolytic activity from day to night time).

Air and water-tight

Ammonia is released much more slowly from the ureolysis process than from an anhydrous ammonia tank injection. The risks of losses of ammonia in the atmosphere is thus reduced since ammonia can bind on the forage cell walls and on the water medium almost simultaneously to its release. However only around 1/3 of the NH_3 released can bind the plant material, the remaining other 2/3 being in a labile form and lost, anyhow.

This point will be as important as the duration of storage is long and the volume of treated material small. The target indeed is to maintain the more anaerobic and ammoniacal atmosphere as possible within the mass of forage in order to achieve not only the best treatment but also the less development of moulds as possible.

Other "urea" treatments

A rather old but not yet really adopted procedure is to utilise urine as the source of urea. The first trials took place in Sri Lanka and Bangladesh in the early 80s. Dias da Silva (1993) 's review on this subject concluded that,

- the treatment efficiency is very variable in view of the urine variability itself (urea dilution, type of animals or, better, of the diet they are fed,...),
- because of the very high urine/straw ratios imposed to get an increase in digestibility values the acceptability of the treated material is somehow reduced or not really improved,
- the urine collection, storage and handling still remain a constraint at the practical level

However, this process still deserves attention.

Practice of urea treatment

The purpose of this chapter is, once the factors controlling the urea treatment have been described, to consider the various practical problems that arise when implementing the urea treatment technique at the practical level. Indeed there is no fixed model technique but rather one which is adapted for the particular local environmental conditions in question.

Strategy and type of treatment depend essentially on,

- the straw or forage conditioning : loose form, either long or chopped; bales, either manually or mechanically (pressed) made;
- the quantity of forage or straw to treat, depending on the number of animals and the time during which they have to be fed;
- the farmer's technical skill and facilities and his financial situation.

Once treated and if well covered to be maintained in anaerobical conditions, the forage can be stored for several months. It is therefore theoretically possible to treat at one time the quantities required for the whole feeding period. These quantities may however sometimes be too large and necessitate too much labour and space for storage. It is then necessary to treat smaller quantities in successive treatment operations repeated during the feeding period.

Depending on the strategy chosen (optimum compromise

between frequency and size) will result various types of treatment implying different constraints.

These are essentially fixing up the compromise between the lower cost as possible for the better treatment quality as possible. The former will depend on the use of locally, instead of purchased, materials; the latter will essentially depend on the air/water tightness of the treatment medium.

Various types of treatments have been described here and there (out of which Schiere and Ibrahim, 1989 and, more recently, Chenost and Kayouli, 1996).

They range from the the small pit digged in the soil (only in firm clay and not draining soils) to the classical pressed bales stack covered with plastic sheets as in the anhydrous ammonia treatment, with all the intermediary solutions such as baskets or any other containers, various types of clamps (3 walls-system), existing construction eg storehouse, unused pens, etc...

One of the subjects of controversy is the air and water-tightness of the treatment medium. Quite often now it is said that the urea treatment doesn't call for any covering : such an advice is dangerous and should not be stated like that. When the treated roughage is to be stored for a long time, "do not dream" it is necessary to cover in order to avoid moulds development and bad ammonia fixation. Some practical field observations allow such statements: this only relates to the case of large stacks, covered with untreated packs or bales of straw that provide a "self covering"; the outer straw which is of course somewhat damaged does represent only a small proportion of the whole bulk of the inner treated straw.

This can, no way, be satisfactory in the case of small quantities treated where covering remains necessary. In these latter cases however the use of local material can solve the problem without resorting to the conventionnal plastic sheets. These have been experienced successfully with banana leaves, seko mats, banco, mud, old plastic bags (sewed with one another), etc... Tunisia and Morocco are presently experiencing the cover of urea-treated large stacks with mud (mud is already beeing used for decades by farmers to protect their stacks of straw in the field against rain).

