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The Use of Salt as a Regulator of Supplemental Feed Intake and Its Effect on the Health of Range Livestock

University of Arizona, Tucson
Agricultural Experiment Station

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Cover picture—Cows taking their turn cafeteria style for a salt-feed mixture on the Coyote Springs Ranch, in Lonesome Valley near Prescott.

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INTRODUCTION AND REVIEW OF THE LITERATURE

Salt is being mixed with cottonseed meal and other feed concentrates by Arizona ranchers and self-fed to range cattle. It is used in this ingenious manner for the sole purpose of limiting the consumption of the feed with which it is fed to a desired level. In much of the range area it has been impractical to provide feed regularly each day to needy stock. The salt feed mixture is made readily accessible to stock when the range forage declines below adequate levels. This practice does subject the animals to an abnormally large intake of salt. The purpose of the experiments herein reported was to determine the influence of this salt on animal health.

Salt is one of the essential minerals needed by all animals and is usually lacking in the diet of range stock. Morrison (14) and Meyer et al. (13) have shown that most of the grasses contain less than 1 per cent salt. Consequently, most salt research has been concerned with salt deficiencies in the diet.

Babcock, in 1905, (2) noted that cows on a salt free diet exhibited an abnormal appetite for salt after two or three weeks but that a year could elapse before any ill effects would be noticed. He also found that salt deficiency symptoms were most likely to occur at calving time or shortly afterward and among high-producing animals.

Most research with diet salt has been done with farm animals since this early work and optimum amounts have been determined covering all types of climate, production and work. Differences in weather, feeding habits, types of feed, and forms of feeding have caused these optimum amounts to vary greatly.

Heller (10) in 1932 published information on the toxicity of salt in drinking water for livestock. He tested the salt tolerance of farm animals under varying conditions of growth, reproduction, and maintenance when compelled to use water of high saline content. Milk cows receiving water containing 1.5 to 2.0 per cent sodium chloride were not adversely affected during a twenty-one month test period. A slight increase in the blood chlorine was recorded. The control cows ran 300 mg. per cent blood chlorine; those on 1.5 per cent salt water, 315 mg. per cent; and the cows drinking water with a salt level

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of 2 per cent tested 345 mg. per cent. Heller found that sheep functioned normally on water containing 2.5 per cent calcium chloride.

Adolph (1) reported that rats would live only a short time on sea water. It did prolong their life a few days longer than those on a water-free diet. Apparently some of the sea water was used. The sea water contained 3.04 per cent salt and the urine tested 3.51 per cent salt. He found rats could not live on a salt liquid of three-fourths sea water strength, but did survive on it when diluted one-half or 1.59 per cent salt.

In a series of experiments with rats Gamble (78) studied the water requirement for removal in urine of a number of salts and urea. He established the water requirements for individual salts and urea and then fed them in mixtures. It was found that the water requirements for the individual salts were additive when fed in mixtures except when urea was added. In the presence of urea, water expenditure was much less than the sum of the requirements for urea and the accompanying salts as separately determined.

Ellis (5) in tests at the Beltsville Research Center fed pigs up to ½ pound of salt per head daily without toxic symptoms being noted. Bolin (3), working with young pigs and lambs, found that up to 1.5 grams of sodium chloride per pound of body weight did not kill but that 2.0 grams per pound was fatal.

Krakawer and Heino (11) have reported that birds and chicks on a salt level diet below 1.35 grams per pound body weight did not reveal any morphological changes in body condition and required no more than normal water intake.

The use of salt in its new role as a self-regulator of feed intake for range livestock was first reported by Texas sheepmen some time during the early 1930's. Depleted, weed infested ranges led to this seemingly unorthodox practice as a means of providing necessary additional feed to the undernourished range-fed sheep.

A cattle rancher near Prescott (6) heeding the assurance of his cowboy, who reported salt-meal mixtures had been fed by a few Texas cattlemen, decided to give the method a trial. With some misgiving he prepared a 50-50 mixture of salt and cottonseed meal and to his surprise the cattle ate rather sparingly, but sufficiently to show marked improvement. The amount of salt was subsequently reduced to 25 per cent to effect an increase in the daily consumption of meal. Used in this way salt can control the desired daily intake, be provided in constant supply and at a minimum of labor.

