Techniques to Reduce Free-Choice Liquid Supplement Consumption in Beef Cattle

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Introduction

Sales of liquid feed, excluding sales to feedlots, have grown by 50% during the 1990's and exceeded one million tons in 1998 (Anonymous, 1999). Many liquid feeds are offered free-choice to cattle grazing pasture, which has advantages of reduced labor costs, less feeder space per animal and feeder accessibility by more timid animals. With these advantages, the use of molasses based liquid supplements is becoming increasingly widespread. However, in some situations such as the Southeastern U.S., over-consumption of supplement is a problem for cattle producers. Information on effective management and supplement formulation techniques to reduce and control consumption is limited. Another issue is variation in consumption of liquid supplement between animals in a group. It is commonly believed that if the target consumption for a group of animals was met, then likewise each individual was at target consumption. However, more recent research has shown that this may be incorrect. Intake variation may be especially important when the supplement is expected to deliver precise quantities of protein, vitamins and minerals or drugs to improve performance and/or prevent disease. This research investigated two approaches to control intake of liquid supplements and monitor variation in supplement intake within groups. The objectives of these studies were to evaluate liquid supplement pH on liquid supplement intake (Exp. 1), to evaluate liquid supplement pH and acid source on liquid supplement intake (Exp. 2), and to evaluate lick wheel width and turning restriction on liquid supplement intake (Exp. 3). Additionally, intake variation among animals within the groups was evaluated in all three experiments.

Liquid Supplement pH on Intake (Experiment 1)

Materials and Methods

Experimental Design and Treatments:

Suga-Lik® No. 500 (U. S. Sugar Corp., Clewiston, FL), 16% crude protein (CP), containing ~2.75% phosphoric acid was offered as a control and the treatments included the same supplement with pH adjusted to 3.4, 2.9, and 2.3 using feed grade phosphoric acid (25.6% phosphorus, “black” acid) added at 3, 6 and 9%, respectively. These four pH treatments were evaluated in a four by four Latin Square balanced for carryover effects (Cochran and Cox, 1956). For the 84-day experiment, each period was 21 days long and each group of cattle (5 head) was kept in the same pasture during all periods.

Cattle and Pastures:

This trial was conducted at two locations, Ona and Gainesville, FL. The experiment at Gainesville was conducted from July 6, 2000 to September 28, 2000 and at Ona from July 13, 2000 to October 10, 2000. At both locations, 20 crossbred (Brangus-type at Gainesville, Braford-type at Ona) yearling beef heifers (770 to 850 lb. initial weight) were randomly assigned to four (3 acres at Ona; 4 acres at Gainesville) predominately bahiagrass pastures. Water and a complete vitamin-mineral mix were on ad libitum offer in each pasture. Liquid supplement pH was adjusted using feed grade phosphoric acid commercially blended with the supplement, then were offered free-choice in 55 gallon commercial liquid supplement feeders (RMI Inc., Bartow, FL) using only one lick wheel.

Measurements and Sampling:

