OPTIONS FOR INCREASING THE UTILIZATION OF CEREAL STRAWS

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ABSTRACT. The available information on methods of improving feeding values of cereal straws to overcome their nutritional deficiencies is presented in the context of alternative options with special reference to goats.

The need to create a favourable rumen environment by addition of nitrogen, carbohydrates and minerals for efficient cell wall digestion is discussed. The merits of chopping, soaking, grinding and pelleting, and the effectiveness and practicality of sodium hydroxide, lime and urea treatments of straws are discussed with emphasis given to urea -NH_3 treatment.

Supplementation strategies are defined and supplements identified. The merits of liberal vs limited supplementations are considered. Feeding strategy involving urea NH_3-treated straw with limited supplementation for optimal production is presented.

Feeding behaviour and digestive efficiency of the goat in relation to straw utilization are discussed.

INTRODUCTION

Straw utilization has been a subject of continuous research and is reflected in voluminous data accumulated over the years. A good deal of those data stems from Asian countries where there are perennial shortages of feed supply during the dry season (Davis et al., 1983 and Jackson, 1978). Most of the research on straw feeding relates to large ruminants and to a lesser extent, sheep. By comparison, only scanty information is available on the utilization of cereal straws by goats (Doyle et al., 1986).

This paper reviews the current knowledge on various options for increasing the utilization of fibrous agricultural residues as feeds for ruminants. It will focus special attention to those technologies applicable to small farmers in the developing countries. Recognizing that the bulk of the work has been done with other ruminant species, the paper will attempt to examine the opportunities that exist for use of cereal straw to increase productivity from goats.

CHARACTERISTICS OF CEREAL STRAWS AS ANIMAL FEEDS

FIBER CHARACTERISTICS AND NUTRITIVE VALUE

Cereal straws are poor quality feeds. They ard bulky and hence expensive to transport and difficult to store. Straws consist mainly of the structural components of plants. They are lignocellulosic in nature, possessing the components cellulose, hemicellulose, pectin and lignin. Chemical composition of some cereal straws is shown in Table 1.

While hemicellulose exists as a complex carbohydrate polymer, cellulose molecules are made of long chains of glucose molecules which in the cell wall exist mostly as crystalline fibers. The degree of crystallinity, together with the degree of lignification of polysaccharides, act as a barrier to microbial degradation of the polysaccharides. The high content of silica in rice straw relative to wheat straw is a major disadvantage since, together with lignin, it reduces straw digestibility. Rice straw also differs from other cereal straws in having a high content of cutin (7%) cutin does not interfere with fiber digestion (Jackson, 1977).

Cereal straws contain very low crude protein (4-5%) which is below the critical level of 7% dietary protein required for acceptable voluntary feed intake. Rice straw has high ash content (15-20%) which includes a large amount of silica. The levels of Ca, P and Mg available from rice straw are usually lower than the range of 0.2-0.8% required for normal growth and fertility of ruminants. The same is true with trace elements like Co, Cu, etc.

THE NEED FOR ADDITIONAL NUTRIENTS

In view of low availability of energy, protein and minerals in cereal straws, the need for supplementary nutrients is obvious to maximize fiber digestion, utilization and to improve animal performance.

It is now generally agreed that levels of about 70 mg ammonia-N/1 are required for optimal rumen microbial activity (Elliot, 1986). To attain this nitrogen (N) level, the diet should contain 2% N. Straws usually contain less than 0.7% N, which is insufficient for rumen fermentation and hence feed intake. Urea, poultry manure and leguminous forages are good sources of fermentable N. Preformed proteins, particularly those protected from rumen degradation, are valuable to the animals for post-ruminal digestion and absorption. Good examples are fish meal and leucaena (Leucaena leucocephala) leaf meal.

Provision of readily fermentable carbohydrate (RFC) is important for growth and functions of rumen bacteria. Orskov and Grubb (1978) reported improved utilization of urea with alkali treated compared to untreated straw, and suggested that this was due to the increased availability of carbohydrates for digestion. There is however ample evidence to suggest that an excess of RFC can adversely affect digestion of cell wall components (CWC) of roughages. The most frequently observed responses to increasing levels of RFC in the diet are increased total dry matter and digestible organic matter intakes but decreased straw intake as well as cellulose digestibility (Mullholland et al., 1976; Devendra, 1978a and Lohani et al., 1985). Dry matter digestibility likewise was found to linearly increase in proportion to the amount of concentrate. However, the rate of digestion of CWC in the rumen was decreased by the ingestion of RFC. This reduction in the rate of digestion is likely to become of practical importance at higher levels of concentrate supplementation (in excess of 0.5% BW, which could cause reduced roughage intake).

IMPROVING FEEDING VALUES OF CEREAL STRAWS

There are a number of methods by which feeding values of straws can be enhanced: physical, chemical, biological treatments, supplementation, or the combination of 2 or more of the above. While all of these processes are technologically possible, many are not economically feasible. The following discussion will identify the available options with emphasis on the more practical aspects of relevance to farmers in the developing countries.

PHYSICAL TREATMENTS

Possible physical treatments include soaking, chopping, grinding, pelleting , boiling, steam under pressure and gamma radiation. Among these methods, chopping and soaking are the simplest and could easily be adopted by farmers. According to reports from India, chaffing of wheat straw and soaking it in water overnight before feeding improved digestibility and voluntary feed intake (VFI) of cattle by 5 units (Ranjhan, 1983). Castillo et al. (1962) on the other hand reported that chopping rice straw increased VFI by carabaos and soaking the chopped straw did not further increase intake in spite of 70% reduction in the oxalate content. Devendra (1982) by comparison expressed apprehension regarding the effect of wetting straw on loss of dry matter. He demonstrated that both VFI and digestibility by sheep were significantly decreased by wetting chopped rice straw. The position regarding soaking and wetting is thus mixed in relation to differential response by ruminants.

More severe physical treatements such as grinding and pelleting can result in dramatic increase in intake of digestible matter. Such treatements, nevertheless, may depress *in vivo* digestiblity. This decrease is generally associated with increased VFI and rate of passage (Minson, 1963).

