EFFECT OF HEAT STRESS ON THE POTASSIUM NEEDS OF LACTATING COWS FED COMPLETE MIXED RATIONS

by

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Introduction

Heat stress contributes significantly to the decline in milk yield occuring in Florida during the summer. A portion of this decline can be attributed to reduced feed consumption. Additionally, it would appear likely that metabolism and utilization of certain nutrients may be affected by the abnormal physiological state of the lactating dairy cow experiencing heat stress. A relatively new research effort in the Dairy Science Department has been initiated to identify and study the effects of heat stress upon nutrient metabolism and requirements of the lactating cow. This report deals with research conducted to evaluate the dietary requirement for potassium and the physiological status of lactating cows consuming complete mixed rations during summer months. Also addressed in this report is the potential deficiency of potassium which might occur when complete mixed rations contain fairly large proportions of grain and/or by-product feedstuffs.

BACKGROUND

Role and Need for Potassium

Potassium is an important component of all animal products, comprising .15% of fluid milk compared to .10% calcium and .06% phosphorus. Physiologically, potassium is of major importance in the maintenance of acid-base balance of the cow. Even though potassium is found in high concentrations within cells, the body does not maintain an appreciable potassium reserve, and it is cycled in and out of the body in a continuous fashion (Ward, 1966).

Only during the last ten years has research been conducted to determine the dietary potassium needs for lactating dairy cows. Recommended (National Research Council, 1978) level of dietary potassium (0.8% of the diet dry matter) is based largely on studies done by University of Kentucky researchers (Hemken, 1980). An appreciable increased in milk yield was found when potassium was increased from 0.5 to 1.0% of the diet dry matter. Most profound effect of low dietary potassium has been a decline in feed consumption with the subsequent reduction in milk yield. Kentucky studies were done with lactating cows housed in a tie-stall barn during milk weather. For this reason the Kentucky results may not be applicable to our Florida summer conditions.

[1]Mention of trade names does not constitute recommendation by the Dairy Science Department, Institute of Food and Agricultural Sciences, University of Florida, and does not imply approval to the exclusion of other products which may be equall suitable.

Effects of Hot Weather

Research from Cornell University (McDowell and Weldy, 1967) where cows were housed in environmental chambers at two temperatures, 20°C (68°F) or 30°C (86°F); indicated a change in the routes by which body water was lost during high environmental temperature (Table 1).

TABLE 1. BODY WATER LOSS IN NONLACTATING HOLSTEIN COWS AT 20 C vs 30 C.[1]

Source of Loss	20 C		30 C	
	Kg/24hr	Percent of Total	kg/24hr	Percent of Total
Feces	13.0	30.3	9.8	14.4
Urine	11.7	27.3	14.7	21.6
Saliva	0.0	0.0	2.4	3.5
Respiratory tract	7.6	17.7	11.7	17.2
Body surface	10.6	24.7	29.3	43.1
Total loss	42.9	----	67.9	----

[1]Adapted from McDowell and Weldy, 1967.

Total body water loss was 37% greater for cows at 30°C than at 20°C. This suggests the paramount importance of adequately accessible drinking water for cows during hot weather.

Table 1 also shows that 2.5 times more water was lost through sweating when cows were exposed to 30°C compared to 20°C. Also, 43% of total body water loss was by sweating for cows housed at 30°C. Sweating is a major mechanism by which cows can lose excess body heat during hot weather.

Potassium loss through sweating

With increased sweating at high environmental temperatures more electrolytes (sodium, potassium, chloride) are lost from the body through sweat. In man and horse the major electrolyte lost during sweating is sodium. This is not the case in the dairy cow which secretes relatively larger quantities of potassium than sodium in sweat. This has been shown in research by Singh and Newton (1978) where potassium loss in sweat increased almost 3.5 times when calves were exposed to 40°C (104°F) compared to 25°C (77°F). On the other hand, sodium loss was only slightly increased.

In another study, Jenkinson and Mabon (1973) exposed calves to 15, 25, 35 and 40°C. Table 2 shows the increase in potassium secretion rate in the sweat as temperature increased from 15 to 40°C.

TABLE 2. MEAN RATES OF POTASSIUM LOSS FROM THE SKIN AND ESTIMATED LOSS AS A PERCENT OF INTAKE AT VARYING AIR TEMPERATURES[1]

Temperature, C	K^+ Secretion Rate ($mg/m^2/hr$)	K^+ Loss (% of intake)[2]
15	1.75	0.20
25	8.50	0.99
35	18.16	2.28
40	48.46	11.45

[1]Adapted from Jenkinson and Mabon (1973).