Assessment of the treatment efficacy

The best assessment of the treatment efficacy is of course the animal response in terms of intake and performances. However, in field conditions, the question is often raised by the extension agents as to how can they be sure, prior to feed it to the animals, that their treatment was successful when opening the silo they prepared with the farmers.

Without going, here also, in the detailed controversy linked with the prediction aspects of the feeding value of treated (and moreover untreated, see earlier) straws and poor quality roughages, we would simplify by saying that,

(a) the first and simplest criteria of a good treatment is the physical aspect of the treated roughage:

- marked change of colour from clear yellow to brown or dark brown (dark yellow is not enough),
- strong but good ammonia smell, without any trace of bad fermentation smell,
- smooth texture of the straw or the stalks which become easy to twist and to fold,
- absence of any mould.

(b) the second stage, if any doubt, is to resort to the Kjeldahl N assay.

A poor alkali treatment is generally associated with a bad N fixation and therefore a low CP content. The increment of the CP content of DM should at least be of 5-6 percentage points (CP/DM going from 3-4 up to 9-10 %, taking into account the systematic 2/3 loss in the form of labile ammonia that cannot bind). One important point, generally misinterpreted, is that a greater increment is not necessarily synonymous of a good treatment : on the contrary, it should ring the bell of residual urea not totally turned into NH_3 because of partial ureolysis (and, therefore, small ammonia production). As a matter of fact a 4 % CP straw "treated" with 5 kg urea / 100 kg ends up with a CP content of 18.6 % when no ureolysis took place.

(c) the third step, only justified when dealing with relatively high producing animals that must not be fed under their requirements, is to resort to the prediction of digestibility / intake in view of the need of more precision.

- the classical feed analysis will by no way be able to predict any feeding value. Neither CF nor NDF, ADF and ADL will help. It is therefore absolutely useless to loose time and money in recommending them.
- the only, but costly, resorts are the *in sacco* technique or gas test for degradability measurement for feed value prediction, or cellulase or *in vitro* digestibility techniques for digestibility prediction.

All these points have already been discussed in the literature (summarized in Chenost and Reiniger, 1989) and earlier in the Conference but it was worth mentioning them in the particular case of poor quality roughages.

Conclusion

As a conclusion it is now possible to say that provided some key rules are observed the "urea treatment" is technically perfectly adapted to the small farmer conditions, at both the individual and the cooperative level. A lot of practical field experience has been acquired now in an extremely wide range of agro-ecological and sociological conditions with success.

Hermeticity is less a concern than with anhydrous ammonia treatment and is not necessarily important when large quantities of plant material is treated (self covering).

What remains to be further analyzed is its actual rate of adoption in practice.

Supplementation of Untreated and Treated Poor Quality Roughages (PQR)

Principles

The principles of a good digestive utilisation of PQR have already been enumerated and discussed earlier. As a consequence let us recall and summarize in saying that any PQR supplementation should, in the following hierarchical order,

- favour the rumen cellulolysis,
- enhance rumen microbial synthesis,
- supply the animal with the required nutrients for maintenance and,

when necessary, for production, bearing in mind that the latter cannot be compared with the one expected with good forages.

The first step is to feed the "rumen" we are talking of "catalytic" supplementation, which can ensure more or less to maintenance level. This supplementation is typically ensured by NPN (namely urea) and minerals supply.

The second step is to feed the "host animal", when the first step is inadequate to sustain more production than the maintenance, we are then talking of "extra supplementation".

This supplementation should,

(a) be as "cellulolytic" (digestible cell-walls) as possible so as to avoid any negative digestive interactions and too high substitution of the roughage for the supplement,

(b) be brought in such quantities that the basal PQR keeps constituting the major part (2/3 when supplementation is rich in starch, 1/2 when supplements is rich in digestible cell-walls) of the diet.

These two points are of particular importance in the case of treated PQR if one does not want to lose the benefit of the treatment because of negative digestive interactions,

(c) bring a maximum amount of digestible nutrients to the intestine (having escaped ruminal fermentation) to satisfy the animals productive needs,

For socio-economical reasons it should be ensured by as much local feed resources as possible and avoid the use of classical concentrates (or their components, ie cereals earmarked for human nutrition and high quality oil cakes earmarked for non ruminant production but unfortunately quite often exported).