CHEMICAL TREATMENTS. The objective of chemical treatments is to increase digestibility by increasing lignin solubility or decreasing the strength of the bonds between lignin and polysaccharides. The following chemicals have been used to improve nutritive value of crop residues: NaOH, $Ca(OH)_2$, CaO, KOH, $NH_4(OH)_2$, ammonia gas, urea/ammonia, Na_2CO_3, Nacl, SO_2 and chlorine gas. Of these, only sodium hydroxide, lime and urea treatments are the most common, and in view of this as well as brevity, the discussion will only include these alkalis.

1. Sodium hydroxide. Extensive studies have been done on NaOH treatment of straw in terms of treatment procedures, effectiveness and animal responses (Jackson, 1978). The general conclusion is that NaOH (at the rate of 4-6 kg/100 kg straw) is more effective than other chemical treatments in improving the potential digestibility of straw (by 10-25 percentage units depending on the method employed). Feeding trials have demonstrated beneficial effects of spraying roughages with NaOH for maintenance, growth, fattening and lactation (Doyle, 1982). For example in India, Sehgal and Punj (1983) demonstrated that feeding NaOH-treated wheat straw to kids over 168 days gave a better (P 0.5) feed efficiency (9.7 vs 11 feed/gain) and total weight gain (8.5 vs 6.2 kg). However, NaOH treatment has not gained acceptance in Asia mainly because of the high cost of the chemical, coupled with the hazards of handling, complicated procedures and pollution problems.

2. Calcium hydroxide and Calcium oxide. Although generally less effective compared to NaOH, it is cheaper and safer to use $Ca(OH)_2$ and CaO, particularly in countries with large surface deposits of limestone and/or calcium hydroxide. Poor solubilities of these chemicals, however, present a considerable disadvantage to their use. In situations with a long monsoon season, wet straw can be dusted with slaked lime at 5% of straw DM and satisfactorily stored for 5 months (Dolberg *et al.*, 1982). Compared to ammonia/urea treatment, lime has an advantage of not demanding an airtight storage condition.

The effectiveness of $Ca(CH)_2$/CaO treatment depends very much on the method used. Spraying has been found ineffective and usually requires a long treatment time (Doyle, 1982). When the Beckmann method is used, lime can be nearly as effective as NaOH without the need for long reaction time. Digestibility data (Dumlao, 1974; Jackson, 1978; Verma, 1981) indicate that effective treatment procedures require soaking straw to suspension at the ratio of 1 part of straw to 8 parts of suspension for 24 hours. Concentrations of 10-15 g $Ca(OH)_2$ per 100 g rice straw or 1-2% CaO solution are sufficient. Washing is not necessary.

Voluntary intake and digestibility of straw treated with lime/$Ca(OH)_2$ gave poor results (Table 2) due to a high Ca content that can produce an imbalance in the Ca/P ratio (Verma et al., 1982). Provision of urea and low-Ca minerals to lime treated straw diets may be a wise feeding strategy. With growing cattle, Verma et al. (1982) obtained daily gains of 38-90 g from lime-treated straw alone. With 40% of the straw replaced by concentrate, Pacho et al. (1977) obtained daily gains of 630-720 g from Philippine cattle.

3. Ammonium hydroxide/ammonia gas/urea. In recent years, considerable interest has been shown regarding the use of anhydrous ammonia (NH_3 gas), aqueous ammonia (NH_4OH) and ammonia released from urea degradation. Anhydrous NH_3 and urea-NH_3 only becomes of value after solution in water to form the hydroxide.

A good effect of ammoniation is N enrichment and rice straw is roughly doubled in N after treatment. The increase in digestibility from NH_3 treatment ranges from 10-15 units (Jackson, 1978). The main constraints to urea treatment are the need to maintain airtight conditions and long treatment time required. The latter disadvantage can be overcome by addition of natural urease sources such as Gliricidia leaves or poultry manure (Lohani et al., 1984). This reduces treatment time from 21 to 4 days.

Effects of urea treatment on VFI and digestibility of straw using large ruminants have been reviewed (Doyle, 1982). Some differences are apparent in the results but in all cases, intake of digestible straw was higher after urea treatment. With goats the findings were similar, as shown in Table 3 (Trung et al., 1986b).

Many studies on ruminant production responses to urea-treated straw have been published but very few of them relate to goats. The absence of such information in goats does not imply that urea-treated straw is not acceptable to goats. This is simply due to the use of management systems in goats which are essentially extensive. Stall feeding of goats is less common, but has been demonstrated (Sehgal and Punj, 1983; Hussain et al., 1983; Hadjipanayiotou, 1984) and is a production system that needs to be more fully explored (Devendra, 1986). More recent data obtained from 6-month trials using urea-treated straw is further evidence of the value of this system to goats (Table 3). Feeding urea-treated straw to buffaloes gave increased milk yield of buffaloes by 34% while better bodyweight maintenance of dams and better growth rate of suckling calves were observed when straw was treated (Perdok et al., 1982). Superior weight gain and feed efficiency have also been reported for cattle (Khan and Davis, 1982). Restricting straw intake of the treated group to the intake level of the untreated group did not change weight gain and feed efficiency and realized 24%

straw saving. This saving is significant to farmers in South Asia where feed shortage is a perennial problem.

SUPPLEMENTATION

The principal objective of supplementing cereal straws is either to optimize animal productivity through improved utilization of the straws by the animal or to meet requirements of the animal for production. The amount of supplement is generally small, and is intended to provide by-pass protein and to establish a favourable rumen environlent in order to optimize microbial growth for efficient fibre digestion. To fully exploit production potential of high-producing animals, supplements are fed in much larger amounts, usually higher than the straw's portion. In such cases, digestibility of the residue is often depressed in favour of increased digestible nutrient intake derived largely from the supplement.

1. Kinds of supplement. In addition to the need for including minerals, fermentable carbohydrate and nitrogen in straw diets, "by-pass" protein and energy in straw-based diets would further improve productivity of ruminants by providing glucose and amino acids post-ruminally.

