A New Supplementary Molasses Block Feed for the Ruminant to Improve the Production Efficiency under Poor Feeding Condition

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Introduction

According to Reid[19], ruminant production during the next 20 years must necessarily result increasingly from the consumption of forages, by-products and other feed resources for which man does not compete and which do not compete for land on which man's primary foods are grown. In some developed countries cereal grains and high quality forages are abundant for feeding the ruminant, but in other countries, especially in developing countries of the tropics, only low quality forages, straws and by-products are available. In the latter circumstances not only the deficiency of energy and protein but also that of mineral and vitamin is liable to occur.

One of the characteristics of the ruminant nutrition is a remarkable symbiosis between the animal and the vast population of the rumen microbes, which entails an entirely different appraisal of the overall nutritive value of dietary carbohydrates and proteins as ration ingredients. Most of the energy is furnished by volatile fatty acids (VFA) which are a major product of cellulose digestion in the rumen. Essential and non-essential amino acids and vitamin B complexes are synthesized by the rumen microbes. With ruminant animals differences in the biological value of different dietary proteins are very small. Thus with sheep it was found that casein has almost the same biological value as urea when the level of substitution of urea for casein was equivalent to 10% of crude protein in the ration. At higher levels of substitution urea appears to be less useful[4]. Even the mineral elements are involved in the close relationship between microbes and their host.

Utilization of straws, molasses and urea

In most of the studies of straw utilization by ruminants in developed countries the straw represents a small proportion of the diet, but in developing countries straws from cereal crops are the basal feed for a large proportion of the ruminants[17]. In this situation, straw must be supplemented to maximize productivity. All cereal straws have three factors in common: 1) they are extremely low in nitrogen, 2) they are composed of relatively undigested cell wall components with little soluble cell contents, and 3) mineral content is generally low and imbalanced.

Molasses from the sugar industry is widely used as a source of energy supplementation and as a carrier of non-protein nitrogen (NPN) supplements like urea as well as nutrients such as minerals and vitamins. Soluble carbohydrates of molasses are rapidly metabolized by rumen microbes to VFA, and VFA neutralize the ammonia released from hydrolized NPN compounds. The carbohydrates of molasses also provide carbon sources for synthesis of amino acids by rumen microbes. The nutritive value of molasses is from 60 to 90% of cereal grains depending on the conditions of feeding[20]. In a molasses-based system in Cuba[16] the molasses (containing 2.5% urea) can be made available to all classes of cattle on a free choice basis. Various forages equal to 2 to 7% of body weight are fed too. The only other supplement required is a source of minerals to supply phosphorus and sodium, as molasses is rich in all other major and trace elements.

For the urea utilization a readily available source of energy is necessary for the microbes to utilize the ammonia as it is released. Starch is the most satisfactory, being fermented at a fairly rapid rate. Molasses is somewhat less valuable as it is fermented too rapidly, while cellulose is least valuable being fermented too slowly. A level of 1 kg of starch per 100 g of urea is often suggested as a guideline[13]. The nutritional factors which are known to be essential for the maximum utilization of urea are as follows[3]: 1) a rapidly available source of energy which can be supplied by grain or molasses is necessary, 2) urea utilization could be improved by combining urea with dehydrated alfalfa meal since the latter contains unidentified nutrients to stimulate the microbial synthesis of protein from urea, 3) sulfur is usually a limiting nutrient in high-urea diets for the microbial synthesis of methionine and cystine, and 4) adequate levels of calcium and phosphorus are required and biologically available phosphorus is especially needed for the synthesis of bacterial protein.

It is well known that dietary urea consumed in large quantities in a short time can be toxic. According to Bartley and Doyoe[2], 244 cattle were given 0.5 g urea per kg body weight and the amount proved toxic to 125 of them. In the toxic cases, blood ammonia was elevated to 0.9 mg/dl blood in 60 min. In the non-toxic cases blood ammonia was significantly lower (0.5 mg/dl in 60 min). Blood ammonia and toxicity were strongly correlated ($r=0.707$). In toxic cases, rumen pH was elevated to 7.41 in 60 min, significantly higher than 7.16 for the non-toxic cases. Rumen pH correlated with toxicity at $r=0.317$. However, rumen ammonia concentration was the same for toxic and non-toxic cases (80 mg/dl rumen fluid) and did not correlate with toxicity ($r=0.039$). High concentrations of rumen ammonia do not necessarily indicate ammonia toxicity. However, high rumen ammonia concentration commensurate with high rumen pH would indicate toxicity because the free NH_3 concentration would be much higher at high pH than at low pH. More ammonia is absorbed at high pH than at low pH because tissue membranes are permeable to the lipid soluble NH_3 form but impermeable to the charged NH_4^+ form.