Cattle weights were recorded at the beginning of each period. Intake of liquid supplement was determined at weekly intervals by weighing each lick tank (disappearance method). Samples of liquid supplement were collected from each tank every 7 days after liquid supplement was added to the tank. These samples were blended by period, subsampled, and analyzed for nutrient composition. Additionally, pH of the supplement was measured weekly. Forage quality and availability were sampled during each 21-day period. Throughout periods 3 and 4 of the Latin square design, a dual marker system (chromium bolus and ytterbium chloride in liquid supplement) was used to estimate supplement intake by each animal on treatments pH 4.2 and pH 2.3. During these periods, ytterbium (Yb) chloride (Rhodia, Inc., Phoenix, AZ) was thoroughly blended into the liquid supplement, using a cordless electric drill with a paint stirrer, at a level of approximately 340 ppm Yb. This was done to allow detection of liquid supplement intake as low as 0.25 lb/day by an animal. On day 1 of periods 3 and 4, all animals assigned to treatments pH 4.2 and pH 2.3 were dosed with a sustained release chromic oxide bolus (Captec®, New Zealand). Fecal samples were collected from each animal assigned to treatments pH 4.2 and pH 2.3 on four separate days between day 10 and day 21 of periods 3 and 4. Supplement containing Yb was offered continuously to treatments pH 4.2 and pH 2.3 during both 21-day periods. Also, during periods 3 and 4, liquid supplement samples from pH 4.2 and pH 2.3 treatments were analyzed individually for Yb concentration. Fecal Cr and Yb concentrations were analyzed in fecal samples for 3 of 4 collection dates for each animal. Results were calculated by day then averaged across days to estimate fecal output (Cr concentration) and supplement intake (Yb:Cr ratio) for each animal in each period/treatment combination as described by Earley et al. (1998). Estimated individual animal intake of liquid supplement within a period and treatment was compared to group intake for the period as a check of techniques.

Results and Discussion

Daily intakes for the 84-day trials are summarized in Tables 1 and 2. At Gainesville, daily supplement consumption for pH 3.4 was similar to control. However, lowering supplement pH to 2.9 tended (P=0.15) to reduce supplement consumption. Consumption of liquid supplement with a pH of 2.3 was decreased (P<0.01) 57% compared to control. Cattle at both locations had adequate quantities of standing forage throughout the trial. At Ona, pH 3.4 had a tendency (P=0.08) to decrease consumption (19%) compared to control. Lowering pH to 2.9 and 2.3 decreased consumption (P<0.01) compared with the control, with reductions of 40% and 72%, respectively. Across both locations, daily consumption was decreased 13% (P=0.08) for pH 3.4, 30% (P<0.01) for pH 2.9 and 64% (P<0.01) for pH 2.3 compared to control.

Table 1. Effect of Liquid Supplement pH on Free-Choice Consumption – Gainesville.

	Treatment = pH of Liquid Supplement [1]				
Period	4.2	3.4	2.9	2.3	Period Avg.
	----------Liquid Supplement Intake lb/head/day----------				
1	5.22	5.66	4.88	3.29	4.76
2	6.17	6.68	7.31	2.93	5.65
3	8.88	6.76	5.39	4.06	6.27
4	8.73	7.42	5.14	2.33	5.91
Avg.	7.24[a]	6.63[a]	5.68[a]	3.15[b]	5.68

[1] Treatments were created using Suga-Lik® #500 (pH 4.2; containing ~2.75% phosphoric acid) with phosphoric acid ("black" acid, 25.6% phosphorus) added at 3, 6 and 9%, respectively
[a,b] Average intakes lacking a common superscript differ (P<0.05); SE=0.67

Table 2. Effect of Liquid Supplement pH on Free-Choice Consumption – Ona.

	Treatment = pH of Liquid Supplement [1]				
Period	4.2	3.4	2.9	2.3	Period Avg.
	----------Liquid Supplement Intake lb/head/day----------				
1	4.70	5.64	3.55	2.30	4.05
2	7.79	4.73	4.54	1.74	4.70
3	6.78	4.46	3.30	1.94	4.12
4	6.01	5.85	3.75	1.11	4.18
Avg.	6.32[a]	5.17[a,b]	3.79[b]	1.77[c]	4.26

[1] Treatments were created using Suga-Lik® #500 (pH 4.2; containing ~2.75% phosphoric acid) with phosphoric acid ("black" acid, 25.6% phosphorus) added at 3, 6, and 9%, respectively
[a,b,c] Average intakes lacking a common superscript differ (P<0.05); SE=0.41

