A STUDY OF THE RELATIONSHIP OF SALT INTAKE TO PERFORMANCE, DIGESTIBILITY OF FEEDS, AND TO THE NUTRITIONAL BALANCE OF SODIUM AND CHLORINE FOR BEEF STEERS

by

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INTRODUCTION

Sodium chloride, or common salt, is widely distributed in nature and is a normal constituent of nearly all animal organs and fluids; it undoubtedly plays an important role in the processes of nutrition.

It is a common practice to allow free access of salt to cattle in addition to their ration. Feeds and water contain some salt, but the amount varies widely in different localities and is rarely sufficient to satisfy the desires or needs of animals. Babcock (1) on the basis of his observations made the assumption that dry cows or full grown steers probably could get along without having salt added to their rations, and it is the common belief that salt does not influence the digestibility of a feed (Morrison, 31).

This study was undertaken for the purpose of determining the influence of salt, when included in rations of beef steers, on digestibility of the components in the ration and upon sodium, chlorine and nitrogen balance.

REVIEW OF LITERATURE

Role of Sodium Chlorine and Potassium in Body Tissues and Fluids

Sodium chloride has several functions in the animal body. It is the only salt that is commonly added to the diet and is needed for both its positive and negative ions (Kleiner, 19).

In the body, sodium ions predominate in the blood and other body fluids, while potassium occurs to a greater extent within the cells, both of the blood and tissues in general. Sodium chloride not only provides for the necessary osmotic pressure, but it is also indispensable for the origin of the heartbeat (Zoethout and Tuttle, 48). Antagonisms of several other ions, including potassium, come into play in this function.

Sodium chloride also helps to maintain osmotic pressure relationships in the body cells and fluids, aids in dissolving certain proteins (for example, globulins and fibrinogin) and is influential in the regulation of water metabolism (13). Sodium, potassium, and chlorine are essential constituents of milk and eggs, and of all body cells. Sodium occurs in largest quantities of any base mineral in the body cells, fluids and alkaline digestive juices (bile and pancreatic juice), while chlorine is essential to the formation of hydrochloric acid in gastric juice. Sodium bicarbonate plays a leading part in the maintenance of the hydrogen ion concentration of the blood.

The need for sodium salts for the body economy is seen in the elaborate regulating mechanism set up for its conservation. When sodium is eliminated from the diet the body reaction is to conserve its sodium resources. Its elimination is diminished and may cease almost entirely (Zoethout and Tuttle, 48).

Even though a striking chemical resemblance between sodium and potassium exists, within the body these two elements cannot replace each other to any great extent. Sodium and potassium metabolism is regulated by hormones from the adrenal cortex.

Early Sodium Chloride Studies

In considering the voluminous literature on sodium and chlorine metabolism, it soon became apparent that it was not practical to review all the papers published on the subject.

McCollum, Orent-Keiles and Day (23) in their book NEWER KNOWLEDGE OF NUTRITION, reviewed most of the important works up to that time. The importance of salt in the animal body has been a field of study for many years. However, few definite experiments dealing with the function of sodium or chlorine alone have been made.

St. John (43) and Richards, Godden and Husband (37) each reviewed pertinent literature in reference to their work and listed bibliographies.

According to Henry and Morrison (15) the first systematic tests to determine requirements of salt for farm animals were carried out in France about 1850. These tests showed that the addition of salt to rations for sheep was accompanied by an increased rate of growth and improvement in general health.

In 1873, Forster (6) fed dogs salt-free meat (extracted with water), starch and lard. These dogs died more quickly than others which were starved completely. He attributed this occurrence to the diuretic properties of urea, with the assumption that the urea, resulting from digestion and metabolism of the salt-free protein, caused increased volume of urine and in so doing caused greater elimination of sodium.

On the basis of a few short experiments upon himself, Bunge (2) formulated the theory that sodium chloride craving was due to the presence of excessive amounts of potassium salts in the diet of vegetable feeders. Increased intake of potassium salts was observed to cause the excretion of excessive amounts of sodium chloride.

Richards, Godden and Husband (38) found that an excessive potassium content of the diet has little effect on the excretion of sodium or chloride for growing pigs. In this same connection, Theiler, Green and DuToit (44) have shown that a relatively high ratio of K to Na in cattle is not the cause of a specific deficiency.

Lengthy feeding experiments on heifers carried out by Hart et al. (12) offer little support of Bunge's theory. They found, in the case of different groups of heifers, fed on rations of different cereals but all having free access to salt, that the amount of sodium chloride consumed bore no relationship to the potassium content of the ration. The most notable result was the smaller consumption of salt by the four oat-fed animals, which used but 29.5 pounds the first year, while a mixture-fed lot (1/3 oats, 1/3 corn, 1/3 wheat) of the same number consumed a total of 377 pounds in the same period; the wheat and corn fed lots consumed 143.5 and 150.5 pounds, respectively.

The most noted early salt studies on farm animals were those of Babcock (1). He deprived dairy cows of salt (NaCl) for long periods of time and found cows that do not have access to salt exhibit an abnormal appetite for it in two or three week's time; however the health of the animals was not affected generally until a much longer time had elapsed. This period of immunity varied with individual cows from less than one month to more than a year.

In every case, there was complete breakdown (losses of two to three pounds of weight daily) from which recovery was rapid if salt was supplied. This breakdown was marked by loss of appetite, a generally haggard appearance, lusterless eyes, a rough-hair coat, and rapid decline in both live weight and yield of milk. The breakdown was most likely to occur at calving or immediately after when the system was weakened and the flow of milk large. In general, the cows giving the largest amount of milk were the first to show signs of distress.

In one case Babcock (1) tried substituting potassium chloride for sodium chloride to a cow that had reached a condition of collapse through lack of salt, the cow consumed a considerable amount, although ordinarily cows refuse it. Recovery followed as quickly as when sodium chloride was given. Babcock drew the conclusion that chlorine was the element supplied by salt that was essential to the health of the animal. Babcock was probably the first to recognize the necessity of long experiments and attributed the success of his experiment to the exceptionally long periods during which salt was withheld.

Effect of Salt Deficient Diets on Growth and Reproduction

Osborne and Mendel (35), using a purified diet, concluded that rats could be raised successfully on a diet containing less than 0.04 percent of sodium or potassium although when both were fed at this low level, growth ceased. The potassium to sodium ratio in the control diet was 4.5:1 and 23.8:1 in the sodium-free diet. However, the particular element being studied was not the only variable in the ration since when one element was eliminated from the diet, it was replaced by an equivalent amount of others in order to adjust the acid-base balance. Since that time, it has been found unnecessary to balance the acid and basic minerals if the other elements in the ration are fed in satisfactory levels (Lamb and Evvard, 21).

Miller (26) obtained satisfactory growth on a synthetic ration including 0.07 percent sodium. This ration had a potassium to sodium ratio of 14:1 and had no deleterious effects on growth of young rats. Miller (25) also investigated the influence of high potassium intakes on urinary sodium and chlorine excretion of pigs. He analyzed only the urine as many of the earlier investigators had done, and found the excessive excretion of sodium and chlorine, indicated by Bunge (2), was only temporary, little excretion was observed after 24 hours. With continued feeding of potassium, the amount of sodium and chlorine excreted decreased to even less than the amount ingested.

Richards, Godden, and Husband (37) found the opposite effect when an excess of sodium salt replaced potassium in the ration of growing pigs. After 14 day's feeding of sodium citrate, the amount of potassium in the urine remained higher than in the pre-period, and withdrawal of the sodium salt was followed by an immediate drop in the urinary potassium excretion. More important was the finding that the excessive urinary excretion of potassium was more or less completely counterbalanced by diminished fecal excretion, with the result that the balance showed very little deviation from the normal.

Later Olson and St. John (32) found by varying the amounts of sodium in a wheat ration for young rats that the most satisfactory results were obtained with rations containing 0.53 percent of sodium. A ration containing no added sodium to the amount present in wheat did not give normal growth or successful reproduction. The addition of sodium as sodium bicarbonate alleviated the deficiency, however, large amounts of sodium caused detrimental effects. It was thought that a proper adjustment of the amount of sodium in the ration caused an economy in the use of feed.