Legumes such as ipil-ipil (*Leucaena leucocephala*), madre de cacao (*Gliricidia maculata*), Sesbania (*Sesbania grandiflora* or *S. rostrata*) and Stylo (*Stylosanthes guinensis* or *S. gracilis*) are available abundantly in many parts of the tropics. They are valuable supplements to cereal straws. In addition to providing fermentable nutrients (N, S, etc.) for rumen microbial growth and functions, they contain significant quantities of protein capable of escaping ruminal digestion (Elliot, 1986).

Fish meal (FM) is perhaps the best "by-pass" protein supplement. In addition to providing essential amino acids, FM is also a source of lipids, Ca, P and other essential minerals. Furthermore, because of its low solubility, it could supply a slow rate of release of proteins within the rumen which may stimulate microbial growth.

In an attempt to determine by-pass quality of different feed ingredients, Saadullah *et al.*, (1983b) indicated that rates of degradability for dry matter and N in the rumen were slowest for FM, followed by ipil-ipil and fastest for oil cakes. The effects of by-pass protein supplementation have been discussed (Davis *et al.*, 1983; Leng and Preston, 1985).

2. Liberal supplementation for maximum production. In developing countries, it may not be economical to be too dependent on concentrate supplements of which the cost is often high. Nevertheless, if meat or milk commands a good price and feed supplements are available abundantly, it is feasible to maximize production. Numerous studies have been

conducted to determine to "upper limit" of straw inclusion in diets of productive animals such as sheep (Devendra, 1975), fattening bulls (Perez, 1982 & Sevilla, 1976) and dairy cattle (Trung et al., 1986a). Utilizing local ingredients such as copra meal, rice bran, ipil-ipil and dried poultry manure as supplements, the studies indicated that rice straw could be maintained at 30-35% of ration dry matter in order to expect high production. The results of 2 feeding trials with dairy goats (Velasco et al., 1986) and fattening Philippine goats (Rasjid and Perez, 1980) are presented in Table 5. Although the performance was rather poor, they demonstrated the usefulness of abundantly available feed ingredients as supplements of rice straw for goats. The liberal supplementation of straw rations has been reviewed (Trung, 1986).

3. Optimizing production through limited supplementation. Because of economic implications, limited supplementation of fibrous residues diets utilizing local feed ingredients is now considered as appropriate technology of feeding ruminants in the tropics. Effects of 30% concentrate in a lime-treated straw diet on intake and digestibility of non-descript goats are shown in Table 2. Marked improvements in straw intake and digestibility resulted in better nitrogen balance and body weight maintenance (Dumlao, 1974). Dose responses of goats fed urea-treated straw to varying levels of concentrate (rice bran and copra meal) supplementation have been studied (Trung et al., 1986b). Digestibility and digestible dry matter intake increased with increasing levels of concentrate given. However as the daily supplement increased fom 0.4% to 0.8% body weight, rice straw intake as well as total dry matter intake slightly decreased (Table 3).

The responses of growing/fattening cattle fed urea-treated rice straw to limited supplementation are highlighted in Table 6. Daily supplementation of 150 g FM resulted in dramatic weight gain and feed efficiency (Saadullah et al., 1982). The amount of fish meal over the control in another experiment was only 50 g a day to increase daily gain by 4 times (Saadullah et al., 1983a). Combinations of fish meal with other supplements and the use of copra meal and/or rice bran have also been tried (Table 6) with straw diets (Perdok, 1982 and Davis, 1983). Davis et al. (1983) concluded in Bangladesh that limited supplement strategy if applied to traditional feeding system could improve feed conversion ratio from 50 to 10 and daily weight gain from 100 g to 300 g, which reduces the period required for the animal to reach 150 kg liveweight from 4 years to 1 year 4 months. Furthermore, the unproductive proportion of animals in a herd is also lowered. Unfortunately no data exist on limited supplemen-tation of fibrous residues diets for goats, which may be an effective strategy for feeding goats in the tropics.

COMPARATIVE BIOLOGICAL AND FEEDING BEHAVIOUR OF GOATS IN RELATION TO STRAW UTILIZATION

FEEDING HABITS IN RELATION TO STRAW ACCEPTABILITY

A major difference betwen goats and other ruminants is their preference for browse. They prefer situations where they can browse and select from a wide variety of feeds. If they are stall-fed, exposure to limited grazing and browsing is something the animals will enjoy. This behavioural pattern suggests that the provision of variety in the feed is an essential component of their efficient nutritional management in order to obtain satisfactory response for them. It is generally observed that goats do not thrive well when kept on one feed for any length of time. Furthermore, they have been shown to distinguish between bitter, sweet, salty and sour tastes. This ability obviously assists the animals in the selection of feeds, discriminating against those that are less acceptable (Devendra, 1978b) and selecting those that can provide nutrients for maintenance and production.

Under extensive conditions, goats may be used to convert otherwise useless browse plants into meat. Those browse plants, often coarse, are valuable feeds for goats. The feeding habits of goats are particularly significant in areas where quantity and quality of feeds are low, as occurs in many parts of the tropics (Devendra and Burns, 1983).

Under stall-fed conditions, however, goats are known to be stubborn when it comes to poor quality feeds. At the University of the Philippines at Los Banos, it is frequently observed that when fed with unsupplemented rice straw/corn stover, it takes a longer time for goats to get accustomed to the feed compared to cattle. Some goats would hardly eat at all after 2 or 3 weeks of adjustment period. This would result in general weakness and death. Dumlao (1974) reported 2 mortalities out of 12 goats due to starvation when untreated rice straw was fed without supplements.

An interesting feeding behaviour of Saanen goats fed on barley straw was recently reported from England. The conventional 15-20% refusal rate when *ad libitum* feeding is referred to may not apply to goats. Owen and Wahed (1986) reported that straw intakes increased by a third with refusal rate of 50 rather than 15-20%.

