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Title: A COMPARISON OF TASTE RESPONSES IN PYGMY GOATS, NORMAL GOATS, SHEEP AND CATTLE

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This study involved the use of the two-choice preference test to determine the taste responses of eight, each, of pygmy goats, normal goats, sheep and cattle to ascending concentrations of sucrose (Suc), sodium chloride (NaCl), acetic acid (HAc) and quinine hydrochloride (QHCl). In addition, sheep and cattle were tested at 2.08 and 8.33% molasses concentrations.

Each animal was individually penned and fed to appetite on a nutritionally adequate diet. Responses were expressed on the basis of percent of total fluid intake comprised by test solution. Goats were allowed two-day test periods per concentration; sheep and cattle were given one-day test periods.

Mean responses and standard deviations of the eight-animal groups were plotted graphically and compared to threshold levels of intake. Response trends were analyzed by stepwise multiple linear

regression. A 95% confidence interval was established for a theoretical mean intake of 50%. The upper confidence limit was at 60% intake and the lower was at 40% intake. They were termed, respectively, upper discrimination threshold (UDT) and lower discrimination threshold (LDT). The rejection threshold (RET) was set at 20% intake and the preference threshold (PRT) at 80% intake. Ascending or descending responses at the various threshold concentrations were identified by ↑ and ↓, respectively.

Molar concentrations of thresholds crossed by responses of pygmies, normals, sheep and cattle, respectively, were for Suc, UDT: .055↑ and .53↓; UDT: .033↑, PRT: .38↑; LDT: .41↓; UDT: .025↑ and .41↓, PRT: .058↑ and .24↓, LDT: .56↓; for NaCl, UDT: .024↑ and .21↓, PRT: .10↑ and .14↓, LDT: .36↓, RET: .60↓; UDT: .027↑↓, LDT: .15↓, RET: .55↓; LDT: .21↓, RET: .53↓; LDT: .016↓, RET: .14↓; for HAc, UDT: .0034↑ and .042↓, LDT: .16↓, RET: > .22↓; LDT: .014↓, RET: .11↓; UDT: .0034↑↓, LDT: .028↓, RET: .094↓; UDT: .0017↑ and .0069↓, LDT: .014↓, RET: .038↓; and, for QHCL, UDT: > .000016↑ and .000047↓, LDT: .00030↓, RET: .00202↓; UDT: .000016↑ and .000063↓, LDT: .00035↓, RET: .00202↓; LDT: .000094↓, RET: .00035↓; LDT: .00013↓, RET: .00038↓.

In general, stimulating effectiveness was greatest for bitter, followed in order by sour, salty and sweet. Cattle were usually first to make a discrimination, goats were generally second and sheep were normally last. The major exception was for the bitter taste group where the order was goats, sheep, cattle. As a rule, goats were more tolerant of high concentrations than were sheep and sheep were more tolerant than cattle. The exception was, again, the bitter taste group where the order was goats, cattle, sheep.

Sheep were indifferent to 2.08 and 8.33% molasses concentrations. Cattle demonstrated strong preference responses to the 2.08% level and weak preference reactions to the 8.33% level.

A Comparison of Taste Responses in Pygmy Goats, Normal Goats, Sheep and Cattle

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INTRODUCTION

The present world food crisis and the fact that it is rapidly intensifying, dictates that man must learn more about the sensory processes involved in the food preferences of livestock species. Obviously, as man continues the proliferation of himself at ever more alarming rates, the point quickly approaches when domestic animals will be almost completely dependent upon agricultural and industrial wastes and range land forages for their nutritional sustenance. We may expect that the sensory characteristics of much of the materials that will eventually be used in livestock feeding will be appreciably different from those of the feedstuffs presently in use. Under such circumstances, the sensory component of the food acceptance process becomes increasingly more important. Taste is one of the major items in the sensory component of the palatability complex.

The sense of taste in higher animals functions in several processes, among which are: control of ingestive behavior, onset of specific appetites, and reinforcement in learning situations. The particulars of this chemical sense, thus, have meaning in the area of nutrition.

Psychologists have, for a great many years, employed the sense of taste in studies on learning. The experimental subject most often used in such studies has been the laboratory rat. Consequently, a sizable amount of data have been accumulated on the sense of taste in this species. However, other species of animals have not fared so well, particularly the domesticated animals. Only in recent times has gustation been studied in livestock species.

A number of theories on the control of dietary intake have emerged from the data derived in studies on the energizing properties of sensory cues on behavior. One unifying concept is that taste, acting as a sensory cue, is involved in the regulation of intake in accordance with its role in linking relief of nutritional stress with some identifying sensory characteristic of the nutrient complex ingested. It is thought that the linking role may be both innate (acting in short term control) and learned (influencing long term regulation).

Behavioral taste thresholds vary depending on two general groups of variables: environmental factors and intraorganic factors. Among the former can be mentioned contamination of taste substance, relative inaccessability of one or another of the taste substances, nature of the taste medium, and temperature of the taste medium. Intraorganic factors of importance include age, presence of disease, nutritional deficits, and species.

Still another important variable affecting taste thresholds is the testing procedure. Thresholds may vary greatly from one method of testing to another.

If literature values are used in a species comparison of taste responses, the resulting interpretation is subject to errors depending on the number of variables left uncontrolled in each of the studies considered. In order to obtain maximum reliability in a species comparison of taste responses, it would be necessary to test those species in a situation such that as many of the variables as possible could be controlled.

The purpose of this study was to compare the taste responses of pygmy goats, normal goats, sheep and cattle under conditions as similar as possible. The work was prompted by the lack of any such comparison among the livestock species.

REVIEW OF LITERATURE

The literature pertaining to a number of topics in the area of taste has recently been reviewed by Goatcher (1969). Among the subjects considered were: existence of water and alkaline tastes, taste groups, factors influencing taste responses (environmental and intraorganic), experimental methods of studying taste reactions, and species and individual differences in taste responses. The literature reviewed will be summarized and expanded, where appropriate, in this report.

Summary of a Previous Literature Review

There are but four basic tastes: sweet, salty, sour and bitter. Tastes which cannot be described in terms of pure sensations of one or another of the primary taste groups are mixtures rather than separate tastes themselves. Of interest also are two other proposed tastes which have at one time or another received appreciable support. These are the water and alkaline tastes.

Studies on the water response have been reviewed by Pfaffmann (1956) and Amerine, Pangborn and Roessler (1965). There seems to be general agreement that the water response is the result of a hypotonic reaction. A water response could not be detected in the goat, sheep and calf (Bell and Kitchell, 1966).

The existence of an alkaline taste remained in controversy for nearly 20 years. Studies in 1948 (Kloehn and Brogden) and 1956 (Liljestrand and Zotterman) indicate that several types of receptors may be involved in the sensations produced by the alkalies: taste, pain, common chemical sense. The general stimulation of several kinds of fiber endings by alkaline solutions indicate that the alkalies produce a complex sensation and not a primary taste.

In general, evidence is most favorable for a classification of taste into four primary groups. Studies have shown that anaesthetics have differential affects on the four types of taste sensations (Skramlik, 1963) and that fibers are differentially sensitive to compounds associated with the four primary taste modalities (Pfaffmann, 1941; Beidler, 1952). The evidence in support of four primary taste systems has been summarized by Wenger, Jones and Jones (1956). In addition to the two points already mentioned, they list: subjective evidence or the capacity of individuals deprived of the sense of smell to classify gustatory stimulants into the four groups, the differential sensitivity of areas of the tongue to the different taste qualities, and the fact that tastes may interact to alter one another's thresholds. Some recent evidence for the four modality theory comes from electrical stimulation studies (Bekesy, 1964a, b) in which only sensations corresponding to the four taste groups could be produced.

Some workers (Kare and Ficken, 1963) object to the use of the four modality classification of tastes in studies with animals other than man. Their objection is based on the findings arising from comparative studies on taste. These studies revealed that the type and strength of within taste group responses varied markedly with species (and with individuals within species). It appears that the appropriateness of the use of the four taste classification with animals other than man is open to serious question. However, its use might be justified on the basis that it serves as a useful frame of reference.

The nature of the chemicals involved in the different tastes has been thoroughly discussed by several authors: Parker (1922); Moncrieff (1946); Amerine, Pangborn and Roessler (1965) and others. There exists no single chemical concept which will completely explain the stimulating properties of the chemicals within taste groups. Several concepts usually must be employed to characterize the substances into taste classes.

The sweet taste is associated with an assortment of non-ionized aliphatic hydroxy compounds, sugar-derivatives, alcohols and glycols. Salt stimuli are exemplified by common salt, sodium chloride. Both the anion and cation are important to stimulation, but the cation is thought to have the greater influence. The sour taste is produced by acids. Stimulation by mineral acids has been found to depend mainly upon H^+ concentration, but with respect to organic acids, the undissociated molecules also are of significance. The bitter and sweet taste are similar in that each are evoked by a variety of compounds. Some of the more common bitter substances are: quinine, tannins, caffeine and strychnine.

Of the environmental factors that influence taste responses, the nature and temperature of the taste medium, and visual and positional cues are of primary concern.

The taste medium may exert its influence in several ways: by changing the solubility of the stimuli, by adsorbing the taste substance, by physically interferring with the migration of taste molecules to receptor sites, or by combinations of these processes (Mackey and Valassi, 1956; Mackey, 1958).

Temperature effects have not been well defined, but it appears that there are differential influences on the four taste modalities as well as species differences in response to the temperature factor (Nagaki, Yamashita and Sato, 1964; Beidler, 1954; Sato, 1963; Bekesy, 1964a, b).

Visual and positional cues play a prominent role in food and liquid choices by laboratory animals (Young, 1945, 1948) and in choices of taste solutions by chicks (Pick and Kare, 1962). Container and positional bias probably also occurs in the large domesticated species, but does not appear to have been studied in these animals.

There are numerous intraorganic factors that bear on behavior in sensory tests. Some of these are: age, presence of disease, nutritional deficits, and genetic constitution.

The literature is not clear on the effect of age upon taste sensitivity. There appear to be sex as well as species differences involved. In general, however, data from several workers (Richter and Campbell, 1940; Cooper, Bilash and Zubek, 1959; Cicala and McMichael, 1964; Glanville, Kaplan and Fischer, 1964) indicate that taste sensitivity is less at earlier and later ages, and reaches a maximum somewhere in between.

Taste responses may be altered by a number of different diseases, resulting in either increases or decreases in sensitivity. For example, adrenal cortical insufficiency increases taste sensitivity to certain chemicals while hypogonadism results in decreases (Henkin, 1967).

When an animal is deprived of a nutrient to the extent that a deficiency state develops, a nutrient hunger typically occurs. Behavioral taste thresholds, then, may be increased, as in the case of vitamin A (Bernard, Halpern and Kare, 1961) and copper deficiencies (Henkin et al., 1967), or they may be decreased, as in the case of sucrose thresholds in chickens when these animals are calorically deprived (Kare, Halpern and Jones, 1961). As a general rule, however, behavioral taste thresholds are decreased in deficiency states and preferences are shifted to higher concentrations.

Reduction in blood levels of glucose (via insulin injections) creates an increased appetite for the sugar (Richter, 1942a) and induces a switch in preference from lower to higher concentrations of sucrose (Mayer-Gross and Walker, 1946). Post ingestion factors play a role in specific-hunger behavior for glucose (McCleary, 1953) as does, apparently, taste (Smith and Duffy, 1957; Bacon, Snyder and Hulse, 1962). Under conditions of *ad libitum* feeding, the intake of glucose solutions is independent of taste (Jacobs, 1961, 1962, 1963). Taste appears to mediate intake of sugar at lower concentrations whereas at higher concentrations, physiological factors seem to be the mediator. Energy deficits increase the animal's dependence on sensory qualities (Jacobs, 1963).

Rats made salt deficient by adrenalectomy have the ability to select sodium chloride in the amounts necessary to maintain life (Richter, 1936). Consumption of the salt is dependent upon an unlearned receptor-effector connection modifiable by the physiological state of the animal (Bare, 1949; Epstein and Stellar, 1955). While sodium appetite in rats can be induced by hypovolemia and/or hyponatremia, the repairing of these conditions, in the absence of taste sensations, is not sufficient to satisfy an existing sodium appetite (Sodium appetite. 1967; Diet preferences . . . 1968). The sense of taste, therefore, is necessary for most efficient satisfaction of a salt appetite. In animals such as ruminants, which often become sodium deficient under normal circumstances, taste assumes a critical role in maintaining "environmental homeostasis" (Bell, 1963); that is, the sense of taste is necessary in order for such animals to identify sodium containing compounds from among a large number of chemicals in the environment.

Organic and mineral acids of identical H^+ concentration evoke different strengths of the sour taste sensation (Crozier, 1916; Gibson and Hartman, 1919). The greater response produced by organic acids over mineral acids at equi-pH is explained on the basis that the undissociated molecules of organic acid are adsorbed to receptor sites and enter into the stimulatory process (Beidler, 1958). The taste qualities of sweet and salty can evoke positive ingestive responses in animals--particularly when deficits exist. The question as to whether or not the sour taste, perhaps signaling for the energy deficient ruminant the presence of a major energy yielding metabolite, would also result in positive ingestive behavior (specific appetite) has not been answered.

Populations of people can be classified, on the basis of reactions to the bitter phenylthiourea-type (PTC) compounds, into "taster" and "non-taster" groups. These groups can be further divided into sensitive and nonsensitive groups according to their reactions to quinine, the distribution of thresholds in both cases being bimodal and indicating a stronger degree of genetic control than for the monomodal distribution of thresholds for such compounds as sodium chloride and sucrose (Fischer, 1967). Sensitive "tasters" of the bitter PTC-type compounds and quinine dislike more foods (on the average) than do "nontasters" of the same two bitter compounds (Fischer and Griffin, 1960; Fischer et al., 1961). Such observations have not been extended to domestic animals.

The usual means of studying taste responses are based either on the electrophysiology of nerves (Zotterman, 1935), on animal behavior or on a physiological response. Behavioral methods include the conditioned-response (developed by Pavlov for use with dogs and modified for use with cattle by Andreev as quoted by Pick, 1961) and the preference test. Preference tests, which may be based on immediate choice or on rate of ingestion (Young, 1948) or on quantity ingested during a standard time period, were developed by Richter (1936) for use with the rat and modified for use with cattle (Stubbs and Kare, 1958; Bell and Williams, 1959), goats (Bell, 1959), and sheep (Goatcher and Church, 1967; Goatcher, 1969). In rats, there is fairly good agreement between threshold values as determined by techniques of conditioned-response, electrophysiology and both single stimulus and two choice (stimulant and water choices) preference tests (Koh and Teitelbaum, 1961; Weiner and Stellar, 1951; Stellar and McCleary, 1952). However, when two or more stimulant choices are allowed in the preference test, selections of sucrose shift to higher concentrations but remain approximately unchanged when sodium chloride is the test chemical (Stellar and McCleary, 1952; Carpenter, 1958).

Species differ in their taste responses and no criteria has yet been found that will explain the reason for the differences (Kare and Ficken, 1963). Species differences have been demonstrated for the rat, rabbit and cat (Pfaffmann, 1953); the cat, rabbit and hamster (Carpenter, 1956); the racoon, cat, dog, rat, hamster and Guinea pig (Beidler, Fishman and Hardiman, 1955) and for the squirrel monkey, rat and human being (Fisher, Pfaffmann and Brown, 1965).

Taste responses have been reported for cattle (Stubbs and Kare, 1958; Bell and Williams, 1959; Bernard and Kare, 1961), goats (Bell, 1959) and sheep (Goatcher and Church, 1967; Goatcher, 1969). All three of these species respond electrophysiologically to stimulants representing the four primary taste groups (Bell and Kitchell, 1966). A comparison of the literature values for taste thresholds of goats, sheep and cattle (Goatcher, 1969) reveals that pronounced differences exist. However, the taste responses of these three species have not been studied in a comparative-type experiment.

Taste Modifiers

There are several compounds which can modify the sensations of taste. Four such compounds are monosodium glutamate (MSG), disodium inosinate (DSI), potassium gymnemate and an unidentified compound occurring in Miracle Fruit. Two of these compounds (MSG and DSI) have similar properties of flavor modification.

Amerine, Pangborn and Roessler (1965) have reviewed the literature on MSG. The compound is widely used in the food industry as a flavor enhancer. Pure glutamates themselves are odorless, but pure MSG, it is reported, has a pleasant, mild flavor with a persistent sweet and salty taste and some tactile sensation. In the amounts commonly added to foods, MSG is itself undetectable, but flavor enhancement occurs even with subthreshold levels. The mechanism of action of MSG has not been determined. However, several theories have been offered. One theory is that the compound acts to increase the acuity of taste receptors or promotes or prolongs sensory acuity for the natural flavor. Others believe that MSG suppresses acuity to undesirable flavors. Still others hold the idea that MSG is a general sensitizer for taste acuity.

Kurtzman and Sjostrom (1964) have reported on the flavor-modifying properties of DSI. The compound was found to be a potent seasoning agent, active in concentrations ranging from .0075 to .05 pph. It was reported to have improved flavor, blend and fullness of food products, and to have the capacity to create the sensation of increased viscosity in liquid or semi-liquid food products.

Potassium gymnemate, a suppressor of sweet taste sensitivity, has been discussed by Warren and Pfaffman (1959). The material occurs naturally in the leaf of a plant, Gymnema sylvestre, found in India. When the leaf is chewed for a short time, the ability to taste sweetness disappears for about an hour and granular sucrose taken into the mouth retains only its sand-like property. The pulverized, dried leaf is active and it is unnecessary to isolate the gymnemic acid.

Of perhaps more interest in the area of practical nutrition would be the observation made in the same report that gymnemic acid reduces the bitter taste sensation. Since a depression in feed intake often occurs when domestic ruminants (cattle, more so than sheep [Schaadt, Johnson and McClure, 1966]) are fed high-urea diets, it would be of interest to determine the effect of gymnemic acid upon consumption of such rations. Other questions of interest might be: Would a reduction in the bitter taste compensate for the elimination of the sweet taste? Could the sweet taste be returned to the ration by artificial sweeteners, such as saccharin or dulcin, while still maintaining the suppressive effect of gymnemic acid upon the bitter taste component?

Inglett et al. (1965) have studied the taste-modifying properties of Miracle Fruit (Synsepalm dulcificum), a small, red berry indigenous to tropical West Africa. It was reported that after the mouth had been exposed to the fruit's mucilaginous substance, sour tasting materials such as lemons, limes and grapefruit and dilute mineral and organic acids are caused to have a pleasant sweet taste, the effect persisting for several hours after exposure. Salty and bitter taste responses did not appear to be affected. Neither the active principle nor the physiological mechanism of action were identified. However, the experimental data indicate that the active substance could be a glycoprotein. The Miracle Fruit concentrate, itself, had no detectable sweetness. It was also suggested that the sweetness produced by the interaction of the Miracle Fruit principle and acid appeared to be too rapid to be accounted for by acid or enzyme hydrolysis of polymeric carbohydrate substances.

It has been suggested that the sour taste may play a role in the rumination process (Bernard and Kare, 1961). It should be possible to test this hypothesis using the sour-taste modifying principle contained in Miracle Fruit. Administration of the material could be accomplished either dietarily or via rumen fistula and the effects upon rumination, noted. Perhaps of interest, also, would be the effect of the Miracle Fruit principle upon the intake of silages, which are acid in nature.

In the case of ruminants, it is a matter of conjecture as to which has the greater influence on intake, the sensory properties of rumination material regurgitated for remastication or the sensory properties of feedstuffs being initially ingested. Feedstuffs may present sensory patterns differing more between themselves after a stay in the rumen than they do when being initially ingested. It would be interesting to know what the effects of the general flavor modifiers, MSG and DSI, would be upon such behavioral acts as feeding and rumination.

There seems to have been no studies reported on the influence of taste modifiers on the ingestive behavior of livestock species, with respect either to food intake or to consumption of solutions containing taste stimulants.

Interaction of Tastes

Taste responses to solutions of pure, individual taste stimulants are of interest. They permit the prediction of ingestive responses when animals are confronted with foods containing high levels of such stimulants--high-urea, protein supplements and high-urea and high-molasses diets, for example. They also allow species comparisons of taste responses to be made. However, in many practical situations, diets contain combinations of taste stimuli and usually these are at moderate to low concentrations. In these cases, the interactions of the tastes become important.