[2]Mean potassium consumption was 51g/d.

A 28-fold increase in the potassium secretion rate was observed as air temperature was increased from 15 to 40°C. Estimated total potassium loss via the skin was about 11.5% of potassium intake during extreme temperature (40C), compared to about 2% or less when air temperature was 35C or lower.

Potassium in Feedstuffs

A lack of high quality roughages has dictated a trend toward increased utilization of complete blended rations to reduce feed costs and simplify feeding management programs for dairy cattle (Marshall, 1978). This has been true particularly in Florida. Accompanying this trend has been an increased usage of by-product feeds and low quality roughage sources. Complete ration feeding also has increased the proportion of cereal grains and corn silage used (Hemken, 1980). Many of these feedstuffs are generally low in potassium content (Table 3). Remembering that the NRC (1978) recommendation for potassium is 0.8%, one can observe that all cereal grains listed would supply a proportion below that needed to meet the recommendation when added in complete mixed diets, if all other ingredients contained at least .8% potassium.

The same is true of sugarcane bagasse, brewer's dried grains, corn gluten meal and distiller's dried grains. Corn silage, corn cobs, cottonseed hulls and distiller's dried grains with solubles also should be considered marginal in potassium content. Notice when the solubles fraction of the distilling process is added back to the grains by-product the potassium content is significantly increased. In situations when these types of feedstuffs are used in diet formulation, potassium supplementation may be necessary to achieve maximum production.

TABLE 3. POTASSIUM CONTENT OF SELECTED FEEDSTUFFS[1]

Ingredient	Potassium (dry basis) %
Forages	
Alfalfa, early vegetative	2.26
Alfalfa, full bloom	1.86
Brome, late vegetative	2.32
Corn silage	1.05
Roughages	
Corn cobs	0.84
Cottonseed hulls	0.84
Sugarcane bagasse	0.50
Grains	
Corn	0.35
Barley	0.45
Oats	0.42
Wheat	0.48
Other	
Brewer's dried grains	0.09
Corn gluten meal	0.03
Cottonseed meal	1.53
Distiller's dried grains	0.15
Distiller's dried grains with solubles	1.00
Molasses, sugarcane	3.68
Soybean meal	2.21

[1]From National Research Council (1978).

EXPERIMENTAL

Objective. Consideration of potential changes in the potassium needs elicited by heat stress lead to design of the following experiment. Objective was to evaluate the lactational, nutritional and physiological responses of cows in early- to mid-lactational, to varying dietary potassium percentages (0.5, 1.0, 1.5% of diet dry matter) while maintained in no shade or shade environments from mid-May through mid-September, 1980.

Procedures. Eight Jersey (early-lactation) and ten Holstein (mid-lactation) cows were maintained continuously in a no shade (NS) open lot or shade (S) structure with adjoining open lot at the Dairy Research Unit, Hague, FL. Cows were assigned to NS or S treatments according to breed and stage of lactation, and assigned randomly to one of six dietary potassium treatment sequences (Table 4). A 3-week preliminary adjustment period preceded three, 30-day treatment periods.

Dyna-K (KCl) replaced the appropriate amount of corn grain to make 1.0 and 1.5% potassium diets. Diet formulation of all other nutrients (including macrominerals) was calculated to meet, but not exceed, NRC (1978) recommendations. Individual cow ad libitum feed intake was monitored between 8:00 am and 6:00 pm and between 6:00 pm and 8:00 am daily the last 14 days of each treatment period. Milk production was measured twice daily (7:00 am and 4:30 pm) the last 14 days of each treatment period. Rectal temperature and respiration rate were monitored between 1:00 and 2:00 pm the last day of each experimental treatment period.

Results and Discussion. Table 6 depicts the average hourly Black Globe environmental temperature for readings taken from 11:00 am to 6:00 pm daily the last 14 days of each period. This, of course, was the hottest interval of the day. Average Black Globe temperature was approximately 11 C higher in the no shade than the shade environment. Cows in the no shade area exhibited signs of hyperthermia (severe heat stress) during this time interval. Cows in shade (33.5 C average Black Globe temperature during this time interval) did not exhibit hyperthermia.

TABLE 6. AVERAGE HOURLY ENVIRONMENTAL BLACK GLOBE TEMPERATURE MEASURED FROM 11:00 AM TO 6:00 PM.