Phosphoric acid is commonly included in liquid supplements, but can be used as an intake limiter in dry feeds as well. A previous experiment using grazing steers (Jensen, 1979) found that the inclusion level of phosphoric acid had to be increased from 3% to 5% of the ration to limit the intake of ground corn to less than 4.4 lb/d. Results from our inclusion rates failed to concur with previous findings, as liquid supplement at pH 3.4, which included an additional 3% phosphoric acid, for a total of 5.75% did not significantly reduce supplement consumption. This was the case at each trial location and across both locations. Davidovich et al. (1977) reported that 3% phosphoric acid added to a molasses-based liquid feed containing 10% urea prevented ammonia toxicity that occurred when cattle were dosed with 0.018 oz of urea per 2.2 lb of body weight. This prevention of ammonia toxicity was apparently due to the decreased ruminal pH and subsequent decline in ammonia absorption caused by the addition of phosphoric acid.

An estimation of liquid supplement intake by individual animals was made by analyzing Yb concentration in feces and liquid supplement, and Cr concentration in feces. Estimated liquid supplement intakes on pH 4.2 and pH 2.3 treatments in periods 3 and 4, were then averaged and a coefficient of variation (CV) for individual animal liquid supplement intake within each treatment and period was calculated. At Gainesville, CV for control was 13% (mean intake 7.24 lb/d) and CV for pH 2.3 was 17% (mean intake 3.15 lb/d). At Ona, the CV was 28% (mean intake 6.32 lb/d) and 64% (mean intake 1.77 lb/d) for control and pH 2.3, respectively. The CV for both treatments at Gainesville (13%, 17%) were lower than 107% CV for molasses-urea supplements reported by Bowman et al. (1995) and 37% CV reported by Langlands and Donald (1978).

Conclusions (Experiment 1)

Phosphoric acid has historically been the additive of choice to increase phosphorus concentration and limit consumption of molasses-based liquid supplements. The findings of this experiment support its effectiveness. However, pH 3.0 seems to be a threshold level, below which significant reductions in consumption are observed. In regard to variation of individual animal intakes, CV increased as daily consumption decreased.

Liquid Supplement pH and Acid Source on Intake (Experiment 2)

Materials and Methods

Treatments and Experimental Design:

In a 42-day experiment, a standard liquid supplement (16% CP; pH 4.2; ~2.75% phosphoric acid) was offered as a control and six additional treatments were included which lowered the pH of this liquid feed to pH 3.2 or pH 2.3 using concentrated forms of sulfuric acid (S, 93%), hydrochloric acid (C, 35%) or phosphoric acid (P, 24%

phosphorus, “green” acid). The seven treatments were: Control, pH 3.2 by adding 2.1% S (S-3), pH 3.2 by adding 3.2% C (C-3), pH 3.2 by adding 5.7% P (P-3), pH 2.3 by adding 4.2% S (S-2), pH 2.4 by adding 6.3% C (C-2), and pH 2.3 by adding 11.3% P (P-2). Each of the 7 treatments was randomly assigned to two groups (5 cows/group) for a 21-day period in a randomized block design. After the first 21-day period, treatments were reassigned (treatments were not assigned to same pasture/group in second period) and another 21-day consumption trial was conducted. This resulted in four consumption measurement periods for each of the seven treatments.

Cattle and Pastures:

This trial was conducted at Gainesville, FL from October 5 to November 16, 2000. Seventy gestating mature Angus beef cows (ages 4-10 years; 1250 lb initial weight) were randomly assigned to fourteen (4 acre) mostly bahiagrass pastures with stockpiled forage (5 head/pasture). Water and a complete vitamin-mineral mix were offered free-choice in each pasture. Each liquid supplement treatment was offered free-choice in a 55 gallon commercial liquid supplement feeder with only one accessible lick wheel.