As early as the late 1800's it was observed that the four basic tastes interacted. In 1938, Hahn, Kuckulies and Taeger (cited by

Amerine, Pangborn and Roessler, 1965) determined the effect of exposure to salts upon the threshold for each of the salts. Prior exposure to a specific salt raised the threshold of that salt but not of the others. Exposure to any sweet or bitter compound, however, increased the thresholds for all compounds having that taste quality.

The interaction of several taste stimulants was studied by Fabian and Blum (1943). They mixed a below-threshold concentration of one substance with an above-threshold concentration of a second substance. The solution was then compared to a series of solutions of the second substance alone until a match was obtained. If the two solutions differed with respect to concentration of the second substance, then the first substance was considered to be increasing or decreasing the stimulating effectiveness of the second. Their results are summarized as follows: 1) sodium chloride increased the sweetness of sugars and reduced the sourness of acids; 2) sugars reduced saltiness and sourness; and 3) hydrochloric acid and acetic acid reduced the sweetness of glucose, but other acids had no affect. Hydrochloric and acetic acid had no affect on the sweetness of sucrose, while lactic, malic, citric and tartaric increased its sweetness.

Kamen et al. (1961) studied the interactions of suprathreshold taste stimuli and summarized their data as follows: 1) bitterness did not affect sweetness, but sucrose depressed bitterness; 2) bitterness did not affect saltiness, nor vice-versa; and 3) salt decreased sweetness. Anderson, Funakoshi and Zotterman (1963) reported on the electrophysiological responses to sugars and their depression by salt. It was observed that, when a solution of .5 M sucrose plus .5 M sodium chloride was applied, following the application of .5 M sucrose to the tongues of dogs, a sucrose response occurred. When the mixture was applied following .5 M sodium chloride, a sucrose response did not occur. Thus, the electrophysiological response of sucrose was depressed by that of sodium chloride. This work would seem to support the observation on salt-sweet interaction made by Kamen and coworkers.

Amerine, Pangborn and Roessler (1965) have reviewed the literature pertaining to the interactions of tastes. They make the general conclusions that when taste stimuli are at or near threshold values, the effect of one stimulant on another is a slight depression in intensity if trained panels are used. At higher levels of the stimuli, interactions are more pronounced.

Hironaka and Bailey (1968) have reported on the effect of sugar upon salt consumption by ruminants. Two groups of yearling steers were fed mixtures of salt and sugar while two other groups were fed mixtures of salt and a combination of 92.5% sugar and 7.5% urea. During the first week, salt and sugar were provided in the ratio 100: 0, each subsequent week the salt being reduced by 10 percentage points until a salt-sugar ratio of 20: 80 was achieved. Consumption of the salt-sugar mixture increased with increases in percent sugar. The salt-sugar-urea mixture was slightly less acceptable than the salt-sugar mixture until a level of 70% sugar was reached. The question arises as to whether or not the addition of relatively high levels of raw sugar or an artificial sweetener, such as dulcin, to high-urea diets would prevent the decline in consumption commonly observed in the use of such rations.

The interactions of tastes do not appear to have been studied in domestic animals. Taste interactions may be of some consequence in light of the intake problems associated with some feed additives.

Taste Thresholds

Threshold values serve as a frame of reference on which to base qualitative and quantitative comparisons of taste reactions of either different groups of animals to single stimulants or single types of animals to different stimuli. They are the most often used procedure in studying the psychophysics of taste.

The absolute (or sensitivity) threshold is defined as the minimum detectable concentration and the recognition threshold as the concentration where the taste can first be recognized, the latter being higher than the former (Amerine, Pangborn and Roessler, 1965).

Absolute and recognition thresholds are usually only obtained for human subjects, the testing method being generally of the single stimulus or paired comparison type. Such thresholds may also be determined for lower animals by using the conditioned response procedure.

Thresholds are, at best, only statistical approximations. In general, they suffer from variations due to such things as age, disease, nutritional deficits, testing procedure, physiological state, environmental conditions (temperature, for example), and perhaps, experience, sex and psychological factors.

The electrophysiological threshold may be defined as that concentration that will elicit nerve activity just discernable from background "noise" in recording instruments. Thresholds obtained by the electrophysiological method are subject to fewer modifying factors than are those thresholds derived from behavioral-type procedures. For example, a salt deficiency will reduce the preference threshold concentration, but has no effect on the electrophysiological threshold (Pfaffmann and Bare, 1950). However, in most cases, bioelectric thresholds do not correlate well with behavioral manifestations. For instance, in calves, both quinine and sucrose produce very weak neural responses (Bernard, 1964) at concentrations that are strongly responded to, behaviorally (Stubbs and Kare, 1958). These same studies indicated that strong neural responses occurred to sodium chloride at concentrations where an absence of preference was observed. It was only with acids that a close neural-behavioral association existed. Thus, taste-dependent behavior cannot be predicted on the basis of bioelectric responses, although the latter, would, at least, suggest that differential behavior is possible (Bernard, 1964).

The use of human subjects in taste studies allows thresholds to be determined through subjective evaluations. In lower animals they must be derived through physiological or behavioral techniques. Tests whereby the experimental subject is allowed to discriminate between water and a sapid solution or between two sapid solutions of different concentration yield preference threshold values. A common procedure is to allow an animal its choice between water and a taste stimulant-water solution for a given period of time, after which the quantities ingested of the two fluids are recorded. Preferences are then expressed on the basis of percent of total fluid taken as test solution. Thus, Bell (1959) suggested that, when the test solution comprised 20% of total fluid intake, this be termed the rejection threshold. It should, then, also be reasonable to arbitrarily set 80% of intake as the preference threshold (Goatcher and Church, 1969a).

In order to adequately describe response patterns to a series of concentrations (for purposes of discussions and comparisons), two other thresholds are useful: the concentrations at which significant discrimination between water and test solution occurs. The discrimination may, depending upon species of animal and particular stimulant, be either in a positive direction, significantly greater than 50% of total fluid intake, or negative, significantly less than 50%. Goatcher and Church (1969a) placed sheep in a two-choice preference test, with tap water as both choices, and determined normal variation around a theoretical mean intake of 50%. They placed a 95% confidence interval around the 50% mean and termed the upper confidence limit, the "upper discrimination threshold" and the lower confidence limit, the "lower discrimination threshold". The numerical value of these two thresholds will vary depending upon number of animals and amount of normal variation involved in the study.

EXPERIMENTAL PROCEDURE

Subjects

The animals used in these experiments were eight, each, of African pygmy goats, normal goats, sheep and cattle. Four different subjects of each of the four species of animals were employed in two successive years. The animals used in the first year (Group 1) were numbered 1 through 4, and those employed in the second year (Group 2) were numbered 5 through 8.

The pygmy goats were castrated male kids. Initial weight averaged about 11 kg and final weight approximately 22 kg. They were identified by the numbers 1P through 8P.

In the first year of the study, four yearling Alpine does (numbered 1NAF through 4NAF) comprised the group of normal goats. In the second year, four male castrates (two Saanens, numbered 5NSC and 6NSC, and two Alpines, numbered 7NAC and 8NAC) were used. One of the Saanen castrates (6NSC) died and was replaced with an Angora buck (designated 6NHM). The mean starting weight of these animals was approximately 30 kg and the finishing weight about 36 kg.

The sheep were all Hampshire ewe lambs. They had an average initial and final weight of about 35 and 68 kg, respectively. The identification numbers for the sheep were 1S through 8S. During the first year, sheep 4S died of pneumonia and was replaced with another Hampshire ewe (designated 4SR).

Both groups of cattle were made up of Holstein heifer calves with a mean starting weight of approximately 160 kg. and ending weight of about 320 kg. Their identification numbers were 1C through 8C.

Diet

Each animal was individually penned and fed to appetite on a common diet. The diet was pelleted through a .95 cm. die. The following ingredients and proportions were used:

Ingredient	%
Alfalfa hay	45
Steam rolled barley	35
Beet pulp	10
Wheat millrun	9
Trace-mineralized salt	1

Testing Procedure

The method of testing was based on the two-choice preference test developed by Richter (1936) for use with laboratory animals and later modified for use with cattle (Stubbs and Kare, 1958), goats (Bell, 1959) and sheep (Goatcher and Church, 1967, 1969a).

In the present study, fluid was provided for each animal in two identical containers: 2 l. glass beakers for pygmy goats, 4 l. glass beakers for normal goats and sheep, and 14 l. galvanized buckets (coated with plastic prior to tests with acid) for cattle. These volumes provided a sufficient amount of fluid in each container to meet an animal's requirement for a given amount of time. Two, 22-hour test periods per concentration were allowed the goats; two 10-hour test periods were used for the sheep and cattle. The goats were given a longer test period because they drink less frequently than do sheep and cattle.

At each concentration of the taste stimulants studied, test solution (chemical dissolved in tap water) was measured into one container (for goats and sheep on a volume basis and for cattle on a weight basis) and tap water was measured into the other container. The percent of total fluid intake comprised by the test solution was determined. The relative positions of the two fluids were then reversed for the second test period in order to reduce errors due to positional bias, and a second percentage figure obtained. These two figures were then averaged to obtain the mean response for each animal at each chemical concentration. The chemicals were tested in series of ascending concentrations.

There are two methods available for determining percent of total fluid intake comprised by test solution at each concentration:

1) by averaging the percent of test solution consumed from right position with that consumed from left position, and 2) by totaling the amount consumed from each position and then determining percent. Patton and Ruch (1943) point out that the two methods may give quite different results and argue that in as much as animals drink different amounts of water from day to day, the second method has the effect of a weighted average and, therefore, allows those cases where more solution is drunk (and presumably where more sampling has occurred) to have a greater influence on the preference value. On the other hand, it may be argued that total fluid intake is primarily a function of environmental temperature on that day and amount of food consumed on the previous day, and may in no way be connected with the preference for a particular test chemical. Thus, the first method has the advantage of eliminating the effect of variations in total fluid intake. Also, ruminant animals drink less frequently than do non-ruminants and the number of their drinking sessions is probably not closely related to total fluid intake. The first method seems to be the more proper one to use with ruminants.

Further, Patton and Ruch argue that the use of a descending series of concentrations is preferable to ascending concentrations because it encourages an animal to acquire the habit of sampling (tasting) before drinking. However, when ascending series of concentrations are used, it is commonly observed that digestive upsets occur in ruminant species--these upsets are characterized by diarrhea and the animals going off feed. The condition is usually encountered (when ascending series are used) shortly after the highest levels are offered. It would be expected that when descending concentrations are employed, the digestive disturbances would be intensified and would probably influence responses to the intermediate and lower levels of test solution. Ascending concentrations allow some amount of digestive adjustment to take place. Also, exposure to high levels of aversive chemicals (quinine, for example) would be expected to produce biasing effects at lower (and, perhaps, otherwise acceptable) levels of the same chemical. The use of ascending series of concentrations would seem to be the more desirable method to use in preference tests involving ruminant species.

Chemicals and Tests

Reagent grade chemicals representing each of the four primary taste groups were used: sucrose (sweet), sodium chloride (salty), acetic acid (sour) and quinine hydrochloride (bitter). The chemicals were tested in the order, sucrose (Suc), sodium chloride (NaCl), acetic acid (HAc), quinine hydrochloride (QHCl).

In addition, the sheep and cattle were tested at two concentrations of molasses. The molasses were estimated to contain 60% sucrose. Concentrations were chosen (2.08 and 8.33%) such that sucrose levels of about 1.25 and 5%, respectively, would occur in the test solution. The testing procedure was identical to that previously described.

A tap water vs. tap water test was performed in order to determine normal variation of intake (with respect to either one of the containers) in the absence of chemical treatments. Twenty individual observations (yielding ten averages) were made on each animal.

Statistical Analysis

Statistical analysis of the data was approached in three ways. First, stepwise multiple linear regression analysis was performed in which the quadratic component was tested for significance in increasing R^2 values or discriptiveness of the regression equation. Second, using individual response points at each concentration, means and standard deviations were determined. Third, the data were plotted graphically in order that mean response points could be compared to the various thresholds as shown in Figure 1.

Individual response points at each concentration were used in the regression analysis. The ascending concentrations of chemicals progressed such that each level was twice as great as the one before. The logarithms of the concentrations are related to, and can be replaced by, a linear scale of integers (Amerine, Pangborn and Roessler, 1965). The relevant concentrations and their related

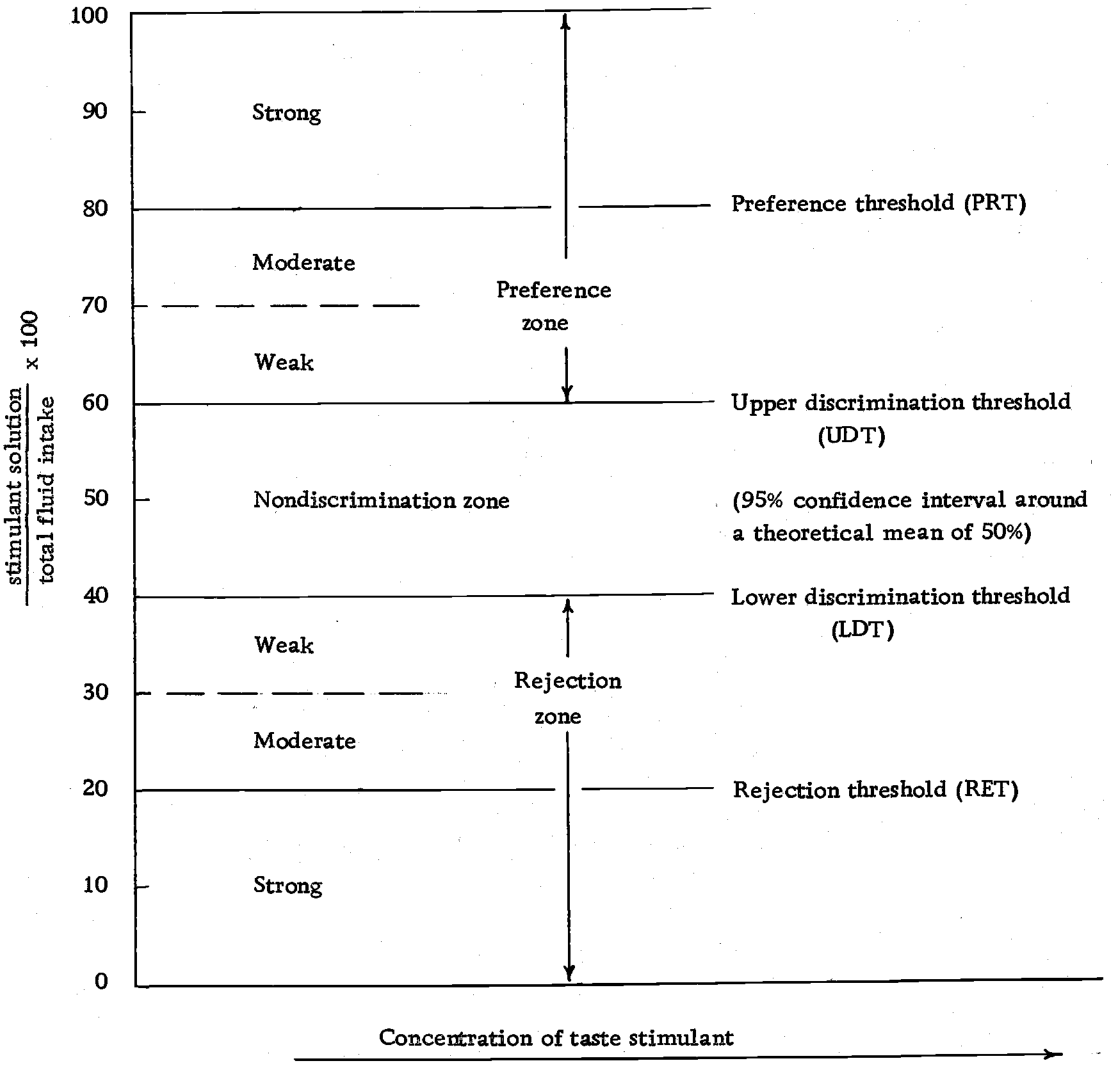

Figure 1. A diagramatic presentation of the relationship between taste responses and various taste thresholds.

integers (the independent regression variable, X) are presented in Appendix Table 1.

The data derived from the tap water vs. tap water test were treated by analysis of variance. F- and t-tests were used to analyze the molasses study.

RESULTS

Water Tests

Appendix Tables 3 through 6 show the consumption data from the water tests. A series of statistical analyses was performed on the data from these tests in order to describe the nondiscrimination zone of responses in two-choice preference tests as proposed by Goatcher and Church (1969a). The analyses involved testing for significance in differences between animal species with respect to variances and means and in differences between means associated with animal types and a theoretical mean of 50% (Goatcher, 1969). Appendix Table 2 presents a summary of the analyses.

The tests indicate that there is a common variance between the responses of the four species of animals, and that group means are essentially equal and closely approach the 50% theoretical mean. Thus, a pooled variance may be used to place a 95% confidence interval around the theoretical mean, and this interval (nondiscrimination zone) will serve equally well for the four species of animals.

The nondiscrimination zone was calculated to be 50% ± 10.41 percentage points. For convenience, the figures were rounded off so that the interval extended from 40 to 60%. A mean response of eight animals falling between 40 and 60% can, therefore, be considered a nondiscrimination reaction--or a reaction that can be expected 19 times out of 20 when water alone is presented in both containers.

Sucrose

The responses to sucrose are given in Appendix Tables 7 through 10 and Appendix Figures 1 through 4. A composite graph of the reactions of the four species of animals is to be found in Figure 2.

Sucrose was tested at concentrations in which increments doubled from .08 to 20%. Mean response points remained within the nondiscrimination zone until a level of 1.25% was reached. At this concentration, normal goats and cattle manifested weak reactions of preference while pygmy goats and sheep were indifferent. At the 2.5% level, pygmies and normals displayed weak preference; cattle, strong preference; and sheep, indifference. Sheep continued to show indifference until the 20% level was reached, at which concentration a moderate strength of rejection was demonstrated. The strength of the preference reactions of normal goats continued to increase through the highest concentration offered (20%); for cattle its strength decreased at the 10% concentration and then became one of moderate rejection at the 20% level. Pygmy goats responded indifferently at the 20% concentration.

