Relationship Between *Halogeton glomeratus* Consumption and Water Intake by Sheep[1]

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Highlight

When sheep are fed diets containing sufficient halogeton to supply 3.2% oxalate in the diet, water consumption is markedly increased, and sheep consume less of the halogeton diet. When water is restricted, there is a decrease in feed intake with the decrease becoming more pronounced with continued water deprivation as compared to control sheep. An association of water deprivation and halogeton poisoning in sheep is indicated.

Halogeton poisoning is one of the serious problems of the range sheep industry in the western United States (Fig. 1). Halogeton (*Halogeton glomeratus*) is an oxalate-producing plant of the Chenopodiaceae family. The oxalate, which is the toxic agent, occurs primarily as sodium oxalate and accounts for 10–30% of the dry weight of the plant (Williams 1960, James et al. 1968).

When halogeton is consumed by a sheep, the oxalate may be degraded by rumen microorganisms (James et al., 1967), combine with calcium in the rumen to form insoluble calcium oxalate, or be absorbed from the rumen into the blood where it can combine with calcium to form calcium oxalate. A hypocalcemia results when the oxalate is absorbed into the blood. Death of the sheep is presently thought to be due to a combination of factors as interference with energy metabolism, hypocalcemia, and tissue damage (James, 1968).

The halogeton plant is high in soluble ash (James et al., 1968). Increased water consumption accompanies halogeton feeding (James et al., 1968). Winchester and Morris (1956) indicated that water intake is related to dry matter consumption and ambient temperature. They also stated that water consumption is increased when salt-protein mix is fed to cattle. Research with halogeton indicates that the soluble ash content of the diet has more effect than dry matter consumption or ambient temperature on water intake (James et al., 1968). Five gallons of urine must be excreted for each pound of salt consumed by cattle (Cardon et al., 1951).

When sheep were given diets containing salt to simulate diets containing saltbush (*Atriplex* spp.) and access to water was restricted to once daily, food intake was reduced; the reduction was more severe with the more salty feeds (Wilson and Hindley, 1968).

In vitro methods showed that considerable oxalate can be degraded by the rumen ingesta from sheep conditioned to the halogeton consumption (James et al., 1967). The effect of this degradation of oxalate on the lethal dose of halogeton to sheep is not known.

The purpose of this research was to evaluate the relationship between halogeton consumption and water intake and their relationship to halogeton poisoning in sheep. The effect of conditioning sheep to halogeton and the resulting change in the lethal dose of halogeton was also examined.

Procedure

The experiment was divided into four periods using 12 sheep. During each period, feed and water were supplied in a different relationship to each other. For the first period, the 12 sheep were sorted by weight into six pairs and randomly alloted within pairs to treatments. One sheep of each pair was fed a diet containing 3.2% soluble oxalate (the oxalate was supplied in the form of halogeton.) while the others served as a control. During this period both sheep of each pair was given an equal amount of feed, the amount being determined by the sheep that ate the least. Water was supplied *ad libitum* twice daily. During period 2, the sheep were changed so that both sheep of each pair received equal amounts of water supplied twice daily and feed *ad libitum*. During period 3, the same sheep were divided into two groups. One group consisted of those fed the diets containing oxalate during periods 1 and 2 and the others were the controls. Feed was given *ad libitum* and water was offered 30 minutes once each 24 hours. The sheep were fed the same but were offered water once each 48 hours during period 4. The sheep fed the halogeton diet received the same diet throughout the experiment. The diets were pelleted. The sheep were fed twice daily. The amount of halogeton in the diet approximates the amount of halogeton that would be eaten when sheep were grazing forage extremely close. This would be equivalent to the diet being made up of 29% halogeton that was 10.4% soluble oxalate (Cook and Stoddart, 1953). Table 1 shows the ingredients of the diets. The feeding and watering schedule is summarized in Table 2.

All sheep were placed in metabolism cages and remained in them throughout the experimental period. The sheep were allowed 7 days to adjust to each change in feeding and watering schedule. Feces and urine were collected for fecal weight and dry matter and urine weight and specific gravity. Collection of feces and urine was made during the 5 days following the adjustment period.

Feed and water were weighed daily. Feces and urine were weighed during the 5-day collection period and dry matter was determined on the feces for the first 3 periods and specific gravity on the urine. Fecal dry matter was not determined during period 4 because of the great variability in feed intake and fecal excretion.