Measurements and Sampling:

Cattle weights were recorded at the beginning of each period. Intake of liquid supplement was determined at weekly intervals by weighing each lick tank. Samples of liquid supplement were collected from each tank every 7 days after liquid supplement was added to the tank. These samples were blended by period, subsampled, and analyzed for nutrient composition. Additionally, pH was measured weekly to determine actual pH of supplement. Forage quality and availability were sampled during both 21-day periods. In both periods 1 and 2, one pen on each treatment was assigned to a dual marker system (Cr bolus and Yb in molasses-based supplement) to estimate supplement intake by each animal. During these periods, ytterbium chloride was thoroughly blended into the liquid supplement at approximately 340 ppm Yb. This allowed detection of liquid supplement intake as low as 0.25 lb/day by an animal. On day 1 of both periods, cows were dosed with a sustained release chromic oxide bolus (Captec®, New Zealand). Fecal samples were collected from each cow on three separate days between day 10 and day 21 of each period. Liquid supplement containing Yb was offered continuously during both 21-day periods. Fecal Cr and Yb concentration were analyzed in fecal samples for each collection date for each animal. Also, during periods 1 and 2, liquid supplement samples from one pasture of each treatment were analyzed individually for Yb concentration. Results were calculated by day then averaged across days to estimate fecal output (Cr concentration) and supplement intake (Yb:Cr ratio) for each animal in each treatment combination as described by Earley et al. (1998). Estimated individual intake of liquid supplement in a treatment was compared to group intake for the period as a check of techniques.

Results and Discussion

Daily average supplement intakes for the 42-day trial are summarized in Table 3. Daily consumption over all treatments averaged 8.77 lb/d. Decreases in liquid supplement intake were observed for each treatment except C-3. However, C-3 tended to decrease ($P=0.13$) consumption by 9% versus control. When pH was lowered to 2.3 using HCL, 30% ($P<0.01$) less consumption than control was recorded. Treatment P-3 reduced consumption by 33% ($P<0.01$) and likewise consumption of P-2 was lowered by 53% ($P<0.01$), both compared to control. Treatments S-3 and S-2, using sulfuric acid, lowered daily supplement intake ($P<0.01$) by 18% and 38%, respectively. When liquid feeds were adjusted to a similar pH, hydrochloric acid proved to be least effective and phosphoric acid was most effective at lowering liquid supplement consumption.

Table 3. Effect of Liquid Supplement pH and Acid Source on Free-Choice Consumption.

------Treatment = pH of Liquid Supplement and Acid Source-----								
	Control [1]	S-3 [2]	C-3 [3]	P-3 [4]	S-2 [5]	C-2 [6]	P-2 [7]	Avg.
PH	4.2	3.2	3.3	3.2	2.3	2.4	2.3	
Period	--------------------Liquid Supplement Intake lb/head/day--------------------							
1	9.86	8.41	8.39	5.97	6.59	6.66	4.87	7.25
2	13.82	10.89	13.12	9.76	8.19	9.86	6.33	10.28
Avg.	11.84[a]	9.65[b,c]	10.76[a,b]	7.87[d]	7.39[d]	8.26[c,d]	5.60[e]	8.77

[1] Standard liquid supplement (pH 4.2; containing ~2.75% phosphoric acid)
[2] Created by adding 2.1% sulfuric acid (93% acid) to control supplement
[3] Created by adding 3.2% hydrochloric acid (35% HCl) to control supplement
[4] Created by adding 5.7% phosphoric acid ("green" acid, 24% phosphorus) to control supplement
[5] Created by adding 4.2% sulfuric acid (93% acid) to control supplement
[6] Created by adding 6.3% hydrochloric acid (35% HCl) to control supplement
[7] Created by adding 11.3% phosphoric acid ("green" acid, 24% phosphorus) to control supplement
[a,b,c,d,e] Average intakes lacking a common superscript differ ($P<0.05$); SE=0.48

Different acid sources produced different individual intake variations. Though hydrochloric acid was least effective at reducing consumption, at pH levels 2.4 and 3.3, CV was less (17% and 25%, respectively) than control (33%). Intake was most limited by adding phosphoric acid and at pH levels 2.3 and 3.2, CV was less (31% and 23%, respectively) than CV of control. Supplement at pH 2.3 using sulfuric acid had CV lower (29%) than control but pH 3.2 with the same acid produced CV higher (39%) than control.

