PRACTICAL APPLICATIONS OF POTASSIUM IN CATION-ANION

BALANCING OF RUMINANT RATIONS

David P. Hutcheson
Professor of Animal Nutrition
Research Beef Cattle Nutritionist
Texas Agricultural Experiment Station

The adequacy of potassium in diets of cattle does not appear to have presented problems in the past. Many feedstuffs, particularly roughages, contain large amounts of potassium. Sub-optimal levels of potassium produces syndromes in animals such as a slower growth, depressed energy utilization, and various non-specific symptoms. Potassium has been known to be of nutritional importance since the early and middle nineteenth century. Since this time, much information has been developed on the physiological functions and distribution of potassium. Potassium is the third most abundant element found in the body and occurs primarily in the cells.

Potassium is a major factor in cellular osmotic balance, it acts as an available base to neutralize acids, in acid-base equilibrium. An ionic balance exists between K^{+}, Na^{+}, Ca^{++}, and Mg^{++}, which affects capillary and cell function and the excitability of nerves and muscles. Potassium activates or functions as a cofactor in several enzyme systems. Potassium functions in maintaining proper water balance. Potassium is not stored in the body as such and needs to be present in the daily diets of cattle.

Cation-anion balancing of rations has been considered in several species and has been used by nutritionists for several years. Cations (acidic) and anions (basic) are chemical components of required elements for mineral nutrition. The major cation sources are Ca, Na, K and Mg. While the major anion sources are P (PO_4), Cl and S (SO_4). The elements are primarily involved with acid based balance. A method of expression of cations-anions for rations would be a ratio as follows:

$$\frac{\text{cation milliequivalent / 100 gram dietary dry matter}}{\text{anion milliequivalent / 100 gram dietary dry matter}}$$

Remembering that milliequivalent is calculated as follows:

$$\frac{\text{atomic weight}}{\text{valance of element}}$$

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Potassium Requirement of Feedlot Cattle:

The majority of the research that has been done to establish the nutrient needs for potassium in feedlot cattle has been developed from healthy, non-stressed cattle. Devlin and others (1) fed varying levels of potassium to feedlot steers for 110 days, Table 1.

Table 1. Performance of Steers Fed Varying Levels of Potassium.

	Feed Potassium Level			
	.27%	.51%	.72%	.85%
Initial weight, lbs.	621	619	642	611
Average daily gain, lbs.	.20	1.98	2.91	2.15
Feed intake, lb/day	8.4	13.9	17.8	17.2

This data suggests that .72% of the diet should contain enough potassium for optimum growth in the feedlot. Subsequent work by this group with steers fed potassium for 104 days is presented in Table 2.

Table 2. Performance of Steers fed Potassium.

	Feed Potassium Level			
	.50%	.69%	.93%	1.05%
Initial weight, lbs.	734	746	729	735
Average daily gain, lbs.	2.46	2.42	2.88	2.54
Feed intake, lb/day	18.0	19.4	19.6	19.8

As can be seen from Table 2, maximum gains were observed from the .93% potassium level in the diet. Other workers (2,3,4) have made observations that .4 to 1.1% potassium in the diet was adequate for finishing steers and heifers. These observations led to the requirement of .6 to .8% potassium in the ration dry matter. If the previous work is expressed as gm of potassium per 100 pounds of body weight and regressed against average daily gain, the requirement for maintenance is 1 gm per 100 pounds of body weight per day and 9 gm per 100 pounds of body weight per day for optimum gains. When these are expressed as meq of K, these amounts add 26 meq/100 lbs of body weight for maintenance and 231 meq/lb of gain as cations. When the other dietary mineral elements are held constant, the ratio of cation to anion is 1.1 to 1.3.