At the conclusion of the feeding and watering trials, the sheep receiving the diet containing oxalate was increased

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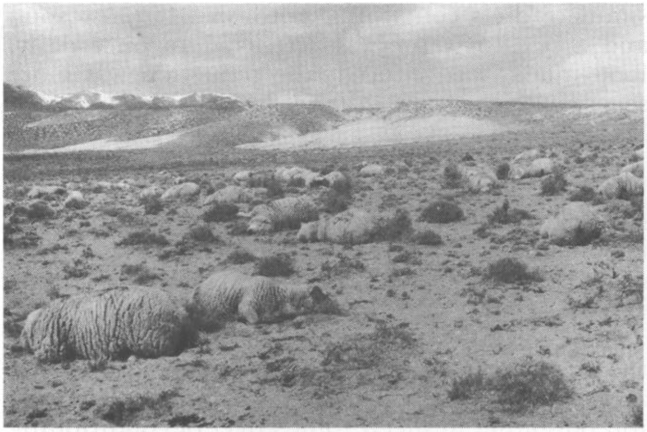

FIG. 1. Sheep dying from halogeton poisoning shortly after being watered then permitted to graze halogeton.

to 5% soluble oxalate, and all sheep were given what was calculated to be a lethal dose of halogeton, *via* stomach tube, (1.21 gm oxalic acid equivalent/kg body wt) approximately 30 minutes after the morning feeding (Table 3). Necropsy was performed on each sheep.

Field observation on desert ranges were also conducted. The feeding, watering and fecal dry matter data were submitted to a statistical analysis.

Results

The feed intake during period 1 was controlled by the sheep receiving the diet with oxalate. However, the sheep fed the diet containing oxalate drank about 25% more water than the control ($P < .01$) (Table 4). The control sheep excreted more fresh feces ($P < .10$), but there was no difference in the amount of fecal dry matter. The sheep receiving the halogeton excreted more urine ($P < .01$) than the control. There was a trend toward a higher urine specific gravity for the control sheep.

During period 2, feed intake was higher ($P < .01$) in the control sheep of each pair (Table 4). The sheep of each pair had equal water intake, but it

Table 1. Formulation of pelleted diet fed experimental sheep.

	Composition	
	Oxalate diet (%)	Control diet (%)
Grass hay	32.4	34.2
Alfalfa hay	32.4	34.2
Barley	12.6	13.4
Halogeton (14.2% soluble oxalate)	22.6	
Straw		18.2
Dry matter	93.0	92.3
Ash	11.9	7.4
Soluble oxalate	3.2	0.0

Table 2. Feeding and watering schedule for the four experimental periods.

Period	Sheep	Experimental method
1	Paired	Equal feed—water ad lib. twice daily
2	Paired	Equal water twice daily—feed ad lib.
3	Unpaired	Feed intake ad lib.—water offered 30 min once each 24 hr
4	Unpaired	Feed intake ad lib.—water offered 30 min once each 48 hr

was limited in each pair by the sheep on the control diet. The control sheep excreted more feces ($P < .01$), than the sheep getting the diet containing halogeton. Even though the water intake was equal, the sheep fed the diet with halogeton excreted more urine ($P < .01$) of lower specific gravity ($P < .01$) than the controls.

The sheep were not paired during periods 3 and 4. The control sheep in period 3 ate more feed ($P < .01$) and excreted more feces of higher moisture content ($P < .01$) and fecal dry matter ($P < .01$). But the sheep receiving the diet containing halogeton drank more water ($P < .01$) and excreted feces higher in dry matter and excreted more urine ($P < .01$) of lower specific gravity ($P < .05$) than the controls (Table 4).

During period 4, the control sheep ate more feed ($P < .01$) and excreted more fresh feces ($P < .01$) than did the halogeton-fed sheep. There was no difference in water consumption, but those receiving halogeton excreted more urine ($P < .01$). There was no difference in urine specific gravity (Table 4). The sheep fed the diet containing halogeton ate rather greedily immediately after watering but were rather reluctant to eat on the day they were not watered. Some sheep fed halogeton almost ceased to eat by the end of the second day. Table 5 shows the average feed consumption at a 12-hour interval with feces and urine on a 24-hour basis over the 48-hour interval for period 4.

The lethal dose of halogeton to sheep is increased by approximately 12% when sheep were conditioned to halogeton consumption. There was a marked tendency to drink large amounts of water when daily dosage was increased. The sheep that survived when fed a dose of halogeton calculated to be lethal recovered within two days. These sheep lost appetite.