On the basis of percent intake of solution, cattle most preferred a concentration of 5%; normals, one of 20%, and pygmies

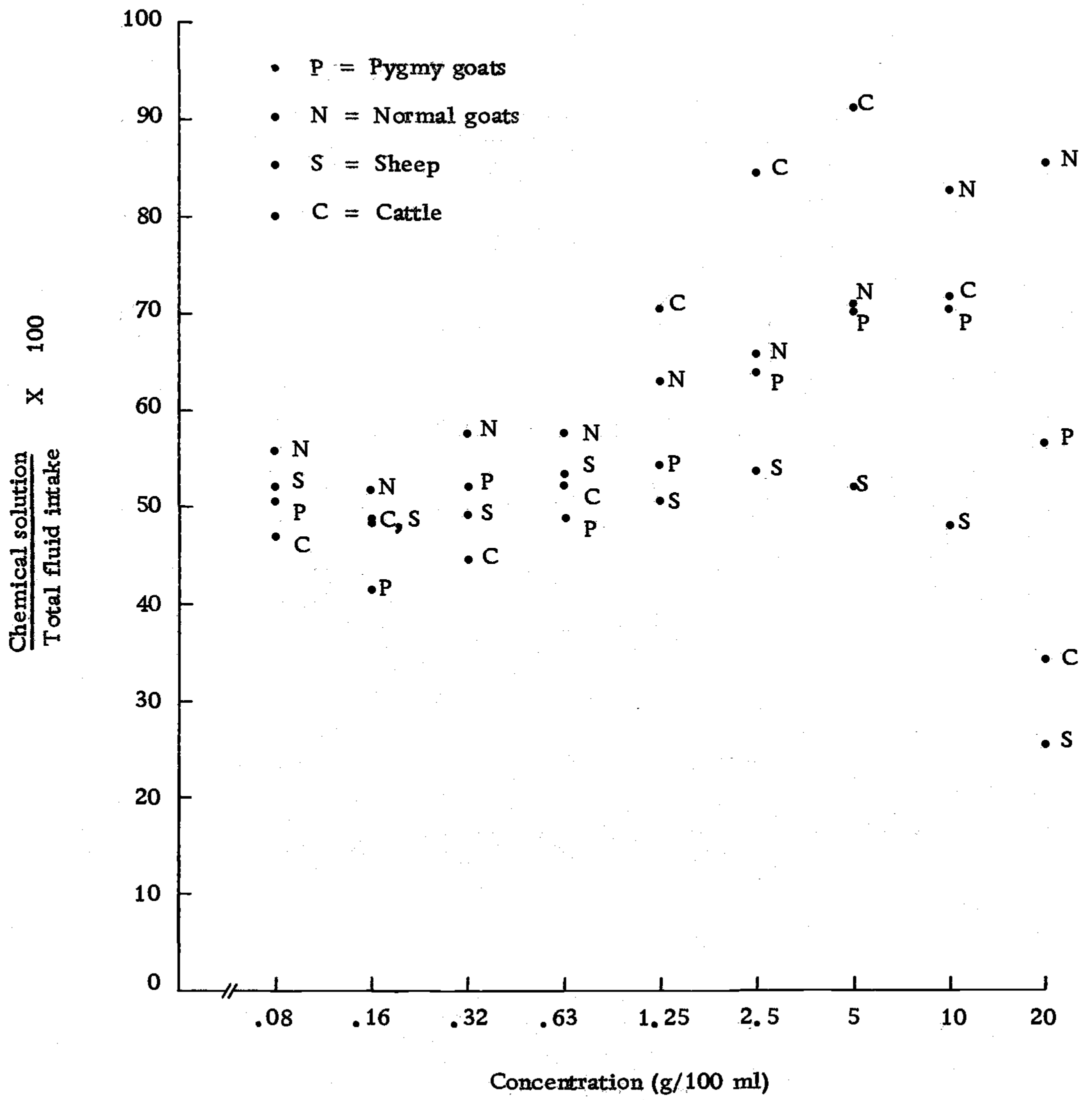

Figure 2. Taste responses of pygmy goats, normal goats, sheep and cattle to ascending concentrations of sucrose.

preferred levels of 5 and 10% equally well. Sheep preferred no concentration offered. Sucrose intake (g/period) increased with increasing concentrations. The most-preferred concentrations did not coincide with concentrations yielding greatest intake in grams.

A summary of thresholds and regressions of taste reactions on ascending concentrations of sucrose is presented in Table 1. The taste reactions of cattle to sucrose crossed the UDT at concentrations of .85% (.025 M), responses ascending (↑), and 14% (.41 M), responses descending (↓). The PRT was crossed at levels of 2%↑ (.058 M) and 8.25%↓ (.24 M). For pygmies, the concentrations at the UDT were 1.88%↑ (.055 M) and 18%↓ (.53 M)--the PRT was not crossed. Responses of normals crossed the UDT and the PRT in only one direction, the concentrations being, respectively, 1.13%↑ (.033 M) and 13%↑ (.38 M). LDT's were obtained only for cattle (19%↓, .56 M) and sheep (14%↓, .41 M). None of the mean responses for the four species of animals crossed the RET.

Inspection of the regression analysis (Table 2) shows that while variation was considerable, trends in responses were significant. This observation holds true for the other three taste stimulants as well.

Sodium Chloride

The reactions to sodium chloride are presented in Appendix

Table 1. Summary of regressions of taste responses on ascending concentrations of sucrose.

Item	Animal Species							
	Pygmies		Normal Goats		Sheep		Cattle	
	↑[d]	↓[e]	↑	↓	↑	↓	↑	↓
Threshold[f]								
UDT								
%	1.88	18.0	1.13				.85	14.00
M	.055	.53	.033				.025	.41
PRT								
%			13.0				2.00	8.25
M			.38				.058	.24
LDT								
%						14.0		19.00
M						.41		.56
RET								
%								
M								
Intercept (a)	32.9		49.1		58.1		31.4	
Slope (b)	24.4 ± 12.2[g]		5.15**				47.1 ± 10.4**	
Slope (c)	-3.89 ± 1.99				3.54		-9.27 ± 1.7**	
% R^2	9.80		24.3		16.2		56.3	
S.E. of est.	21.1		18.5		27.7		18.0	

[d] Responses ascending.

[e] Responses descending.

[f] Thresholds: upper discrimination (UDT), preference (PRT), lower discrimination (LDT), rejection (RET).

[g] Coefficient ± S.E. Slope = 0: **(P < .01).

Table 2. Summary of regressions of taste responses on ascending concentrations of sodium chloride.

	Animal Species							
	Pygmies		Normal goats		Sheep		Cattle	
Item	↑[d]	↓[e]	↑	↓	↑	↓	↑	↓
Threshold[f]								
UDT								
%	.14	1.25	.16	.16				
M	.024	.21	.027	.027				
PRT								
%	.59	.82						
M	.10	.14						
LDT								
%		2.12		.85		1.25		.096
M		.36		.15		.21		.016
RET								
%		3.50		3.25		3.12		.82
M		.60		.55		.53		.14
Intercept (a)	46.3		61.2		55.9		42.2	
Slope (b)	16.8 ± 5.09[g], **				-15.9**			
Slope (c)	-2.93 ± .55**		-.73**				-1.2**	
% R^2	63.0		45.0		45.4		21.0	
S.E. of est.	20.2		21.7		14.9		20.8	

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[d] Responses ascending.

[e] Responses descending.

[f] Thresholds: upper discrimination (UDT), preference (PRT), lower discrimination (LDT), rejection (RET).

[g] Coefficient ± S.E. Slope = 0: **(P < .01).

Tables 11 through 14 and Appendix Figures 5 through 8. A composite graph of the responses of the four species of animals is given in Figure 3.

Salt was tested at concentrations in which succeeding increments doubled from .02 to 10%. Mean response points were essentially of an indifferent nature until a level of .16% was reached. Here, pygmy goats displayed a weak preference; normal goats, a very weak preference; sheep, indifference; and cattle, weak rejection. Responses of cattle continued to be in the direction of rejection while those of pygmies progressed erratically in the preference direction. Sheep remained indifferent up to 1.25%, at which time rejection began to occur. The trend of responses of normal goats was consistently toward rejection after the .16% level. At 2.5%, the preference response of the pygmies turned to moderate rejection.

The most preferred concentration was for pygmies, .63% and for normals, .16%. Sheep and cattle manifested no preferences. Salt consumption was greatest for pygmies at the 1.25% level; for normals, at 10%; for sheep, at 1.25%; and for cattle, at .63%. The concentration at which greatest salt consumption occurred did not coincide with most-preferred concentration. In general, salt consumption peaked at high-intermediate levels and then tailed off at higher concentrations.

A summary of thresholds and regressions of taste responses

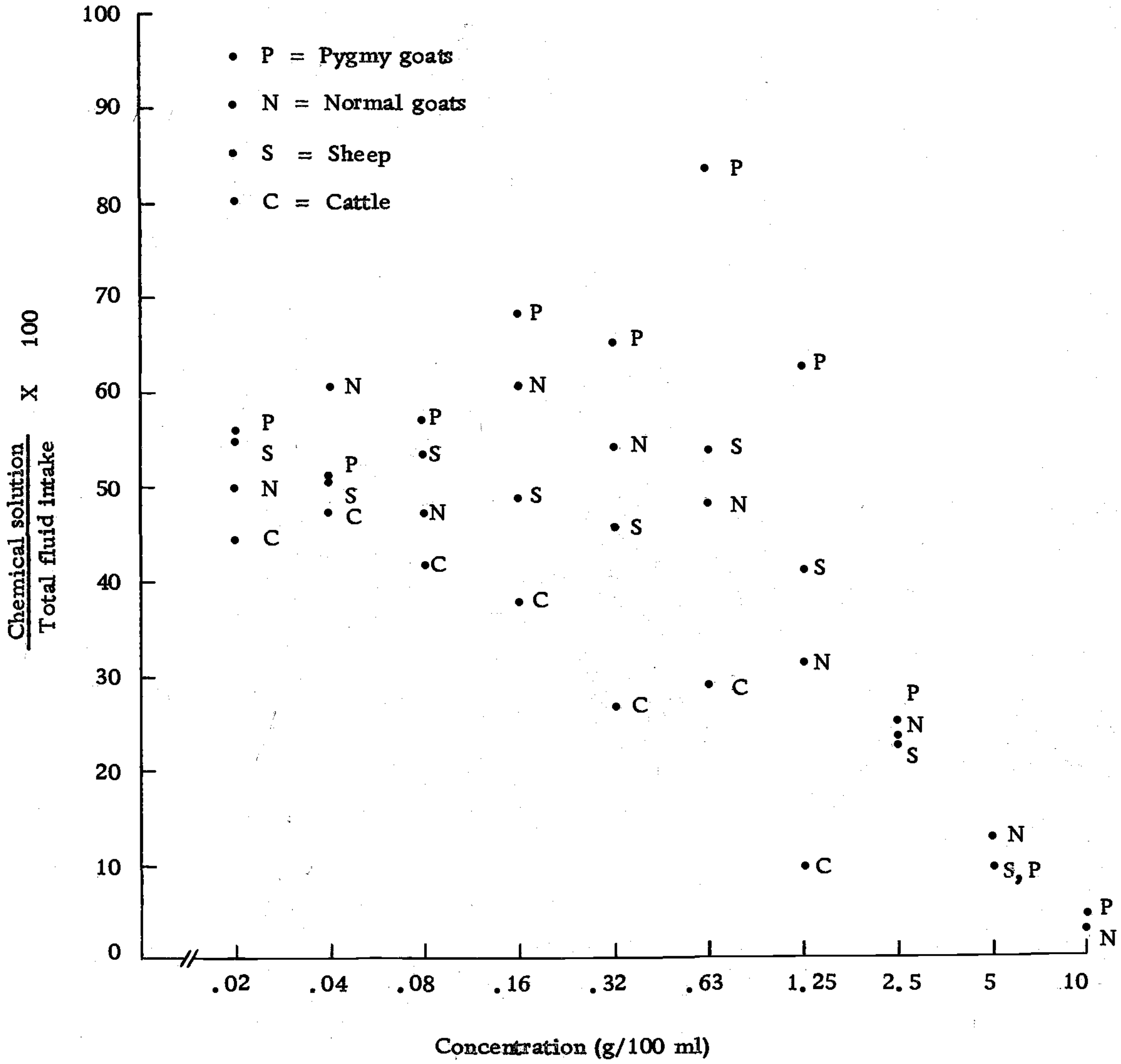

Figure 3. Taste responses of pygmy goats, normal goats, sheep and cattle to ascending concentrations of sodium chloride.

on ascending concentrations of salt is displayed in Table 2. The UDT was approached only by taste responses of normal goats (.16%↑↓ .027 M) and crossed only by those of pygmy goats (.14%↑, .024 M; 1.25%↓, .21 M). The PRT was crossed only by the reactions of pygmies (.59%↑, .10 M; .82%↓, .14 M). The LDT was crossed first by cattle responses (.096%↓, .016 M), second by normals (.85%↓, .15 M), third by sheep (1.25%↓, .21 M) and last by pygmies (2.12%↓, .36 M). The lowest concentration at the RET was obtained with cattle and was at .82%↓, .14 M. RET levels for sheep, normals and pygmies were similar: 3.12↓, .53 M; 3.25%↓, .55 M and 3.5%↓, .60 M, in the same order.

Acetic Acid

The responses to acetic acid are reported in Appendix Tables 15 through 18 and Appendix Figures 9 through 12. A composite graph of the reactions of the four types of animals is presented in Figure 4.

Acid was tested at concentrations in which succeeding increments doubled from .005 to 2.5 ml%. Cattle commenced to discriminate between acid solution and water at .01 ml% (pH 4.8), and demonstrated moderate preference at .02 ml% (pH 4.4). Sheep and pygmy goats began to discriminate at .02 ml% (pH 4.4) in the preference direction. Normal goats failed to discriminate until the .04 ml% (pH 3.9) level was reached, such level prompting a weak

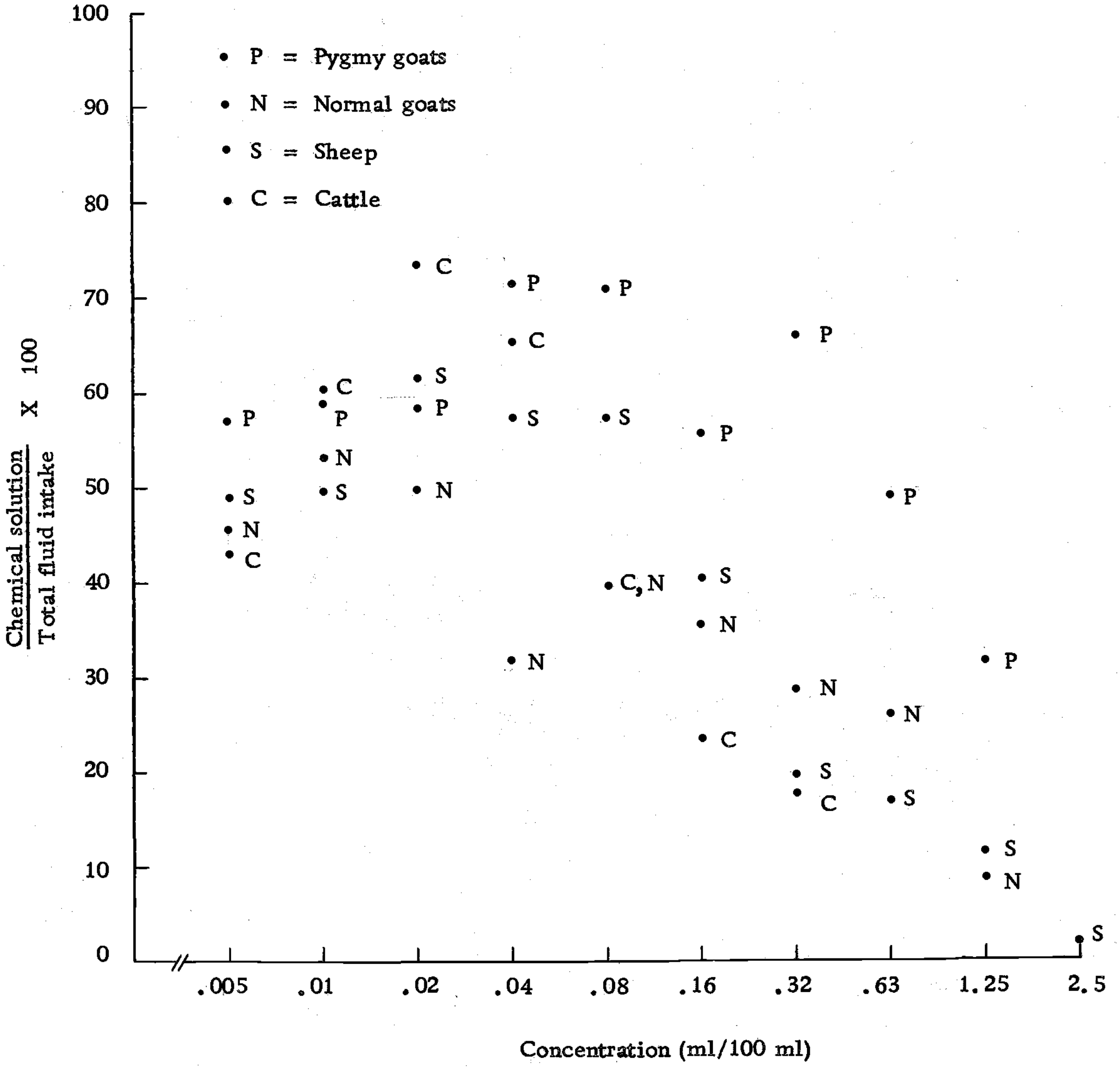

Figure 4. Taste responses of pygmy goats, normal goats, sheep and cattle to ascending concentrations of acetic acid.

rejection reaction. The responses of normals remained in the zone of weak rejection until the .32 ml% (pH 3.1) level was encountered, and then commenced a further decrease. The reactions of sheep fell back within the nondiscrimination zone at levels of .04 (pH 3.9) and .08 ml% (pH 3.6), and at .16 ml% (pH 3.3) declined to rejection responses. Pygmy goats maintained a moderate preference at concentrations of .04 (pH 3.9) and .08 ml% (pH 3.6). Responses then commenced to decline slowly and erratically. After the moderate preference demonstrated by cattle at .02 ml%, responses started to fall rapidly and became rejection reactions at .08 ml% (pH 3.6).

Cattle and sheep most preferred a .02 ml% (pH 4.4) acid concentration. Pygmies most preferred levels of .04 (pH 3.9) and .08 ml% (pH 3.6). Normals preferred no concentration offered. Quantity-wise, pygmies ingested the greatest amount of acid at a concentration of 1.25 ml% (pH 2.7); normals, at .63 ml% (pH 2.9); sheep, at 1.25 ml% (pH 2.7); and cattle, at .32 ml% (pH 3.1). Levels at which the greatest amounts of acid were ingested did not correspond to most-preferred concentrations. In general, acid consumption was greatest at the .32, .63 and 1.25 ml% levels.

A summary of thresholds and regressions of taste reactions on ascending concentrations of acid is given in Table 3. The UDT was crossed by the responses of cattle (.01 ml%↑, .0017 M, pH 4.8; .04 ml%↓, .0069 M, pH 3.9) and pygmies (.02 ml%↑, .0034 M, pH 4.4;

Table 3. Summary of regressions of taste responses on ascending concentrations of acetic acid.

	Animal Species							
	Pygmies		Normal goats		Sheep		Cattle	
Item	↑[d]	↓[e]	↑	↓	↑	↓	↑	↓
Threshold[f]								
UDT								
ml%	.02	.24			.02	.02	.01	.04
M	.0034	.042			.0034	.0034	.0017	.0069
pH	4.4	3.2			4.4	4.4	4.8	3.9
PRT								
ml%								
M								
pH								
LDT								
ml%		.94		.08		.16		.08
M		.16		.014		.028		.014
pH		2.8		3.6		3.3		3.6
RET								
ml%		> 1.25		.63		.54		.22
M		> .22		.11		.094		.038
pH		> 2.7		2.9		3.0		3.2
Intercept (a)	42.4		39.4		59.6		70.7	
Slope (b)	12.1 ± 5.94[g],*							
Slope (c)	-1.43 ± .58*		-.73*		-.77**		-1.59**	
% R^2	11.5		12.5		40.0		43.7	
S.E. of est.	28.7		24.2		25.4		22.5	

[d] Responses ascending.

[e] Responses descending.

[f] Thresholds: upper discrimination (UDT), preference (PRT), lower discrimination (LDT), rejection (RET).

[g] Coefficient ± S.E. Slope = 0: *(P < .05), **(P < .01).

.24 ml%↓, .042 M, pH 3.2). The UDT was approached by sheep responses: .02 ml%↑↓, .0034 M, pH 4.4. The PRT was not crossed by any of the four species of animals. The LDT was crossed first by responses of cattle and normals (.08 ml%↓, .014 M, pH 3.6), second by sheep (.16 ml%↓, .028 M, pH 3.3) and last by pygmies (.94 ml%↓, .16 M, pH 2.8). Rejection (RET) for cattle was at .22 ml%↓, .038 M, pH 3.2; for sheep, .54 ml%↓, .094 M, pH 3.0; for normals, .63 ml%↓, .11 M, pH 2.9; and for pygmies, > 1.25 ml%↓, > .22 M, < pH 2.7.

Quinine Hydrochloride

The reactions to quinine are to be found in Appendix Tables 19 through 22 and Appendix Figures 13 through 16. A composite graph of the responses of the four species of animals is presented in Figure 5.