Research studies were initiated by a few stations in the Southwest (12, 16, 17, 21) to secure reliable information concerning the use and subsequent effects of salt-feed mixtures for range cattle.

This method of feeding range livestock has been adopted in Australia and New Zealand. In the 1946 *Grazier's Annual of Australia* the following was published:

"The use of salt fodders for drought feeding is fairly recent in application. They have been widely used in Northwestern New South Wales, and as far as can be judged have been successful. Those who favor the use of salt fodders claim they make mustering unnecessary and thus greatly reduce labor. The large amount of salt ingested apparently has no ill effects on the sheep, but from the scientific aspect the method has little to recommend it.

"The following is an example of a salt fodder: linseed meal —40 per cent, crushed grain—40 per cent, and salt—20 per cent."

PRELIMINARY TOLERANCE STUDIES

Little was known concerning the amount of salt a cow would consume (free choice when mixed with supplemental feed) or the amount which would produce toxic symptoms previous to this study. A number of preliminary experiments were made to secure general information on this problem.

In one test a 1,100 pound cow was fed 12 pounds of good quality ground alfalfa hay daily. A weighed amount of salt was added to this ration each day.

The cow consumed 1.8 pounds of salt mixed with the hay. Above this level intake was reduced.

This high salt ration was fed for approximately three months without noticeable effect on the cow.

Salt was given as a drench in another test. A 1,000 pound cow was administered 2 pounds of salt without apparent harmful effects.

Another animal was given 2 pounds of salt per day, 1 pound morning and night as a drench, for three weeks. The only noticeable effect was a loose bowel condition which developed during the first few days; otherwise, the animal appeared normal throughout the feeding period.

The amount of the salt-cottonseed meal mixtures consumed by range cattle was noted. Arizona ranchers had reported range cattle consuming as much as 3 pounds per day of 30:70 salt-cottonseed mixture.

In a co-operative test conducted by this station with the Rain Valley Ranch, Elgin, Arizona, forty-two heifer calves averaging 385 pounds per head were fed a 30:70 salt-cottonseed meal mixture as a range supplement. The experiment was started March 11, 1947, and terminated on July 20, a period of 101 days. The calves consumed 0.71 pound of the mixture during this period and gained 1.26 pounds per head daily.

Consumption records have been kept during the past two years of various salt-feed mixtures by range cows of the Papago Tribal Herd near Sells, Arizona. A summary of the data ob-

TABLE 1.—THE AVERAGE DAILY CONSUMPTION OF SEVERAL RANGE HIGH-SALT SUPPLEMENTAL FEED BY ANIMALS OF THE PAPAGO TRIBAL HERD.

Herd No.	Supplement No.	Average daily consumption animal (lb.) (Jan. 1 - April 30)	(May 1 - 31)	(June 1 - 30)
1	1	0.50	1.27	1.70
2	2	0.83	1.05	1.70
3	2	1.18	2.30	2.00
4	3	0.61	1.16	1.06
5	4	0.87	1.29	1.50
6	5	0.52	0.44	0.90

Note: Supplement No.
1. 30 per cent salt, 70 per cent cottonseed meal.
2. Commercial supplement containing 25 per cent salt mixed with cottonseed meal, alfalfa meal, molasses, bone meal, calcium carbonate, and trace mineral salt.
3. Same as No. 2 except 33.3 per cent salt.
4. Same as No. 3 except cubed.
5. Same as No. 3 except some urea added.

tained during the first half of 1950 was made available to this station by Mr. Albert Lent of the Arizona Flour Mills, Tucson, Arizona, and is reported in Table 1. The cattle to which these supplements were fed were maintained for the entire period on a typical desert-type range of low carrying capacity. Each supplement listed was fed exclusively to one group of cows.

Results of the foregoing studies, together with many favorable reports by stockmen of this practice, were convincing evidence that cattle were tolerant of abnormally large amounts of salt taken voluntarily in feed mixture and without apparent harmful effect.

PHYSIOLOGICAL STUDIES

ABSORPTION OF SALT

The use of a high concentration of salt in range supplemental feeds is to limit the consumption of the mixture. This is the only major function of the salt when used in this manner. As this large amount of salt must be eliminated after being eaten, its rate of absorption and excretion is important.