Discussion

The higher water intake by the sheep fed halogeton was evidently due to the higher soluble ash in the diet containing halogeton. This effect is similar to that caused by diet high in salt (NaCl). The need of water by these sheep to carry the solute load in the urine was also reflected by the excretion of feces lower in moisture. The water is

Table 3. Results of feeding amounts (gm) of *Halogeton glomeratus* calculated to be lethal to sheep conditioned and unconditioned to the consumption of *Halogeton*.

Sheep No.	Wt. (kg)	Diet	*Halogeton* force fed (16.5% oxalate)	Pelleted *Halogeton* diet fed free choice (5% oxalate)	Control diet fed	Total oxalate fed	Calculated lethal dose oxalate[a]	Observation after feeding
613	75	oxalate	545	100	0	95	90	Lost appetite after 2 days; killed after 19 days
701	73	oxalate	510	475	90	108	88	Appetite normal; killed after 1 day
650	68	oxalate	500	740	0	120	82	Died in 8 hours
533	73	oxalate	510	400	400	104	89	Appetite normal; killed after 3 days
519	64	oxalate	495	425	425	103	77	Died in 36 hours
636	67	oxalate	495	220	220	93	81	Appetite normal; killed after 6 days
740	82	control	600		180	99	99	Died in 9.5 hours
617	73	control	510		800	84	88	Died in 10.5 hours
550	67	control	490		800	81	81	Died in 10 hours
823	73	control	510		550	84	88	Died in 14.5 hours
783	66	control	495		450	82	80	Died in 10.5 hours

[a] 1.21 gms oxalic acid equivalent/kg body weight.

Table 4. Average feed and water intake and urine and fecal excretion from sheep on a *Halogeton* experiment (all values on a 12-hour basis).

Period	Diet	Treatment: Sheep	Treatment: Intake	Feed (gm)	Water (gm)	Feces (gm)	Fecal dry matter (gm)	Urine (gm)	Specific gravity
1	control	paired	equal feed; water ad lib.	1033	3080*	1150†	385	1052**	1.038†
1	oxalate	paired	equal feed; water ad lib.	1033	4189	1030	382	2692	1.028
2	control	paired	equal water; feed ad lib.	1130**	3160**	1385**	423**	878**	1.050**
2	oxalate	paired	equal water; feed ad lib.	750	3136	652	267	1830	1.032
3	control	unpaired	feed ad lib; water ad lib; once daily	1040**	2419**	1067**	386**	891**	1.055**
3	oxalate	unpaired		800	2833	710	270	1820	1.033
4	control	unpaired	feed ad lib; water ad lib. every other day	790**	1722	740**	not available	552**	1.059
4	oxalate	unpaired		540	1773	520	not available	928	1.054

** $P < .01$ Comparing control vs. oxalate within each period.
* $P < .05$ Comparing control vs. oxalate within each period.
† $P < .10$ Comparing control vs. oxalate within each period.

Table 5. Average daily feed and water intake (gm), and urine and excretion (gm) during Period 4.

Treat	Time (hr)	Feed	Water	Feces (wet)	Urine
Control*	12	1017	6890		
	24	1017		1302	1020
	36	773			
	48	355		1668	1190
Oxalate*	12	820	7092		
	24	820		960	1414
	36	372			
	48	140		1123	2296

* This cycle was repeated 5 times.

apparently used in excreting excessive amounts of small molecular materials in halogeton that act as diuretics. The kidney's ability to concentrate urine maximally decreases as the solute load increases (Sodemon, 1961). The larger the solute load the nearer urine osmolarity approaches that of plasma. Small molecular substances may be absorbed by the kidney tubules where they bind water and increase urine flow.

The decline in feed intake from period 1 to 2 in the sheep fed the diet containing halogeton was thought to be due to water restriction. Although the water intake was the same for both sheep of the pair, the sheep receiving the oxalate excreted more urine. The water used in the formation of this urine was derived at least in part by excreting drier feces.

The further restriction of water during period 3 resulted in little change in feed intake or excretion of feces or urine.

Water restricted to once every other day, resulted in a decrease in feed intake, the decrease being greatest in the sheep receiving the halogeton diet. At this point, there was no difference in water intake between groups suggesting that both were apparently consuming all the water they could during the allotted time.

During all four periods, it is apparent that urine volume from the sheep fed diets containing halogeton is derived in part by the sheep excreting drier feces.

Urine specific gravity increases as water is restricted (Period 2 or Period 1). There is no further change in the relationship of specific gravity of the urine between the sheep receiving halogeton and the control, except for the marked increase between period 3 and 4 for the sheep fed halogeton. This increase probably represents the sheep's attempt to excrete maximum amount of salt with minimum water (Table 4).