Miller (27) was unable to promote normal growth in rats using a ration which included 80 percent of corn and contained 0.03 percent of sodium. With sufficient sodium carbonate or sulfate to make 0.42 percent sodium in the diet satisfactory growth was obtained.

Mitchell and Carman (28) secured some rat growth from a ration containing 87 percent corn, including 0.047 percent Na and 0.041 percent Cl. However, with sodium chloride added at the 1 percent level, much better growth was obtained. "The growth data of this experiment afford a striking demonstration of the fact that the utilization of food energy by growing animals may be greatly impaired by an improper balance among indispensable dietary factors" (28). The addition of 1 percent of NaCl to the sodium-low ration evidently greatly improved the utilization of its available energy, "probably by decreasing its stimulating effect on heat production; i.e., its specific dynamic effect". One point of interest in connection with the nitrogen balance trial on the rats was that the rats on both rations digested the nitrogen of their food about equally well. If chlorine was a limiting factor, Mitchell and

Carman (28) theorize, "the deficiency of chlorine seems to be related more to the requirement for growth than to the requirements for gastric secretion". Furthermore, the metabolizable energy derivable from a given weight of corn is not lowered by the sodium and chlorine deficiency of such a ration. In this test, chlorine balances were generally more favorable than the sodium balances, suggesting that the sodium deficiency of corn is more pronounced than its chlorine deficiency.

Richards, Godden, and Husband (37) fed a ration of corn, oats, barley, and blood meal to pigs and found the addition of sodium chloride or citrate led to increased assimilation and retention of nitrogen, calcium, and phosphorus.

In paired feeding experiments using one of the first sodium deficient chlorine adequate diets, Kahlenberg, Black and Forbes (18) noted no impairment of digestion for rats; however, heat loss was significantly higher in sodium-deficient than in the control rats.

Orent-Keiles, Robinson and McCollum (33) restricted rats to a diet containing only 0.002 percent of sodium but adequate in other respects. A syndrome of symptoms developed which finally resulted in death. Retarded growth, eye lesions, and disturbance of the reproductive functions were the principal manifestations. The same investigators studied the effects of chlorine deprivation. Growth was retarded similarly to that of a sodium chloride-deficient ration but no other symptoms developed during a period of 90 days. In neither case was the deficiency manifested so severely as that of sodium deficiency alone.

South African workers DuToit, Malan and Groenewald (5) found that heifers on a chlorine deficient ration actually secreted more chlorine in their milk during the first lactation period than that contained in the food. Results of blood analyses for chlorine indicated that low-chlorine in the ration is associated with low-chlorine in the blood.

Improvement in growth by the addition of sodium chloride to natural diets has been attributed to the sodium ion more than to the chloride ion (27, 28, 43). However, Voris and Thacker (46) in comparison of a chloride deficient diet with one of normal chloride content, by means of metabolism and body analysis studies with rats, found the chloride deficient rats showed a depression of appetite, increased consumption of water, increased heat production and diminished body gain of nitrogen and energy.

Thus, the nutritional effects of a deficiency of dietary chloride are similar to the effects of deficiencies of sodium or of sodium chloride. In fact, Orent-Keiles, Robinson and McCollum (33) and Kahlenberg, Black and Forbes (18) observed that the effects of chloride deficiency are not much different than those of a general mineral deficiency as described by Kriss and Smith (20).

Orent-Keiles and McCollum (34) state "the effects of sodium deficiency in the rat appear to be general in character rather than specific". During an experimental period of 19 weeks, the average total body weight gain per rat of animals on a sodium-deficient diet was 57.7 g as compared to 97.5 g for the controls. The average amount of water consumed was 1074 ml and 1720 ml respectively. The amount of food consumed per gram of body weight was 7.5 g and 4.6 g, respectively.

In the same trial nitrogen balance figures indicated that sodium-deficient rats did not have the ability to utilize protein as efficiently as the controls. The sodium-deficient rats retained only 760 mg per rat during the entire period whereas the average total retention of the controls was 2095 mg. The control animals also had larger deposits of fat. The most striking effect of the deficiency was on potassium, which showed a marked retention, 310 mg, as contrasted with 78 mg for the control animals. They explained the difference in water consumption of the sodium-deficient rats and those receiving sodium on the fact that changes in the base and water content of the organism closely parallel one another. Therefore, conditions which deplete base are attended by equivalent losses of water. If the water changes affect chiefly the extracellular fluids, the base simultaneously retained or lost is chiefly sodium. Sodium appears to be directly related to the water content of tissues.

Sinclair (39) found by increasing the amount of salt to 3 percent of the ration for pigs, water consumption was increased and that there was excessive urination. However, it did not give rise to excessive retention of moisture in muscle samples and did not exert any significant effect on dressing percentage of pigs.

Parthosarathy (36) found that addition of 0.5 percent salt to the diet of laying hens improved the utilization of dietary nitrogen. During a ten-day nitrogen balance test, sodium-supplemented hens retained 37 percent of their ingested nitrogen as compared to 22.5 percent for deficient birds.

Even though a mineral is present in a ration in sufficient amount to meet the animals' requirements, the presence of other minerals in unsuitable proportions may lead to insufficient assimilation and retention.

Burns et al. (3) observed a sparing action by sodium on potassium. About 0.08 percent sodium was found sufficient with 0.74 percent potassium to produce optimum chick growth, but if the potassium intake dropped to 0.30 percent, about 0.15 percent sodium is required to produce the same growth. Loss of weight, egg production or hatchability could be prevented by addition of 0.10 percent of sodium chloride (equivalent to 0.04 percent Na). In studies involving sodium, potassium and chlorine individually the same workers found that sodium is a more critical ion than chlorine; potassium deprivation was more severe than sodium deprivation; deprivation of both sodium and potassium, however, was less severe than that of potassium alone. Hatchability was greatly impaired on low-potassium rations but was relatively unaffected by low-sodium rations.

This work was in agreement with Wisconsin workers Grunert, Meyer and Phillips (9) who found the requirement for sodium to be 0.05 percent when 0.25 percent of potassium was present in the ration for rats and that an increased requirement for sodium results when the potassium was raised to 0.5 percent. Potassium requirements were not constant but decreased from 0.18 to 0.09 percent in the presence of 0.1 percent sodium.

High levels of sodium seemed to have a slight sparing action on the requirement for potassium but high potassium levels were antagonistic to and tended to increase the requirement for sodium, especially when the latter was limited.

Salt Requirements and Factors Influencing Salt Consumption of Farm Animals

Recent investigations on the mineral requirements of growing animals make it increasingly evident that the adjustment of the proportions of the inorganic constituents of a ration require as much consideration as the absolute amounts of these elements in the diet. While it is recognized as desirable to add salt to the rations of all farm animals, very little information is available as to the exact requirements for its component minerals. South African workers, Theiler, Green and DuToit (44), have concluded that for growing cattle, the daily requirements are only 1.5 g of sodium and 5 g of chlorine. Successful reproduction was not obtained at these low levels, however. The practice of allowing salt free-choice to farm stock undoubtedly results in an intake in excess of requirements, but since salt increases the palatability of rations, an intake in excess of the minimum physiological requirements may be desirable (Maynard, 22). However, if salt influences the palatability of feed, it should affect feed intake and possibly feed efficiency. In an experiment conducted at Cornell University, Heuser (14) found that including varying amounts of salt up to 4 percent in the chick ration did not influence feed consumption.

Experiments conducted at Kansas State College, in which steers were full fed on corn with and without salt showed that the steers receiving no salt consumed more concentrates than steers receiving salt indicating that salt did not influence palatability nor increase their appetite (41).

As early as 1901 Haney (11) reported that cattle bought and brought to Kansas State College were always salt hungry. It was reported that if these cattle were allowed to satisfy their desire, they would consume so much salt that it would greatly derange the processes of digestion. After the large intakes of salt, the cattle would drink large amounts of water, which with the salt would cause diarrhea, they would go off feed and continue to be upset for a week or more.