The above mentioned feeding behaviours may probably be among the reasons that discourage researchers from feeding fibrous residues to goats, hence the paucity of information quality feeds such as straws, improvement of palatability of the feed is important, for example by sprinkling with molasses solution. Provision of fermentable nitrogen for the growth and functions of rumen microorganisms is another consideration to ensure satisfactory intake.

COMPARATIVE DIGESTIVE EFFICIENCY OF THE GOAT

From the limited research findings on the utilization of straw by goats and in relation to their feeding habits, there is no doubt that straws are acceptable to them, provided appro-priate treatment and supplementation of straw diets are made. This last session is devoted to a brief reference to digestive efficiency of the goats compared to other ruminants in the utilization of low quality roughages.

It is generally accepted that goats digest coarse fibre more efficiently than other ruminants. There is no conclusive evidence for this but the limited data available support this view. Devendra and Burns (1983) compiled 32 reports on comparative digestive efficiency between goats and other ruminants and found that there were 22 reports showing statistically significant differences in favour of higher digestive efficiency for cellulose by goats. These differences were apparent with decreaasing quality of roughages (Devendra and Burns, 1983). Thus in situations where the quality of feeding-stuffs is of a high fiber content, as is often the case in the tropics, goats are nutrients much better than sheep or cattle, and in this situation their value increases with decreasing quality of feed available (Devendra, 1978).

Experimental evidence for the reasons of the higher digestive efficiency is conflicting but are related to several factors which include retention time, rate of passage, rate and quantity of saliva secretion, urea recycling and possibly also increased concentration of cellulolytic splitting microorganisms. A lot more informa-tion is required in this area.

Recently, attention has been drawn to the higher NH_3-N in goats which has been attributed to greater rumen protein degradation as a result of a longer retention time of digesta in the rumen (Watson and Norton, 1982). Since goats drink less water than sheep per unit dry matter intake (Gihad, 1976; Gihad et al., 1980; Owen and Ndosa, 1982; Alam et al., 1983), it has further been suggested that the lower water intake may be the cause of the higher rumen NH_3 nitrogen concentration (Alam et al., 1984).

CONCLUSION

Information on feeding values of cereal straws by sheep and large ruminants is abundant but there is a paucity of data for goats. It is not appropriate to extrapolate figures obtained from other ruminants to goats due to established physiological differences among the species.

The limited research findings do nevertheless emphasize the tremendous potential that exists to encourage goats to utilize fibrous agricultural residues including straws more efficiently. Urea-treated straw should receive a high priority in feeding trials with goats and wider use of this crop residue among others needs to be encouraged in more intensive management systems.

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Straw	Crude Protein	Cell Wall	Cellulose	Hemi Cellulose	Lignin	Silica
Rice	4	79	33	26	7	13
Barley	3	81	44	27	7	3
Wheat	4	80	39	36	10	6
Oat	4	73	41	16	11	3
Sorghum	4	74	31	30	11	3
Corn	6	67	-	-	11	-

TABLE 1. CHEMICAL CONTENTS OF CEREAL STRAWS (% DRY MATTER). (Devendra 1982 and Trung 1986).

Treatment	Digestibility (%)		Straw intake (kg)	Nitrogen balance (g)	BW changes (kg)
	in vitro	in vivo			
Untreated straw	50.15	30.33	1.03	-14.76	-1.48
Lime-treated straw (L)	69.38	34.60	1.12	-8.45	-1.00
70% L + 30% CS*	76.61	50.86	1.82	-2.08	-0.07

TABLE 2. INTAKE AND DIGESTIBILITY OF PHILIPPINE GOATS FED LIME-TREATED STRAW WITH LIMITED CONCENTRATE SUPPLEMENTATION (CS).

* LARGELY COPRA MEAL AND RICE BRAN (Dumlao, 1974).

Diet	Dry matter intake (DMI)			Digest. DMI	Digestibility
	Straw (g)	Concentrate (g)	Total (75 g/kg)	(g)	(%)
Untreated straw	518	-	52.1	186.6	36.37
UTS	630	-	63.5	373.2	58.19
UTS+ 0.2% BW conc.*	688	36	75.4	372.8	51.54
UTS+ 0.4% BW conc.	801	74	89.3	461.1	54.48
UTS+ 0.8% BW conc.	779	150	88.6	553.2	59.68

TABLE 3. INTAKE AND DIGESTIBILITY OF PHILIPPINE GOATS FED UREA-TREATED RICE STRAW (UTS) WITH VARYING LEVELS OF CONCENTRATE SUPPLEMENT.

* RICE BRAN AND COPRA MEAL (Trung _et al_., 1986b).

Source/Parameter	Untreated	Urea treated straw	
		Ad lib.	Restricted
Nursing Surti buffalo cows (Perdok *et al.*,1982)			
Dry matter intake (g/kg 0.75)	119	163	-
Milk yield (kg)	2.2	3.0	-
Cow's B.W. changes (g)	-93	59	-
Calf's B.W. gain (g)	165	295	-
Growing cattle (Khan and Davis, 1982)			
Dry matter intake (g/kg 0.75)	91.2	104.6	86.7
Liveweight gain (g)	125	310	303
Feed/Gain	28	14	12

TABLE 4. DAILY MEANS OF PRODUCTION RESPONSES TO FEEDING UREA-TREATED STRAW.

Ration/Study	Dry matter intake (g/kg 0.75)	Daily gain or milk yield (g)	Feed/milk gain
Dairy goats, 90-day mid-lactation (Velasco *et al.*, 1986)			
35% grass + 65% C	73.83^{a}	850^{a}	1.69^{a}
35% RS + 65% C	52.52^{a}	370^{a}	2.64^{a}
35% RS + 15% C + 50% PM & I^{+}	75.82^{a}	500^{a}	2.42^{a}
Philippine goats fattening, 84 days (Rasjid and Perez, 1980)			
30% RS + 70% I	64.83^{a}	35.7^{b}	12.56^{b}
30% RS + 50% I + 20% RB	71.82^{a}	68.6^{a}	7.65^{a}
30% RS + 50% I + 20% M	70.40^{a}	50.0^{ab}	10.54^{b}

Table 5. RESPONSES OF GOATS TO RICE STRAW (RS) RATIONS SUPPLEMENTED WITH IPIL-IPIL (I), DRIED POULTRY MANURE (PM), COMMERCIAL CONCENTRATE (C), RICE BRAN (RB), AND MOLASSES (M).

