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Abstract
Liquid supplement manufacturers must provide a product that is effectively utilized and is nontoxic. Toxicity can be reduced if the supplement's pH is below 3.8, but low pH alone does not improve nutritive value. A good fermentable source of carbohydrate, like molasses or cooked starch, should be provided in adequate amount. When water or lignin sulfonates are substituted for good carbohydrate, urea utilization is reduced and the risk of toxicity is increased. Cattle that are hungry or starved from blizzard conditions or feed restriction are much more susceptible to ammonia toxicity than cattle kept full, so limit the availability of liquid supplements to hungry cattle. Urea is safer if cattle are adapted to it. Always start cattle on urea-containing feeds slowly and keep them full of other feed.

Keywords
Cattlemen's Day, 1981; Report of progress (Kansas State University. Agricultural Experiment Station); 394; Beef; Toxicity; Urea; Liquid supplements

The Toxicity of Liquid Supplements Containing Urea

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Summary

Liquid supplement manufacturers must provide a product that is effectively utilized and is nontoxic. Toxicity can be reduced if the supplement's pH is below 3.8, but low pH alone does not improve nutritive value. A good fermentable source of carbohydrate, like molasses or cooked starch, should be provided in adequate amount. When water or lignin sulfonates are substituted for good carbohydrate, urea utilization is reduced and the risk of toxicity is increased.

Cattle that are hungry or starved from blizzard conditions or feed restriction are much more susceptible to ammonia toxicity than cattle kept full, so limit the availability of liquid supplements to hungry cattle. Urea is safer if cattle are adapted to it. Always start cattle on urea-containing feeds slowly and keep them full of other feed.

Introduction

The present and future use of liquid supplements depends primarily on two factors: efficient utilization of the nonprotein nitrogen (NPN) source (usually urea) and freedom from toxicity. Ammonia toxicity is always possible when liquid supplements are improperly used. Ammonia toxicity cases from liquid supplements are brought to our attention regularly and many wind up in the courts. In recent years we have learned much about urea utilization in liquid supplements and how to reduce its potential toxicity.

Urea utilization in liquid supplements

Rumen bacteria convert such nonprotein sources as urea to ammonia. A good share of feed proteins also are converted to ammonia. This rumen ammonia "pool" is used by rumen microorganisms to make microbial protein, which is finally used in the small intestine.

Ammonia cannot be converted to microbial protein unless carbohydrate energy is available. But not all carbohydrates are equally useful. Cellulose from roughage is fermented too slowly. The best source appears to be starch, and cooked starch is better than raw. Molasses or hemicellulose extract (the carbohydrate in liquid supplements) are generally less effective than starch but are satisfactory.

In liquid supplements containing 10% urea and maximum molasses, energy for the microbes is marginal. So any attempt to cut costs by substituting water or lignin sulfonates for molasses may reduce urea utilization and increase the risk of ammonia toxicity. Lignin sulfonate, a byproduct of the wood pulp industry, has many of the physical properties of molasses, and has been substituted into liquid supplements. But our research shows it is a poor energy source. Water has also been added to liquid supplements, obviously cutting the supplements' energy.

Ammonia toxicity of liquid supplements

Urea consumed in large quantities over a short time can be toxic. Ammonia is produced in the rumen faster than it can be incorporated into microbial protein. The excess is absorbed into the blood, reaches the brain, and causes toxicity. The rumen must have a good energy source to allow the bacteria to convert the ammonia to microbial protein and to form volatile fatty acids (VFA) to lower the rumen pH. Ammonia occurs as free ammonia (NH_3) or the ammonium ion (NH_4^+), depending on pH. Low rumen pH shifts ammonia to the NH_4^+ form. Tissue membranes are permeable to NH_3 but are impermeable to NH_4^+, so more ammonia is absorbed when pH is high. In a study by a K-State team of researchers involving 244 cattle given 23 g urea per 100 lbs body weight, the urea was toxic to 125. In both toxic and nontoxic cases, total rumen ammonia concentration (NH_3 and NH_4^+) was the same. But rumen pH one hour after dosing averaged 7.41 in animals that showed toxicity and 7.16 for those that did not. The higher rumen pH for the toxic cases permitted about twice as much ammonia to be absorbed into the blood. The absorbed ammonia elevated the blood ammonia to .89 mg/100 ml blood in 60 min. In the nontoxic cases the free ammonia in the rumen was only approximately half that of the free ammonia in the toxic cases. Consequently the blood ammonia of the nontoxic cases reached only 0.53 mg in 60 min. Usually the blood ammonia needs to reach 0.8 mg before toxicity will occur. The rumen can handle considerable ammonia without toxicity, provided rumen pH is not much above 7.0.

If the rumen pH can be kept consistently below 7, ammonia toxicity from liquid supplements would be minimal. Low rumen pH can be achieved two ways: volatile fatty acid (VFA) production from carbohydrate fermentation, or adding acid (phosphoric) directly to the liquid supplement. Molasses-based supplements contain barely enough fermentable carbohydrate to sustain a low rumen pH through VFA production, so when molasses is diluted with water or with lignin sulfonates, the supplement may be toxic because fermentable carbohydrate is reduced.