Use of supplementary molasses block feed

The new generation of supplementary feed blocks is an innovative approach for self-feeding complementary nutrients and feed additives to the ruminant. There are two types of blocks; pressed blocks and poured blocks (chemical blocks)[12]. The former are compressed supplemental blocks and the latter use the exothermic reactions between key components of the feed mixture. An example of the latter is the Schroeder chemical block[21]. This manufacturing process utilizes the reactions of calcium oxide, phosphoric acid and molasses to provide the necessary heat. Magnesium oxide may also be incorporated to give sufficient hardness.

In India and Australia a molasses-urea-mineral block feed has been developed and used[6,18]. The block contains 45% molasses, 15% urea, 15% minerals, 8% salt, 4% calcite, 3% bentonite and 10% cottonseed meal, and heating process is adopted to make the block. Supplementation of straws with this block has been found to be very useful in increasing digestibility of straw and the voluntary intake as well. Although the primary purpose of the supplementary block feed is to provide urea and thereby ammonia for the rumen microbes, it can also provide a broad spectrum of minerals and serve as the carrier for a wide range of compounds which could be used to manipulate rumen fermentation[18].

A new supplementary MPU block feed

We developed a new supplementary block feed (MPU feed). The composition of this feed is shown in Table 1. The most important characteristic of this block feed is to include propylene glycol with urea. The preparation method is as follows. First, to a mixture of the ingredients devoid of calcium hydroxide and phosphoric acid, calcium hydroxide was added. After stirring phosphoric acid was added and stirred again. Within one or two hours the mixture could be poured into appropriate vessels since the viscosity of the mixture was not high. The gelatinization progressed and reached the final hardness in three or four days. Calcium hydroxide and phosphoric acid are preferred to calcium oxide and phosphoric acid in our case, because the former is more suitable in obtaining the stable product due to lower heat production. The rapid and extensive exothermic reactions seemed to cause a detrimental effect on the gelatinization process.

Table 1. The composition of MPU block feed

Molasses (cane)	45.0(%)
Propylene glycol	9.0
Urea	9.0
Alfalfa meal	3.0
Seaweed	3.0
Corn starch	3.0
NaCl	2.0
Na_2SO_4	2.0
MgO	2.0
$MgCl_2 6H_2O$	3.0
Trace minerals[1)]	0.5
Vitamins[2)]	0.5
$Ca(OH)_2$[3)]	7.0
H_3PO_4[4)]	11.0

1) : Composed of 9.8% $CuSO_4 5H_2O$, 24.6% $MnSO_4 H_2O$, 35.1% $ZnSO_4 7H_2O$ and 30.5% starch.
2) : Composed of 70% vitamin A, D_3 premix containing 10,000 IU vitamin A and 2,000 IU vitamin D_3 per 1 g, 6% vitamin E premix containing 50% vitamin E, 12% nicotinamide and 12% calcium pantothenate.
3) : Finely pulverized particles containing more than 95%.
4) : 85% in concentration.

Table 2. Mineral and vitamin contents of MPU block feed

Minerals[1)]		Vitamins[2)]	
Ca	4.2%	Vitamin A	3,500 IU/100 g
P	3.4%	Vitamin D_3	700 IU/100 g
Mg	1.7%	Vitamin E	15 IU/100 g
K	1.7%	Nicotinamide	60 mg/100 g
Na	1.5%	Ca pantothenate	60 mg/100 g
Zn	500 ppm		
Mn	300 ppm		
Fe	170 ppm		
Cu	160 ppm		

1) : Determined.
2) : Calculated.

The MPU block feed contained 2,350 cal/g and 26.3% crude protein. The mineral and vitamin contents are shown in Table 2. To make different kinds of block feeds, the amounts of calcium hydroxide and phosphoric acid should be 5–14% and 7–15% by weight, respectively, so that the ratio of calcium to phosphorus in the final product must be in a range from 1 : 1 to 1.5 : 1.

A group of adult Japanese meat-type goats was fed daily 600 g of low quality hay and 50 g of MPU feed, and another group was fed the same amount of hay and molasses-urea block feed without propylene glycol. Feeding was continued over 6 months. Animals in the former group survived for the entire period, maintaining their body weights, while many in the latter group lost their appetite and died. Blood ketone levels of the former group were significantly lower than those of the latter. Reciprocal relationship between blood glucose and ketone levels has been noted and blood ketone levels become a useful indicator of the ruminant nutrition[7)].

Metabolism experiments were done in a condition to provide all necessary protein by urea. Nitrogen balance was maintained by feeding daily 500 g rice straw with 200 g MPU feed in 30 kg goats[11)]. Similar result had been shown by feeding hay or rice straw with a liquid molasses diet containing urea and propylene glycol[14)].