During the same year, Haney (11) kept salt consumption records of 130 head of yearling steers in the feed lot. These steers consumed an average of 0.022 pound of crushed salt daily. The following data are a part of Haney's table on salt consumption. These data indicate that kafir corn and either soybean or prairie hay caused an increase in salt consumption.

20 Head of Steers Per Lot Fed 102 Days

Lot		Daily salt consumption, pounds per steer
1	Shelled corn and alfalfa hay	.0176
2	Kafir corn and alfalfa hay	.0206
3	Shelled corn 2/3, Soybeans 1/3, prairie hay 1/3	.0245
4	Kafir 2/3, Soybeans 1/3, prairie hay 1/3	.0294

In Iowa experiments carried out over several years, Evvard (8) found cattle fattened in dry lot ate an average of about two-thirds pound of block salt per head per month.

Cattle on pasture consume much more salt than those fed in drylot, and they eat more in spring and early summer when the forage is abundant and succulent than later in the season. In

Kansas tests (16), yearling and two-year-old steers on pasture consumed about 2.8 pounds of block salt per head in July, 1.8 pounds in August and 1.2 pounds in September and October.

Dowe (4) kept salt consumption records on steers in wintering trials and found that silage as a roughage caused greater salt consumption than oat straw. Steers, receiving silage as the only roughage, consumed 0.14 pound of salt daily while steers, receiving oat straw as the only roughage, consumed only 0.04 pound per day, and steers receiving a combination of silage and oat straw as roughage consumed 0.08 pound of salt per day in a 140 day wintering period. The following data are taken from Dowe's thesis.

Ten steers per lot	Lot I	Lot II	Lot III
Average daily ration Pounds			
Atlas silage	27.46		13.75
Oat straw		9.18	4.81
Cottonseed meal	1.00	1.00	1.00
Salt	0.14	0.04	0.08

Further data to bear on the matter of succulence in relation to salt consumption were collected at the Kansas Experiment Station in 1921 (17). Two lots of 20 steers each were fed alfalfa hay and corn-silage. Loose evaporated salt was fed free-choice. The average consumption was practically three times as great for the corn-silage-fed steers as for the alfalfa-hay-fed steers.

Evvard et al. (8) found the reverse to be true when corn silage and alfalfa was fed to lambs. In their trials they reported that replacement of silage with alfalfa hay increased the average daily salt consumption. Inversely, substituting corn silage for alfalfa hay appeared to decrease the lamb's appetite for salt.

A comparison of salt consumption in relation to limited and full-feeding was studied at the Montana Station. Woodward, Clark and Cummings (47) found that heifers on limited-feed of roughage consumed about three times as much salt as those on full-feed of roughage. The results were repeated on calves, yearlings, and two-year-olds. This is not in agreement with the theory that increased roughage intake increases salt consumption.

Research with wintering ewes at Iowa indicates that salting the feed may be as easily overdone as underdone (8). An absence of salt in the feeds allowed ewes resulted in smaller gains, less efficient use of feeds, an impaired lamb crop and a decreased wool yield. The adverse effects of heavy salting (one ounce daily) were not observed to a considerable extent in the ewes, but were manifested in decreased vigor of the new-born lambs. They were even less vigorous than lambs from "no salt" ewes. The heaviest and most vigorous lambs were secured from a flock receiving one-half ounce of salt daily. These ewes also sheared the heaviest fleeces.

When it is fed free-choice, the nature of the ration is a large factor governing salt intake. This may be in part a response to a variation in physiological need according to the mineral and to other relations in the ration fed. Records kept on 1306 winter-fed lambs by Iowa workers show an average daily salt consumption of 0.011 pounds per lamb (8). It was estimated that lambs fed at

Iowa secured about one-half their total sodium, and three-fourths of their chlorine from the salt (self-fed). The feed supplied most of the rest. Feeding beet molasses markedly decreased salt consumption whereas alfalfa hay had the opposite effect. From their records, Evvard et al. (8) observed that fattening lambs consume much more salt per unit weight than steers fed under similar conditions, and whereas the daily salt consumption of lambs increased during the feeding period, the consumption for steers decreased. Lambs in the feed lots consume more roughage in proportion to concentrates than do steers; this ratio of roughage to concentrates is more marked as the period of feeding progresses. The greater the proportion of roughage, the greater, apparently, the salt consumption.

This is in agreement with results of Slinger, Pepper and Motzok (40). They noted the salt requirement of chickens is influenced by several factors. Using low-fiber-high-energy rations, maximum growth was obtained with 0.25 percent of added salt. As the low-fiber-high-energy ration was replaced by a high-fiber-low-energy ration, the salt requirement increased progressively to at least 2.0 percent. The same workers found that the calcium and phosphorus level in the ration modified the salt requirement for growth of chickens. Salt requirements were low with diets deficient in calcium or phosphorus. As the phosphorus content was raised, the data suggested a sparing interaction between salt and phosphorus. At high calcium levels, there appeared to be an antagonistic interaction between this element and salt. This observation is in agreement with Evvard et al. (8). In an experiment with steers, they found that the addition of a mineral mixture composed of high-calcium limestone, boneblack and potassium iodide to the ration increased the salt consumption materially (from 0.022 to 0.028 pound) per steer daily.

Sinclair (39) found the addition of salt to a ration composed of oats, barley, and wheat supplemented with 10 percent of a 55 percent tankage mixture fed to pigs led to a slightly larger consumption of feed, but that it was not accompanied by more efficient utilization of the feed. This suggests that the sodium chloride content of the basal ration must be considered in making recommendations regarding the addition of salt. They estimated the daily requirements of sodium chloride for a pig increasing in weight at the rate of one pound per day, based on chlorine retention, to be approximately 1.33 grams.

Meyer et al. (24) reported a study in which they used balance trials to establish the minimum sodium, chlorine, and potassium requirements of swine. Growth data indicated that swine fed a purified ration required 0.09 percent sodium for optimum growth. The balance study substantiated this observation. The pigs on 0.09 percent sodium retained about the same amount of sodium as the controls. In this trial, pigs retained only 85-89 percent of either sodium or chlorine when on sub-optimum levels indicating that pigs cannot retain 100 percent of the sodium chloride intake. Adding 11-15 percent to that actually retained by the pigs makes the optimum growth requirement approximately 40 milligrams of Na and 50 milligrams of Cl per kilogram of body weight, or 0.09 g Na, 0.11 g Cl per pound of body weight daily.

In relation to the problem of oversupplying salt, it has been observed by South African Workers (45) that cattle and sheep that have been deprived of salt on gaining access to it may consume a sufficient amount to cause toxic effects, i.e., 4-8 ounces in the case of sheep and 1.5-5 pounds for cattle. In acute cases, the animals show extreme thirst, depression, abdominal pain and death. In less acute cases, profuse watery diarrhea which often became hemorrhagic was evident.

An excess of salt in the ration of chickens up to 8 percent of the ration exerts no apparent detrimental effect on their condition, nor after they become accustomed to such salty rations, on their rate of growth (29).

Heller (13) found that, with salt solutions for drinking water, within 10 days no rats receiving 2.5 percent or more salt were alive. At lower levels, the amount of water consumed became greater with increasing amounts of salt until a concentration was reached which they refused to drink, refraining from drinking until thirst finally compelled them to drink a large quantity at one time causing death in a short time. From his observations, he drew the conclusion that there was some physiological readjustment which would explain how man and animals in certain sections thrive on waters that kill or injure those not accustomed to it. Little of the exact nature is known concerning the mechanism by which the excretory organs function in selecting the ratios of these elements for excretion, although it is clear that they do.