The purpose of the experiments reported here was to determine the site and rate of absorption of salt in the four-stomached animal. It has been recognized for many years that absorption of food, minerals, and water in man and animals takes place from the small and large intestines. It has also been shown that there is very little or no absorption from the simple stomach. Digestion and absorption in the ruminant is more complicated than in the simple-stomached animals. In the rumen, soluble sugars and other carbohydrates are rapidly converted to short-chained, fatty acids by the microbial population. English workers (4, 9, 15) have recently shown that these fatty acids are readily absorbed through the walls of the

rumen. This is the first indication that there is absorption of food in these structures. To determine whether salt was also absorbed through the rumen, was the design of the following experiment.

A 60-pound Angora goat in good physical condition was anesthetized and opened up sufficiently to expose the rumen and upper part of the small intestine. The esophagus was ligated just above the cardiac valve and the duodenum was tied off close to the pyloric opening of the stomach. After all matter in the rumen was removed, 40 grams of sodium chloride in 3 liters of distilled water were introduced. The rumen was closed and the incision sutured together. The animal was allowed up and seemed to be showing no ill effects from either the operation or the salt solution. Ten hours later the animal was killed, and the contents of the stomach were carefully measured and tests for salt were made on the blood, urine, and the rumen fluid.

Results of this experiment showed that 55 per cent of the salt added to the rumen was absorbed through the walls of the rumen into the blood stream. This indicates that an appreciable amount of the salt may be absorbed before it reaches the small intestine.

In order to determine the rate of absorption and the time for complete elimination of a large amount of salt, experiments were conducted as follows: (1) food and water were eliminated from the animal's diet for twenty-four hours; (2) a measured amount of salt and water was then injected directly into the rumen; (3) salt determinations were made at regular intervals on the blood, urine, and rumen fluids of the animals used.

The results of many experiments made as described above clearly show that all the salt which is eaten is absorbed and that the rate is quite rapid, 2 pounds of salt being absorbed in a mature cow in approximately twelve hours. This rapid absorption causes an increase in the concentration of salt in the blood. The blood in turn passes the salt on to the kidney where it is collected in the urine and eliminated.

SALT TOLERANCE AND WATER INTAKE

Reports in the literature and from stockmen adequately show that under certain conditions the consumption of large amounts of salt may be fatal to livestock. Reported deaths are invariably shown to occur under conditions where there is a high concentration of salt in the drinking water or there is actually a shortage of drinking water.

It was stated in the preceding section that ingested salt is almost completely absorbed. This causes an increase in the blood salt which must then be eliminated via the urine. Water is needed to form urine. Presumably then, if water is lacking, urine cannot be produced, the amount of salt builds up in the

TABLE 2.—THE PHYSICAL CONDITION, TREATMENT, AND MILLIGRAM PER CENT SALT IN THE BLOOD AND URINE OF A 950-POUND COW INGESTING 2 POUNDS OF SALT ON A RESTRICED WATER INTAKE

Time (hrs.)	Treatment	Condition	Mgm. Per Cent NaCL	
			Blood	Urine
0	2 lb. salt in 3 gal water		451	925
2		Normal	520	1454
5		Normal	554	1819
8		Gait unsteady, trembling in hind quarters	642	2025
12	Rumen washed free of salt.	Difficulty in standing, very nervous, trembling excessively	637	1928
24		Normal except for muscular stiffness	546	1606

blood until it becomes toxic and possibly fatal. The following experiments were designed to test the influence of water intake upon salt tolerance.

To insure uniform rumen conditions, all animals used in these experiments were kept from food and water twenty-four hours before the test began. A known amount of water in the salt was administered, and the changes in chloride concentration in the blood and urine before, during, and after treatment were determined.

In Tables 2 and 3 are recorded the results of experiments made to determine the effect of drenching a 950-pound cow with 2 pounds of salt. In the first test (Table 2) the amount of water given to the animal was restricted; while in the second part, (Table 3) the animal was allowed an unlimited supply. The same animal was used for both experiments, though one month was allowed to elapse between the experiments to assure the animal's being in normal physical condition.

The animal showed every symptom of salt poisoning when the water was limited, and undoubtedly would have died had not the salt been washed from the rumen. No similar symptoms were observed where the animal was given an ample supply of water.