Conclusions (Experiment 2)

Acidification of liquid supplements shows promise as a method of reducing liquid supplement consumption in beef cattle. In this experiment, lowering the pH of molasses-based liquid supplements reduced intake. The effectiveness of acid source varied, with phosphoric being most effective and hydrochloric being least effective when liquid supplements were adjusted to a similar pH. Another objective of this experiment was to evaluate the effect of acid source on intake variation among individual animals. All treatments except C-3 significantly reduced supplement consumption and all treatments except S-3 reduced variation in supplement consumption. Previous research is limited and more research is needed to validate these findings.

Lick Wheel Width and Turning Restriction on Intake (Experiment 3)

Materials and Methods

Experimental Design and Treatments:

Standard, 2.0 inch wide (S), and 0.75 inch wide (N) supplement feeder lick wheels were evaluated. Both wheel widths were evaluated with non-restricted, normal, continuous turning capability (NR) and with an added restrictor (R). The standard width wheel, non-restricted feeder was used as a control. Different wheel widths (2.0 vs 0.75 inches) and restrictions (none vs restricted) were accomplished by modifying the feeder lick wheels in commercial 55 gallon liquid supplement feeders, using a circular saw to reduce wheel width and by inserting a 6 inch carriage bolt through a wheel spoke near the licking surface, thereby restricting turning to approximately 330° in one direction. These four treatments were evaluated using a two by two factorial arrangement of treatments in a four by four Latin Square design balanced for carryover effects (Cochran and Cox, 1956). For the 84-day experiment, each period was 21 days and each animal group (5 head) was housed in the same pasture during all periods.

Cattle and Pastures:

The wheel width and restriction trial was conducted at two locations, Ona and Gainesville, FL. At both locations, 20 crossbred (mostly Angus at Gainesville, Braford-type at Ona) yearling beef heifers (770 to 850 lb initial weight) were randomly assigned to four (3 acres at Ona; 4 acres at Gainesville) predominately bahiagrass pastures. Water and a complete vitamin-mineral mix were on ad libitum offer in each pasture. Suga-Lik® No. 500 was offered free-choice to all animal groups in their respective feeders with only one lick wheel being accessible.

Measurements and Sampling:

Cattle weights were recorded at the beginning of each period. Intake of liquid supplement was determined at weekly intervals by weighing each lick tank (disappearance method). Samples of liquid supplement were collected from each tank every 7 days after liquid supplement was added to the tank. These samples were blended by period, subsampled and analyzed for nutrient composition. Additionally, pH was measured weekly to determine actual pH of the supplement. Forage quality and availability were sampled during each 21-day period. Throughout periods 3 and 4 of the Latin square design, a dual marker system (Cr bolus and Yb chloride in liquid supplement) was used to estimate supplement intake by each animal on treatments S-NR and N-R. During these periods, Yb chloride (Rhodia, Inc., Phoenix, AZ) was thoroughly blended into the liquid supplement, using a cordless electric drill with a paint stirrer, at a level of approximately 340 ppm Yb. This was done to allow for detection of liquid supplement intake as low as 0.25 lb/day by an animal. On day 1 of periods 3 and 4, all animals assigned to treatments S-NR and N-R were dosed with a sustained release chromic oxide bolus (Captec®, New Zealand). Fecal samples were collected from each animal assigned to treatments S-NR and N-R on four separate days between day 10 and day 21 of periods 3 and 4. Supplement containing Yb was offered continuously to treatments S-NR and N-R during both 21-day periods. Also, during periods 3 and 4, liquid supplement samples from S-NR and N-R treatments were analyzed individually for Yb concentration. Fecal Cr and Yb concentrations were analyzed in fecal samples for 3 of 4 collection dates for each animal. Results were calculated by day then averaged across days to estimate fecal output (Cr) and supplement intake (Yb:Cr ratio) for each animal within each period and treatment combination as described by Earley et al. (1998). Estimated individual animal intake of supplement in each period and treatment was compared to group intake for the period as a checkpoint.