The problem of salt poisoning was also taken up at the Beltsville Research Center. In this study, Ellis et al. (7) fed pigs on a series of diets containing 0, 1, 2, 4, 8, and 12 percent of salt. The average daily gains of the pigs on the diet containing 2 percent of salt exceeded those of the other pigs. Increasing levels of salt resulted in decreased feed intake and retardation of gains. Nevertheless, the pigs on the highest level ate sufficient feed to give them an intake of approximately one-half pound of salt per day.

In another experiment, Ellis (7) fed shoats a ration containing only 0.1 percent of sodium chloride for three- and six-week periods and then gave them free-access to salt. In no case was there any unusual effects that could be attributed to salt poisoning. When the salt content of this diet was adjusted to 15 percent, the feed intake was not greatly depressed. The salt intake increased in one case to approximately 225 g per 100 pounds of live weight. Thus, this animal weighing 218 pounds, after being fed 26 days on the high-salt ration, was consistently consuming an average of 8.4 pounds of total ration and 495 g of salt a day.

All pigs used apparently were in good health at the conclusion of the salt feeding. No unusual conditions were observed either at slaughter or under microscopic examination of the tissues. Sodium chloride analysis of samples of lean tissue showed no significant difference from samples taken from hogs on ordinary diets.

Information of the voluntary consumption of salt, even though it is not a good measurement of the actual physiological requirement, is of value when used to calculate the intake of supplements of iodine, iron, copper, etc. when mixed with salt. Only by knowing the likely salt consumption and the proportion of these elements in the salt offered can their consumption be predicted.

The following statements of the daily free-choice consumption of salt were taken from National Research Council Bulletin 99 (10):

Sheep	
Winter-fed lambs	.011 pound per head daily
Fattening lambs	3.78 pounds per 100 pounds gain
Pregnant ewes	.026 pound per head daily
Swine	.03-0.12 ounce per head daily
Horses	0.11-0.125 pound per head daily
Cattle on pasture	0.040-0.093 pound per head daily depending on season; higher in hotter weather
Steers	0.028 pound per head daily or 1.03 pounds per 100 pounds gain
Cows	0.06-0.25 pound per head daily

It seems that the craving of animals for salt is due more to a deficiency of sodium and chlorine in feeds of plant origin than to any specific K:Na antagonism.

EXPERIMENTAL PROCEDURE

Management and Care of Animals and Rations Used

The animals used in this experiment were range-bred, Hereford steer calves of good grade. Their average initial weight at the beginning of the wintering period was 448 pounds. They were selected and alloted for uniformity of size, weight and condition as well as for general thriftiness, Plate 1.

The group feeding trial was carried out during the wintering period to measure growth response and economy of gain on the two rations as well as to deplete the one lot of calves of their sodium and chloride reserves.

Two groups of five steers each averaging 448 pounds per head were wintered on Atlas Sorgo silage plus one pound of soybean pellets per head daily. Lot 1 received salt free access while Lot II received no salt. The steers were given all the silage they would consume twice daily - morning and evening. One-half the daily portion of soybean pellets was sprinkled over the silage at each feeding. Water consumption records were kept during the last 30 days of the period.

During the last two weeks of the wintering period the steers were haltered and brushed each afternoon to gentle them for the digestion trial. The wintering phase ran from December 14, 1949, to April 25, 1950, a total of 132 days.

An average of three-day weights was used as the initial weight. After the trial started, the steers were weighed individually every 28 days while on feed. Three-day weights were again used at the end of the period and these weights were used as initial weights for the digestion trial which began immediately.

The two lots were put into the nutrition barn in individual stanchions April 25, 1950. Due to lack of facilities for urine collection only six steers could be used on the mineral and nitrogen balance study. Three representative steers were picked at random from each lot for this study. The results of the other two steers from each lot were figured in the digestion trial only.

The steers were fed similarly according to appetite for a five-day adjustment period. On the fifth day one of the advisors noticed some steers chewing at the wooden fence to which they were tied to be brushed during the daily exercise period. It was thought that this added fiber might upset the digestion determinations for fiber so the adjustment period was lengthened to 10 days and henceforth the steers were led by attendants on a concrete floor and not allowed near the fences. Every effort was made to make the steers comfortable as possible during the digestion trial.

The ration was composed of Atlas Sorgo silage fed ad libitum and soybean meal fed at levels adjusted to the silage consumption for each steer so that each steer was fed a ration of the same nutritive ratio (ratio of digestible protein to total digestible nutrients). Salt was fed to Lot 1 at the rate of 20 g daily and was fed with the evening feed. Each steer was watered in an individual trough that was before him at all times except during the feeding periods. Fresh water was weighed out to each steer daily and the remaining water was weighed back.

During the 10 day adjustment period the exact feed consumption for each steer was determined as nearly as possible. As soon as the intake for each steer was established, it was never altered and the same quantity was fed throughout the remainder of the trial.

This procedure allowed the steers a few days to become accustomed to the feeding schedule, the general noise and activity associated with feeding, exercising, sweeping and handling necessary to carry on the trial. The steers were also harnessed to hold the urinal funnels for the mineral and nitrogen balance study during this period.

The adjustment period was followed by a 10 day preliminary period during which time the steers received the same quantity of each ingredient that they were to receive during the 10 day collection period. There were no weigh-backs of feed. It was intended during this period to fill the animals' digestive tracts with the same amount and kind of feeds that they would receive during the collection period which was to follow.

Methods of Sample Collection, Storage and Analysis

The feces were caught on shovels and put into large cans that were sprayed with formaldehyde to keep down bacterial action. An attendant was present at all times to make the collections. The floor was kept clean to prevent contamination of the samples if the feces were not caught as voided. Aliquots of 1/30 of the weight of the feces from each steer were taken daily, placed in a pan marked with the steer's number and dried in a forced draft oven at a temperature of 70° C. Each day's aliquot was added to the pan containing the previously collected portions from each respective steer.

A urine sample of 1/30 the weight of the urine from each steer was also taken daily for the six steers on the balance study. Care was taken to stir the urine to keep the precipitable solids in suspension while the sample was being taken. A few drops of toluine was used in the galvanized collection cans to keep down bacterial decomposition. These samples were taken in duplicate and kept in a refrigerator at 3° C. until the analysis could be made.

Two pound samples of silage were collected daily; one pound from the morning feed which was taken fresh from the silo and one pound from the evening feed which was algo fed fresh from the silo. The samples were taken at random while each individual steer's silage was weighed. The samples were kept in a tight can with a few drops of chloroform until they were collected once daily and taken to the refrigerator. They were kept in tight foodsaver bags at 3° C. until the feeding trial was terminated.

The soybean meal was sacked in paper bags during the preliminary period, each bag containing one feed for one steer. Each steer's feed was kept separate in a barrel with a cover to keep out mice. Samples for analysis were taken at random as the sacks were weighed. The salt samples for analysis were also taken during the preliminary period while the daily salt allowances were being weighed. Water samples were taken daily at the time fresh water was added and were kept under refrigeration at 3° C.

When the collection period was finished the feces and silage samples were dried to constant weight in a forced draft oven at 75° C. This lower temperature is thought to be less harmful to the nutrients involved than the 100° C. temperature commonly used. They were then brought into atmospheric equilibrium by leaving them in an open front covered hood for a few days after which they were ground in a Wiley Mill to one millimeter fineness. Routine feedstuff analysis was made on all feeds and feces. The chlorides were analyzed by A.O.A.C. method 1945.* Sodium was analyzed by a modified method developed by Glendening and Schrenk.** A special flame photometer assembly consisting of a Beckmor exciter flame and a large littrow quartz spectrograph was employed in this analysis.

DISCUSSION OF RESULTS

Table 1 summarizes the results of the winter group feeding trial which extended from December 14, 1949 to April 25, 1950. The steers in Lot 1, which received salt, made the largest and most economical gains. The average daily gain per steer was 1.05 pounds for Lot 1 and .61 pound for Lot 2. The steers in Lot 1 made an average total gain of 139 pounds as compared to 80 pounds for Lot 2 receiving no salt. The extra 59 pounds of gain was made with an extra feed cost of only 275 pounds of silage plus 7.13 pounds of salt. These results are in agreement with those of Smith and Parrish (41).