The maximum concentration of sodium chloride in the blood was reached after approximately eight hours in each test, and

TABLE 3.—THE PHYSICAL CONDITION, TREATMENT, AND MILLIGRAM PER CENT SALT IN THE BLOOD AND URINE OF A 950-POUND COW INGESTING 2 POUNDS OF SALT ON AN ADEQUATE WATER SUPPLY

Time (hrs.)	Treatment	Condition	Mgm. Per Cent NaCL	
			Blood	Urine
0	2 lb. salt in 9 gal. water	Normal	371	1226
3	2 gal. water	Normal	568	1350
6	1 gal. water	Normal	572	1758
9		Normal	595	1960
12		Normal	586	1789
24		Normal	508	2291

remained at this high level for several hours. The apparent reason for this is that the rate of excretion equaled the rate of absorption.

The third experiment consisted in subjecting various animals to a large dose of salt with and without free access to water. The results of these tests are reported in Table 4.

Salt toxicity must always be considered in conjunction with water intake. A dose of salt which is fatal when water is restricted can be readily tolerated with an adequate supply. Compare test animals 1 and 2, and test animals 4, 5, 6, 7, and 8. These results stress the importance of an adequate supply of water to animals on a high salt diet.

Schmidt-Nielsen *et. al.* (18, 19, 20) showed that some desert mammals are able to concentrate their urine when without water and eliminate a urine as high as 5.26 per cent salts. According to the results obtained here, the ruminant kidney apparently cannot eliminate salt in the urine at a higher concentration than 2.3 per cent. The kidneys maintain the proper osmotic pressure by eliminating water or by eliminating the excess salts. If sufficient water is not available for the kidney to eliminate the salt the animal will draw water from its tissues. On a restricted water intake, the amount of water the animal can draw from the tissues to eliminate the salt is not sufficient to balance the rate of absorption of salt into the blood stream. As a high concentration of salt builds up in the blood and tissues under these conditions, fatal results may be expected. The elimination of the salt must be equal to the rate of absorption. As the salt concentration of the blood in animals that died from salt poisoning rose 35 to 60 per cent above normal, an inadequate amount of water was available to eliminate the salt. If the urine contains 2.3 per cent salt, approximately 5 gallons will be required to eliminate 1 pound.

Considering our experience with the animals which died in these experiments, the symptoms of salt poisoning in the ruminants followed a fairly constant pattern. The first noticeable signs were those of anxiety and hypersensitivity to touch; as the effects of poisoning continue, there was a loss of coordination beginning with the hind quarters and progressing slowly forward on the animal. Eventually the animal lost all sense of equilibrium and would fall if standing. No blindness was observed as reported by Bolin (3). Rumen contractions increased in rate and intensity. Gas formed in the rumen. The animal tried to eliminate it without success.

Vomiting sometimes occurred just before death, but due to a progressive weakness, the animals generally died without struggling. The autopsies performed revealed similar findings: the rumen and intestines were distended and full of gas, the oesophagus was dilated, the gall bladder was distended and full of a brown granular fluid, the musoca of the stomach was only slightly congested, the duodenum was edematous but not

TABLE 4.--SUMMARY OF CHANGES IN SALT CONCENTRATION AND SALT TOLERANCE

Animal	Weight	Treatment	Mgm. % NaCl, Blood Start	Mgm. % NaCl, Blood Max.	Max. % NaCl, Urine	Mgm. % NaCl in Rumen at time of death	Final disposition
Cow	950 lb.	2 lb. NaCl 3 gal. water	451	642	2.02	.....	Animal recovered after salt wash from rumen
Cow	950 lb.	2 lb. NaCl 12 gal water	371	595	2.29	.....	Animal normal
Yearling	350 lb.	1 lb. NaCl	497	671	0.02	1.147	Died 36 hrs. after NaCl adm.
Calf		1200 ml. water					
Goat	70 lb.	100 gm. NaCl 1200 ml. water	540	768	1.70	1.3	Died 17 hrs. after NaCl adm.
Goat	70 lb.	70 gm. NaCl 1200 ml. water	.....	.....	.....	.....	Animal normal
Goat	70 lb.	100 gm. NaCl 1200 ml. water	.....	.....	....	.....	Animal normal
		Free access to water					
Goat	70 lb.	150 gm. NaCl 1200 ml. water	.....	.....	.....	.....	Animal normal
		Free access to water					
Goat	70 lb.	150 gm. NaCl 1200 ml. water	513	877	2.24	.988	Animal died 8 hrs. after NaCl adm.

inflamed, and the kidney, other than appearing slightly ecomotic, appeared normal.