Potassium Requirement for Beef Cows:

There has been even less work done in establishing the potassium requirement for beef cows. It is generally accepted that forages contain enough potassium for optimal production. However, work has been presented to indicate that supplemental potassium has enhanced cow performance (5). An additional 57 gm (1,462 meq of cation) of potassium was fed daily from December to March to one group of cows. The results were 5.8% higher calf survival, weaned calves were 37 pounds heavier, cows lost less weight during winter, and conception rate was better. While this was a field trial study, this indicates a potential need for potassium in cow calf operations.

Based on a survey of minerals of four native grasses, buffalo, blue grama, little bluestem, and sideoats grama, in the Panhandle of Texas, potassium was found to be from .09 to .45%, Table 3.

Table 3.

	% Potassium (Range)	Rainfall (inch/month)
April	.12 (.11-.12)	0.5
May	.09 (.08-.10)	2.0
June	.20 (.15-.23)	4.5
July	.38 (.33-.45)	0.0
August	.33 (.23-.43)	1.7
September	.28 (.19-.38)	0.8
Average	.23	1.6

Therefore, according to NRC recommendations, these pastures do not meet potassium requirements of .6 to .8% diet dry matter for growing, finishing cattle. However, using the calculated value of 1 gm per 100 pounds of body weight for maintenance, a 1,000 pound cow would require 10 gm (256 meq of cation) potassium per day. Milk has been reported to contain from 1.6 gm of potassium per liter. A beef cow producing 10 pounds of milk would require 8 gm (205 meq of cation) of potassium per day for the milk (6).

While potassium is readily absorbed in the small intestine, these calculated data would suggest that lactating cows require a minimum of 2 to 3 gm (51 - 77 meq of cation) potassium per 100 pounds of body weight.

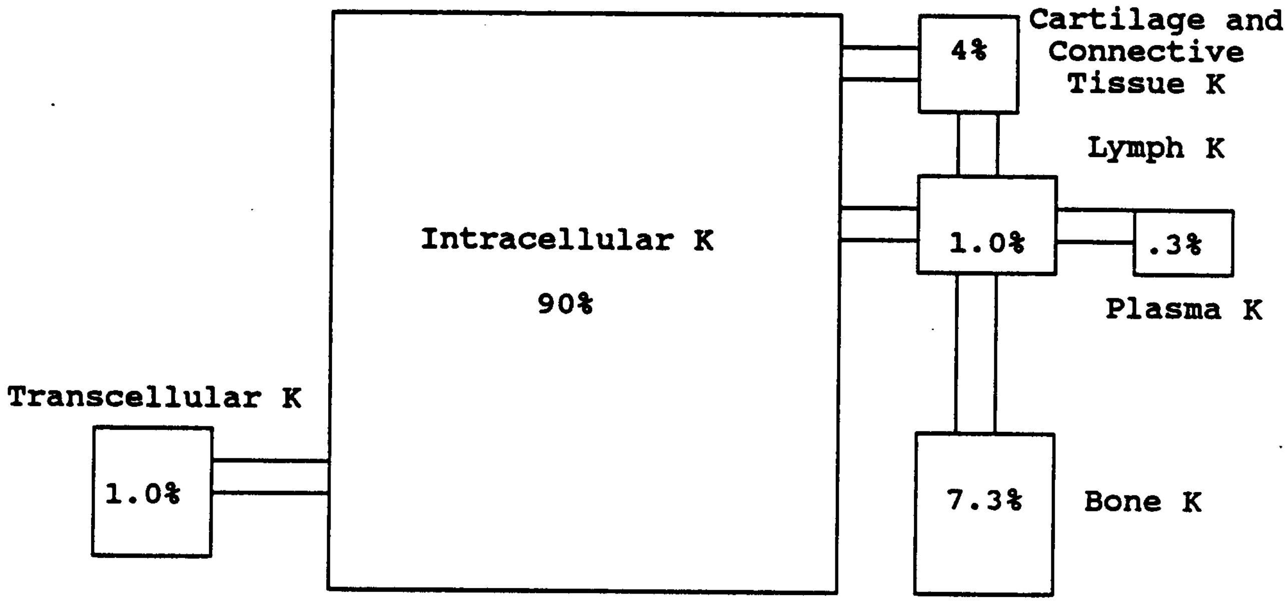
Potassium Toxicity:

Potassium toxicity occurs when there is an excess of potassium in the plasma and extracellular water spaces. If the extracellular potassium rises up to 10 meg per liter, then toxicity occurs and death results (7). Toxic concentration can develop due to injury or over correction of a deficiency by infusion. Normally ingested potassium beyond that required point is excreted and potassium toxicity is not a practical problem.