The catalytic supplementation for subsistence or moderate production

The strategic supplements are urea and minerals. Various ways exist of bringing them to the animal. The older one is utilizing liquid molasses as a carrier. Molasses-urea mixtures are still being used and commercialized in certain countries such as Egypt.

A more convenient practice, developed through FAO projects, which becomes popular all over developing countries is the multi-

nutritionnal block (Sansoucy, 1986). The carrying medium is solid and therefore easier to transport. The block is licked, which ensures a small progressive and regular intake of urea. These blocks provide the opportunity of utilizing any type of locally available agro-industrial by-products eg brans, pulps, poultry litters, etc..., which provide the animal with other nutrient sources than urea and mineral, the strategical ones.

Average daily intakes are 400 to 800 g for large ruminants, 300 to 500 g for camels and 100 to 150 g for small ruminants. With a urea incorporation rate of 5 to 10 %, these intakes allow a N ingestion that covers the N microbial requirement to ferment the potentially degradable Organic Matter contained in the straw or roughage fed or grazed (otherwise impossible). As this degradation is accelerated the actual intake of roughages is increased. As a result of expressing the potential digestibility of the roughage and improving its intake, the physiological status of the animals, its liveweight gain or working efficiency or milk production, are improved in a substantial way but, at the same dose of urea, not to the same extent as with urea treatment (table 1).

Such blocks can be manually manufactured by the small farmer himself with the minimum investment.

Supplementation for a higher production level (untreated and treated PQR)

The most common "strategic" supplements, as opposed to the conventional ones, consist in,

- farm residues such as haulms and leaves of pulse crops and vegetables, etc. They provide green or digestible matter of plant origin (and of course vitamins) and their N concentration is interesting,
- by-products of locally processed food and, to a lesser extent, cash crops (the latters are processed in cities and their co-products seldom come back to the farmers village); these are essentially brans and broken cereals (rice,etc.), cotton seed (lintless) and cakes, palm oil kernels, etc.: they provide both proteins of relatively low degradability and energy,

Table 1. Comparison of the effect of the same quantity of urea, used either as a supplement of for treating rice straw on intake and growth rate of cattle.

| | Straw | NT | CU | TU |
|-------------------------------|-------|-----|---------------------------|---------|
| Animals LW (kg) | | | Straw intake (kg DM/d) | |
| Cattle (130-140) ¹ | | 1.7 | 1.7 | 1.9 |
| Cattle ² | | 2.1 | 2.3 | 2.9-3.0 |
| Cattle (75-78) ³ | | | 2.2 | 2.4 |
| Cattle (166-178) ⁴ | | | | 3.9-4.8 |
| Cattle ⁵ | | | 2.8 | 4.0 |
| Cattle (177-196) ⁶ | | 4.3 | | 3.6 |

NT = untreated; CU = supplemented with urea; TU = urea treated

| | Straw | NT | CU | TU |
|-------------------------------|-------|-----|--------------------------|---------|
| Animals LW (kg) | | | Liveweight gain (g/d) | |
| Cattle (130-140) ¹ | | 35 | 75 | 110 |
| Cattle ² | | 103 | 213 | 238-30 |
| Cattle (75-78) ³ | | | 207 | 297 |
| Cattle (166-178) ⁴ | | 141 | | 207-336 |
| Cattle ⁵ | | | 111 | 246 |
| Cattle (177-196) ⁶ | | 304 | | 598 |

¹Saadullah *et al.*, 1981 and 1982

²Perdok *et al.*, 1984

³Saadullah *et al.*, 1983

⁴Kumarasuntharam *et al.*, 1984

⁵Jaiswal *et al.*, 1983

⁶Promma *et al.*, 1985

- tree (mainly legumes) foliages: they provide digestible cell-walls and, overall, naturally protected nitrogen (tannin content). However, tannin content should not be too high (counteracting proteolysis). Attention should also be paid to the possible presence of other antinutritional factors,
- by-products of animal origin (fishing, slaughter house) and animal excreta (poultry litter): they provide high quality proteins.