HIGH SALT DIET AND PREGNANCY

Stockmen and scientific personnel alike were skeptical concerning the subsequent effects upon animal health, of ingesting relatively large amounts of salt over an extended period of time. It was speculated that abortion would result or that calves would be born in poor condition.

The following test was planned to investigate this problem:

Five mature Hereford cows were placed in individual pens November 3, 1949, to May 12, 1950, and each fed the same ration to which 1 pound of salt was added daily. After two to three months of the salt feeding, four of the cows gave birth to normal calves; one cow was not pregnant.

The salt content of the blood, milk, urine, and feces was determined at periodic intervals during the experiment. Blood samples were also taken from the calves and analyzed for salt.

The result of these works was to show that even though these animals consumed a pound of salt each day for seven months there was no abnormal build up of salt in the body fluids and tissues.

The salt content of the milk from these cows was the same as that from animals on a normal diet. In no way were the calves of these cows affected by the high salt diet.

Salt determination made on the urine showed that the salt eaten was readily eliminated this way.

The five cows were rebred by the time the experiment was terminated on May 12, 1950, and all were returned to the farm herd in healthy condition.

The cows all maintained a normal appetite throughout the experiment and showed no aversion to the abnormally high quantity of salt in their feed.

The results of this experiment are reliable evidence that a high salt diet during pregnancy has no harmful effect upon the cows or their calves. The large amount of salt ingested daily did not alter the over-all level of sodium chloride found in the blood, milk, or feces. Throughout the period of salt feeding the animals exhibited a normal appearance, and the high salt content of the ration did not noticeably inhibit their appetite.

SELF-FEEDING RANGE SUPPLEMENTS

The advent of self-feeding salt-feed concentrate mixtures to grazing cattle marks an eventful development in livestock production — particularly in the western range country. Grass and other native vegetation in this area is the sole feed resource of a very material segment of our beef cattle and sheep population. Despite its invaluable use for this purpose, reliance

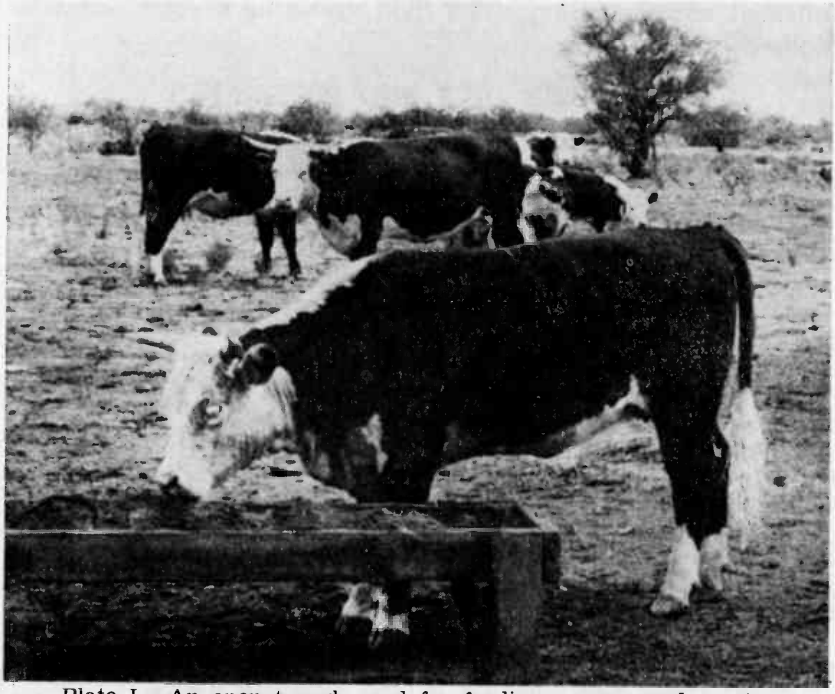

Plate I.—An open trough used for feeding range supplements.

upon herbage vegetation constitutes a major problem of the cattle ranching industry. The greatest difficulty to cope with in this regard is the unpredictable nature and irregularity of the feed supply. A constantly changing nutrient content adds to the complexity of this prevailing condition.

Adoption of the self-feeding method to range and pasture practices has served to provide a supplemental feed in the necessary amount and quality to adequately satisfy the normal animal requirements.