* MEANS WITHOUT A COMMON SUPERSCRIPT ARE DIFFERENT (P/.05).
EACH RATION MEAN IS THE AVERAGE OF 5 REPLICATIONS.
+AVERAGE OF 3 RATIONS CONTAINING DIFFERENT LEVELS OF I/PM.

Source, basal ration and daily supplement (s)	Daily gain (kg)	Feed/gain
Saadullah et al., 1982		
1. 0.15 kg DM green grass + minerals	0.15	23
2. 1. + 0.15 kg fish meal	0.36	10
3. 2. + 0.3-0.6 kg rice bran	.34-.35	11-12
4. 1. + 0.3kg oil cake	0.19	20
5. 4. + 0.3-0.6 kg rice bran	.24-.25	15-18
Davis, 1983		
1. Straw intake at 2.2% BW + 0.16 kg DM Napier	0.19	47
2. 1. + 0.2-0.4kg oil cake	0.37	16-13
3. 1. + 0.6 kg oil cake	0.51	10
Perdok, 1982		
1. 1 kg green grass + Minerals	0.33	-
2. 1. + 0.18 kg fish meal (FM)	0.42	-
3. 1. + 0.54 kg copra meal (CM)	0.50	-
4. 1. + 1.08 kg rice bran (RB)	0.52	-
5. 1. + 0.09 kg FM + 0.54 kg R	0.49	-
6. 1. + 0.27 kg CM + 0.54 kg RB	0.50	-
Saadullah et al., 1983		
1. 1 kg fresh water hyacinth + minerals	0.05	-
2. 1. + fish meal, 0.05 kg	0.20	-
0.10 kg	0.21	-
0.15 kg	0.19	-

TABLE 6. GROWING/FATTENING RESPONSES OF CATTLE TO VARIOUS SUPPLEMENTS IN UREA-TREATED RICE STRAW DIETS (STRAW FED AD LIB. UNLESS OTHERWISE STATED).

STRATEGIES FOR MINERAL SUPPLEMENTATION

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ABSTRACT. The review highlights the role and functions of minerals, their metabolic and nutritional disorders, requirements, factors affecting availability and utilization of a particular element, together with appropriate detection techniques and preventive methods with special reference to goats. The patterns of appearance of signs and clinically detectable metabolic changes which occur in relation to minerals, generally in ruminants and specifically in goats are briefly described. Some possible nutritional problems related to minerals might arise under the grazing conditions with goats are also considered. Several methods of detecting and diagnosing of mineral deficiencies and excesses in farm animals, including clinical, pathological and biochemical examinations along with soil, water, plant and animal tissues and fluid mineral analysis are described. Mineral requirements of goats remain to be accurately defined. The mineral requirements of animals are influenced by nature and level of production, age, sex, breed, level and chemical form of elements, mineral balance and adaptation are briefly discussed. The factors that might affect mineral bio-availability and utilization by ruminants, including source and form of mineral and interactions with other nutrients are considered. Mineral supplementations and methods of supplementation for both stall fed and grazing animals are discussed.

INTRODUCTION

More than 400 million goats around the world kept for the production of milk, meat and fiber. Recent surveys of mineral contents of tropical forages (Conrad and McDowell, 1982) showed that they were all below NRC-recommended allowances for dairy and beef cattle and properly for goats in P, Na, Zn, and Mg. Likewise, in studies around the world many soil and plant conditions have been reported with forages being deficient, imbalanced, or containing toxic excesses of many nutritionally important minerals (Underwood, 1966). Also, many problems might arise concerning mineral adequacy due to changing production systems to more concentrated operations and use of better quality feedstuffs which may be low in minerals or, for some products, contain excessive amounts of mineral elements. Moreover, the growing interest in minerals is also related to the gradual disappearance of minor or trace elements from our soils as a result of intensive cropping.

The present review is intended to highlight the role and function of mineral elements, requirements and their metabolic and nutritional disorders in farm animals with specific reference to goats, together with appropriate detection techniques and preventive methods.

IMPORTANCE OF FEEDING MINERALS AND THEIR BIOLOGICAL ROLES

The biological roles and functions of minerals has been extensively reviewed (Underwood, 1966; 1977; Church, 1979). The role of minerals in the organism is highly variable and intimately connected with their form and condition. Each of the essential minerals serves a variety of functions, which may be predominantly physical, chemical or biological in nature, depending on the chemical form or combination of the mineral and its location in the body tissues and fluids. The functions include, participation in the formation of connective tissues; maintenance of homeostais in the internal fluids; maintenance of cell membrance equilibrium, activation of biochemical reactions by acting on the enzyme systems; direct or indirect effects on the functions of endocrine glands; and effects on the symbiotic microflora of the gastrointestinal tract.

NUTRITIONAL DISORDERS INVOLVING MINERALS IN GOATS

The patterns of appearance of signs and the clinically detectable metabolic changes which occur, generally, in ruminants where deficiencies of individual mineral element are imposed experimentally are well described in classical studies; these have been detailed else where (Underwood, 1966; 1977; Church, 1979). A deficiency of Ca in young animals leads to retarded growth and development, and can predispose them to rickets (NRC, 1981). Rations for lactating goats, as in all lactating animals need a higher Ca level. This may be critical in goats since goat's milk high in Ca (Parakash and Jenness, 1968). Inadequate dietary Ca and P in the diets of lactating goats for a long period resulted in a decrease in body store of Ca and finally decreased milk production and vice versa (Haenlein, 1980).