The increase of the lethal dose of halogeton to sheep resulting from conditioning to halogeton consumption agrees with *in vitro* work (James et al., 1968). A feeding level of 1.21 gm oxalic acid equivalent/kg of body weight has been found to be lethal under any of our conditions. However, a lethal dose of halogeton varies with the amount of material in the sheep's rumen. A sheep with greater fill can consume more with less chance of adverse affect. Dosages of 1.05 gm soluble oxalate/kg of body weight are lethal under most conditions even when sheep have had access to alfalfa hay for one hour before feeding the halogeton (James, 1968).

The increase in the dose of halogeton lethal to sheep resulting from feeding sublethal amounts before being given a lethal challenge dose illustrates the value of allowing sheep to be exposed to small amounts of halogeton before grazing heavy stands. This has been demonstrated by *in vitro* (James et al., 1967) and *in vivo* methods. The *in vivo* results of this experiment are in agreement with earlier preliminary research where the amount of halogeton fed was increased periodically until a considerable more than lethal dose was fed.[2]

Under natural conditions, a sheep grazing desert range areas such as those where halogeton grows and with restricted water intake may decrease feed intake or change the diet to include the less salty plants. The sheep also have the situation of grazing immediately following watering after an extended period without water. This time appears to be critical as far as halogeton poisoning is concerned. As has been demonstrated, feed intake decreases when water intake is restricted. When animals are watered they will then eat. Under many range conditions, large amounts of halogeton are available to be grazed. At these times, great numbers of sheep may be poisoned on halogeton (Fig. 1). The problem is compounded by the fact that the sheep's rumen is relatively empty and therefore the toxic oxalate is more rapidly absorbed. Sheep with an empty stomach are poisoned on less oxalate than those that have a rumen full of feed (Cook and Stoddard, 1953). Our experiment demonstrated that when sheep are not watered for extended periods, feed consumption declines rapidly. When water is supplied, the sheep will eat readily. Field observations of halogeton poisoning indicate that most deaths occur during these periods.

Adequate water is important in maintaining an adequate and constant intake of feed by the sheep. The economic value of watering sheep has been discussed by Hutchings, 1954 and 1958.

Literature Cited

Cook, C. Wayne, and L. A. Stoddart. 1953. The halogeton problem in Utah. Utah Agr. Exp. Sta., Bull. 364.

[2] James, L. F., 1967, unpublished data.

CARDON, C. P., E. B. STANLEY, W. J. PISTOR AND J. C. NESBITT. 1951. The use of salt as a regulator of supplemental feed intake and its effect on the health of range livestock. Ariz. Agr. Exp. Sta., Bull. 239.

HUTCHINGS, SELAR S. 1954. Managing winter sheep range for greater profit. U.S. Dep. Agr. Farmers Bull. 2067, p. 19.

HUTCHINGS, SELAR S. 1958. Managing winter sheep range for greater profit. U.S. Dep. Agr. Leaflet 423.

JAMES, LYNN F., JOSEPH C. STREET AND JOHN E. BUTCHER. 1967. The *in vitro* degradation of oxalate and of cellulose by rumen ingesta from sheep fed *Halogeton glomeratus*. J. An. Sci. 26:1438–1444.

JAMES, LYNN F., JOSEPH C. STREET, JOHN E. BUTCHER AND WAYNE BINNS. 1968. Oxalate metabolism in sheep. I. The effect of low level *Halogeton glomeratus* intake on nutrient balance. J. An. Sci. 27:718–723.

JAMES, LYNN F. 1968. Serum electrolyte, acid-base balance, and enzyme changes in acute *Halogeton glomeratus* poisoning in sheep. Canadian J. of Comparative Med. 32:539–543.

SODEMAN, WILLIAM A. 1961. Pathologic Physiology—mechanisms of disease. 3rd Ed. W. B. Saunders, Philadelphia, Penn.

WILLIAMS, M. COBURN. 1960. Effects of sodium and potassium salts on growth and oxalate content of halogeton. Plant Physiol. 25:500–505.

WILSON, A. D., AND N. L. HINDLEY. 1968. Effect of restricted access to water on the intake of salty foods by Merino and Border Leicester Sheep. Aust. J. Agr. Res. 19:597–604.

WINCHESTER, C. F., AND M. J. MORRIS. 1956. Water intake rates of cattle. J. An. Sci. 14:722–739.