Hour	Environment	
	No Shade	Shade
	--Black globe temperature, C--	
1100 (11 am)	43.3	32.0
1200 (12 pm)	45.5	33.2
1300 (1 pm)	45.8	33.7
1400 (2 pm)	45.5	33.6
1500 (3 pm)	48.1	35.0
1600 (4 pm)	43.3	33.9
1700 (5 pm)	41.8	33.5
1800 (6 pm)	39.7	33.4
Average	44.1	33.5

Respiration rate and rectal temperature are reported in table 7. Respiration rate was higher for cows without shade than for cows with shade (132 vs 88/min, P<.001). Respiration rate was not affected by dietary potassium level. Rectal temperature also was higher in no shade cows than shade cows (41.16 vs 39.95 C, P<.001); rectal temperature above 40 C indicates probable hyperthermia (Jenkinson and Mabon, 1973). Though dietary potassium level did not affect rectal temperature, there was a significant shade or no shade by potassium level interaction (P<.06). Visual observations of cows in the no shade group indicated hyperthermia with severe panting and drooling and frequent trips to the drinking water. Such signs were not observed in the shaded cows.

TABLE 7. MEASUREMENTS OF HEAT STRESS IN DIETARY POTASSIUM LEVEL BY NO SHADE OR SHADE ENVIRONMENT EXPERIMENT.

RESPIRATION RATE/min.			
Dietary Potassium,%	No Shade	Shade	Mean
0.5	126	89	108
1.0	133	83	108
1.5	136	91	113
Mean[a]	132	88	

[a]Shade or no shade effect (P<.001)

RECTAL TEMPERATURE, C			
Dietary Potassium,%	No Shade	Shade	Mean
0.5	41.10	40.14	40.62
1.0	41.26	39.78	40.52
1.5	41.13	39.94	40.53
Mean[b,c]	41.16	39.95	

[b]Shade or no shade effect (P<.001)

[c]Shade or no shade * potassium level interaction (P<.06)

[1]Measurements taken at 2:00 p.m., the last day of each experimental period.

It was desired to measure individual cow feed intake during the hottest part of the day and also during the cooler portion. This would provide information about the diurnal pattern of feed intake of the heat stressed cow. Individual bunks were used in which only one cow could open a respective bunk with aid of a magnetic key (Calan magnetic feeding gates). Table 8 shows results of feed intake between 8:00 am and 6:00 pm and between 6:00 pm and 8:00 am. During the hotter part of the day (8:00 am to 6:00 pm) cows with shade consumed 2.3 times mo[re] feed than cows without shade (9.2 vs 4.0 kg, P<.01). Cows within the no shade environment consumed larger amounts of feed as dietary potassium level increased.

TABLE 8. AVERAGE INTAKE IN DIETARY POTASSIUM LEVEL BY NO SHADE OR SHADE ENVIRONMENT EXPERIMENT.

FEED INTAKE (8:00 am to 6:00 pm), kg			
Dietary Potassium,%	No Shade	Shade	Mean[b]
0.5	3.7	8.5	6.1
1.0	4.0	9.6	6.8
1.5	4.7	9.6	7.0
Mean[a]	4.0	9.2	

[a]Shade or no shade effect (P<.01)

[b]Potassium level, curvilinear effect (P<.03)

FEED INTAKE (6:00 pm to 8:00 pm), kg

Dietary Potassium,%	No Shade	Shade	Mean
0.5	14.2	12.3	13.3
1.0	15.3	12.1	13.7
1.5	14.5	12.6	13.5
Mean[c]	14.7	12.3	

[c]Shade or no shade effect ($P<.05$)

TOTAL DAILY FEED INTAKE, kg

Dietary Potassium,%	No Shade	Shade	Mean[e]
0.5	18.0	20.7	19.4
1.0	19.3	21.7	20.5
1.5	18.8	22.2	20.5
Mean[d]	18.7	21.3	

[d]Shade or no shade effect ($P<.05$)

[e]Potassium level, curvilinear effect ($P<.1$)

During the cooler portion of the day (6:00 pm - 8:00 am) feed intake was 16% higher for the no shade cows than for the shaded cows ($P<.05$). This was apparently an attempt to compensate for decreased feed consumption during the hot part of the day. Dietary potassium level had no significant effect on feed intake during this time interval (6:00 pm - 8:00 am).

Total daily feed intake was higher for cows maintained in the shaded environment than for cows without shade (21.3 vs 18.7 kg/d, $P<.05$). These data indicate that heat stress did decrease feed intake during the hottest part of the day; there was an attempt to compensate for this reduction during the cooler night hours; however, the net result was a 12% reduction in feed intake for the total day for the heat stressed cows. There was an increase in feed intake as dietary potassium level was increased from 0.5 to 1.0%; these results are similar to results of Hemken (1980). However, there was no additonal overall benefit by increasing the potassium level to 1.5% nor a significantly greater benefit of added potassium in the no shade compared to the shade treatment.