Apart from the importance and the nature of the energetic fraction of the supplement, one point may have generally been under appreciated, particularly in the case of treated roughages : it is the quality and the quantity of the supplementary protein. Research and practical work show clearly the interest of protein supplementation of treated PQR. This is illustrated by the very interesting responses of intake, digestibility and growth-rate of growing Yellow Cattle to increasing levels of supplementary cottonseed cake (table 2) in commercial operations in China. (Dolberg and Finlayson, 1995)

This "synergetic" supplementation is, in the practice, unfortunately quite often not respecting the rules considered above. In systems where cereals may in certain parts of the year be cheaper than straw (Maghreb, Near East, ...) the synergic properties of local resources are neglected in favour of commercial concentrates inefficiently utilized in too high proportions.

When lower animal performances levels are acceptable (for animals kept at maintenance level) the simple treatment without supplementation will be enough. However it will be very important to make sure that the minerals be not a limiting factor to fully express the treatment effect.

Conclusion

Urea treatment as such and multinutritional blocks are now widely divulged in practice since they represent the simplest and easiest way of optimizing PQRuse by ruminants.

Urea treatment, superior to urea supplementation, improves the nutritional status of animals and their performances. An average improvement of 200 g/d of the ADG of growing cattle, an increase of 1.0 to 2.5 kg of milk produced per day and a better efficiency of draught animals are observed.

Table 2. Response of “Yellow Cattle” intake and growth rate to increasing levels of cotton seed cake as supplements of urea treated rice straw.1. Fan *et al.*, 1993

| | | | | | | | |
|---------------------------------|-----|------|-----|-----|-----|-----|-----|
| Cotton seed cake offered (kg/d) | 0 | 0.25 | 0.5 | 1.5 | 2 | 2.5 | 3 |
| Straw intake (kg DM/d) | - | - | - | - | - | - | - |
| Initial weight (kg) | 175 | 170 | 183 | 193 | 175 | 194 | 215 |
| Final weight (kg) | 184 | 204 | 231 | 263 | 249 | 269 | 294 |
| ADG (g/d) | 99 | 370 | 529 | 781 | 819 | 841 | 880 |

2. Zhang Wei Xian *et al.*, 1993

| | | | | |
|---------------------------------|-----|-----|-----|-----|
| Cotton seed cake offered (kg/d) | 0 | 1 | 2 | 3 |
| Straw intake (kg DM/d) | 5.0 | 5.1 | 4.5 | 4.2 |
| Initial weight (kg) | 182 | 183 | 183 | 183 |
| Final weight (kg) | 205 | 237 | 246 | 258 |
| ADG (g/d) | 250 | 602 | 704 | 836 |

One important feature to bear in mind is that the lower the production level of animals, the better response to feeding treated PQR. As a matter of fact treated PQR are all the more valuable as their proportion in the diet is important.

Recommendations given relative to urea treatment should not be followed rigidly but, to the contrary, should be reasoned and adapted to the agro-ecologic conditions under which the treatment is carried out.

Improved knowledge of the capacity of straws to respond to alkaline treatment should allow the modulation of the urea dosages to be used with a view to economically improving the efficiency of the treatment. This capacity remains, unfortunately, difficult to predict, through a lack of simple or reliable criteria.

More attention should be paid to the use of locally available feed resources as "synergetic" supplementation of either untreated or treated PQR. As an example, the relatively fair quality of the nitrogen generated via treatment justifies the importance of correct reasoning of the quantity and, above all, the nature of the nitrogen supplement in treated forages.

Development measures, to be followed along with the extension programmes of such techniques, and agro-economical and sociological considerations regarding rate of adoption and impact of such techniques have voluntarily not been considered in this paper. However they deserve the uppermost attention when launching poor quality roughages-based development programmes.

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