Symptoms of Mg deficiency are anorexia excitability, and calcification of soft tissues. The most noted problem associated with hypomagnesmia is grass tentany. Maintaining goats on diets low in Mg resulted in marked decrease in milk yield (Razifard, 1972). Insufficiency of Na in the diet, led to loss of appetite and weight, reduced urine volume and cessation of lactation in goats (Haenlein, 1980). Excessive Na shortage led to diarrhoea, muscle trembling and death. Increase of dietary chloride (as ammonium chloride) in the diets of goats produced acidosis that resulted in reducing feed intake to the point of even complete refusal (Host and Jorgensen, 1974). Iron deficiency seldom occurs in mature grazing animals. However, it may occur in young goats' kids because of their minimal body stores of iron at birth and the low Fe content of milk (Jenness, 1980). Iodine deficiency may cause goitre which is most frequently observed in the young at birth, especially in weak or dead kids. Goats, appear to be different with respect to iodine metabolism. They show much higher concentrations of radioiodine in milk than cows under similar conditions (Lengemann, 1970). Young goats developed Cu-deficiency symptoms, even where Cu supplies seemed adequate, but where industrial emissions were high in Cd and S (Henning et al., 1974). These symptoms had been aggravated by the relatively high amount of Mo in their diets. Lowering Zn in the diets of goats resulted in symptoms resembling Zn deficiency in cattle (Neathery et al., 1973). Also, male kids of goats raised on diets low in Zn (6-7 ppm) severely became stunned, but females were not affected until they were lactating (Neathery et al., 1973). Manganese deficiency in goats may result in symptoms include lower birth weight, reluctance to walk, deformity of forelegs, and reduced reproductive efficiency (Haenlein, 1980).

Mineral problems under grazing conditions.

Mineral deficiencies or excesses in livestock under grazing conditions have been reported from almost all regions of the world (Underwood, 1966; Conrad and McDowell, 1978). The most prevalent mineral deficiencies for livestobk is lack of P with reports of deficiencies in at least 38 tropical developing countries (McDowell and Conrad, 1977). Next to P, the mineral most likely to be deficient for grazing livestock are Co and Cu. Also, deficiencies of Na and I are equally widespread as are lack of Co and Cu. a phosphorus deficiency in grazing goats is more likely than a Cu one. It might be encountered with type of goat grazing on P-deficient forages.

However, documented examples of P deficiency in grazing goats are rare. This can be explained by their varied habitats and tendency to browse plants that may be high in P.

Most natural feeds are lower in Na than they are in chlorine. According to Underwood (1966) a dietary deficiency of Na is most likely to occur under tropical or hot semi-arid conditions where large losses of water and Na occur in the sweet and where the grass herbage and the seeds products are low in this element. However, goats in arid regions may have problems with the salt content of some water sources, which can reduce intake of water and feed (NRC, 1981). Grazing of animals on lush green (low in Mg) or winter cereals inpastures fertilized with N and K may cause hypomagnesemia (grass tentany). Study by Wheeler et al., (1975) indicate potential shortages of sulphur in forage sorghums. Another study by Gartner and Hurwood (1976) indicates that tannic acid containing plants such as Acacia aneura may provide inadequate amounts of available sulphur. This of particular true of range goats, which liberally graze and browse tannin-containing plants.

Copper deficiency in ruminants, as with Co, occur mainly under grazing conditions, with clinical signs of the deficiency being rare when concentrates are fed (Ammerman, 1970). A simple Cu deficiency in grazing stock is comparatively uncommon. Most of the Cu deficiencies which exist are "conditioned" by the presence of dietary factors i.e. Mo, S, Cd, etc. in the affected areas that interfere with the utilization of Cu by the animal. Cobalt deficiency occurs in grazing ruminants, including goats, with varying degrees of severity, in many countries. A naturally occurring Zn deficiency in grazing stock has also been reported in various parts of the world (McDowell and Conrad, 1977). Zinc deficiencies reported in cattle and probably other ruminants species like goats under grazing conditions resulted in skin disorders and reduced performance. Manganese deficiency is seldom encountered in ruminants fed diets composed of natural ingredients (Underwood, 1966). However, low Mn forages have been reported in some of Latin American countries (McDowell and Conrad, 1977) and certain Dutch farms (Underwood, 1966) especially those with sandy and peat soils of high pH. Consumption of feedstuffs containing both toxic ($>$ 5 ppm) and low ($<$ 0.1 ppm) concentrations of Se presents a world wide problem to grazing livestock (McDowell and Conrad, 1977). In grazing animals, distinct Se-deficiency syndromes have been described (White muscle diseases) in newborn of young lambs and calves; and unthriftiness, with poor growth rates. Whether such a condition would be applied for goats, still yet has to be investigated.

MINERAL REQUIREMENTS OF GOATS

The knowledge of metabolic pathways of mineral elements in goats is very scanty and have not received adequate attention. Nevertheless, some basic information on these elements in relation to mineral nutrition and requirements of goats do exist (Haenlein, 1980; Kessler, 1981; Lamand, 1981). The following points should be considered when fulfilling such requirements (NRC, 1981):

1. Calcium contents of goat's milk is higher than dairy cattle, (Parakash and Jenness, 1968), suggesting higher requirements for Ca of lactating goats than dairy cattle.

2. The Ca to P ratio should not drop below 1.2: 1 in diets for goats.

3. Goats may well not get their requirements for K if they are restricted to high-concentrate diets in which major ingredient is low in K, or to diets of severely weathered or winter range forage.

4. Recommendations for S requirements are normally expressed in terms of a sulphur to nitrogen ratio of 1:10. However, this ratio may be misleading if either or both sulphur and nitrogen are unavailable because of the presence of complexing substances such as tannic acid. Also, the high producing Angora goat may have an elevated S requirement because of mohair growth, but this possibility needs to be investigated.

5. Although Fe deficiency seldom occurs in grazing animals, it may occur in young kids because of their minimal body stores of Fe at birth and the low Fe content of milk (Jenness, 1980). Accordingly, injections of iron dextran (150 mg) at two to three weeks intervals is recommended to kids suffering from Fe deficiency and if it is desired to continue the kids on milk diets.

6. Concerning Cu, it appears that sheep are sensitive to Cu toxicity and resistant to molybdenosis, but it is not known whether this is also the case with goats.

Factors influencing mineral requirements.