Results and Discussion

Forage available to all animals was adequate at both locations for the duration of the trial. Liquid supplement intakes for the wheel width and restriction trials are summarized in Tables 4 and 5. In Gainesville, daily supplement consumption was reduced ($P<0.01$) by 25%, to 4.41 lb/d for treatment S-R compared to control. Reducing wheel width to 0.75 inch, treatment N-NR, reduced consumption ($P<0.02$) by 17%, to 4.86 lb/d. Greatest decline in consumption occurred by narrowing the lick wheel and restricting the rotation. N-R lowered consumption by 40% to 3.51 lb/d ($P<0.001$). At the Ona location, reductions in consumption occurred less frequently and were less than those at Gainesville. The restriction of a standard width lick wheel (S-R) resulted in daily consumption similar to control ($P=0.79$). Reducing the wheel width to 0.75 inch also failed to reduce consumption ($P=0.12$). The most effective treatment was narrowing and restricting rotation of the lick wheel. N-R treatment gave a 23% decline in daily consumption to 5.24 lb ($P<0.01$). Although, it is not well documented, the physical manipulation of feeding devices is commonplace within the livestock-producing community. McLennan et al. (1991) compared consumptions of molasses-urea liquid supplement delivered in a lick tank and an open trough. As expected, the study showed that use of an unmodified lck wheel feeder provided a significant reduction in supplement consumption.

Individual animal liquid supplement intake was estimated using the same dual-marker technique as Exp. 1. These estimates were averaged and a coefficient of variation (CV) was calculated. At Gainesville, CV for control was 26% (mean intake 5.87 lb/d) and CV for N-R was 15% (mean intake 3.51 lb/d). At Ona, CV for control was 23% (mean intake 6.78 lb/d) and CV for NR was 35% (mean intake 5.24 lb/d). The CV's from both treatments at both locations were lower than 107% CV for molasses-urea supplements reported by Bowman et al. (1995) and 37% CV reported by Langlands and Donald (1978).

Technologies now exist and have been employed to limit consumption of liquid supplements by grazing ruminants. Lick feeders capable of dispensing predetermined, programmed quantities of supplement from a main tank into lesser feeding tubs using a metered gravity flow system are now available (Bowman et al., 1995). This is being done in an effort to more closely control individual animal consumption and compliments the objectives of this research. The effectiveness of these delivery systems was reported by Bowman et al. (1999).

Table 4. Effect of Feeder Wheel Width/Restriction on Free-Choice Consumption – Gainesville.

	Treatment = Wheel Width and/or Restriction				
Period	S-NR[1]	S-R[2]	N-NR[3]	N-R[4]	Period Avg.
	----------Liquid Supplement Intake lb/head/day----------				
1	4.94	2.53	4.46	1.09	3.26
2	4.05	4.37	5.10	3.14	4.17
3	6.64	5.91	4.44	3.59	5.15
4	7.85	4.83	5.42	6.21	6.08
Avg.	5.87[a]	4.41[b]	4.86[b]	3.51[c]	4.66

[1] Standard liquid supplement feeder, 2.0 inch wide lick wheel.
[2] Standard liquid supplement feeder, 2.0 inch wide lick wheel, wheel rotation restricted to ~330°.
[3] Liquid supplement feeder, 0.75 inch wide lick wheel.
[4] Liquid supplement feeder, 0.75 inch wide lick wheel, wheel rotation restricted to ~330°.
[a,b,c] Average intakes lacking a common superscript differ ($P<0.05$); SE=0.27.

Table 5. Effect of Feeder Wheel Width/Restriction on Free-Choice Consumption – Ona.