The steers of Lot 2, which did not have access to salt, were licking the mangers and a craving for salt was evident after about three weeks on the no salt ration. A noticeable unthriftiness was noted in the no salt steers by the end of February. Two months later at the end of the period the steers of Lot 2 were gaunt, lacked smoothness and fleshing as compared to Lot 1 which received salt, Plate 2.

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*Association of Official Agricultural Chemists, Official and Tentative Methods.

**B. L. Glendening and W. G. Shrenk unpublished.

At the completion of the wintering period on April 25 the steers were used in a digestion and balance trial. Table 2 shows the daily feed consumption per steer during the digestion trial. The steers consumed only about .75 as much silage and only about .5 as much water during the digestion trial as they did during the wintering period as shown in Tables 1 and 12. Adverse conditions of standing on a cement floor in a stanchion probably account for the lower feed and water consumption in the nutrition barn, Plate 3.

Lot 2 consumed more water than Lot 1 during the 30 day period in the nutrition barn. This observation is in reverse of records for the last 30 days of the wintering period shown in Table 12 and is also contrary to observations of the water consumption of sodium deficient rats (34). However, Voris and Thacker (46), working with chlorine deficient rats, found increased water consumption of the deficient animals.

Table 3 shows the feed consumption and the amount of each nutrient furnished by each feed. In obtaining these data for intake of nutrients, the feed intake was multiplied by its percentage composition as determined by Chemical Analysis, Table 6. Table 3 also shows the amount of feces and the portion of each nutrient excreted. The difference between the amount of nutrients consumed and the amount excreted divided by the amount consumed can be expressed as a percentage and is known as a digestion coefficient.

Table 4 summarizes the individual results presented in Table 3 and shows the individual and average apparent digestion coefficients. It will be seen that the steers receiving salt, Lot 1, apparently digested their ration more completely than did the no salt steers, Lot 2. However, the differences are small and are probably nonsignificant, also in agreement with Smith and Parrish (41).

Composition of the feed and feces collected during the digestion trial is presented in Table 6. The nutrients were determined by routine Chemical Analysis.

Table 5 shows the recommended feeding allowances for wintering 500 pound steer calves recommended by Morrison (31) and the National Research Council (10) to gain .75 to 1 pound. The nutritive ratios have been added. The nutritive ratio (NR) is the ratio of digestible protein expressed as one, to the sum of digestible carbohydrates and fat, the fat being multiplied by 2.25. The digestible fat is multiplied by the factor 2.25 because fat contains 2.25 times as much energy value as an equal amount of digestible carbohydrates. Table 5 also presents the digestible protein, total digestible nutrients and nutritive ratios of the rations fed during the wintering period, and during the digestion trial as compared to the recommended standards (10 and 31).

The narrow nutritive ratio used during the digestion trial was thought advisable in order to keep the protein content of each steer's ration in the same proportion to silage intake and still stay within the recommended standards. The protein content of each ration had to be increased because the silage intake of some steers was low.

The balance study run in conjunction with the digestion trial made use of three steers from each lot. The results of the nitrogen balance study are shown in Table 7 which also shows the proportion of nitrogen furnished by each ingredient of the ration and the proportion of nitrogen in the feces and urine for each individual steer. Table 8 summarized the data presented in Table 7. It shows the individual and average percent of nitrogen retained by each lot. The steers were all in positive nitrogen balance. Lot 1 retained 8.33 percent of their nitrogen intake and Lot 2, receiving no salt, retained 6.46 percent. Considering the small number of steers used and the great variability in retention between steers in this trial as can be seen in Table 8 this difference is probably nonsignificant.

In Table 9 data from the sodium and chloride balance study are presented by individual steers. The amount of sodium and chloride furnished by each ingredient in the ration and the amount excreted in the urine and feces are also shown. The data from the individual sodium and chloride balances are summarized by lots in Table 10. It shows the amount and the percent of sodium and chlorine retained by each steer and the average for each of the two lots. The steers of Lot 1, receiving salt, were all in positive sodium and chlorine balance while the steers of Lot 2 receiving no salt were all in negative sodium balance; in other words they were excreting more sodium in the urine and feces than they were taking in in their daily ration. On the other hand the steers of Lot 2 were definitely in positive chlorine balance; in fact they retained about twice as much chlorine as did the controls. Lot 2 receiving no salt retained 53.7 percent of their chlorine intake while Lot 1, the controls receiving salt, retained only 6.3 percent of their chlorine intake. The steers of Lot 1 receiving salt retained 30.5 percent of their sodium intake while Lot 2 receiving no salt excreted an average -.38 g daily below their intake.

It is realized that this short collection period probably does not represent the whole wintering period and therefore these data cannot be used as conclusive evidence to apply to both periods.

Results of the full feeding period are summarized in Table 11. Both lots made good gains; however, Lot 2 receiving no salt outgained Lot 1 receiving salt. Their average daily gains were 2.25 pounds and 2.11 pounds per day, respectively. Considering the total gains, Lot 2 gained 386 pounds while Lot 1 receiving salt gained 361 pounds or 25 pounds less during the 171 day fattening period. The difference is small, but indicates that steers on a grain ration evidently do not require as much salt as do steers on a roughage ration. This observation is in agreement with Smith, Parrish and Clawson (42). However, this increased gain of Lot 2, receiving no salt, may have been partly the result of the steers of this lot having been in thinner condition at the start of the full feeding period. It is commonly known that thin steers tend to gain faster than steers in better condition.

Lot 2 receiving no salt consumed slightly more corn than Lot 1. This is not in agreement with the popular idea that salt increases the palatability of the ration. When figured on the basis of the feed required per 100 pounds of gain the steers in Lot 2 were also most efficient in their gains.

The water consumption records presented in Table 12 show that Lot 2 receiving no salt drank more water during the fattening period than did Lot 1 receiving salt. The records kept during the digestion trial also indicated this trend in water consumption. Lot 2 consumed an average of 7.15 gallons per head daily while Lot 1, receiving salt, consumed only 6.07 gallons per head daily.

Table 13 summarizes the wintering and full feeding periods of 333 days. In considering the combined periods Lots 1 and 2 made an average daily gain of 1.41 pounds and 1.34 pounds, respectively. Lot 2 receiving no salt made a total gain of 448 pounds and Lot 1 receiving salt gained 470 pounds or 22 pounds more for the entire period. There was virtually no difference in the selling price or marked grade. Similarity of the two lots at the end of the full feeding period can be seen in Plate 4. There was only small differences in carcass grade between the two lots. Lot 2 receiving no salt dressed 1 percent higher than Lot 1.

Table 1. Results of feed-lot trial (5 steers per lot) December 14, 1949, to April 25, 1950 (132 days).

	Lot 1, salt	Lot 2, no salt
	Pounds	
Average daily ration		
Atlas Sorgo silage	28.22	26.14
Soybean meal	1.00	1.00
Salt	0.054	None
Average initial weight	448.00	448.00
Average final weight	587.00	528.00
Average total gain	139.00	80.00
Average daily gain	1.05	0.61
Feed required per 100 lbs gain		
Atlas Sorgo silage	2679.86	4312.50
Soybean Oil meal	94.86	165.00
Salt	5.18	None

Table 2. Feed consumption during the digestion trial May 16, 1950 to May 25, 1950 (10 days).

Steer	Atlas sorgo silage	Soybean meal		Salt		Water	Weigh-back
	lbs	g	lbs	g	lbs	lbs	
			Lot 1, salt				
65	22	749	1.65		None	21.0	None
60	18	612	1.35		"	14.3	"
62	16	544	1.20		"	14.2	"
67	22	749	1.65		"	17.0	"
71	20	681	1.50		"	19.3	"
Average	19.6	666.8	1.47			17.8	
			Lot 2, no salt				
63	18	612	1.35	20	.044	13.9	None
73	22	749	1.65	20	.044	19.0	"
66	18	612	1.35	20	.044	14.8	"
76	18	612	1.35	20	.044	19.1	"
74	22	749	1.65	20	.044	25.9	"
Average	19.6	666.8	1.47	20	.044	19.2	

Table 3. Digestion trial data for individual steers. Nutrient intakes, fecal outgo and digestion coefficients.