Many factors affect the mineral requirements of animals. Among these are nature and level of production, age, sex, breed, level and chemical form of elements, mineral balance and adaptation; these have been extensively discussed in Underwood (1966).

The ability of an animal to absorb or utilize some minerals is influenced by the amounts of other minerals or organic compounds in the whole diet. Thus, estimates of the minimum requirements or of the maximum safe intakes of any mineral is based on the dietary concentrations of the other minerals or organic compounds in the diet. Also, adequate intake of forage by ruminants is essential in meeting mineral requirements. Thus, factors that greatly reduce forage intake, such as low protein content and increased maturity, lingnification, and stem-to-leaf ratios, likewise reduce the total minerals consumed (Conrad et al., 1982).

The bio-availability and utilization of minerals.

The relative biological availability of the desired element in a compound or supplement is one of the major considerations in the selection of a suitable source of the element. In the study of mineral metabolism, it is generally recognized that the total content of a mineral element in a particular compound or in a complete ration has little significance unless it is, qualified by a factor indicating the biological availability of the element to animals. Sources of the minor and major mineral elements customarily used to supply adequate dietary levels and their relative biological availability are extensively described in the literature (Peeler, 1972; Ammerman and Miller, 1972; Church, 1979).

Animal requirements were originally determined using compounds with relatively high availability (i.e. sulphates and chlorides). If compounds that are less available are used in a mineral supplement, a larger amount of these substances must be added in order to meet the animal's requirement for the mineral involved. In addition to availability, the stability of the compound used to supply the mineral element is also important. Unstabilized potassium iodide, for example, is less effective under wet tropical conditions, since iodine in this form is readily volatilized or leached (Houser et al., 1978).

Numerous dietary factors influence bio-availability and utilization of mineral ions by the ruminants. Among these are chemical and physical form of the mineral elements, interrelationships among the mineral ions and the role of chelation (Fritz, 1976).

Miller (1979) gave many examples to elucidate the importance of chemical form of mineral elements and their effect on bio-availability. For example, iron oxide is much less available for dairy cattle than many other iron compounds. Also, cattle are able to tolerate substantially less flouride from a soluble source, such as sodium or calcium flouride, than from the less soluble flouride in phosphate compounds.

Recently animal nutritionists have come to realize that organic chelates of minerals may be the most important factor controlling absorption of these elements. Chelates are compounds in which the mineral atom is bound to an organic complex. Feeding of chelated minerals is proposed on the basis that chelates will prevent the formation of insoluble complexes in the gastrointestinal tract and reduce the amount of the particular mineral that will be required in the diet or by preventing its strong absorption on insoluble colloids which would prevent its absorption (Scott et al., 1977).

Interaction with other nutrients has an important bearing on the extent to which an essential mineral will be utilized in the body. An excess of one mineral in the diet may interfere with the utilization of another essential one. For example, the two elements may compete for binding sites on carrier proteins. Another possibility is that the mineral present in excess may combine with the second mineral to form a compound that is excreted, thus causing a deficiency of the second mineral.

Unfortunately, information on the effects of chemical form on metabolism and utilization of mineral elements is quite limited. Such answers remain to be investigated in goats. This presents both a challenge to research workers and a justification for practical feed formulators to allow some margin of safety to cover unexpected problems.

DETECTION AND DIAGNOSING OF MINERAL DEFICIENCIES AND EXCESS

Underwood (1966; 1977) reported several ways of establishing the existence or likely existence of particular mineral deficiencies or excesses in farm animals which they could be greatly applied for goats. These include clinical, pathological examinations along with soil, water, plant and animal tissue and fluid mineral analysis, all of which have all been used with varying degrees of success in such purpose. However, the information obtained from any one of these sources alone is rarely sufficient to provide conclusive evidence of specific mineral deficiency or toxicity in animals, except perhaps when this is severe and uncomplicated. More frequently, mineral deficiency and toxicity syndromes are complicated by current occurance of other nutritional disabilities, or by the existence of metabolic disturbances, and various types of parasitism. Differential diagnosis under those circumstances can be difficult and expressed as vague unthriftiness or unsatisfactory growth and production.

Mild or marginal mineral deficiencies and toxicities, which occur over large areas and affect a high number of animals, are also difficult to diagnose because their effects on the animal are often indistinguishable from those arising from a primary dietary energy and/or protein deficits, and because they are seldom accompanied by specific clinical signs (Underwood, 1977).

Mineral nutrition disorders range from acute mineral deficiency or toxicity diseases, characterized by well-marked clinical signs and pathological changes to mild and transient conditions. The diagnostic limitations of clinical and pathological observations, particularly in mild deficiency and toxicity states, can be minimized by concurrent biochemical studies of appropriate body tissues and fluids. Animal tissue and fluid levels of minerals, in addition to concentrations of particular enzymes, metabolites, or organic compounds with which the mineral in question is functionally associated, are important indicators of mineral statues. Whole blood or blood serum or plasma is widely employed for studies in mineral nutrition. Values significantly and consistently above or below "normal" concentrations or range provide suggestive but not conclusive evidence of a dietary excess or deficiency of particular minerals as they frequently arise prior to the appearance of clinical or pathological signs of deficiency or toxicity (Underwood, 1966).

Soil mineral analysis can sometimes provide clues to livestock mineral deficiencies, but more often they are unreliable and difficult to interpret. Conrad et al. (1982) reported the major disadvantage of forage element analysis to assess mineral adequacy for grazing livestock as: 1) Uncertainty of samples representing what livestock consume; 2) Difficulty of estimating forage intake; 3) Variation in the availability of forage elements; and 4) The possibility of soil contaminated forage samples. Nevertheless, forage mineral analysis are preferable to soil analysis, while appropriate animal tissue and fluid analysis most accurately portray the contribution of the total dietary environment (Forage, soil, water, etc.) in meeting livestock mineral requirements.