	Treatment = Wheel Width and/or Restriction				
Period	S-NR[1]	S-R[2]	N-NR[3]	N-R[4]	Period Avg.
	----------Liquid Supplement Intake lb/head/day----------				
1	7.14	5.57	7.28	2.46	5.61
2	6.61	7.50	7.28	6.70	7.02
3	6.48	7.98	6.59	6.06	6.78

4	6.90	5.61	8.84	5.77	6.78
Avg.	6.78[a]	6.66[a]	7.49[a]	5.24[b]	6.55

[1] Standard liquid supplement feeder, 2.0 inch wide lick wheel.

[2] Standard liquid supplement feeder, 2.0 inch wide lick wheel, wheel rotation restricted to ~330°.

[3] Liquid supplement feeder, 0.75 inch wide lick wheel

[4] Liquid supplement feeder, 0.75 inch wide lick wheel, wheel rotation restricted to ~330°.

[a,b] Average intakes lacking a common superscript differ (P<0.05); SE=0.31.

Conclusions (Experiment 3)

Physical manipulation of feeder lick wheels appeared to be an effective means of limiting intake at the Gainesville location. Reducing the surface area of the lick wheel and restricting its rotation was the most effective method at both experimental locations. Reducing surface area of lick wheel or only restricting its rotation was ineffective at Ona. Mixed responses were found in individual animal intake. At Gainesville, as consumption decreased the CV was decreased also. However, results from Ona mimicked those found in the phosphoric acid pH trial, with CV increasing as consumption decreased.

Summary

Three experiments were conducted to evaluate effects of acid source, pH and lick wheel modifications on sugarcane molasses-based liquid supplement consumption by heifers or cows grazing bahiagrass pastures in summer or fall. In experiment 1, a 16% crude protein liquid supplement was offered as a control and pH was adjusted to 3.4, 2.9, and 2.3 using feed grade phosphoric acid added at 3, 6 and 9%, respectively. These supplements were offered to heifers grazing bahiagrass during the summer at two locations. Across both locations, daily consumption was decreased 13% for pH 3.4, 30% for pH 2.9 and 64% for pH 2.3 compared to control (pH 4.2). Variation in individual animal intake for the control supplement showed a 13% and 28% coefficient of variation (CV) for the two locations, and the pH 2.4 supplement showed a 17% and 64% coefficient of variation at the two locations. In experiment 2, the pH of liquid supplements were reduced from pH 4.2 to pH 3.2 or pH 2.3 using phosphoric acid, sulfuric acid, or hydrochloric acid. These supplements were offered to gestating beef cows grazing bahiagrass during fall. When liquid supplements were adjusted to a similar pH, phosphoric acid was the most effective and hydrochloric acid was least effective in reducing liquid supplement consumption. Phosphoric acid (P) added to pH 3.2 lowered consumption 33% and P added to pH 2.3 lowered consumption 53%. Sulfuric acid (S) added to pH 3.2 lowered consumption 18% and S added to pH 2.3 lowered consumption 38%. Hydrochloric acid (H) added to pH 3.3 lowered (trend, P=0.13) consumption by 9% and H added to pH 2.3 lowered consumption 30%. Variation in individual animal intake for the control supplement showed a 33% CV and the six supplements with lower pH had similar variations (17% to 39% CV). In experiment 3, lick wheel width (2.5 vs 0.75 inches) and turning restrictions (none vs restricted) were evaluated using a 16% crude protein liquid supplement offered to heifers grazing bahiagrass during the summer at two locations. Limiting the rotation of the standard width lick wheel reduced consumption 23% at one location but had no effect at the other location. Reducing wheel width to .75 inches reduced consumption 17% at one location but tended to increase (11% higher) consumption at the other location. Limiting lick wheel rotation of a narrow wheel (.75 inches) reduced intake by 23% and 40% at the two locations. Variation in individual animal intake for the standard lick wheel showed a 23% and 26% CV for the two locations, and the narrow-restricted rotation wheels showed a 15% and 35% CV at the two locations.

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