Quinine was tested at concentrations in which succeeding increments doubled from .63 to 80 mg%. Pygmies and normals responded with weak preferences at concentrations of .63 and 1.25 mg%. At levels of 2.5 mg% and up, the trend of mean reactions was in the direction of rejection. Cattle remained indifferent to quinine solutions at concentrations of .63 and 1.25 mg%; at the 2.5 mg% level their responses assumed a rejection trend. Sheep reactions remained within the non-discrimination zone until the 5 mg% level was

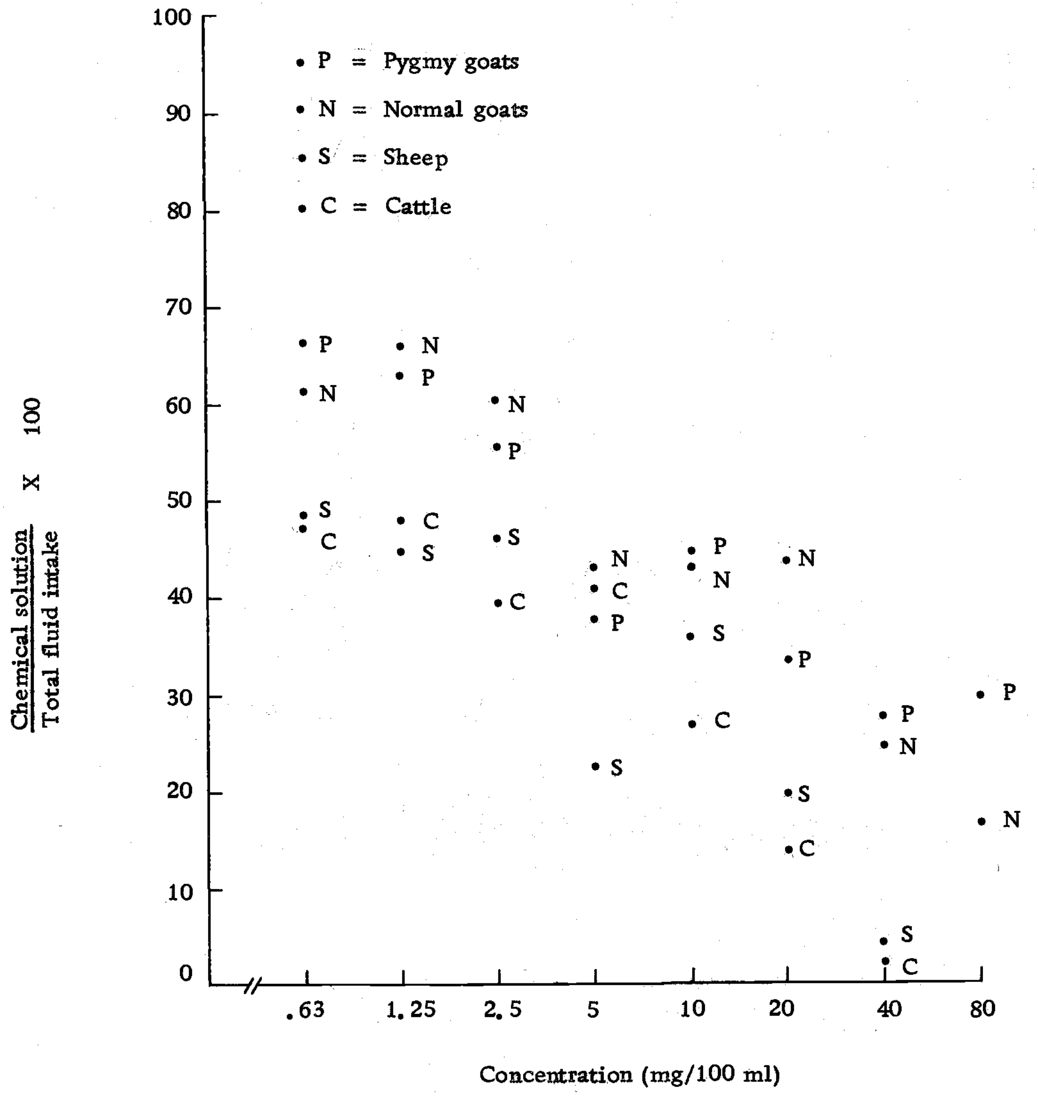

Figure 5. Taste responses of pygmy goats, normal goats, sheep and cattle to ascending concentrations of quinine hydrochloride.

reached--they then declined erratically.

The concentration most preferred by pygmies was .63 mg% or lower, and that by normals, 1.25 mg%. Sheep and cattle preferred no concentration offered. Both pygmies and normals ingested increasingly greater amounts of quinine as concentrations increased. The greatest consumption for both was at the highest level offered: 80 mg%. Consumption by both sheep and cattle, peaked at an intermediate level: 10 mg%. There was no correspondence between most-preferred concentrations and levels at which greatest quinine consumption occurred.

A summary of thresholds and regressions of taste responses on ascending concentrations of quinine is displayed in Table 4. The UDT was exceeded by reactions of pygmies (< .63 mg%↑, < .016 M; 1.88 mg%↓, .047 M) and normals (.63 mg%↑, .016 M; 2.5 mg%↓, .063 M), but not by sheep or cattle. The PRT was not crossed by any of the four species of animals. LDT values were for pygmies, 12 mg%↓, .30 M; and for normals, 14 mg%↓, .35 M. For sheep and cattle, LDT's were at lower levels: 3.75 mg%↓, .094 M and 5 mg%↓, .13 M, respectively.

Molasses

The responses of sheep and cattle to two concentrations of molasses (2.08 and 8.33%) are displayed in Appendix Tables 23 and

Table 4. Summary of regressions of taste responses on ascending concentrations of quinine.

	Animal Species							
	Pygmies		Normal goats		Sheep		Cattle	
Item	↑[d]	↓[e]	↑	↓	↑	↓	↑	↓
Threshold[f]								
UDT								
mg%	$<$.63	1.88	.63	2.50				
mM	$<$.016	.047	.016	.063				
PRT								
mg%								
mM								
LDT								
mg%		12.0		14.0		3.75		5.0
mM		.30		.35		.094		.13
RET								
mg%		80.0		80.0		14.0		15.0
mM		2.02		2.02		.35		.38
Intercept (a)	71.3		64.0		40.7		43.1	
Slope (b)	-5.9**							
Slope (c)			-.75**		-1.39**		-1.71**	
% R^2	26.8		40.3		24.7		47.2	
S.E. of est.	22.7		19.6		21.6		16.1	

[d] Responses ascending.

[e] Responses descending.

[f] Thresholds: upper discrimination (UDT), preference (PRT), lower discrimination (LDT), rejection (RET). Slope = 0: **(P $<$ .01).

24, and a statistical analysis of the data is presented in Appendix Table 25. A composite graph of their reactions is presented in Figure 6.

The mean response of sheep did not differ appreciably from the 50% theoretical mean ($P > .10$). Cattle responses were greater than 50% intake at the 2.08% concentration ($P < .01$) and the 8.33% level ($P < .10$). Cattle responded more strongly to both the 2.08% ($P < .05$) and 8.33% ($P < .10$) molasses solution than did sheep. There was no appreciable difference between sheep responses at low and high molasses levels ($P > .10$), but between cattle responses, the difference was significant ($P < .05$).

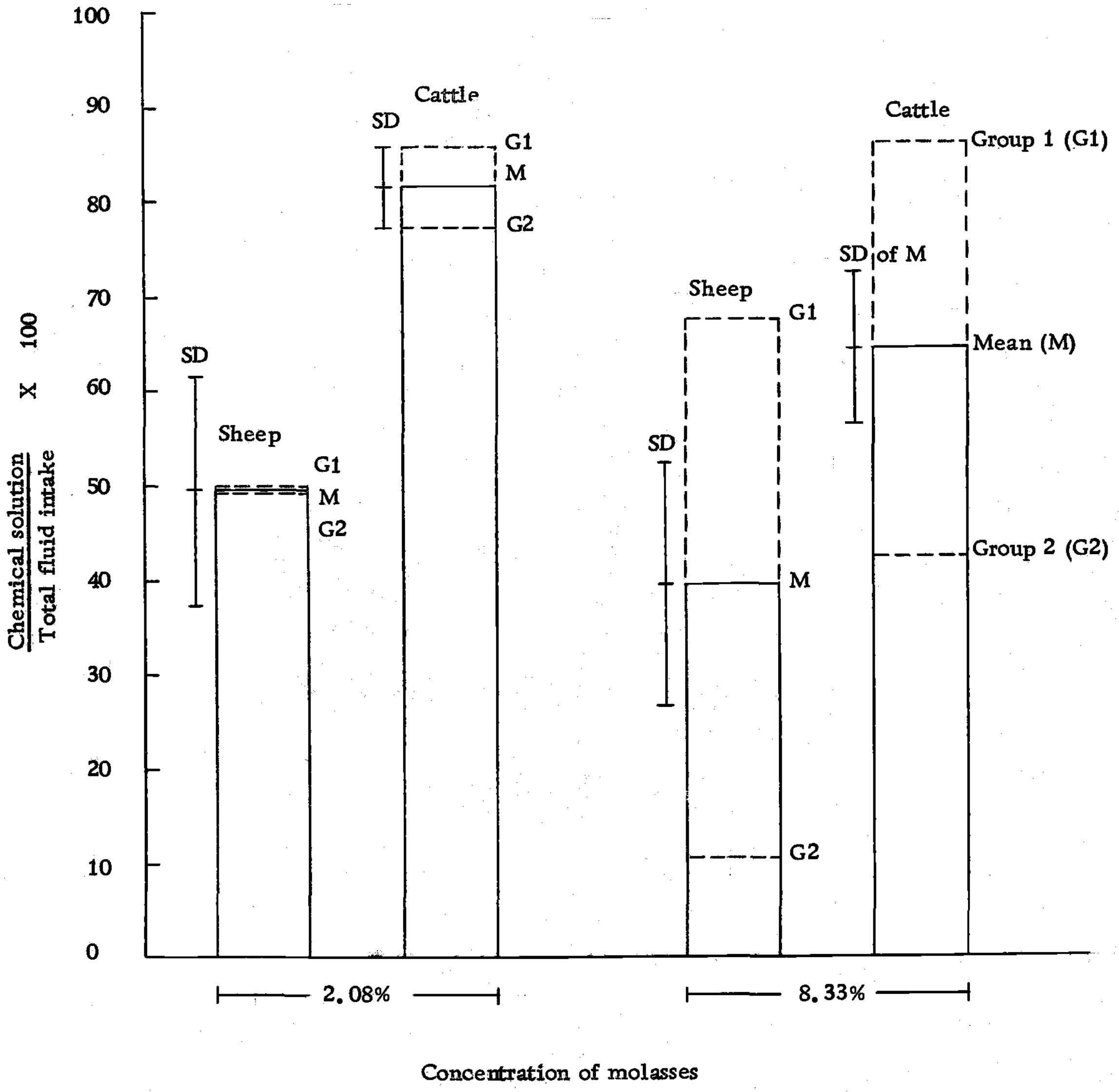

Figure 6. Responses of two groups of sheep and two groups of cattle to two concentrations of molasses, with water as the alternate choice at each concentration.

DISCUSSION

Taste thresholds of the four species of animals for the four chemicals are reported in Table 5.

Cattle were the most sensitive tasters of sucrose. They commenced to discriminate between sucrose solution and water at concentrations lower than did the other species and they reached a higher level of intake (91.5% intake at 5% concentration). However, the strength of their preference responses began to decline at relatively lower concentrations. The next most sensitive tasters of sucrose were normal goats. Unlike cattle, which showed a peak strength of preference at an intermediate concentration, normals responded with increasing strengths of preference up through the highest level of sucrose offered (20%). Pygmies were somewhat less sensitive than normals and displayed weaker strengths of preference than either cattle or normals. Sheep were the least sensitive of all at lower and intermediate sucrose concentrations. At the 20% level of sugar, normals reacted with strong preference; pygmies, with indifference; cattle, with weak rejection; and sheep, with moderate rejection. Based upon the lowest concentration discriminated, the sensitivities of the four species were in the order: cattle > normal goats > pygmies > sheep.

The most sensitive tasters of sodium chloride were cattle. The

Table 5. Taste threshold concentrations of sucrose, sodium chloride, acetic acid and quinine hydrochloride for pygmy goats, normal goats, sheep and cattle.

Chemical	Pygmies	Normal Goats	Sheep	Cattle
Sucrose				
UDT (M)	.055	.033	--	.025
PRT (M)	--	.38	--	.058
LDT (M)	--	--	.41	.56
RET (M)	--	--	--	--
Sodium Chloride				
UDT (M)	.024	.027	--	--
PRT (M)	.10	--	--	--
LDT (M)	.36	.15	.21	.016
RET (M)	.60	.55	.53	.14
Acetic acid				
UDT (M, pH)	.0034,[a] 4.4[b]	--	.0034, 4.4	.0017, 4.8
PRT (M, pH)	--	--	--	--
LDT (M, pH)	.16, 2.8	.014, 3.6	.028, 3.3	.014, 3.6
RET (M, pH)	>.22, 2.7	.11, 2.9	.094, 3.0	.038, 3.2
Quinine				
UDT (mM)	<.016	.016	--	--
PRT (mM)	--	--	--	--
LDT (mM)	.30	.35	.094	.13
RET (mM)	2.02	2.02	.35	.38

---

[a] Molarity.

[b] pH.

trend of responses was toward rejection. Pygmies were the next most sensitive tasters of salt, but the response trend was toward preference. These animals manifested a strong preference reaction at the .63% level of salt. The only other preference response obtained with salt was for normals, the third most sensitive taster, but the reaction was one of only very weak preference. As was the case with sucrose, sheep were the least sensitive to sodium chloride. Their response pattern was one of rejection. At the highest concentration of salt offered to all four species (1.25%), pygmies demonstrated strong preference; sheep and normals, indifference; and cattle, strong rejection. With respect to the lowest level of salt discriminated, the sensitivities of the animals are in the order: cattle > pygmies > normal goats > sheep.

Cattle were the first to make a discrimination in the acetic acid solutions. The responses were ascending and they reached a maximum strength of preference at a low concentration in the series. Pygmies and sheep were about equal in sensitivity and were next in order following cattle. Sheep displayed a weak preference at .02 ml% concentration; their reactions thereafter assumed a rejection trend. Pygmies, on the other hand, continued to prefer the acid solution until a relatively high concentration (.32%) was reached. Normals were the least sensitive to, and demonstrated no preference for, acid solution. At the highest concentration offered to the four species (.32%), pygmies reacted with weak preference; normals, with moderate rejection; and sheep and cattle, with strong rejection. As determined by lowest concentration of acid discriminated, the sensitivities of the animal species are in the order: cattle > pygmies = sheep > normal goats.

Pygmies and normals were first to discriminate between quinine solution and water. Weak preference was indicated by both at the lowest concentration offered (.63 mg%). The responses of pygmies and normals were similar in strength and both declined as concentrations increased. Sheep were next in sensitivity, followed fairly closely by cattle. Neither sheep nor cattle displayed preference for any level of quinine. At the highest concentration of quinine offered to all four species of animals, pygmies and normals responded with moderate rejection, and sheep and cattle demonstrated strong rejection. Based upon concentration first discriminated, the sensitivities of the animals are in the order: pygmies = normal goats > sheep > cattle.

In summary, the sensitivities of the animal species within taste groups are:

Sensitivity series:	animal species within taste group (discrimination).
Sweet:	cattle > normals > pygmies > sheep
Salty:	cattle > pygmies > normals > sheep
Sour:	cattle > pygmies = sheep > normals
Bitter:	pygmies = normals > sheep > cattle

With respect to molarity of first concentration discriminated, the sensitivity series of the four taste groups for pygmies, normals and cattle was: sweet, salty, sour, bitter. For sheep it was: salty, sweet, sour, bitter. The reversal of the relative positions of sweet and salty taste groups within the sensitivity series for sheep, reflects the indifference demonstrated by sheep at concentrations where goats and cattle react with preference. Sensitivity series for animal species are summarized as follows:

Sensitivity series:	taste group within animal species (discrimination).
Pygmies:	sweet < salty < sour < bitter
Normals:	sweet < salty < sour < bitter
Sheep:	salty < sweet < sour < bitter
Cattle:	sweet < salty < sour < bitter

If tolerance (rejection threshold concentration) is used as the criteria, the series remains unchanged for pygmies, normals and cattle, but for sheep it changes to one corresponding to that for the other animals (that is, sweet < salty < sour < bitter).

Likewise, the sensitivity series for animal types within taste groups are altered markedly when RET levels are the basis for comparison. RET levels are not available for the sweet taste group. This comparison may be summarized as follows:

Sensitivity series: animal species within taste group (tolerance).

Salty: cattle > sheep > normals > pygmies
Sour: cattle > sheep > normals > pygmies
Bitter: sheep = cattle > normals = pygmies

In general, stimulating effectiveness was greatest for bitter, followed in order by sour, salty and sweet. Cattle were usually first to make a discrimination, goats were generally second and sheep were normally last. The major exception was for the bitter taste group where the order was goats, sheep, cattle. As a rule, goats were more tolerant of high concentrations than were sheep and sheep were more tolerant than were cattle. The exception was, again, the bitter taste group where the order was goats, cattle, sheep.

Individual responses varied appreciably from means. For example: At the 5% level of sucrose, the mean response of sheep was 57.4% intake, the reaction of sheep 3S was 3.5% intake and that of sheep 5S, 84.5% intake. This pattern was characteristic over species within chemicals and over chemicals within species. There was no apparent relationship between individual responses toward one chemical and responses toward another chemical. For example: With respect to individual response patterns relative to mean response patterns, those of heifer 6C were high for sucrose and low for sodium chloride, those for heifer 7C were low for sucrose and high for salt, and those for heifer 8C were low for both sucrose and salt. Neither were responses toward one concentration of a chemical consistently related to responses toward another concentration. In illustration: For pygmy goat 2P, the individual response pattern relative to mean response pattern was low at lower concentrations and high at higher concentrations; for pygmy goat 7P the reverse was true.

The range in differences between responses of groups within species to single chemical concentrations varied from 0 to 71.1 percentage points. The greatest single difference was demonstrated by sheep at .08 ml% acetic acid: the difference between responses of Group 1 and 2 was 71.1 percentage points. However, pygmy goats exhibited large differences more consistently than did the other three species.

There is no proven explanation for group differences nor is there a proven explanation for individual differences within groups. A great deal of the individual variation can probably be attributed to normal biological variation. With respect to individual variations in taste responses, there is probably an evolutionary survival value involved. Such a process would allow groups of animals to more effectively utilize the natural foods growing in a particular area. With a diversity of taste preferences within a group of animals, the result would be less grazing pressure on individual species of vegetation. Also of importance with respect to individual variations is the variable physiological state of the animal. This process might on one day dictate one response to a certain concentration of a given chemical and on the next day dictate a considerably different response to the same concentration of the same chemical.

Two factors that may have influenced group variation were: 1) environmental temperature differences between testing periods for the two groups, and 2) the psychological makeup of the animals. Group 1 was tested during a different year from Group 2, and environmental temperatures were likely seldom the same for the test periods for both groups. These temperature differences may have affected the taste responses to varying degrees. The psychological makeup of the animals would include, among other things, the influence of prior treatment on their propensity to accept the taste solutions offered. This factor may be responsible for the large differences in group responses of pygmy goats. Group 1 pygmies were suckled by their mothers and were handled only infrequently, the result being that they were not unusually docile. Group 2 pygmies, on the other hand, were early taken from their mothers and bottle fed. As a result, they were extremely docile and trusting. An inspection of Appendix Figures 1, 5, 9 and 13 shows that Group 2 was consistently more tolerant of the chemical solutions offered. This may be reflecting their more psychologically dependent nature due to the bottle feeding experience.

An examination of the graphical presentations of means and standard deviations given in Appendix Figures 1 through 16 shows that the magnitude of group variations depends upon animal species, chemical and concentration. In illustration: The deviation of cattle responses at 5% sucrose was less than that at 10% sucrose, and was less than that of pygmy goat responses at 5% sucrose. The deviation of normal goat responses at 1.25% sodium chloride was less than that at 1.25% acetic acid.

Based on concentration at the LDT, goats and sheep were about 10 times more tolerant of salt than were cattle. Thus, in environments where water supplies contain appreciable amounts of sodium chloride and/or sodium carbonates, sheep and goats would seem to be the most suitable to use for production purposes.