Most salt-feed mixtures used on southwestern ranges contain approximately 30 per cent salt. By reducing or elevating the salt content the daily consumption of the mixture can be varied. The salt content of the range forage and drinking water have an important influence. On ranges where there is appreciable salt in these materials experience has shown that the amount in the supplement must be reduced to get the desired consumption.

Cottonseed meal or cake has served an important role as a range supplement feed. It was the logical choice to use with salt. In addition to needed protein it provides both phosphorus and readily available energy-producing nutrients.

Factors other than protein and phosphorus may be lacking under poor range conditions. Some of these may be vitamin A, trace minerals, and the necessary nutrients for proper rumen

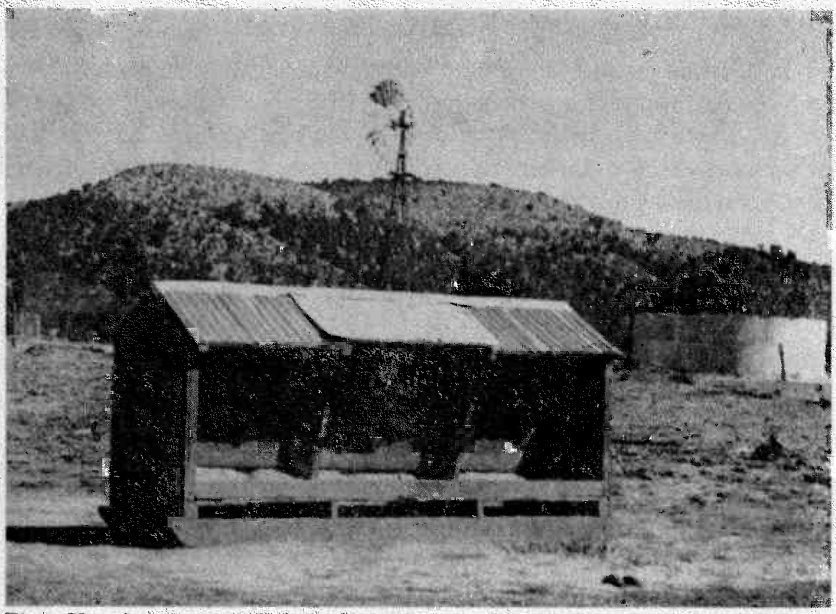

Plate II.—A covered type of self-feeder used for feeding range supplement.

fermentation. These deficiencies can be supplied by incorporating alfalfa meal, trace minerals, and grain or molasses in the salt-cottonseed meal mixture. Supplemental feed used should contain all the essential factors which are not supplied by the range forage available to the animals.

Covered self-feeder containers with trough attachment, portable, and of 100-1500-pound capacity are in rather common use. Plans for the self-feeder shown in the accompanying photograph can be obtained from your County Agricultural Agent or the Agricultural Extension Service, College of Agriculture, University of Arizona. Open troughs are less expensive though subject feed to spoilage and loss from blowing.

A committee on animal nutrition of the National Research Council makes this significant statement: "Data demonstrate that if a greater proportion of the concentrate feeds now available for beef cattle in the United States were used in the earlier stages of production to alleviate qualitative and quantitative deficiencies of range pasure, and wintering rations, these feeds would be utilized more effectively, continuous growth and development would be promoted, and a significantly greater tonnage of better-quality beef would result."

Arizona cattlemen by demonstrating the effective use of salt for making nutritionally balanced feeds readily available to range stock, have made it possible to promote the continuous growth of young stock and achieve a more efficient use of range feed.

SUMMARY

1. Cows, during pregnancy and subsequent lactation, are capable of ingesting excessive quantities of salt without apparent harmful effects. The salt is readily eliminated via the urine and, except for an immediate increase at the time of ingestion which soon returns to normal, does not alter the normal salt concentration of the blood.

2. Salt is readily absorbed through the rumen wall.

3. With adequate water intake, salt is rapidly and almost quantitatively absorbed into the blood stream. This rapid absorption causes an immediate increase in the salt concentration of the blood, followed very soon by an increased excretion in the urine. The blood concentration remains high until the salt has all been absorbed. The excretion rate remains high until after absorption is complete and the blood level has dropped to normal.