	Crude protein	Ether extract	Crude fiber	Dry matter	Ash	N. F. E.
			Lot 1, salt			
Steer 65						
Silage g	91.89	63.92	926.89	260.687	247.70	1276.47
Soybean meal g	325.81	41.79	40.67	675.00	42.99	223.73
Total g	417.70	105.71	967.56	3281.87	290.69	1500.20
Feces x 1395g	147.31	37.11	373.16	1316.32	195.16	563.58
Total minus feces g	270.39	68.60	594.40	1965.55	95.53	936.62
Digestion coefficient	0.647	0.648	0.614	0.598		0.624
Steer 60						
Silage g	75.18	52.30	758.36	2132.89	202.66	1044.38
Soybean meal g	266.61	34.20	33.28	552.34	35.18	183.07
Total g	341.79	86.50	791.64	2685.23	237.84	1227.45
Feces x 1065g	116.62	27.26	273.70	1005.57	49.10	438.99
Total minus feces g	225.17	59.24	517.94	1679.66	88.74	788.46
Digestion coefficient	0.658	0.684	0.654	0.625		0.642
Steer 62						
Silage g	66.83	46.49	674.10	1895.90	180.15	928.34
Soybean meal g	236.98	30.40	29.58	490.10	31.27	162.73
Total g	303.81	76.89	703.68	2386.00	211.42	1091.07
Feces x 1023g	100.36	24.76	299.74	962.34	136.88	409.81
Total minus feces g	203.45	52.13	403.94	1423.66	74.54	681.26
Digestion coefficient	0.690	0.677	0.574	0.596		0.624

Table 3 (cont.)

	Crude protein	Ether extract	Crude fiber	Dry matter	Ash	N. F. E.
Steer 67						
Silage g	91.89	63.92	926.89	260.687	247.70	1276.47
Soybean meal g	325.81	41.79	40.67	675.00	42.99	223.73
Total g	417.70	105.71	967.56	3281.87	290.69	1500.20
Feces x 1425g	143.35	37.76	411.97	1355.60	181.54	580.97
Total minus feces g	274.35	67.95	555.59	1926.27	95.53	919.23
Digestion coefficient	0.656	0.642	0.574	0.586		0.612
Steer 71						
Silage g	83.54	58.11	842.62	2369.88	225.18	1160.42
Soybean meal g	296.23	38.00	36.98	613.72	39.09	203.41
Total g	379.77	96.11	879.60	2983.60	264.27	1363.83
Feces x 1290g	126.55	32.12	350.49	1222.02	177.89	534.96
Total minus feces g	253.22	63.99	529.11	1761.58	86.38	828.87
Digestion coefficient	0.666	0.665	0.601	0.590		0.607

Table 3 (cont.)

	Crude protein	Ether extract	Crude fiber	Dry matter	Ash	N. F. E.
			Lot 2, no salt			
Steer 63						
Silage g	75.18	52.30	758.36	2132.89	202.66	1044.38
Soybean meal g	266.61	34.20	33.28	552.34	35.18	183.07
Total g	341.79	86.50	791.64	2685.23	237.84	1227.45
Feces x 1125g	113.96	28.46	315.34	1060.31	153.56	448.99
Total minus feces g	227.83	57.04	476.30	1624.92	84.28	778.46
Digestion coefficient	0.666	0.659	0.601	0.605		0.634
Steer 73						
Silage g	91.89	63.92	926.89	2606.87	247.70	1276.47
Soybean meal g	325.81	41.79	40.67	675.00	42.99	223.73
Total g	417.70	105.71	967.56	3281.87	290.69	1500.20
Feces x 1380g	142.28	36.43	386.95	1302.58	174.57	562.35
Total minus feces g	275.42	69.28	580.61	1979.29	116.12	937.85
Digestion coefficient	0.659	0.655	0.600	0.603		0.625
Steer 66						
Silage g	75.18	52.20	758.36	2132.89	202.66	1044.38
Soybean meal g	266.61	34.20	33.28	552.34	35.18	183.07
Total g	341.79	86.50	791.64	2685.23	237.84	1227.45
Feces x 1177g	118.41	28.60	336.39	1113.44	151.95	478.10
Total minus feces g	223.38	57.90	455.25	1571.79	85.89	749.35
Digestion coefficient	0.653	0.669	0.575	0.585		0.610

Table 3 (concl.)

	Crude protein	Ether extract	Crude fiber	Dry matter	Ash	N. F. E.
Steer 76						
Silage g	75.18	52.30	758.36	2132.89	202.66	1044.38
Soybean meal g	266.61	34.20	33.28	552.34	35.18	183.07
Total g	341.79	86.50	791.64	2685.23	237.84	1227.45
Feces x 1200g	130.56	33.60	330.84	1140.48	153.24	492.24
Total minus feces g	211.23	52.90	460.80	1544.75	84.60	735.21
Digestion coefficient	0.618	0.611	0.582	0.575		0.598
Steer 74						
Silage g	91.89	63.92	926.89	260.69	247.70	1276.47
Soybean meal g	325.81	41.79	40.67	675.00	42.99	223.73
Total g	417.70	105.71	967.56	3281.87	290.69	1500.20
Feces x 1410g	154.25	35.39	387.04	1335.97	178.93	580.36
Total minus feces g	263.45	70.32	580.52	1945.90	111.76	919.84
Digestion coefficient	0.630	0.665	0.599	0.592		0.613

Table 4. Individual and average apparent digestion coefficients obtained in digestion trial conducted May 16, 1950 to May 25, 1950 (10 days).

Steer	Dry matter	Crude protein	Ether extract	Crude fiber	N. F. E.
			Lot 1, salt		
65	59.8	64.7	64.8	61.4	62.4
60	62.5	65.8	68.4	65.4	64.2
62	59.6	66.9	67.7	57.4	62.4
67	58.6	65.6	64.2	57.4	61.2
71	59.0	66.6	66.5	60.1	60.7
Average	59.9	65.9	66.3	60.3	62.1
			Lot 2, no salt		
63	60.5	66.6	65.9	60.1	63.4
73	60.3	65.9	65.5	60.0	62.5
66	58.5	65.3	66.9	57.5	61.0
76	57.5	61.8	61.1	58.2	59.8
74	59.2	63.0	66.5	59.9	61.3
Average	59.2	64.5	65.2	59.1	61.6

Table 5. Recommended feeding standards for wintering 500 pound steer calves to gain 0.75 to 1.0 pound per head daily compared with results obtained during the wintering period and during the digestion trial.

Recommended Standards	Expected daily gain, lbs	Dig. protein per steer daily, lbs	T.D.N. daily per steer, lbs	Nutritive ratio
Morrison Standard	0.75 - 1.	0.71 - 0.78	5.7 - 6.7	1:8.2
National Research Council Standard	1.0	0.80	7.0	1:8.7
		Wintering Period*		
Lots				
1	1.05	0.64	6.37	1:9.9
2	0.61	0.62	5.96	1:9.6
		Digestion trial		
Lots				
1	0.0	0.64	4.11	1:6.4
2	0.0	0.64	4.11	1:6.4

*Based on average feed composition figures

Table 6. Composition of feeds and feces (air dry basis) collected during the 10-day digestion trial, May 16, 1950 to May 25, 1950.