Goats and sheep (as is pointed out later in this discussion) are more tolerant of bitter-tasting materials than are cattle. This tolerance of goats and sheep for bitterness is reflected in their dietary preferences. Both of these species evolved at higher elevations than did cattle, where they were obliged to consume browse-type vegetation which is normally bitter in taste.

As was pointed out in Review of Literature, threshold values are useful primarily in comparisons of taste responses between species and chemicals. On a practical basis, threshold values may be used as a guide in selecting the chemical and concentration necessary to achieve a desired response in dietary intake--either an increase or decrease.

Bell (1959) has reported on taste thresholds of goats and cattle. Goatcher and Church (1969a, b) have presented data pertaining to taste thresholds of sheep. Table 6 shows a comparison of these literature values with the values obtained in the present study.

In comparing the values for normal goats, there is fairly good agreement in NaCl levels at both the LDT and RET, and in quinine levels at the RET. The other values do not compare well, HAc and quinine concentrations at the LDT not even being of the same order of magnitude. Much the same is true in the comparison of values for sheep. With the exception of LDT concentrations of sucrose and RET levels of NaCl and HAc, differences are about one order of magnitude in size. In the cattle comparison, only RET levels of NaCl and HAc compare favorably. Considering the comparisons for all animal species, RET values were generally in closer agreement.

Much of the discordance between threshold values of the studies can perhaps be explained on the basis of differences in testing procedure. Bell's study involved the use of descending series of concentrations. Descending, as opposed to ascending series, results in quite different response patterns (Patton and Ruch, 1943; Kare and Ficken, 1963). Also, Bell used quinine dihydrochloride and glucose, whereas, in the present study, quinine monohydrochloride

Table 6. A comparison of some taste threshold values for normal goats, sheep and cattle.

	Normal Goat			
	LDT		RET	
Stimulant	This study	Bell (1959)	This study	Bell (1959)
Sugar (M)	--[a]	2.2[b]	--[a]	--[b]
NaCl (M)	.15	.21	.55	.84
HAc (M)	.014	.208	.11	.833
Quinine (mM)	.035[c]	.31[d]	2.0[c]	3.1[d]

	Sheep			
	LDT		RET	
	This study	Goatcher and Church (1969a, b)	This study	Goatcher and Church (1969a, b)
Suc (M)	.41	.47	--	--
NaCl (M)	.21	.043	.53	.38
HAc (M)	.028	.0024	.094	.028
QHCl (mM)	.094	.48	.35	3.7

	Cattle			
	LDT		RET	
	This study	Bell (1959)	This study	Bell (1959)
Sugar (M)	.56[a]	1.11[b]	--[a]	--[b]
NaCl (M)	.016	.105	.14	.42
HAc (M)	.014	.0083	.038	.026
Quinine (mM)	.013[c]	.024[d]	.38[c]	.097[d]

[a] Sucrose

[b] Glucose

[c] QHCl

[d] Q2HCl

and sucrose was used. Sucrose is about twice as sweet as glucose. Goatcher and Church employed ascending concentrations of taste stimulants in their study, but used two units of five animals, each, and placed each unit on alternate concentrations. This provided a series of concentrations ascending at twice the rate of those used in the present study. Another item that might help explain the differences in thresholds between studies is the length of time of exposure to each concentration. In Bell's work, two-day testing periods were used at each concentration. In the present study, two-day testing periods were used only for pygmy and normal goats.

Goatcher (1969) presented LDT and RET values for quinine taste responses in three groups of ten sheep, each. The LDT values for Groups 1, 2 and 3, respectively, were .82, .11 and .15 mM; and the RET values were 4.4, .5 and 3.0 mM. He assumed that a prior test with urea had biased the results for Group 2 and, thus, accounted for the relatively low values obtained with those animals. The values were, therefore, disregarded when average figures for thresholds were determined. The values obtained with sheep in the present study agree rather closely with those that he obtained with Group 2 animals. It is likely that the results reported for the group of sensitive quinine tasters were not biased but reflected a natural sensitivity.

If the figures reported by Goatcher are averaged with the ones obtained in the present study, a quinine concentration at the LDT of

.29 mM and one at the RET of 2.06 mM is obtained. These two figures agree quite well with the values reported for the goat by Bell (1959), as is shown in the upper portion of Table 6.

Electrophysiological thresholds have been reported for cattle by Bernard and Kare (1961) and for goats, sheep and cattle by Bell and Kitchell (1966). Andreev (1954) has determined taste thresholds for cattle by the conditioned-response technique. A comparison of thresholds obtained by these methods with discrimination thresholds determined by the preference test is given in Table 7.

In cattle and goats, sucrose is less effective electrophysiologically than behaviorally; in sheep it is of about equal effectiveness. In all three species, NaCl is more effective electrophysiologically than behaviorally, the greatest disparity being between the values for sheep. In cattle, preference and bioelectric thresholds for HAc were in close agreement. The correspondence between values for goats and sheep cannot be readily assessed because of the lack of preciseness of the electrophysiological value reported. As was the case with sucrose, quinine is more effective behaviorally than electrophysiologically. The difference in effectiveness is very substantial and is greater in goats than in sheep or cattle.

Referring to the comparison involving threshold values for cattle derived by three different testing techniques, it can be seen that there is good agreement between conditioned-response and

Table 7. A comparison of taste threshold values determined by different testing techniques.

	Goats		Sheep		Cattle	
Stimulant	P[a]	E[b]	P[a]	E[b]	P[a]	E[b]
Suc (M)	.033	.45[d]	.41	.45[d]	.025	.45[d]
NaCl (M)	.027	.005[d]	.21	.005[d]	.016	.001[e]
HAc (M)	.014	<.2[d]	.0034	<.2[d]	.0017	.001[e]
Quinine (mM)	.016[f]	20[d, g]	.094[f]	20[d, g]	.13[f]	20[d, g]

	Cattle		
	P[a]	CR[c]	E[b]
Suc (M)	.025	.3	.45[d]
NaCl (M)	.016	.002	.001[e]
Acid (M)	.0017[h]	.001[i]	.001[e, h, i]
Quinine (mM)	.13[f]	.01[f]	20[d, g]

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[a] Present preference test, values are lowest concentration discriminated.

[b] Electrophysiological method.

[c] Conditioned-response technique, Andreev (1954).

[d] Bell and Kitchell (1966).

[e] Bernard and Kare (1961).

[f] QHCl.

[g] Q2HCl.

[h] HAc

[i] HCl

electrophysiology in all but the quinine values. Preference values corresponded more closely to conditioned-response values than to those derived electrophysiologically. The preference value obtained for sucrose (.025 M) agrees well with a value of .022 M reported by Pick and Kare (1959). Thus, for sucrose, conditioned-response values are some 12 times greater than preference values, and electrophysiological values are about 18 times greater. Preference values obtained for NaCl are eight times greater than values derived by conditioned-response, acid values are 1.7 times greater and quinine values are 13 times greater.

The conditioned-response technique would be expected to yield lower values than those obtained by the preference test. This is so because the conditioned-response method probably more closely measures the absolute threshold (minimum detectable concentration), whereas the preference-test technique measures the discrimination threshold (the concentration where an animal significantly differs in its favor of one solution over another).

It is not clear why the sucrose threshold determined by conditioned-response is greater than that derived by preference test.

Sheep are indifferent to molasses. This response would be expected, based upon their reaction to sucrose. The preference for molasses demonstrated by cattle would also be expected, in light of the reactions of these animals to sucrose.

The reason is not apparent for the wide divergence in response to 8.33% molasses demonstrated by Group 1 and 2 sheep. There was also a substantial difference in the reactions of the two groups of cattle at this concentration. However, most of the difference in the cattle responses can be explained: Two of the heifers in Group 2 commenced to show behavioral signs of estrus at the time that the 8.33% molasses solution was offered. The result was an obvious disinterest in both feed and molasses solution offered. The activities of the two animals that were in heat also appeared to influence the other two animals in the group, the net result being that the responses of three of the heifers fell within the nondiscrimination zone and the reaction of the fourth was one of moderately-weak rejection.

The major weakness in the method used in this experiment was the use of an insufficient number of experimental subjects to produce adequate repeatability between groups. In studies of this nature, the number of test chemicals and/or the number of animal species studied should be limited to the extent that a sufficient number of animals in each species could be employed in order to obtain reasonable differences between groups treated the same. However, the marked and apparently normal individual variation in responses makes it difficult to arrive at statistically precise estimates. Another, and perhaps less important, weakness in the study was the failure to control the temperature variable. Such control could probably only be obtained in a controlled-environment building. In addition, there are several other variables (with uncertain influences on taste reactions) which should have been controlled: 1) sex, 2) breed, 3) previous treatment, and 4) length of time of testing period (24 hours vs. 48 hours per concentration).

There are a number of areas of importance for future research on the sense of taste in domestic animals: 1) effect of the Miracle Fruit principle upon rumination, 2) effect of taste modifiers upon ingestive behavior, 3) interaction of tastes, 4) reaction of calorically deprived sheep to sweet-tasting substances, 5) reaction of calorically deprived ruminants to acetic acid, 6) sex and breed differences in taste responses, 7) effect of temperature upon taste reactions, 8) effect upon consumption, of adding taste stimulants to bland diets, 9) relative influence on ingestive behavior of initial taste vs. taste of regurgitated material, 10) relative merits of using two-choice preference tests vs. single stimulus methods in assessing taste preferences, 11) effect of adding olfactory cues to solutions of taste stimulants, and 12) effect of prior treatment (psychological factor) upon tolerance for taste stimulants.

SUMMARY AND CONCLUSIONS

This study involved the use of the two-choice preference test to determine the taste responses of eight, each, of pygmy goats, normal goats, sheep and cattle to ascending concentrations of sucrose (Suc), sodium chloride (NaCl), acetic acid (HAc) and quinine hydrochloride (QHCl). In addition, sheep and cattle were tested at 2.08 and 8.33% molasses concentrations.

Each animal was individually penned and fed to appetite on a nutritionally adequate diet. Responses were expressed on the basis of percent of total fluid intake comprised by test solution. Goats were allowed two-day test periods per concentration; sheep and cattle were given one-day test periods.

Mean responses and standard deviations of the eight-animal groups were plotted graphically and compared to threshold levels of intake. Response trends were analyzed by stepwise multiple linear regression. A 95% confidence interval was established for a theoretical mean intake of 50%. The upper confidence limit was at 60% intake and the lower was at 40% intake. They were termed, respectively, upper discrimination threshold (UDT) and lower discrimination threshold (LDT). The rejection threshold (RET) was set at 20% intake and the preference threshold (PRT) at 80% intake. Ascending or descending responses at the various threshold concentrations were identified by ↑ and ↓, respectively.

Molar concentrations of thresholds crossed by responses of pygmies, normals, sheep and cattle, respectively, were for Suc, UDT: .055↑ and .53↓; UDT: .033↑, PRT: .38↑; LDT: .41↓; UDT: .025↑ and .41↓, PRT: .058↑ and .24↓, LDT: .56↓; for NaCl, UDT: .024↑ and .21↓, PRT: .10↑ and .14↓, LDT: .36↓, RET: 60↓; UDT: .027↑↓, LDT: .15↓, RET: .55↓; LDT: .21↓, RET: 53↓; LDT: .016↓, RET: .14↓; for HAc, UDT: .0034↑ and .042↓, LDT: .16↓, RET: > .22↓; LDT: .014↓, RET: .11↓; UDT: .0034↑↓, LDT: .028↓, RET: .094↓; UDT: .0017↑ and .0069↓, LDT: .014↓, RET: .038↓; and, for QHCl, UDT: > .000016↑ and .000047↓, LDT: .00030↓, RET: .00202↓; UDT: .000016↑ and .000063↓, LDT: .00035↓, RET: .00202↓; LDT: .000094↓, RET: .00035↓; LDT: .00013↓, RET: .00038↓.

In general, stimulating effectiveness was greatest for bitter, followed in order by sour, salty and sweet. Cattle were usually first to make a discrimination, goats were generally second and sheep were normally last. The major exception was for the bitter taste group where the order was goats, sheep, cattle. As a rule, goats were more tolerant of high concentrations than were sheep and sheep were more tolerant than cattle. The exception was, again, the bitter taste group where the order was goats, cattle, sheep.

Sheep were indifferent to 2.08 and 8.33% molasses concentrations. Cattle demonstrated strong preference responses to the 2.08% level and weak preference reactions to the 8.33% level.

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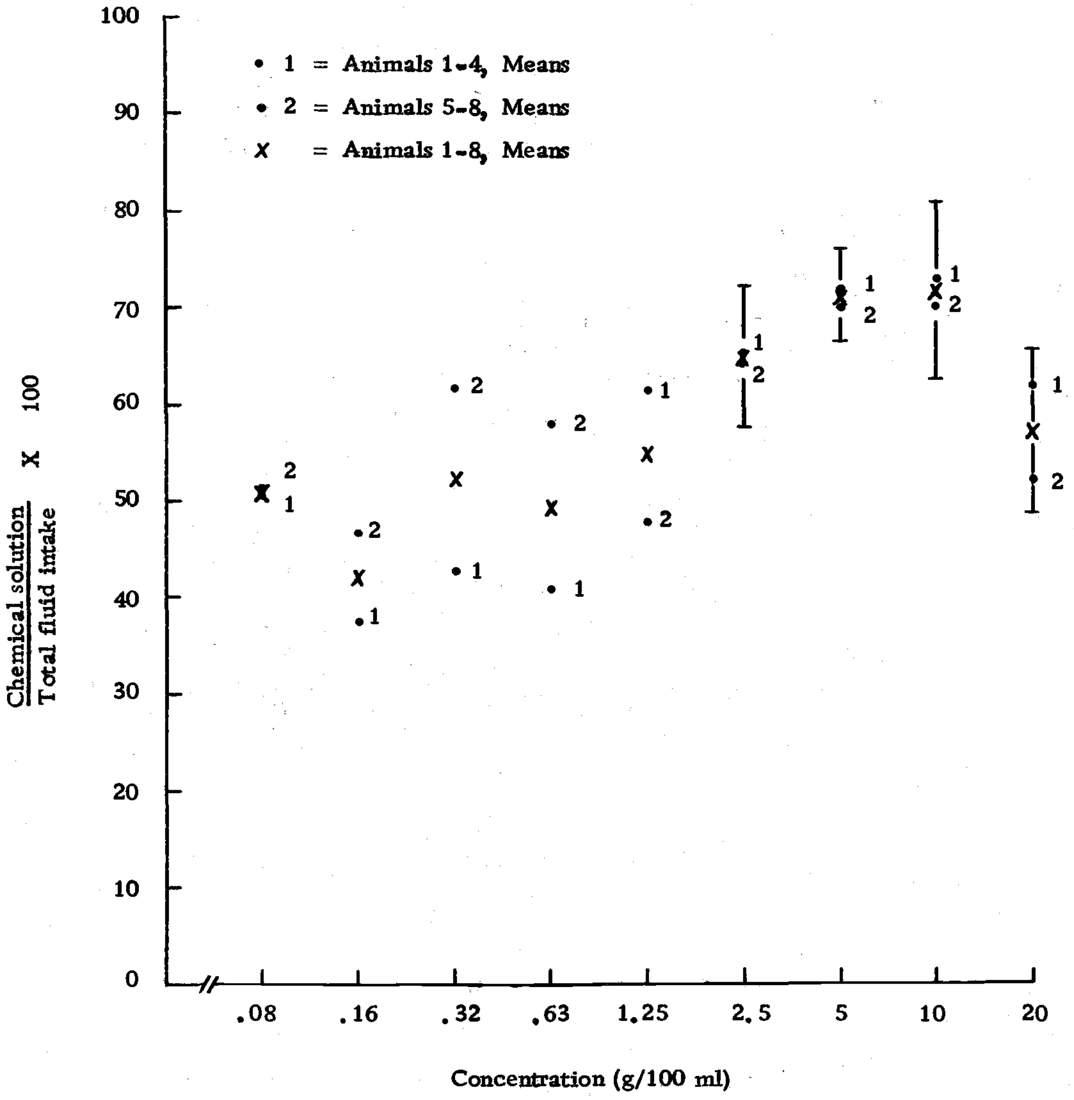
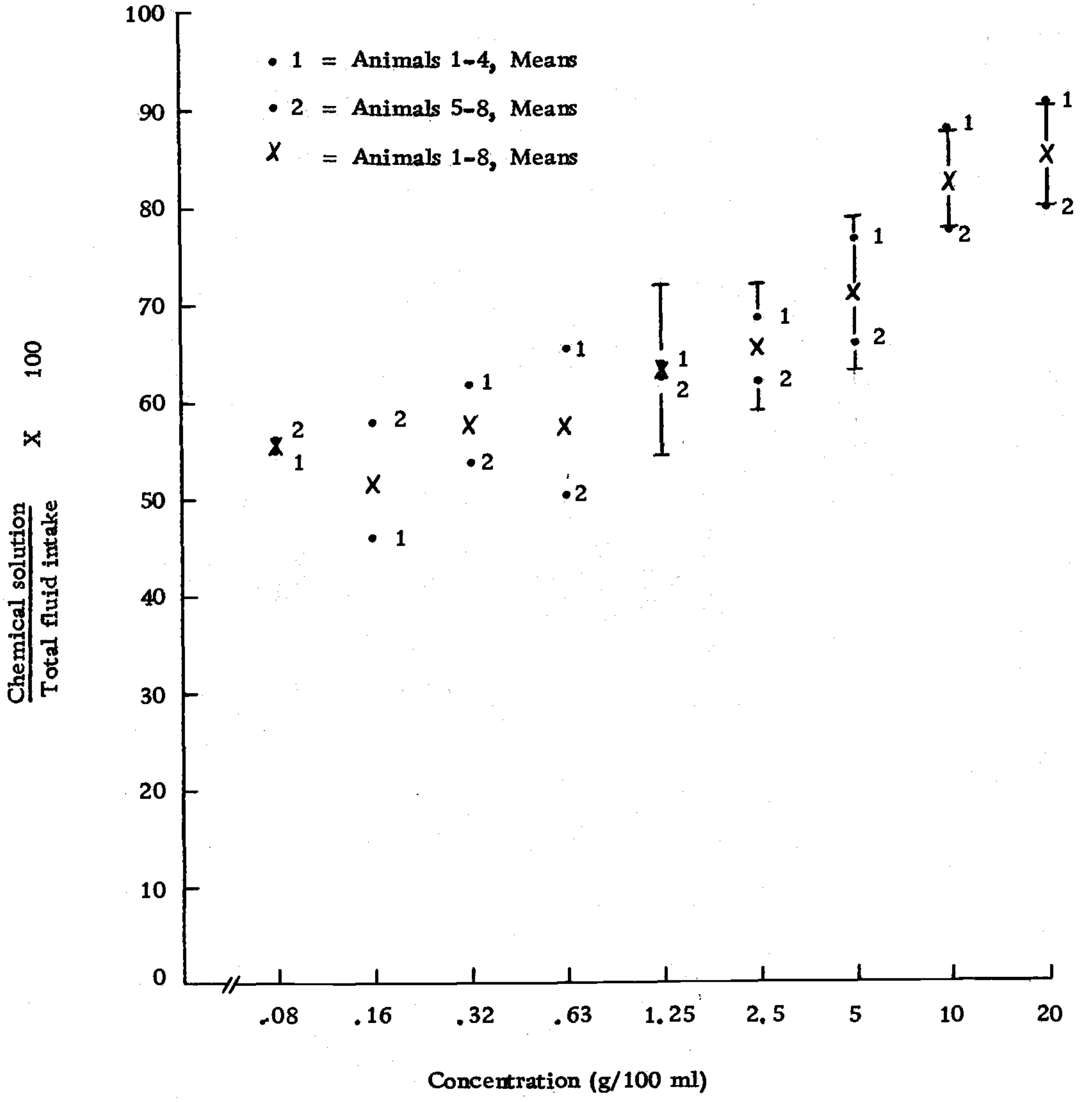
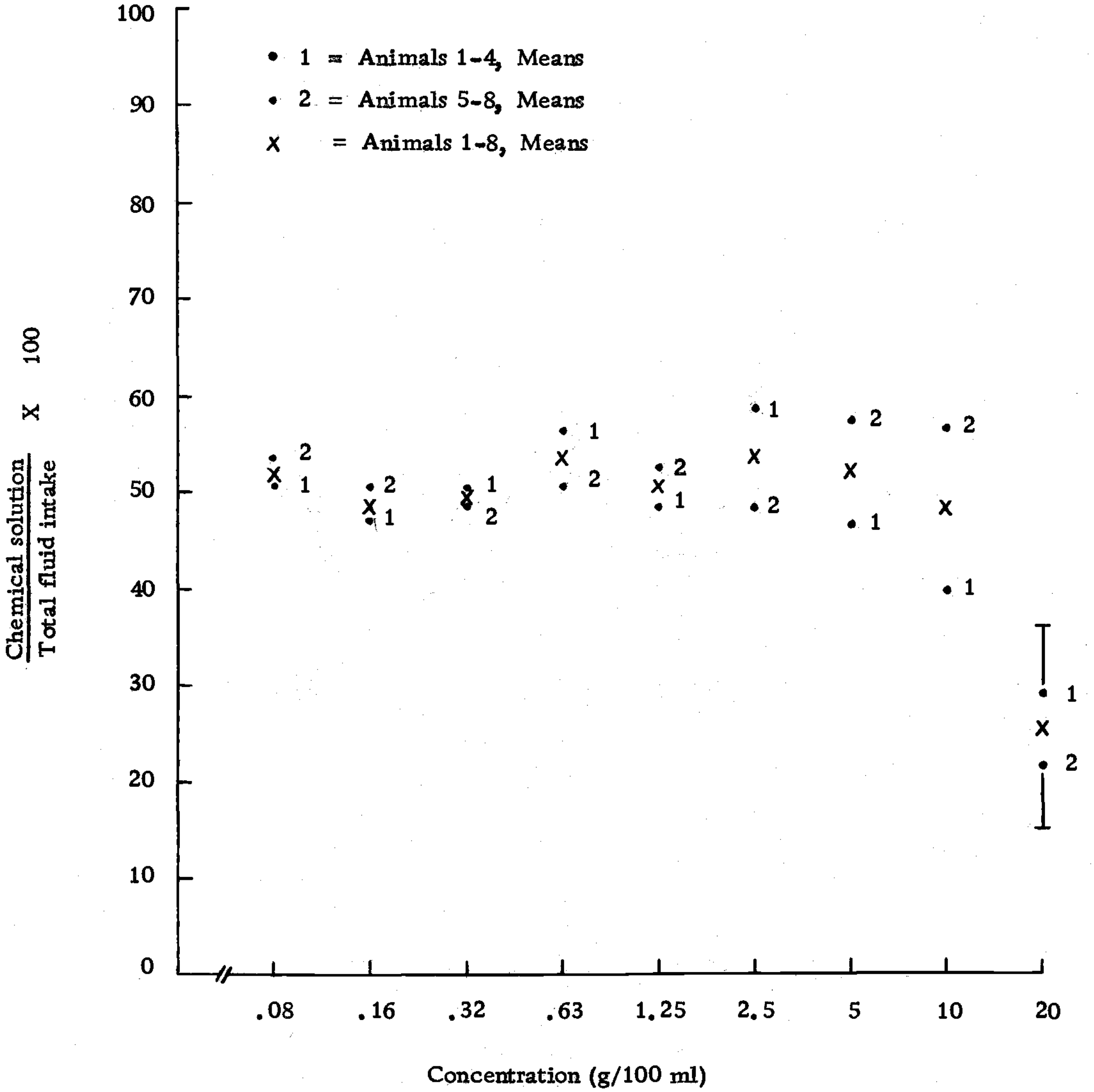
APPENDIX