Potassium in Stress:

Potassium (K) is the third most abundant mineral element in the animal body. Potassium is about .3% of adult cattle; whereas, sodium (Na) is 15%. Potassium is present primarily inside the cells, while Na is present in plasma and extracellular fluids (8,9). The calculated average K is 48.3 meq per kg of body weight (10). Figure 1 represents the distribution of body K.

Figure 1. Potassium Distribution.



Potassium deficiency has not been an apparent problem in animal nutrition. However, cattle fed high concentrate diets might have suboptimal K levels. The deficiency of K is manifested by slow growth, depressed energy utilization, muscular weakness, stiffness, decreased feed intake, intracellular acidosis, and nervous disorders. Diarrhea is a common cause of acute K deficiency. Potassium is a dietary essential that should be supplied daily since very little or no reserves are built up. There is some storage of K in bone; however, as previously pointed out, this amount of K is less than 10%.

Potassium has many functions and is essential for life. Potassium is a major factor in cellular osmotic balance acting as an available base to neutralize acids. If K is not available and Na replaces K, there is an alternation of cellular metabolism and persistent alkalosis occurs (11). An ionic balance exists among K^+, Na^+, Ca^{++}, and Mg^{++}. These ions affect capillary and cell function (8,11,12), as well as the excitability of nerve and muscle (13). Proper water balance in the body is associated with K. Several enzyme systems are activated with K or K acts as a cofactor (14,15). These enzyme systems include energy transfer and utilization, protein synthesis, and carbohydrate metabolism. Potassium may accelerate an enzymatic reaction or may act along with certain other ions such as Mg^{++}, Na^+, and Ca^{++}. Inside the cell, K metabolic reactions are involved with phosphate and K acts either as a buffer or a neutralizer of phosphate esters (16).

The kidney plays the important role of maintenance and control of K. The hormones of the adrenal cortex control electrolyte balance through the kidney (11). The hormone aldosterone has the important effect of reabsorption of Na and excretion of K. Insufficient production of aldosterone results in excess loss of Na and retention of K. However, hyperactivity of the adrenal cortex and increased production of aldosterone results in excessive reabsorption of sodium and urinary excretion of K. Normally, adrenal cortex hormones are controlled by various receptors, which in turn are affected by circulating concentration levels of Na and K. When stress conditions tend to increase the activity of the adrenal gland, the adrenal cortex increases secretion of aldosterone; therefore K excretion is increased.

Normal body water distribution is 33% as extracellular and 67% an intracellular, Figure 2.

Figure 2. Distribution of Body Water.

Extracellular Water	Intracellular Water
33%	67%
10% of Body K	90% of Body K

When dehydration or body water loss occurs, water leaves the extracellular compartment and water moves from the intracellular to the extracellular compartment. When this occurs, the K concentration increases in the extracellular space and aldosterone is activated to excrete K. Thus, when stress occurs with dehydration or shrink, it is very likely an acute K deficiency could exist.

Cattle subjected to the stresses of marketing and shipping encounter many metabolic changes, one of which is weight loss, primarily due to digestive tract and body water loss. As discussed, this may lead to a K deficiency. A series of experiments has been completed to define the K requirements of the shipped stressed calf (18). Table 4 illustrates the diet used in these studies.

Table 4.