	Moisture	Crude protein	Ether extract	Crude fiber	N. F. E.	Ash
			Percent Feed Analyses			
Atlas sorgo silage*	26.1	0.93	0.66	9.41	12.96	2.51
Soybean meal	9.9	43.50	5.58	5.43	29.87	5.74
Salt	0.1					98.
			Feces Analyses Lot 1, salt			
Steer						
65	5.64	10.56	2.66	26.75	40.40	13.99
60	5.58	10.94	2.56	25.70	41.22	14.00
62	5.03	9.81	2.42	29.30	40.06	13.38
67	4.87	10.06	2.65	28.91	40.77	12.75
71	5.27	9.81	2.49	27.17	41.47	13.79
Average	5.28	10.23	2.56	27.57	41.78	13.58
			Lot 2, no salt			
Steer						
63	5.75	10.13	2.53	28.03	39.91	13.65
73	5.61	10.31	2.64	28.04	40.75	12.65
66	5.40	10.06	2.43	28.58	40.62	12.91
76	4.96	10.88	2.80	27.57	41.02	12.77
74	5.25	10.94	2.51	27.45	41.16	12.69
Average	5.39	10.46	2.58	27.93	40.69	12.93

*As fed basis

Table 7. Nitrogen balance study of steers receiving a soybean meal-silage ration with and without salt.

Nitrogen intake and outgo	Daily feed intake			Daily outgo			Retained	
	Silage	Soybean meal	Total	Feces	Urine	Total	Grams	Percent
			Lot 1, salt					
Steer 62								
Daily ration	1896	544.8						
Feces and urine g				1023	5179			
Nitrogen percent	0.56	6.96		1.56	0.48			
Nitrogen g	10.62	37.92	48.54	15.96	24.86	40.82	7.72	15.90
Steer 60								
Daily ration	2133	612.9						
Feces and urine g				1065	5051			
Nitrogen percent				1.75	0.67			
Nitrogen g	11.95	42.66	54.61	18.64	33.84	52.48	2.13	3.90
Steer 65								
Daily ration	2607	749.1						
Feces and urine g				1395	4752			
Nitrogen percent				1.69	0.79			
Nitrogen g	14.60	52.14	66.74	23.58	37.54	61.12	5.62	8.42
			Lot 2, no salt					
Steer 66								
Daily ration	2133	612.9						
Feces and urine g				1177	3679			
Nitrogen percent				1.61	0.87			
Nitrogen g	11.95	42.66	54.61	18.95	32.01	50.96	3.65	6.68
Steer 73								
Daily ration	2607	749.1						
Feces and urine g				1380	4246			
Nitrogen percent				1.65	0.82			
Nitrogen g	14.60	52.14	66.74	22.77	34.82	57.59	9.15	13.71
Steer 63								
Daily ration	2133	612.9						
Feces and urine g				1125	3584			
Nitrogen percent				1.62	0.98			
Nitrogen g	11.95	42.66	54.61	18.23	35.12	53.35	1.26	2.31

Table 8. Nitrogen intake, outgo, and retention of steers receiving a soybean meal-silage ration with and without salt.

Steer	N intake daily g	N outgo daily g	N retained g	N retained percent
		Lot 1, salt		
62	48.54	40.82	7.72	15.90
60	54.61	52.48	2.13	3.90
65	66.74	61.12	5.62	8.42
Average	56.63	51.47	6.16	9.41
		Lot 2, no salt		
66	54.61	50.96	3.65	6.68
73	66.74	57.59	9.15	13.72
63	54.61	53.35	1.26	2.31
Average	58.65	53.96	4.69	7.57

Table 9. Individual sodium and chlorine intakes and excretions during the balance study May 16 to May 25, 1950 (10 days).

Daily intake or outgo	Dry basis, g	Na Percent	Na, g	Cl, Percent	Cl, g
		Lot 1, salt			
Steer 62					
Silage	1895.90	0.009	0.1706	0.165	3.1282
Soybean meal	490.90	0.008	0.0392	0.016	0.0785
Water	6719.20	0.000035	0.2351	0.000022	0.1478
Salt	20.00	36.3	7.260	56.1	11.220
Total			7.71		14.58
Outgo feces	971.54	0.030	0.2014	0.116	1.1269
Urine	5179.00	1.25 ppt*	6.474	2.48 ppt	12.8439
Total			6.77		13.97
Steer 60					
Silage	2132.89		0.1919		3.5192
Soybean meal	552.35		0.0441		0.0883
Water	6734.60		0.2367		0.1488
Salt	20.00		7.260		11.220
Total			7.73		14.98
Outgo feces	1005.00	0.032	0.3216	0.102	1.0251
Urine	5051.00	1.10 ppt	5.556	2.52 ppt	12.7235
Total			5.88		13.75
Steer 65					
Silage	2606.86		0.2346		4.3013
Soybean meal	675.09		0.0540		0.1080
Water	9851.80		0.3443		0.2167
Salt	20.00		7.260		11.220
Total			7.88		15.85
Outgo feces	1316.32	0.046	0.6055	0.290	3.8173
Urine	4752.00	0.62 ppt	2.9462	2.32 ppt	11.0246
Total			3.55		14.84

*Parts per thousand.

Table 9 (concl.)

Daily intake or outgo	Dry basis, g	Na Percent	Na, g	Cl, Percent	Cl, g
			Lot 2, no salt		
Steer 66					
Silage	2132.89		0.1919		3.5192
Soybean meal	552.35		0.0441		0.0883
Water	7037.00		0.2462		0.1548
Salt					
Total			0.48		3.76
Outgo feces	1113.44	0.0073	0.0812	0.119	1.3249
Urine	3679.00	0.21 ppt	0.7726	0.07 ppt	0.2575
Total			0.85		1.58
Steer 73					
Silage	2606.86		0.2346		4.301
Soybean meal	675.09		0.0540		0.1080
Water	8898.40		0.3114		0.1957
Salt					
Total			0.60		4.61
Outgo feces	1302.58	0.0074	0.0963	0.140	1.8236
Urine	4246.00	0.22 ppt	0.9341	0.07 ppt	0.2972
Total			1.03		2.12
Steer 63					
Silage	2132.89		0.1919		3.5192
Soybean meal	552.35		0.0441		0.0883
Water	6583.00		0.2304		0.1448
Salt					
Total			0.47		3.75
Outgo feces	1060.31	0.0100	0.1060	0.137	1.4526
Urine	3584.00	0.20 ppt	0.7168	0.13 ppt	0.4659
Total			0.82		1.92

Table 10. Sodium and chloride balance of steers receiving a soybean meal-silage ration, with and without salt.

Steers	Na intake daily, g	Na outgo daily, g	Na Retained g	Na Retained Percent	Cl intake daily, g	Cl outgo daily, g	Cl Retained g	Cl Retained Percent
Lot 1, salt								
62	7.71	6.77	0.94	12.2	14.58	13.97	0.61	4.2
60	7.73	5.88	1.85	23.9	14.98	13.75	1.23	8.2
65	7.88	3.55	4.33	54.9	15.85	14.84	1.01	6.4
Average	7.77	5.40	2.37	30.5	15.14	14.19	.95	6.3
Lot 2, no salt								
66	0.48	0.85	-.37		3.76	1.58	2.18	58.0
73	0.60	1.03	-.43		4.61	2.12	2.49	54.0
63	0.47	0.82	-.35		3.75	1.92	1.83	48.8
Average	0.52	0.90	-.38		4.04	1.87	2.17	53.7

Table 11. Results of feed-lot trial full feeding period (5 steers per lot) May 25, 1950 to November 11, 1950 (171 days).

	Lot 1	Lot 2
	Pounds	
Average daily ration		
Prairie hay	6.43	6.38
Alfalfa hay	1.96	1.96
Corn	11.56	11.92
Soybean meal	1.05	1.05
Water, gal.	7.27	8.89
Salt	0.025	None
Average initial weight	557.00	510.00
Average final weight	918.00	896.00
Average total gain	361.00	386.00
Average daily gain	2.11	2.25
Feed required per 100 lbs. gain		
Prairie hay	304.38	282.59
Alfalfa hay	93.07	87.05
Corn	547.51	528.19
Soybean oil meal	49.72	46.50
Salt	1.19	None

Table 12. Water consumption of steers fed rations with and without salt added, March 16 to November 13, 1950 (242 days).