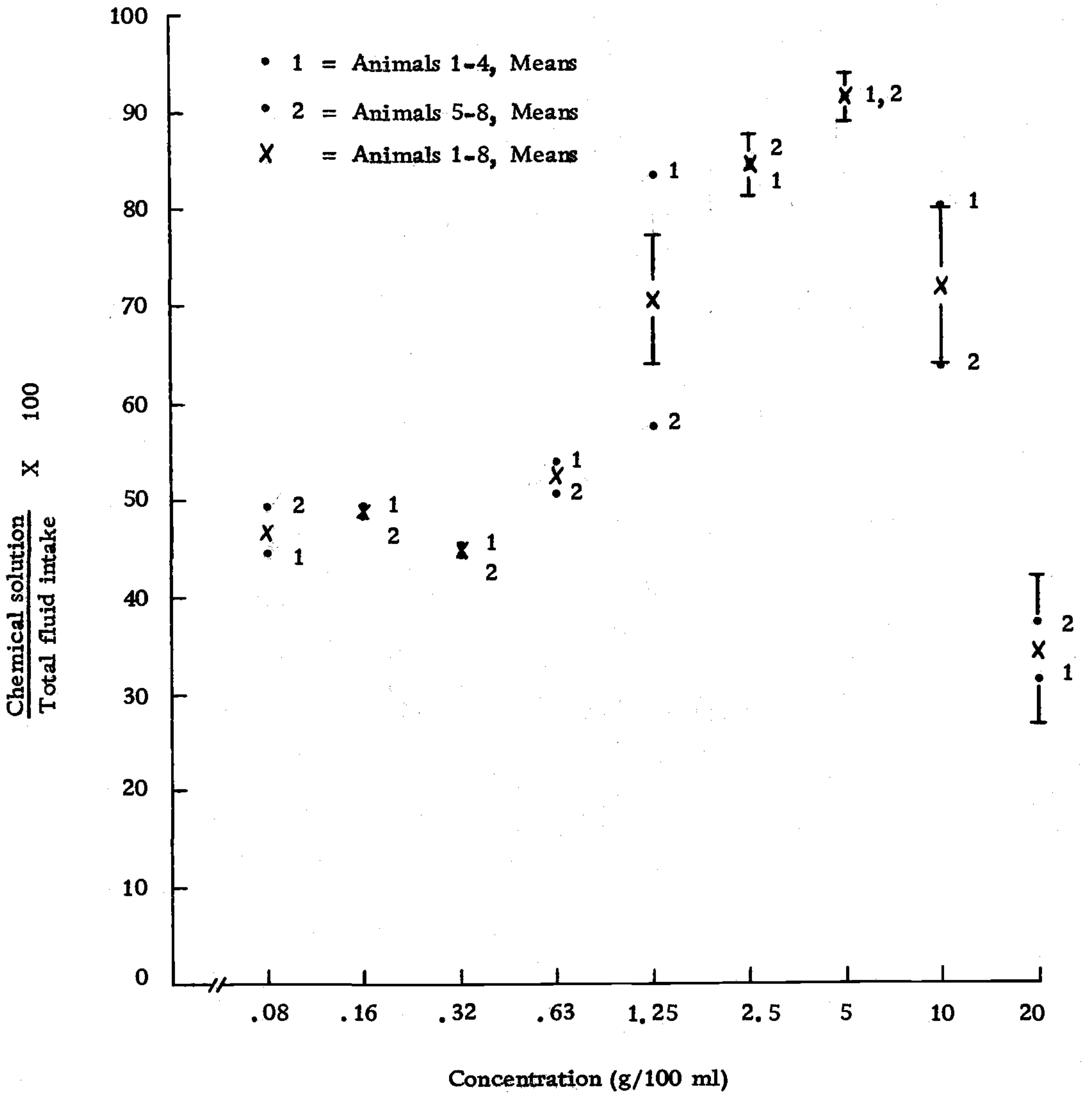
Appendix Figure 1. Taste responses of two groups of pygmy goats to ascending concentrations of sucrose.



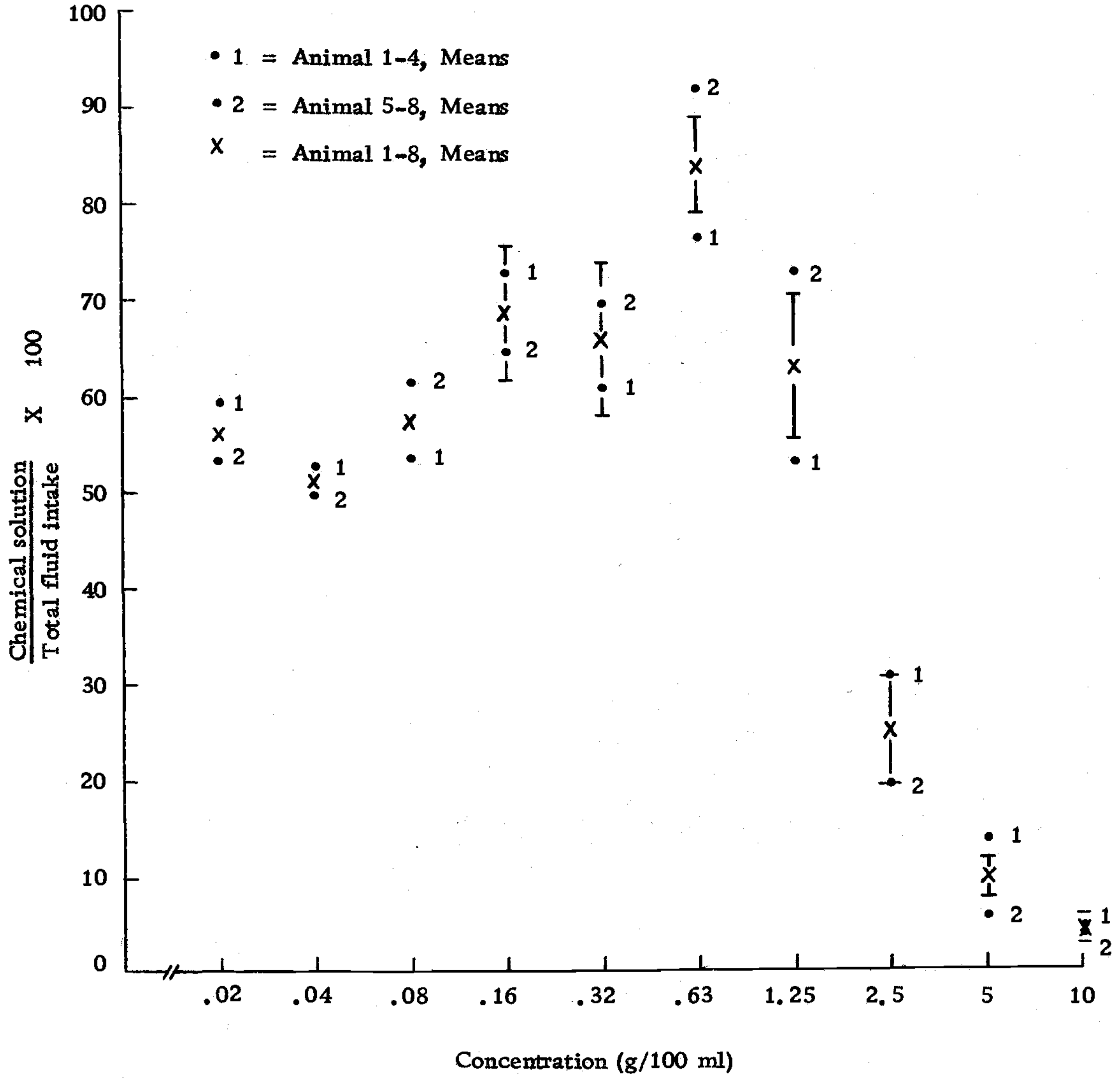
Appendix Figure 2. Taste responses of two groups of normal goats to ascending concentrations of sucrose.



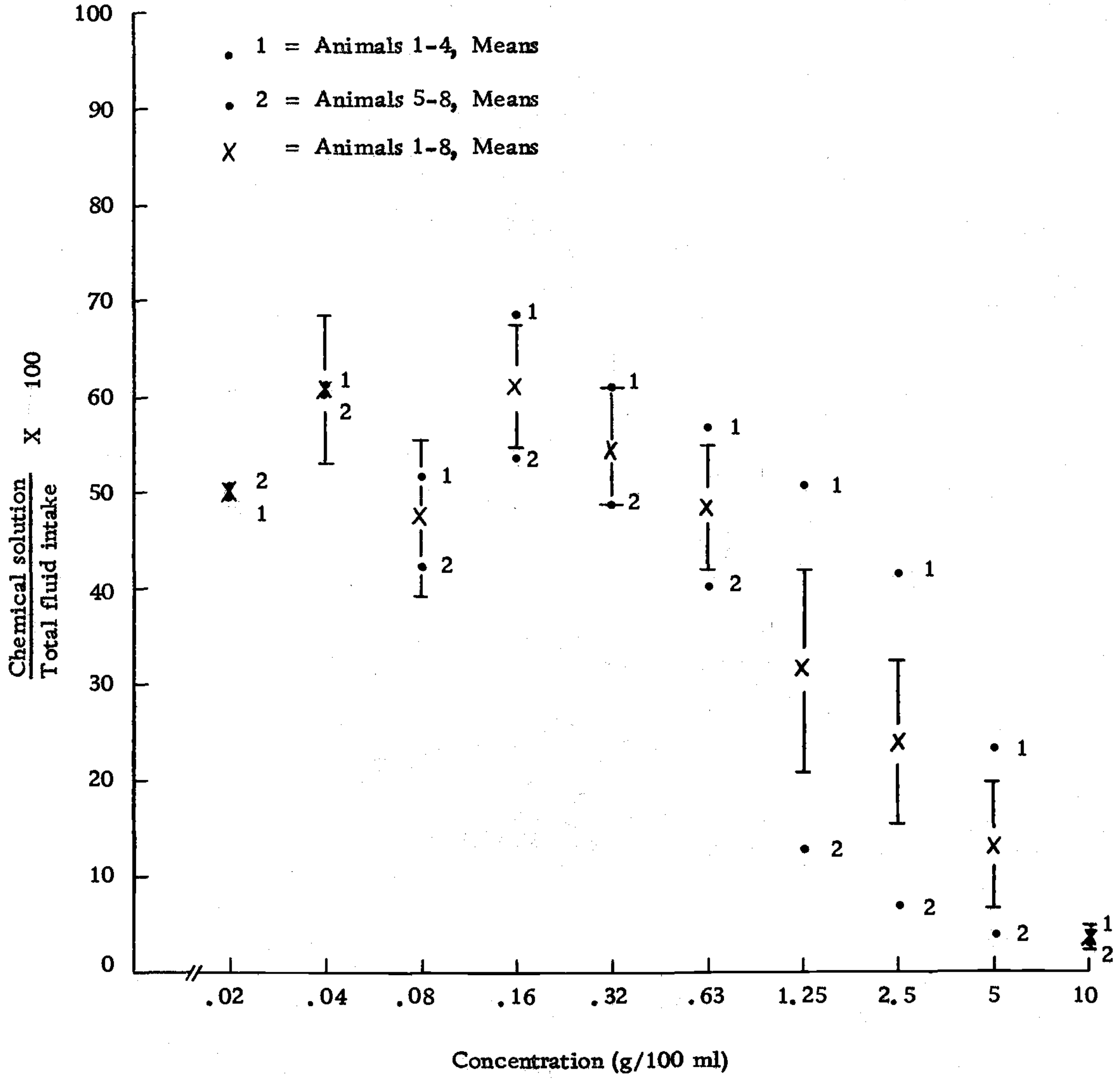
Appendix Figure 3. Taste responses of two groups of sheep to ascending concentrations of sucrose.



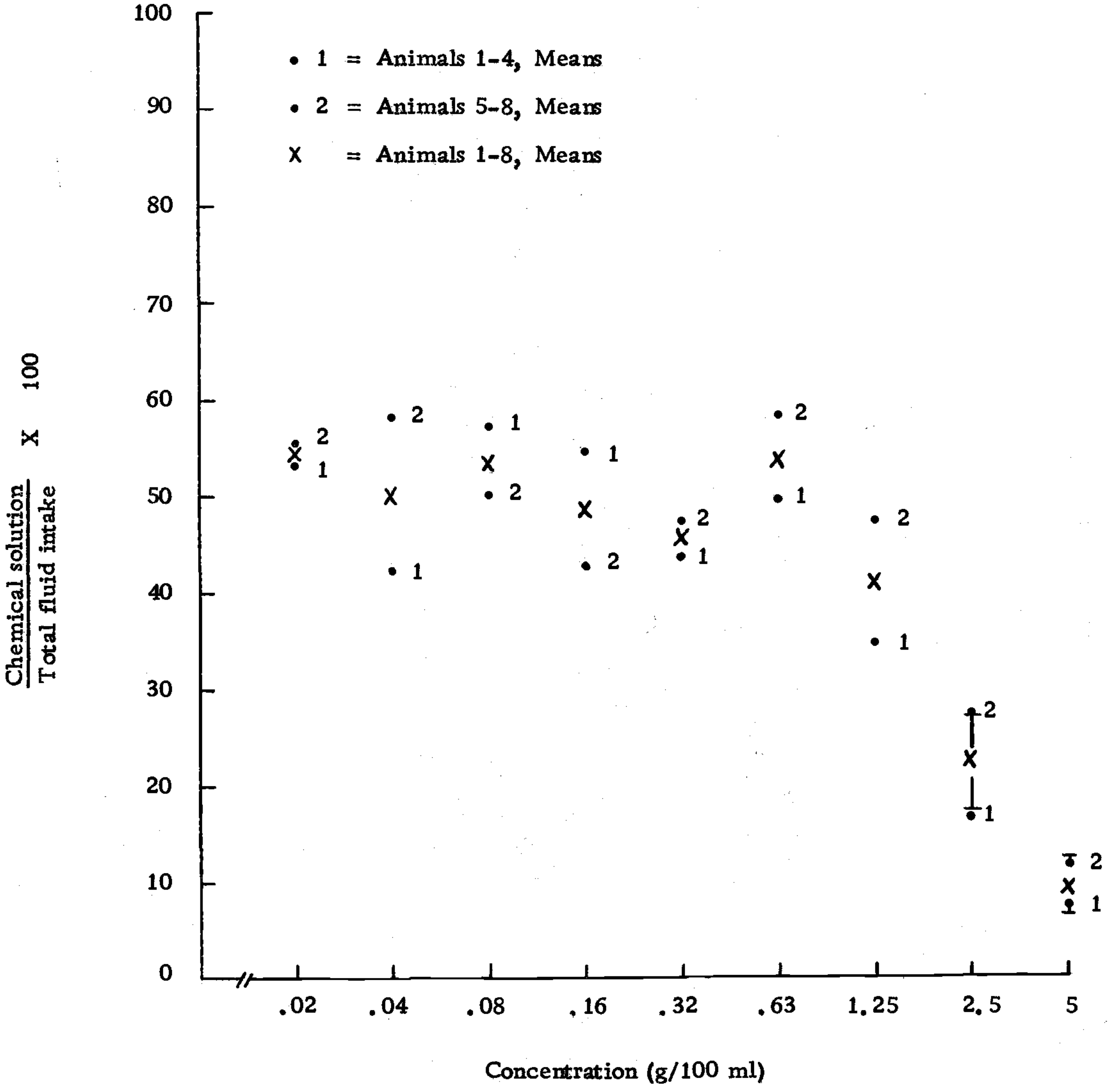
Appendix Figure 4. Taste responses of two groups of cattle to ascending concentrations of sucrose.