Lowering a supplement's pH to 3.7 with phosphoric acid reduced rumen pH by .5 unit and prevented toxicity in animals fed 2 pounds of supplement per day. The 3.7 pH compared with a pH of 4.5 for the same supplement with less phosphoric acid.

We used rumen-fistulated adult cattle in 73 toxicity tests of 24 liquid supplements containing molasses, hemicellulose extract, or cooked starch as the major energy source (Table 1.1). Most supplements contained 10% urea. Phosphoric acid ranged from zero to 3%. All liquid supplements were added directly to the rumen at 23 g urea equivalent per 100 lb body weight The cattle were fasted 16 hr before dosing.

The results of the 73 tests are summarized in Table 1.2. The rumen ammonia concentrations at 60 min between the toxic and nontoxic supplements were similar (67.1 vs 72.9 mg/100 ml). Rumen pH remained below 7.0 for the nontoxic supplements, even when rumen ammonia increased 10-fold. When toxicity occurred, rumen pH increased, so free ammonia was readily absorbed into the blood.

Reducing phosphoric acid from 2.9 to 1.0% increased toxicity from 0 to 67% with a liquid supplement containing processed carbohydrate (cooked starch) and 10% urea (supplements 1 and 2, Table 1.1). Reducing phosphoric acid from 3.0 to 1.39, and molasses from 68.00 to 31.10% increased toxicity from 17 to 83% (supplements 3 and 4, Table .1). Undoubtedly both the reduction in acid and molasses contributed to the increased toxicity. Because reducing molasses alone (supplements 5 and 6, Table 1.1) did not affect toxicity, we can assume that the low pH of liquid supplements helped reduce their toxicity. Reducing the hemicellulose extract from 80 to 40% and increasing water from 10 to 40% increased toxicity from 25 to 75%. The response difference between molasses and hemicellulose extract probably stems from molasses being fermented faster than hemicellulose extract, as W. Anderson reported in a K-State thesis.

In another study (Table .3) we compared a liquid supplement with 69% molasses and 11% water (No. 1) with one containing 19% molasses and 61% water (No. 2). Though both contained 3% phosphoric acid, supplement No. 1 was toxic. Thus even with 3% phosphoric acid, there must be enough fermentable carbohydrate or toxicity will occur. Neither 20 or 40% lignin sulfonate (No. 3 and 4) provided enough fermentable carbohydrate to prevent toxicity.

Table 1.1. Composition and toxicity of liquid supplements

Ingredients	Supplement no. and composition (%)							
	1	2	3	4	5	6	7	8
Urea	9.90	9.90	10.00	10.00	10.00	10.00	10.00	10.00
Cane molasses	-	-	68.00	31.10	40.00	80.00	-	-
Hemicellulose extract	-	-	-	-	-	-	40.00	80.00
Processed carbohydrates	31.06	31.06	-	-	-	-	-	-
Phosphoric acid	2.91	1.00	3.00	1.39	-	-	-	-
Water	56.13	58.04	19.00	57.00	50.00	10.00	50.00	10.00
pH	3.8	4.3	3.3	4.1	5.2	5.1	4.5	4.6
				Toxicity				
No. toxic/no. tested	0/6	4/6	1/6	5/6	2/4	2/4	3/4	1/4
Percentage toxic	0	67	17	83	50	50	75	25

Table 1.2. Effects of urea containing liquid supplements on rumen pH, total rumen ammonia, free rumen ammonia, and jugular blood ammonia concentration.

Item	Time after liquid supplements were administered intraruminally (min)		
	0	30	60
		Rumen pH	
Nontoxic[a]	6.8	6.7	6.9
Toxic[b]	7.0	7.1	7.3
		Total rumen ammonia-N (mg/100 ml)	
Nontoxic	6.9	59.7	72.9
Toxic	7.0	68.3	67.1
		Free rumen ammonia-N (mg/100 ml)	
Nontoxic	.07	.47	.89
Toxic	.10	1.43	2.25
		Jugular blood ammonia-N (mg/100 ml)	
Nontoxic	.12	.36	.50
Toxic	.13	1.14	.88

[a]Mean of 53 observations.

[b]Mean of 20 observations.

Table 1.3. Effect on blood ammonia concentration of diluting molasses in liquid supplements with water or lignin sulfonate.

Formula	Blood ammonia
	mg/100 ml
1. 69% molasses, 11% water, 3% APP[a], 3% phos. acid	.29
2. 19% molasses, 61% water, 3% APP, 3% phos. acid	.78[b]
3. 49% molasses, 11% water, 3% APP, 3% phos. acid	.67[b]
4. 29% molasses, 11% water, 3% APP, 3% phos. acid 40% lignin sulfonate	.81[b]

[a]APP = ammonium polyphosphate

[b]Blood ammonia in the toxic range