Periods	Meter reading (cu ft)	Evaporation*** (cu ft)	Total/lot (cu ft)	Total/lot (gal)	Daily/lot (gal)	Daily steer (gal)
Lot 1, salt						
March 16 - April 25	137.52	16.95	120.57	895.8	22.40	4.48
*April 25 - May 25				244.8	8.16	1.63
May 31 - June 23	145.2	12.0	133.2	989.7	41.24	8.25
**June 23 - July 21	122.9	14.0	108.9	809.1	31.12	6.22
July 21 - August 10	161.5	14.0	147.5	1095.9	39.14	7.83
August 19 - September 29	244.3	21.0	223.3	1659.1	38.58	7.72
September 29 - November 13	211.2	22.0	189.2	1405.7	31.95	6.39
Average						6.07
Lot 2, no salt						
March 16 - April 25	103.53	16.95	86.58	643.3	16.08	3.22
*April 25 - May 25				267.7	8.93	1.79
May 31 - June 23	167.2	12.0	155.2	1153.1	48.05	9.61
**June 23 - July 21	164.3	14.0	150.3	1116.7	42.95	8.59
July 21 - August 19	199.4	14.0	185.4	1377.5	49.20	9.84
August 19 - Sept. 29	294.7	21.0	273.7	2033.6	48.42	9.68
Sept. 29 - November 13	238.7	22.0	216.7	1610.1	36.59	7.32
Average						7.15

*Digestion trial period
**Two days consumption was missed in this period
***.5 cu. ft. of water evaporated daily estimated from records kept from March 16 to April 25, 1950 (40 days)

7.43 gal. of water per cu. ft.
8.41 lbs. per gal. of water

Table 13. Results of wintering and full feeding periods combined (5 steers per lot) December 14, 1949 to November 11, 1950 (333 days).

	Lot 1	Lot 2
	Salt free access	No salt
Initial weight per steer . . lbs	448	448
Final weight per steer . . . lbs	918	896
Total gain per steer . . . . lbs	470	448
Daily gain per steer . . . . lbs	1.41	1.34
Dressing percent		
Carcass grades*	58.3	59.3
Low good	2	1
Top commercial		2
Average commercial	3	2
Selling price per hundredweight		
at the market	$28.00	$28.00
Shrinkage, percent	1.1	1.3

*Graded by Federal grader L. P. Stream.

EXPLANATION OF PLATE I

Steers at the beginning of the Experiment, December 14, 1949

Fig. 1. Steers receiving salt free access

Fig. 2. Steers receiving no salt

PLATE I

Fig. 1

Fig. 2

EXPLANATION OF PLATE II

Steer at the end of the wintering period, April 25, 1950

The hair was clipped from the rear quarters to prevent contamination of the feces during the digestion trial which was to follow

Fig. 1. Steers receiving salt free access

Fig. 2. Steers receiving no salt

PLATE II

Fig. 1

Fig. 2

EXPLANATION OF PLATE III

Steers in the nutrition barn during the collection period of the digestion trial, May 25, 1950

PLATE III

EXPLANATION OF PLATE IV

Steers at the close of the full feeding period, November 10, 1950

Fig. 1. Steers receiving salt free access

Fig. 2. Steers receiving no salt

PLATE IV

Fig. 1

Fig. 2

SUMMARY AND CONCLUSIONS

Hereford steer calves were used in a study of the influence of salt in the ration on the digestibility, nitrogen, and sodium chloride balances. Ten good quality steers were divided into two lots of five steers each. Both lots were treated alike throughout the experiment except that one lot was given free access to salt and the other was not. The calves were started on test December 14, 1949, wintered in dry lot on silage, used in digestion and balance trials, then full fed in dry lot for 171 days and marketed on November 13. Dressing percentages and carcass grades were obtained.

From the data obtained, the following conclusions are justified:

1. Lot 2, which did not receive salt, showed a marked desire for it early in the wintering period.

2. Lot 1, which received salt, gained faster and was more efficient in the conversion of feed to body gains than was Lot 2 during the wintering period.

3. The only evidence of salt deficiency of the calves of Lot 2 at the end of the wintering period was their rougher, thinner appearance.

4. During the digestion trial the steers in Lot 2 digested their feed more completely, however the difference in digestibility was small.

5. Both lots were in positive nitrogen balance. However, Lot 1, receiving salt, retained slightly more of their ingested nitrogen than did Lot 2.

6. Lot 1 receiving salt was in positive sodium and chlorine balance, Lot 2 was in negative sodium balance, but the steers of

this lot retained a higher percentage of their chlorine intake than did those of Lot 1 receiving salt.

7. Lot 2 receiving no salt consumed more water than Lot 1 during the digestion trial and during the full feeding period. The reverse was true during the last 30 days of the wintering period.

8. Both lots were started on full feed May 25 immediately following the digestion trial and were fed 171 days or until November 13, 1950. Both lots made satisfactory gains. However, Lot 2 receiving no salt gained slightly more than Lot 1.

9. The fact that the no salt steers gained slightly more during the full feeding period than the steers receiving salt indicates that steers on a full feed of corn do not require as much salt as do steers on a roughage ration.

10. During the fattening period Lot 2 receiving no salt consumed about 1 gallon more water per head daily than Lot 1. As mentioned previously, this observation is contrary to results of other workers working with rats and with swine.

11. During the combined wintering and full feeding periods the steers receiving salt, Lot 1, gained 22 pounds more per steer than Lot 2, not having access to salt. There was no difference between lots in market selling price or in carcass grade.

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A STUDY OF THE RELATIONSHIP OF SALT INTAKE TO PERFORMANCE, DIGESTIBILITY OF FEEDS, AND TO THE NUTRITIONAL BALANCE OF SODIUM AND CHLORINE FOR BEEF STEERS

by

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This study was undertaken primarily for the purpose of determining the effects of adding to or withholding salt from the rations of beef steers, on digestibility of the components in the ration and upon sodium, chlorine and nitrogen balance. It also served to familiarize the author with the procedures and calculations involved in running a digestion and balance trial.

The experimental part of the study was divided into three periods. First, the wintering period in which two lots of five steers each were fed on a ration of silage plus one pound of soybean meal with which one lot received salt free choice and the other lot received no salt except the small amount that would be included in the drinking water and feed consumed. During this period which lasted 132 days, the steers receiving salt made an average daily gain of 1.05 pounds as compared to .61 pounds for the steers receiving no salt. At the end of the period, the no-salt steers were thinner in fleshing and lacked the smoothness and thriftiness shown by the lot receiving salt.

A digestion trial was conducted following the wintering period. The steers were confined in stanchions and fed individually. Each steer's ration was determined by his appetite. This adjustment period was followed by a ten-day preliminary period. During this period, the objective was to fill the animals' digestive tracts with the same amount and kind of feeds that they would receive during the collection period which followed. During the collection period, the feces was recovered from each steer and samples dried and retained for chemical feedstuff analysis. The urine was also collected, sampled and analyzed. By determining the chemical analyses of the feeds, and recording the feed consumption of each steer as well as the analyses and total excretion of the feces it is possible to calculate digestion coefficients for the different constituents in the ration. If the total excretion of urine and its composition are also known, it is possible to figure mineral and nitrogen balances also. In each case, the apparent coefficients of digestibility of dry matter, crude protein, ether extract, crude fiber and nitrogen free extract were from one to two per cent greater for steers receiving salt than for those not receiving salt. The steers receiving salt were all in positive sodium and chlorine balance, while the steers receiving no salt were in negative sodium balance. Both lots were in positive nitrogen balance; however, the lot receiving salt retained slightly more of their ingested nitrogen than did the steers receiving no supplemental salt.

The third phase of the experiment was a full-feeding or fattening period. During this period, which ran for 171 days, both lots made satisfactory gains. However, the steers receiving no salt made the most rapid gains, 2.25 pounds daily compared with 2.11 pounds daily for the steers receiving salt. The fact that the no-salt steers gained slightly more during the full feeding period than the steers receiving salt indicates either that steers on a full feed of corn do not require as much salt as do steers on a roughage ration or that the body mechanism was able to adjust for excretions of sodium and chlorine to the lower intake.