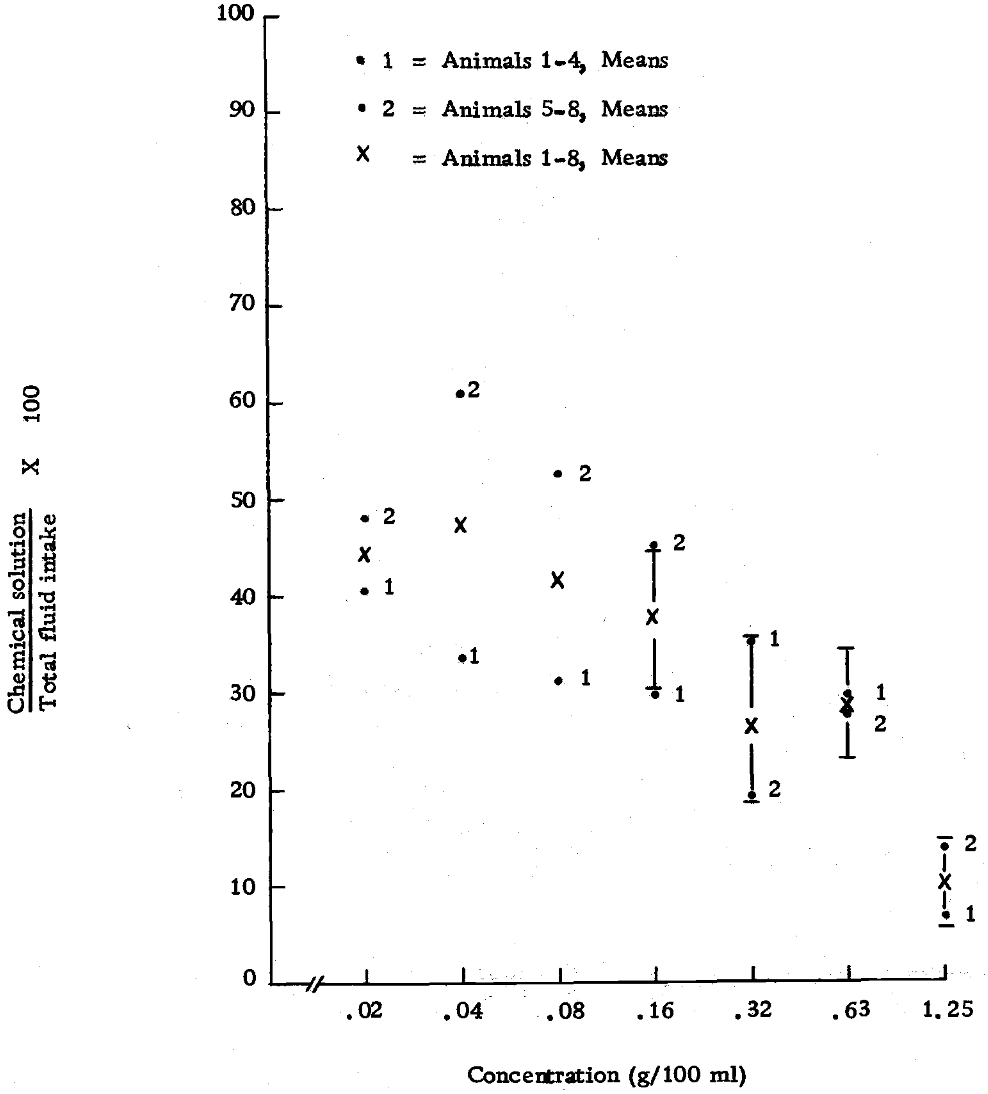
Appendix Figure 5. Taste responses of two groups of pygmy goats to ascending concentrations of sodium chloride.



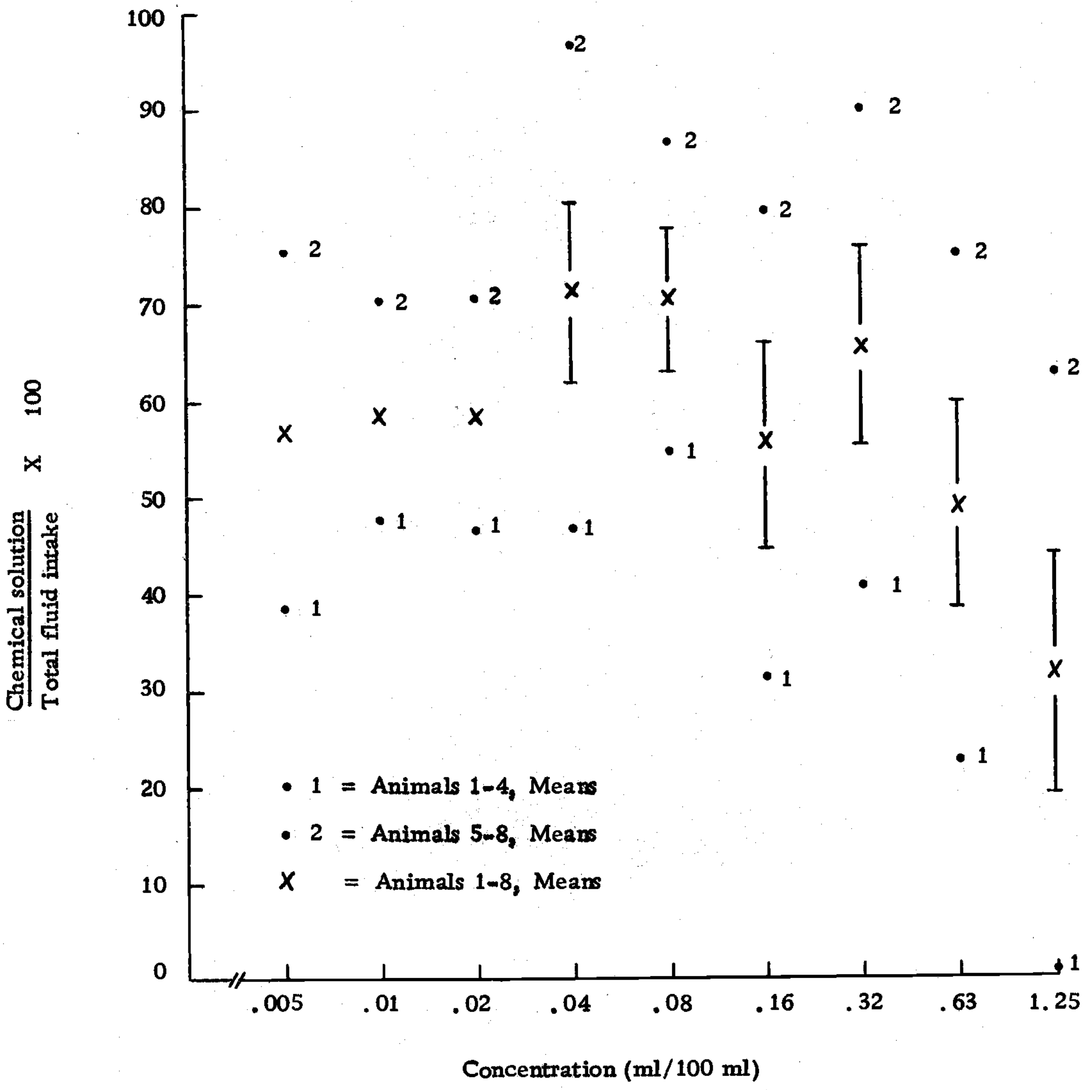
Appendix Figure 6. Taste responses of two groups of normal goats to ascending concentrations of sodium chloride.



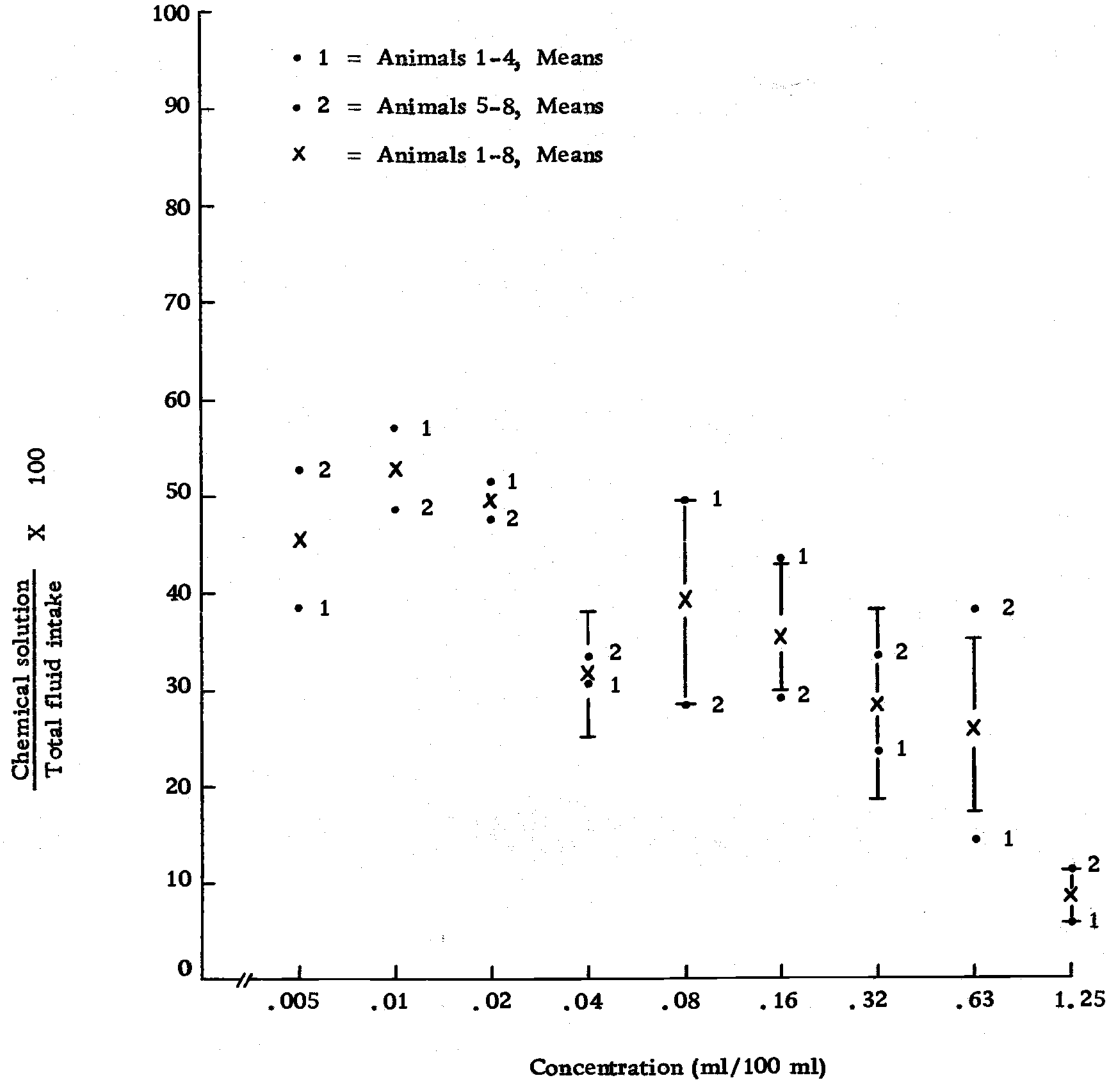
Appendix Figure 7. Taste responses of two groups of sheep to ascending concentrations of sodium chloride.



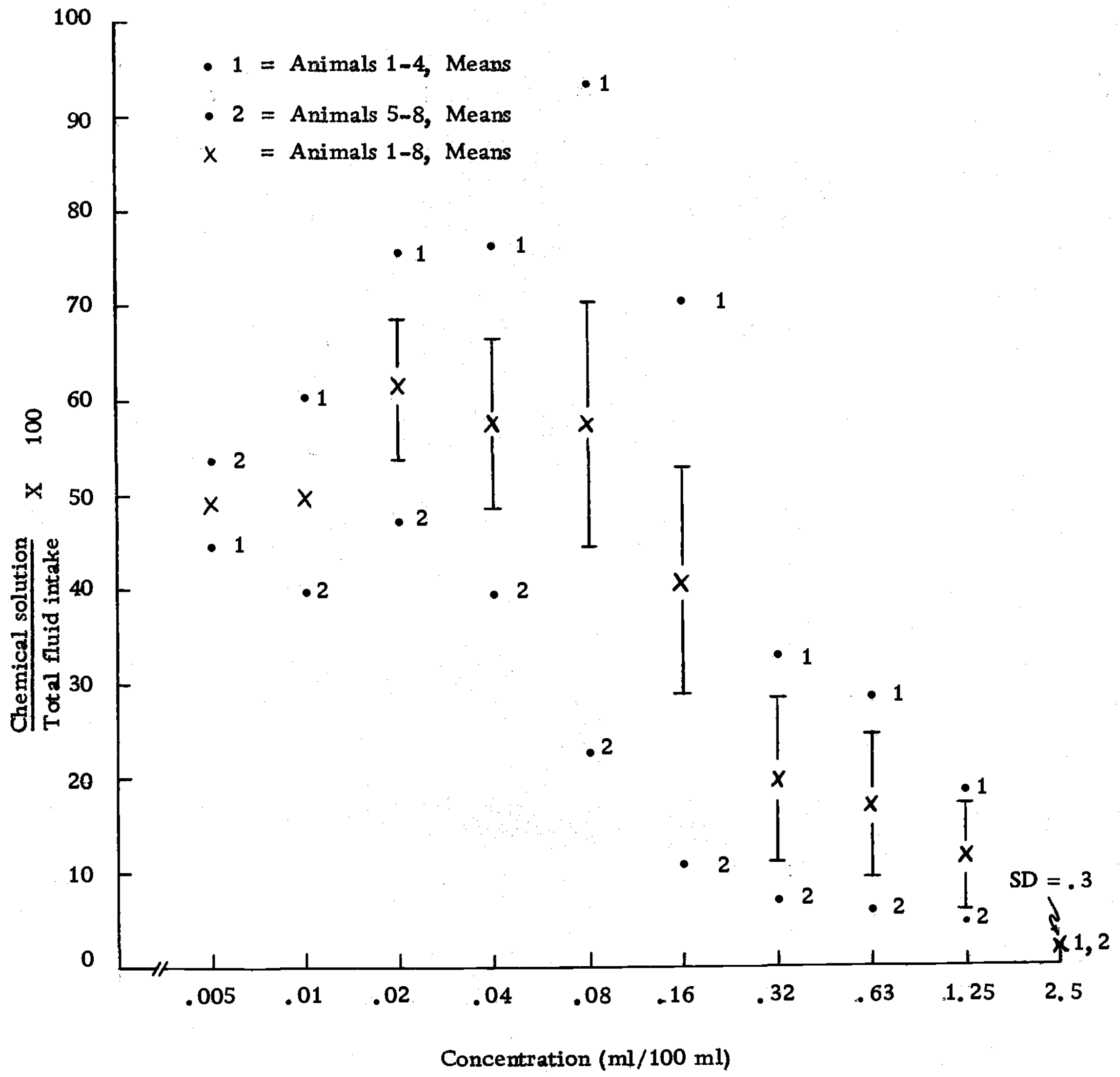
Appendix Figure 8. Taste responses of two groups of cattle to ascending concentrations of sodium chloride.



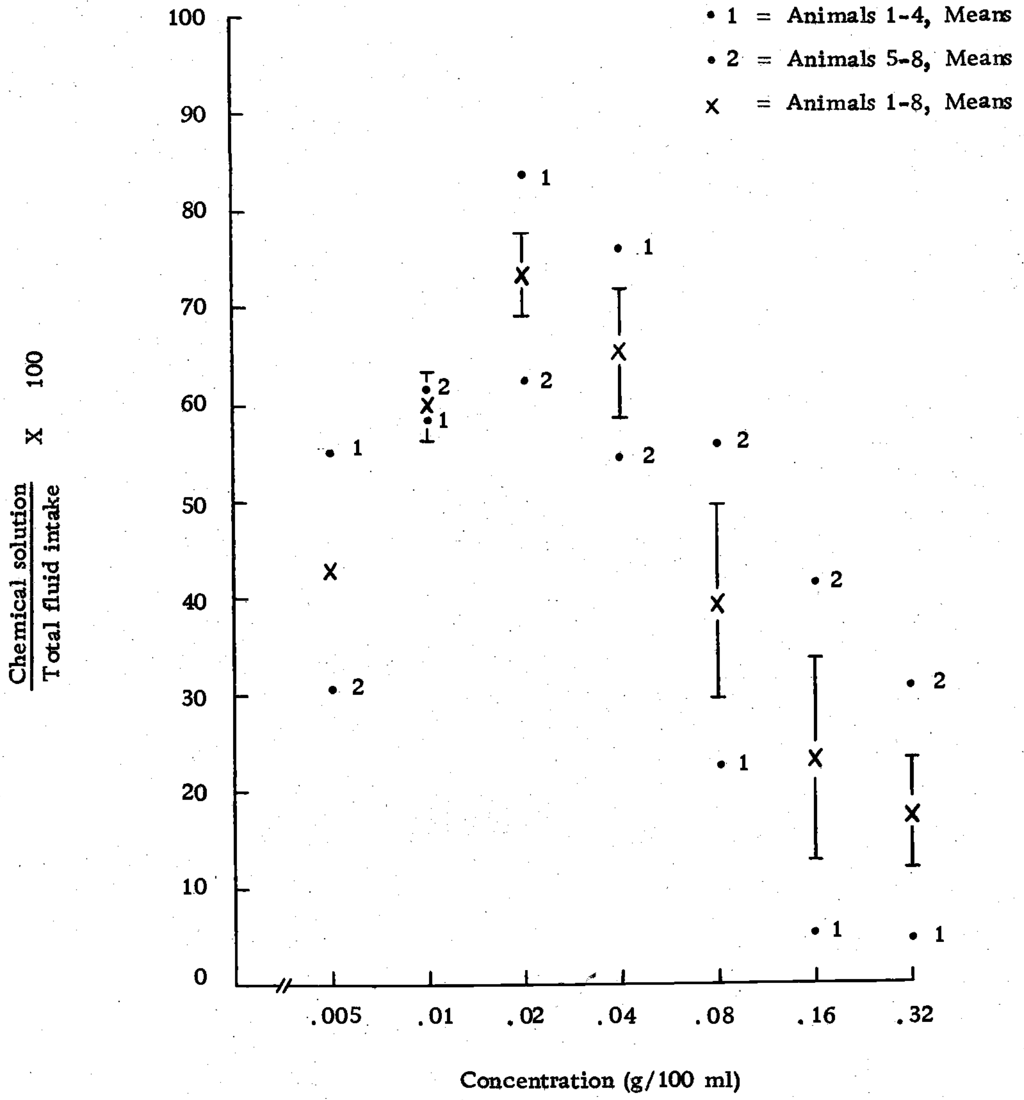
Appendix Figure 9. Taste responses of two groups of pygmy goats to ascending concentrations of acetic acid.



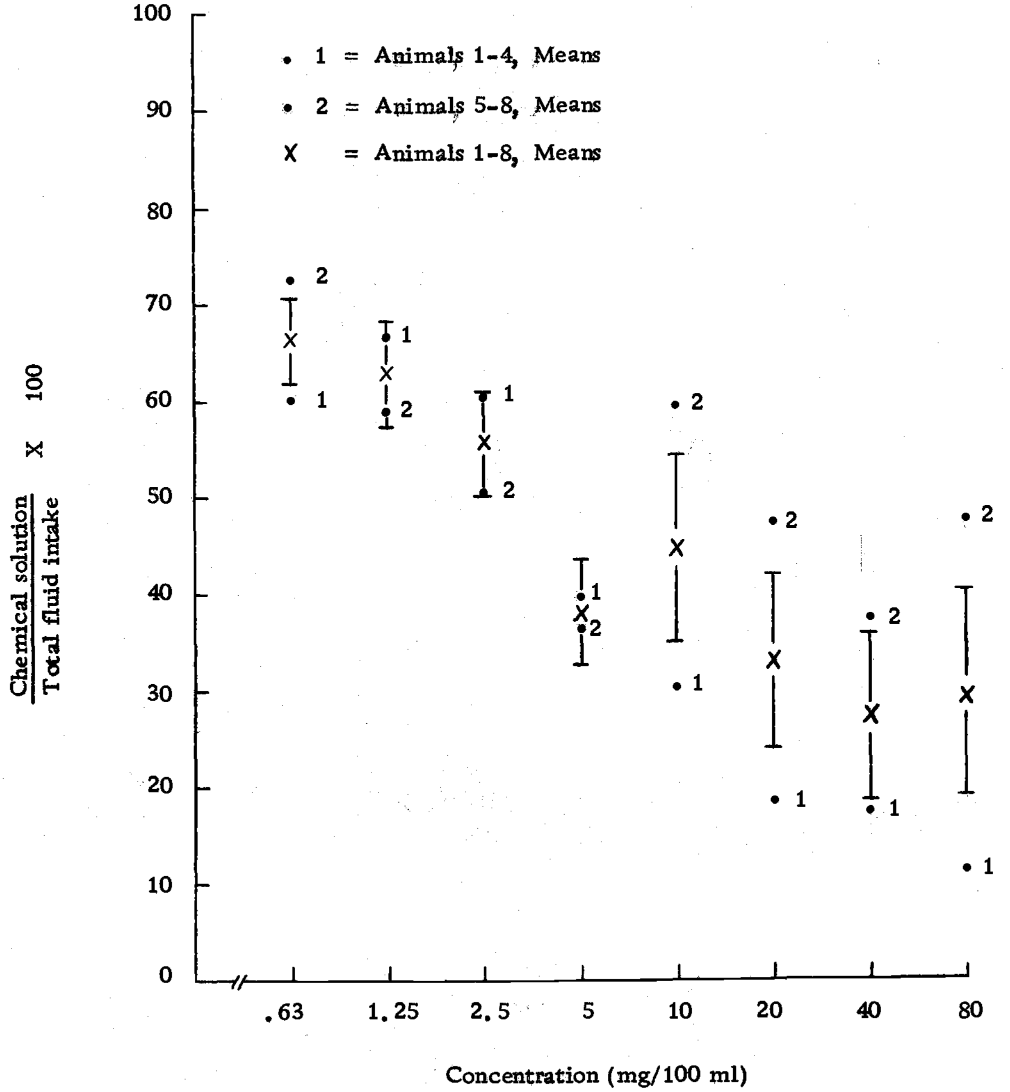
Appendix Figure 10. Taste responses of two groups of normal goats to ascending concentrations of acetic acid.