Changes in compositions of rumen VFA and ammonia are shown in Table 3. In Ex-

Table 3. Concentrations and molar proportions of volatile fatty acids (VFA) and ammonia-N concentrations in the rumen fluid of goats

	Concentration		Molar proportion of VFA (%)			
	Ammonia-N (mg/dl)	VFA (mmol/dl)	Acetate	Propionate	Butyrate	Others
Experiment 1 (Effect of sampling time)[1)]						
0 hr	31	4.2	70	20	7	3
1 hr	65	9.6	57	36	6	1
2 hr	44	10.0	57	34	8	1
3 hr	38	7.8	61	30	8	1
Experiment 2 (Effect of feeding levels of MPU feed)[2)]						
0 g	23	5.9	52	34	14	0
50 g	26	6.9	46	40	13	1
100 g	38	6.4	48	42	10	0
200 g	79	6.1	44	46	10	0
Experiment 3 (Effect of propylene glycol and starch)[3)]						
Control	47	6.2	57	35	7	1
Starch	58	8.8	58	30	11	1
Propylene glycol (PG)	59	7.0	47	47	4	2
Experiment 4 (Comparison of propylene glycol and starch inclusion)[4)]						
Starch-0 hr	12	6.2	72	19	6	3
Starch-1.5 hr	66	11.4	63	30	6	1
Starch-2.5 hr	47	12.3	65	28	6	1
PG-0 hr	6	5.7	67	22	9	2
PG-1.5 hr	81	13.5	56	36	7	1
PG-2.5 hr	45	10.8	53	36	6	5

1) : Fed 300g hay+100g MPU feed after 0 hr.
2) : At 4 hr after feeding 600g hay+0 g MPU feed, 600g hay+50g MPU feed, 300g hay+300g rice straw +100g MPU feed and 500g rice straw+200g MPU feed, respectively.
3) : Three groups of weaned kids were fed ad libitum hay and three kinds of block feeds (containing 10% urea) with either 10% starch or propylene glycol or none of these (control) as shown before[5)].
4) : Rumen-fistulated goats were fed 300g hay and administered intraruminally 100g of the above block feed containing either starch or propylene glycol at 0 hr.

periments 1 and 2, feeding of MPU feed contributed to increase the concentrations of VFA and ammonia and the molar proportion of propionic acid in the rumen fluid. In Experiments 3 and 4, the inclusion of propylene glycol in the block feed showed a higher molar ratio of propionic acid in the rumen fluid than the inclusion of starch.

Significance of the present innovation

The ruminant feed named MPU block feed is expected for use under conditions that roughage like straw must become an important feed resource. If poor quality roughage is fed, deficiencies of energy, protein, minerals and vitamins are liable to occur, and in particular, the lack of protein and minerals may result in inhibition of rumen fermentation and retardation of cellulose decomposition by the rumen microbes. However, by feeding of MPU block feed, increases in both nutritional value and roughage intake are expected, due to high concentration of ammonia over a longer period in the rumen and activation of rumen fermentation itself. By adding propylene glycol, the ratio of propionic acid to acetic acid in VFA produced in the rumen increases and the production efficiency of protein synthesis and other processes can be improved. Further, the present supplementary block feed serves to protect the animals from urea toxicity, even if a large amount of the supplementary block feed exceeding the safety limit is ingested by the animals.

The present feed is also efficient for replenishing calcium, phosphorus, magnesium and the like for cows or other ruminants before and after parturition. Further, it is also useful for replenishing materials such as rumen-bypass amino acids and the like which are effective to improve the production efficiency of animals. The mineral elements most likely to be lacking under tropical conditions are Ca, P, Na, Co, Cu, I, Se and Zn, and in some regions under specific conditions, Mg, K, Fe and Mn may be deficient[15]. MPU feed can be used to furnish these elements.

By including propylene glycol in the diet, a propionic acid-dominant fermentation pattern has been established in the rumen, which has lower pH than an acetic acid-dominant one[9]. This fact is important to contributing to protect the animals from ammonia toxicity. Furthermore, propylene glycol enters into the hepatic metabolism by two routes; a part of it is directly absorbed through the ruminal wall, while another is converted into propionic acid by rumen microbes. So in the hepatic mitochondria propylene glycol can be changed into oxaloacetate via pyruvate (by direct absorption) or via malate (after propionate conversion). These two pathways are competing with each other[1]. Oxaloacetate is the most important metabolite in the gluconeogenesis, anti-ketogenesis and ureogenesis (by ATP production). If oxaloacetate is supplied sufficiently, the ruminant can cope with any such stressful condition as high ammonia inflow. Propylene glycol may be the most efficient converter to oxaloacetate[8,10]. Furthermore, the inclusion of propylene glycol in the block contributes to improve quality of final product, since it is an excellent solvent of fat-soluble vitamins and also plays a role as an anti-mold agent.

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