Milk production data are shown in table 9. Morning milk yield was about 19% higher in shade compared to no shade cows ($P<.1$). Overall milk production was greater with 1.0% potassium compared to 0.5%, but additional benefit was not observed by increasing to 1.5% potassium. Milk production during the evening milking showed similar trends to those observed during the morning milking. Production at the evening milking was significantly affected by no shade compared to shade (6.4 vs 8.1 kg/d, $P<.025$).

TABLE 9. AVERAGE MILK YIELD IN DIETARY POTASSIUM LEVEL BY NO SHADE OR SHADE ENVIRONMENT EXPERIMENT (SUMMER, 1980)

MORNING MILK YIELD, kg

Dietary Potassium,%	No Shade	Shade	Mean[b]
0.5	7.2	9.2	8.2
1.0	8.6	9.6	9.1
1.5	7.7	10.0	8.8
Mean[a]	7.8	9.6	

[a]Shade or no shade effect (P<.1)

[b]Potassium level, curvilinear effect (P<.07)

EVENING MILK YIELD, kg

Dietary Potassium,%	No Shade	Shade	Mean[d]
0.5	6.1	7.9	7.0
1.0	6.6	8.5	7.5
1.5	6.4	8.1	7.3
Mean[c]	6.4	8.1	7.3

[c]Shade or no shade effect (P<.025)

[d]Potassium level, curvilinear effect (P<.1)

TOTAL DAILY MILK YIELD, kg

Dietary Potassium,%	No Shade	Shade	Mean
0.5	13.4	17.0	15.2
1.0	15.2	18.1	16.6
1.5	14.1	18.1	16.1
Mean[e]	14.2	17.7	

[e]Shade or no shade effect (P<.05)

[f]Potassium level, curvilinear effect (P<.03)

Total daily milk production was 14% lower for cows maintained in the no shade environment than in the shade (P<.05). A curvilinear effect of dietary potassium level on total milk yield was noted (P<.03). Milk production was improved as potassium level was increased from 0.5 to 1.0%. However, increasing the level to 1.5% provided no additional benefit. Within environment, the magnitude of response to added potassium (from .5 to 1.0% potassium) was greater with no shade (12% increase) compared to shade (6% increase).

Figure 1 shows the change in percentage milk potassium in NS and S treatments as the dietary potassium level changed. Interestingly, in the NS cows as the dietary potassium concentration increased, so did milk potassium percentage.

This was not true for cows maintained in the shade structure. Similar milk potassium concentrations in NS and S treatments when 1.5% potassium was fed would suggest that adequate feed potassium was availble.

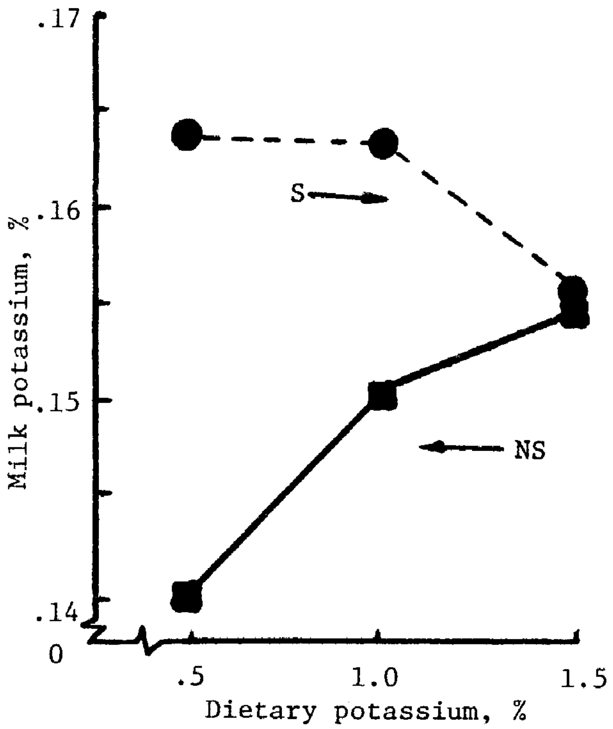

Figure 1. Milk potassium (%) in NS and S treatments as affected by dietary potassium.

Additional experimentation will be conducted in future summers to more precisely define this trend for additional beneficial response to a dietary potassium inclusion above the NRC (1978) recommendation. It could certainly be recommended to formulate diets which contain 1% potassium for summer lactation rations in Florida.

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