4. Stock water in plentiful supply must be made available to animals consuming more than average amounts of salt. Since absorption of the salt is almost quantitative, water must be used by the animal to produce urine for its elimination. The maximum concentration of salt in the urine is **2.3 per cent.** Consequently, for each pound of salt absorbed, the animal must produce about 5 gallons of urine for its elimination.

5. The use of salt in high concentration in supplemental feeds has made it possible to self-feed these supplements to range and pasture livestock.

BIBLIOGRAPHY

1. Adolph, E. F. Rats drinking sea water. Amer. Jour. Physiol. 140:25 (1943).
2. Babcock, S. M. The addition of salt to the ration of dairy cows. Wisc. Agric. Expt. Sta. Annual Report No. 22, p. 129 (1905).
3. Bolin, F. M. Salt poisoning in sheep and swine. S. D. Bimonthly Bul. 11:127 (1950).
4. Danneilli, J. F., M. W. S. Hitchcock, R. A. Marshall, and A. T. Phillipson. The mechanism of absorption from the rumen as exemplified by the behavior of acetic, propionic, and butyric acid. Jour. Expt. Biol. 22:75 (1945).
5. Ellis, R. N. Salt Tolerance and salt poisoning of swine. U.S.D.A. Yearbook for 1942. U. S. Govt. Printing Office, Washington, D. C. (1943).
6. Fain, D. Cottonseed-meal salt mixtures. Arizona Cattlelog (October, 1949).
7. Gamble, J. L., M. C. Putnam, and C. F. McKhann. The optimal water requirements in renal function. Amer. Jour. Physiol. 88:571 (1929).
8. Gamble, J. L., C. F. McKhann, A. M. Butler, and C. Tuthill. An economy of water in renal function referable to urea. Amer. Jour. Physiol. 109:127 (1934).
9. Gray, G. V. The absorption of volatile fatty acids from the rumen. Jour. Expt. Biol. 25:135 (1948).
10. Heller, V. G. The effect of saline and alkaline waters on domestic animals. Okla. Agric. Mech. Expt. Sta. Bul. 217 (1933).
11. Krakower, C. A. and H. E. Heino. Relationship of growth and nutrition to cardio-renal changes induced in birds by a high salt intake. Nut. Abst. Rev. 19:399 (1949).
12. McIlvain, E. H., D. A. Savage, and L. E. Johnson. Grazing, feeding, and other range improvements studies on the Southern Plains experimental range. Sixteenth semi-annual progress report, U.S. D.A. Bureau of Plant and Animal Industry and the Okla. Agric. Expt. Sta. (1945).
13. Meyer, J. H., R. R. Grunert, R. H. Grummer, P. H. Phillips, and G. Bohstedt. Sodium, potassium, and chlorine content of feeding stuff. Jour. Anim. Sci. 9:150 (1950).
14. Morrison, F. B. Feeds and Feeding. The Morrison Pub. Co., Ithaca, N. Y. (1947).
15. Phillipson, A. T. Fermentation in the alimentary tract and the metabolism of the derived fatty acids. Nut. Abs. Rev. 17:12 (1947).
16. Savage, D. A. Self-feeding of salt-meal mixtures to range cattle. Progressive Report of Forage Div., B.P.I., U.S.D.A. and the B.A.I., and the Okla. Agric. Expt. Sta. (Feb. 15, 1950).
17. Savage, D. A. and E. H. McIlvain. Self-feeding of salt-meal mixtures to range cattle. Progress Report of Forage Div., B.P.I., U.S.D.A. and the B.A.I. and the Okla. Agric. Expt. Sta. (Feb. 5, 1951).
18. Schmidt-Nielsen, B., K. Schnidt-Nielsen, A. Brokaw, and H. Schneiderman. Salt excretion in desert mammals. Amer. Jour. Physiol. 154:163 (1948).
19. Schmidt-Nielsen, B., K. Schmidt-Nielsen, A. Brokaw, and H. Schneiderman. Water conservation in desert rodents. Jour. Cell. Comp Physiol. 32:331 (1948).
20. Schmidt-Nielsen, K., B. Schmidt-Nielsen, and A. Brokaw. Urea excretion in desert rodents exposed to high protein diets. Jour. Cell. Comp. Physiol. 32:361 (1948).
21. Stanley, E. B. Ranchers use salt-feed mix. Prog. Agric. Ariz. 1:3 (1949).