Ingredient	% Composition
Milo, steam flaked	42.5
Corn, steam flaked	24.5
Sugarcane Molasses	3.0
Cottonseed Hulls	23.6
Supplement*	6.4

*Supplement was a commercial 35% crude protein supplement.

Potassium was added to these experimental diets as KCl. Potassium levels fed were .71, .86, 1.27, 1.41, 2.15, and 3.11%. All calves received the experimental diet for two weeks, then the control diet, .71% K, the next two weeks. Table 5 illustrates the response to gains of calves fed the varying level of K.

Table 5.

% Dry Matter	Grams of Potassium Per 100 lbs. Body Weight 0-14 Days	0-28 Days	Average Daily Gain (28)
.71[1]	7.9	9.1	1.21
.86[2]	8.6	10.2	1.50
1.27[1]	11.5	11.6	1.70
1.41[2]	14.6	12.9	1.76
2.15[1]	21.1	15.5	1.36
3.11[1]	29.3	19.1	1.25

[1]Trial 1.
[2]Trial 2.

The best gains were obtained when either the 1.27% K or the 1.41% K was fed. The optimum grams of K per 100 lbs. of body weight were 12.15 grams (17). The requirement for growing, finishing cattle is between .6 and .8% of ration dry matter (16,5). By using the data of Devlin and others (1) from healthy feedlot cattle, the K requirement can be partitioned in maintenance requirement and growth requirement. Converting the intakes of K to grams K per 100 lbs. of body weight and regressing this against average daily gain, the maintenance requirement is 1 gm K per 100 lbs. body weight per day, and 9 gm K per 100 lbs. body weight per day for optimum gains. Thus, the 12 gms K per 100 lbs. of body weight necessary for optimum gain is 20% more than the requirement.

Potassium plays an integral role in stress. It is possible that acute K deficiency occurs during stress where water balance is upset or an increase in aldosterone is evident.

Potassium Interaction with Ionophores:

Gado (19) reported that monensin or lasalocid increased apparent absorption of Ca, P, Mg and K in the small intestine. Greene et al. (20) found increasing K increased Mg excretion when monensin was infused into the rumen. Lambs were used in a metabolism study to determine the effects of monensin and infused K on the absorption of magnesium. The addition of monensin to the diet at 20 ppm resulted in an increase of apparent absorption and retention of Mg. Increasing levels of K resulted in increasing Mg in the feces. In the presence of high levels of K, monensin appeared to be more effective in reducing the acetate to proportionate ratio.

Spears (21) reported performance data from steers that were fed lasalocid with varying levels of Na and K. Table 6 illustrates the results.

Table 6. Performance of Steers Fed Lasalocid and Varying Levels of Na and K.

	Control	Lasalocid			
K	.5	.5	.5	1.4	1.4
Na	.25	.05	.25	.05	.25
Initial Weight	785	781	788	790	781
Final Weight	1,039	1,074	1,089	1,030	1,066
Daily Gain, lbs/hd/day	2.49	2.86	2.95	2.33	2.79
Daily Feed, lbs/hd/day	18.7	19.6	19.1	17.8	18.5
Feed/Gain	7.6[a]	6.9[a,b]	6.6[b]	7.6[a]	7.7[a]

The data indicates that when Lasalocid was fed (30 mg/ton), that the best response was with .5% K and .25% Na. The higher level of K seemed to negate the feed to gain effect of Lasalocid. As observed by Johnson (1988), increased K decreased ruminal soluble Na.

Recent research has demonstrated that a biologically active ionophore present in the G.I. tract alters the site and rate of absorption of macro and micro-elements. The change in absorption and retention of elements indicates that ionophores could alter the mineral requirement of the ruminant or could alter the cation to anion ratio. The ratio of 1.4 gave the best feed to gain and average daily gain.

The cation to anion ratio for optimum performance of cattle seems to be from 1.0 to 1.2. The optimum rate for stressed cattle seems to be 1.5 to 1.8. Even though these rates have been calculated, there are minimum requirements for each of these mineral elements.

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