None of the criteria mentioned above is completely satisfactory when considered in isolation. When these are used together and their combined evidence is assessed, deficiency and toxicity signs can be securely recognised and confidently predicted, even when these are mild. Of course, the most reliable method of confirming mineral deficiencies is response derived from specific mineral, supplementation. However, such studies are costly in time and resources if conducted with adequate control and assessment. Also, the complications and high cost of mineral analysis may lead to select and analyse the minimum number of plant and animals tissues which are more indicative of the mineral status as suggested by Conrad (1978).

MINERALS SUPPLEMENTATION FOR LIVESTOCK

Mineral supplementation for stall fed animals.

It has been suggested (Underwood, 1966) that feed wherever possible and practicable should meet the requirements of animals for minerals through the proper selection and combinations of available feed alone. Any minerals needed but not furnished by the major feed ingredients, should be provided as supplemental minerals. Nevertheless, it must be stressed that the addition of minerals to diets adequate in the mineral nutrients confers no additional benefit on the animal and can sometimes be seriously harmful. Most practical combinations of feed chosen for energy, protein and fiber will be inadequate in Na which normally is supplied as common salt. Likewise, such combinations frequently do not contain a sufficient concentration of one or more of the following: P, Ca, Mg, Co, I, Cu, S or K (Miller, 1979). Milk is very low in Fe, thus calves or kids given only milk for extended periods will become deficient.

Supplemental minerals may be provided in a number of ways with the most desirable method depending on the feeding system used. (Miller, 1979). Frequently, all the supplemental minerals for lactating animals are mixed with the concentrate of the complete feed. When concentrates are not fed, as is especially common with growing animals and dry cows or does, the supplemental minerals can be fed "free choic". If only supplemental trace elements are needed, they may be provided as trace-mineralized salt, either in granular form or in a block. A more complete mineral mixture should be given when some of the major minerals are needed. Another relatively widespread method of providing essential mineral elements is as part of a "liquid feed supplement" along with non-protein nitrogen (Miller, 1979). This method presents special solubility and stability problems with a few of the elements including Ca and I.

Mineral supplementation for grazing animals.

Two categories of methods of prevention and control of mineral deficiencies and excesses are suggested (Underwood, 1966). Indirect methods of providing minerals to grazing animals which include use of mineral-containing fertilizers, altering soil pH and encouraging growth of specific pasture species. Where economic and climatic considerations are favourable, fertilizer treatment of the soil is successful to improve both the yield and mineral composition of herbage. Direct administration of minerals to ruminants in water, mineral licks, mixtures and drenches rumen preparation, (i.e. Co bullets and copper oxide needles) and injections are generally the most economical methods of supplementation. However, none of these procedures is ideal for all situations. The choice depends partly upon the physiology of the element in question, particularly the storage capacity of the animal body, the nature of environment, and upon economic factors. The provision of palatable salt-based mineral licks containing appropriate proportions of the deficient elements is the easiest, cheapest and most common form of treatment in many areas, since concentrate are not generally provided.

An acceptable mineral supplement should provide a "significant portion" of the requirement for each mineral and it is generally believed that this figure should be at least 25 to 50%. However, in known trace mineral deficient regions it may be desirable to provide 100% of specific elements required especially in areas where they are known to be low in forages (Conrad et al., 1982).

In some circumstances, the incorporation of mineral compounds to feed mixture or use of mineral licks in permissible or desirable, and drenching or dosing of the animal with minerals can be tedious and costly. Use of various organic complexes of the deficient mineral, e.g. Cu-glycinate intramuscularly to provide the tissues with supplies of Cu for periods of several months or use of heavy pellets e.g., the so called Co-bullets, which lodge in the reticulorumen and remain there to provide a steady supply of Co to the animal for prolonged periods is feasible.

Mineral toxicities are more difficult to control than deficiencies, especially under grazing conditions. Molybdenosis is controlled by additional doses of Cu, flourosis by periodic removal of animals from flourinated feed or water, and selenosis by rotational grazing to avoid continuous excess to forages high in Se or by diluting the ration with low-Se feeds (Underwood, 1966; Conrad et al., 1982).

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Element	Soil	Diet	Liver	Blood Plasma	Saliva	Milk	Urine	Other
Ca		Ca		Ca				
P		P		P				Whole blood
Mg		Mg,K,N		Mg				
Na		Na			Na,K			
Co	Co	Co	Co,B_{12}					
Cu		Mo,S	Cu	Cu**				
Fe				Fe_+				
I						I		Serum
Mn		Mn,Ca,P	Mn					Hair
Se			Se	Se				Kidney cortex
Zn		Zn		Zn				Hair

TABLE 1. ANALYSIS OF GREATEST VALUE IN ASSESSING MINERAL DEFICIENCIES IN RUMIMANTS.

UNDERLINED INDICATED GREATEST VALUE

* PERCENT SATURATION OF TRANSFERRIN, HAEMOGLOBIN AND HAEMATOCRIT OF BLOOD

** ALSO PLASMA CAERULOPLASMIN

\+ ONLY IN CASE OF LOW HAEMOGLOBIN

SOURCES : IAEA (1971) Conrad (1978).

Item	Cu	P	Mg	Na
Maintenance/kg $BW^{-0.75}$	0.19	0.14	0.045	0.045
Lactation/kg milk	4.30	1.70	0.70	0.50
Maintenance + pregnancy, 1-3 months	4.00	3.00	1.00	1.00
(60 kg BW), 4-5 months	10.00	4.50	1.50	1.50
Male and female kids/d	30 to 3.5	1.50	0.50	0.50

TABLE 2. MAJOR DIETARY MINERAL REQUIREMENTS OF GOATS*

* VALUES ARE EXPRESSED AS G/D.

SOURCE : Kessler (1981).

Element	Deficiency Limit*	Requirements* (Standard diet)
Fe	15	30
Cu	7	10
Co	0.07	0.1
I	0.15	0.80
Mn	45	60
Zn	45	45
Se	0.10	0.10
Ni	0.10	1.00
Mo	0.20	0.20

TABLE 3. TRACE MINERAL ALLOWANCES FOR GOATS.

* VALUES ARE EXPRESSED IN MG/KG DM. INGESTED.

SOURCE : Lamand (1981).