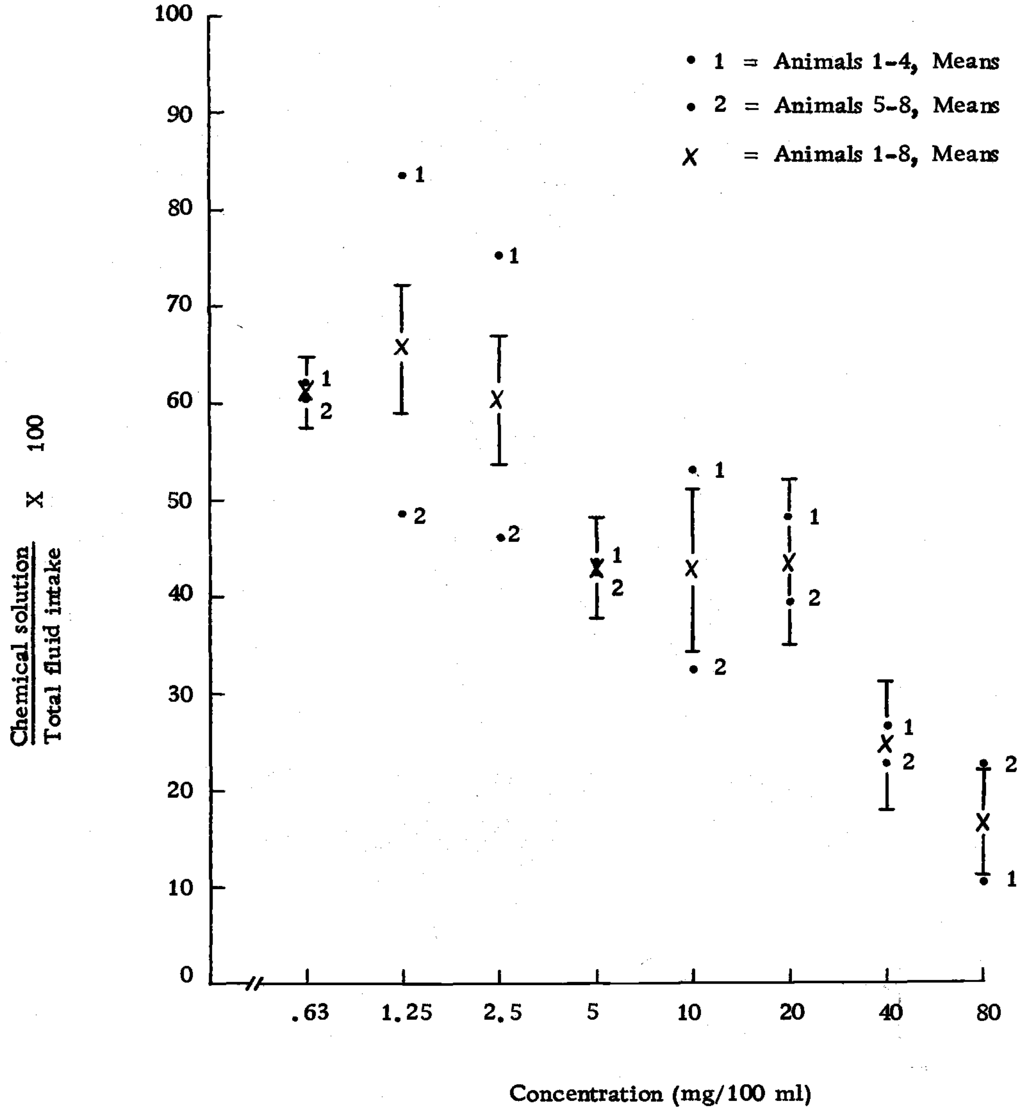
Appendix Figure 11. Taste responses of two groups of sheep to ascending concentrations of acetic acid.



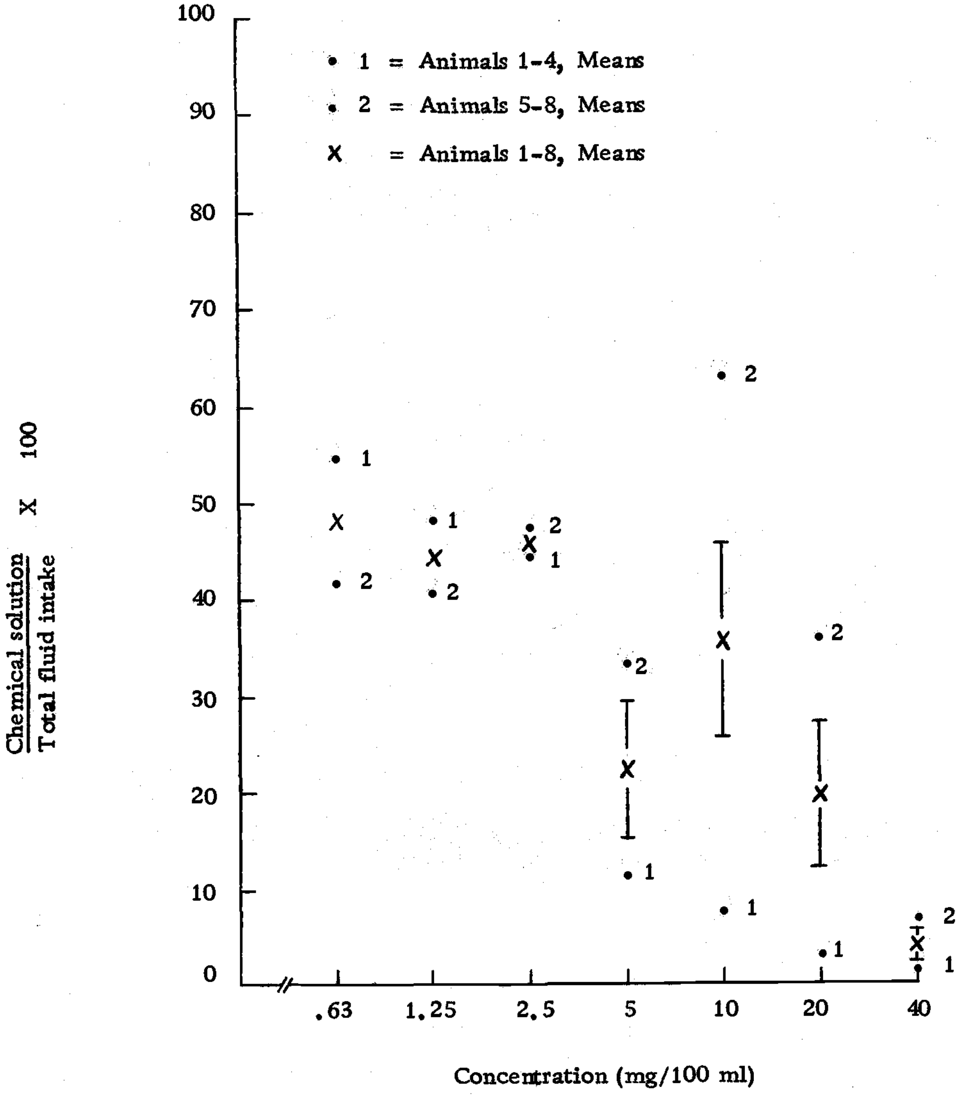
Appendix Figure 12. Taste responses of two groups of cattle to ascending concentrations of acetic acid.



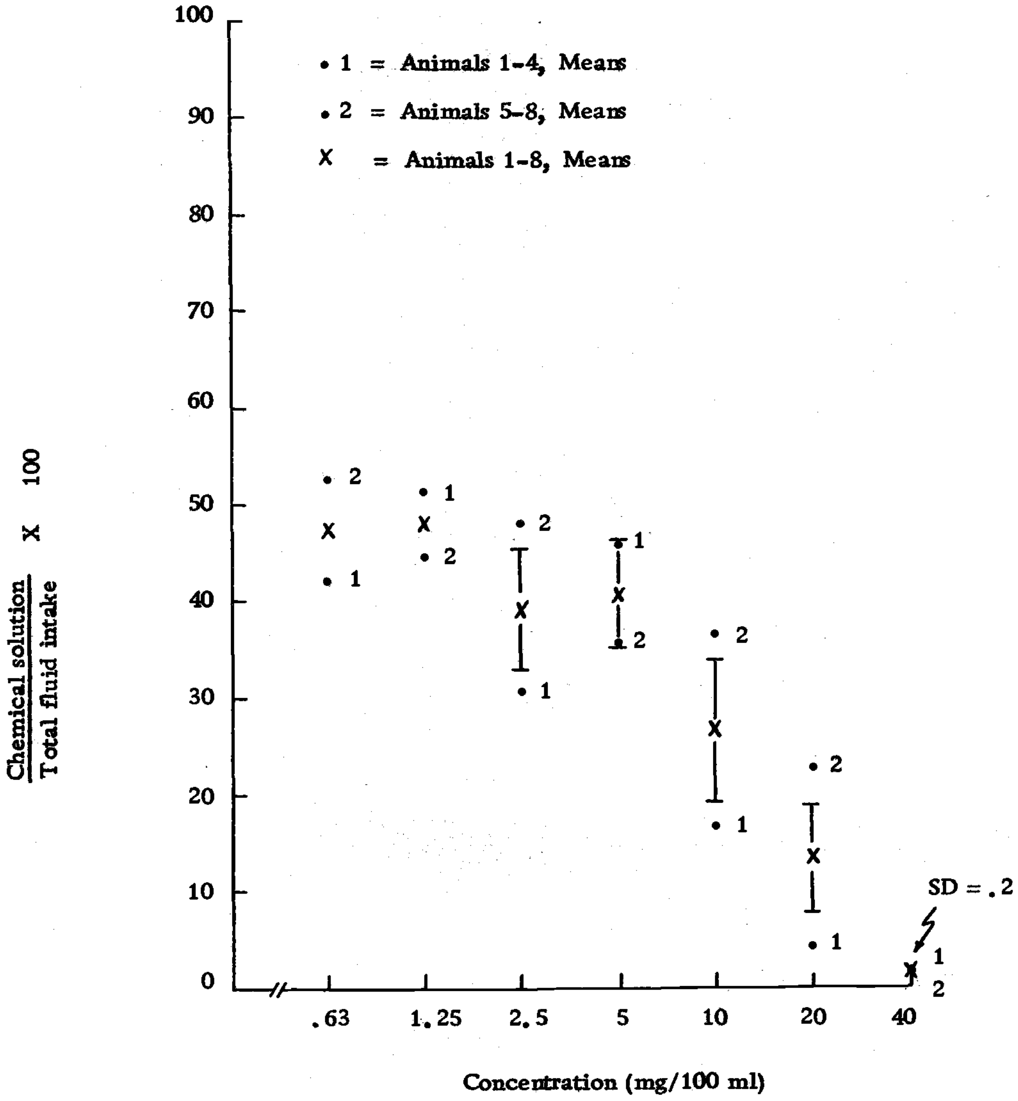
Appendix Figure 13. Taste responses of two groups of pygmy goats to ascending concentrations of quinine hydrochloride.



Appendix Figure 14. Taste responses of two groups of normal goats to ascending concentrations of quinine hydrochloride.



Appendix Figure 15. Taste responses of two groups of sheep to ascending concentrations of quinine hydrochloride.



Appendix Figure 16. Taste responses of two groups of cattle to ascending concentrations of quinine hydrochloride.

Appendix Table 1. Relevant concentrations of taste stimulants submitted to regression analysis and their related X values, the independent regression variable.

Sucrose (g/100 ml)				Sodium chloride (g/100 ml)				
P[a]	N[a]	S[a]	C[a]	P	N	S	C	X Value
1.25	.32	5	1.25	.08	.04	1.25	.08	1
2.5	.63	10	2.5	.16	.08	2.5	.16	2
5	1.25	20	5	.32	.16	5	.32	3
10	2.5		10	.63	.32		.63	4
20	5		20	1.25	.63		1.25	5
	10			2.5	1.25			6
	20			5	2.5			7
				10	5			8
					10			9

Acetic acid (ml/100 ml)				Quinine (mg/100 ml)				
P	N	S	C	P	N	S	C	X Value
.005	.04	.01	.01	.63	.63	2.5	2.5	1
.01	.08	.02	.02	1.25	1.25	5	5	2
.02	.16	.04	.04	2.5	2.5	10	10	3
.04	.32	.08	.08	5	5	20	20	4
.08	.63	.16	.16	10	10	40	40	5
.16	1.25	.32	.32	20	20			6
.32		.63		40	40			7
.63		1.25		80	80			8
1.25		2.5						9

[a] P = pygmy goats, N = normal goats, S = sheep, C = cattle.

Appendix Table 2. Various statistics and tests used to determine the nondiscrimination zone of responses in the present testing situation.

Statistics and Tests	Animal species Pygmies	 Normal Goats	 Sheep	 Cattle	Pooled Value
Variance	23.8	31.6	20.1	30.7	26.5
S.D., %	4.9	5.6	4.5	5.5	5.2
Mean, %	50.9	51.4	49.5	51.4	50.8
F-value[a]					
P vs. N	1.33[d]				
P vs. S	1.18[d]				
P vs. C	1.29[d]				
N vs. S	1.57[d]				
N vs. C	1.03[d]				
S vs. C	1.53[d]				
t-value[b]	.60[d]	.78[d]	.35[d]	.77[d]	

Analysis of Variance[c]

Source	d.f.	S.S.	M.S.	F
Treatment	3	23.197	7.732	.258[d]
Error	36	1097.971	29.999	
Total	39	1103.168		

[a] A test of whether group variances differ significantly from each other.

[b] A test of whether group means differ significantly from a theoretical mean of 50%.

[c] A test of whether group means differ significantly from each other.

[d] Not significant ($P > .05$).

Appendix Table 3. Consumption by two groups of pygmy goats of water as an average of the percent taken from container A during the first 22 hours and from container B during the second 22 hours of 44-hour test periods, and corresponding volume intake in hundreds of milliliters.

	Period									
Animal	1	2	3	4	5	6	7	8	9	10
1P	51.0[a]	67.0	94.5	55.0	45.5	70.0	32.0	59.5	40.0	41.5
	5.2[b]	6.0	4.8	4.4	3.0	3.0	8.0	3.7	2.0	2.0
2P	44.0	77.5	26.0	49.0	31.0	74.0	39.0	18.0	97.0	54.0
	7.0	6.5	2.5	5.0	2.5	7.0	3.2	1.2	6.2	3.5
3P	66.5	33.0	1.0	43.0	37.0	8.5	64.0	41.0	28.0	46.0
	3.5	2.5	.2	4.6	4.0	1.0	6.8	4.7	2.4	5.5
4P	37.0	38.0	25.0	24.5	22.0	25.5	44.0	83.0	8.7	90.5
	2.8	2.5	1.0	2.5	1.2	2.0	1.5	4.8	5.0	4.3
Means	49.6	53.9	36.6	42.9	33.9	44.5	44.8	50.4	63.0	58.0
	4.6	4.4	2.1	4.1	2.7	3.2	4.9	3.6	3.9	3.8
5P	63.0	42.5	48.5	49.0	51.5	47.0	54.5	47.5	53.0	51.0
	4.0	3.5	4.1	3.8	6.2	8.2	6.3	7.0	5.4	5.7
6P	36.5	70.0	69.0	65.5	59.0	49.5	49.0	49.0	46.5	47.5
	5.6	11.0	1.6	12.3	12.6	6.7	8.4	7.6	6.1	5.9
7P	58.5	6.5	90.0	9.5	72.5	50.0	51.5	50.5	48.0	53.0
	3.1	.6	5.1	.5	4.0	7.2	6.4	8.0	9.1	4.3
8P	92.0	8.5	74.0	49.0	87.5	49.0	47.5	48.5	49.0	50.0
	6.7	.6	7.0	1.7	7.6	6.5	7.9	4.8	7.3	8.2
Means	62.5	31.9	70.4	43.2	67.6	48.9	50.6	48.9	49.1	50.4
	4.8	3.9	4.4	4.6	7.6	7.2	7.2	6.8	7.0	6.0
Grand Means	56.0	42.9	53.5	43.0	50.8	46.8	50.5	56.0	53.6	56.2
	4.7	4.2	3.2	4.4	5.2	6.0	5.4	5.4	5.4	5.2

[a] Percent intake

[b] Volume intake

Appendix Table 4. Consumption by two groups of normal goats of water as an average of the percent taken from container A during the first 22 hours and from container B during the second 22 hours of 44-hour test periods, and corresponding volume intake in hundreds of milliliters.

	Period									
Animal	1	2	3	4	5	6	7	8	9	10
1NAF	62.0[a]	83.5	32.5	68.5	45.0	49.0	86.0	55.0	54.5	50.0
	9.3[b]	11.0	5.7	10.0	4.5	7.0	9.0	7.5	8.0	2.0
2NAF	83.5	80.0	99.9	99.9	99.9	87.5	50.0	36.5	58.0	69.0
	9.0	9.8	13.0	10.0	7.8	9.5	6.3	2.1	5.0	3.0
3NAF	34.5	5.0	83.5	34.5	61.0	5.0	77.5	50.0	50.0	62.5
	3.5	.5	9.0	5.0	2.0	.5	2.0	3.9	3.0	1.2
4NAF	30.0	15.0	31.5	21.5	50.0	33.0	50.0	24.0	90.0	59.0
	1.5	1.0	5.2	.5	3.0	1.0	3.1	2.4	9.0	3.8
Means	52.5	45.9	61.9	56.1	64.0	43.6	65.9	41.4	63.1	60.1
	5.8	5.3	8.2	6.4	4.3	4.5	5.1	4.0	6.2	2.5
5NSC	75.5	40.5	47.0	6.0	23.0	63.0	44.5	11.5	39.0	33.0
	7.0	6.0	6.5	1.5	2.5	12.0	9.0	2.0	11.2	7.5
6[c]	47.5	60.5	70.0	44.0	49.5	50.0	30.5	7.5	66.5	77.5
	14.5	11.5	15.5	8.0	4.8	16.0	15.0	2.2	8.1	15.0
7NAC	65.0	63.5	49.5	44.0	37.5	70.0	39.0	95.0	52.5	67.5
	1.0	9.0	7.5	6.1	13.2	17.5	12.0	18.0	7.6	8.3
8NAC	75.5	49.0	26.0	34.0	5.0	48.5	58.5	52.5	47.5	26.5
	9.0	9.5	4.5	4.5	.7	18.0	19.0	12.0	9.4	7.0
Means	65.9	53.4	48.1	32.0	28.8	57.9	43.1	41.6	51.4	51.1
	7.9	9.0	8.5	5.0	5.3	15.9	13.8	8.6	9.1	9.4
Grand Means	59.2	49.6	55.0	44.0	46.4	50.8	54.5	41.5	57.2	55.6
	6.8	7.2	8.4	5.7	4.6	10.2	9.4	6.3	7.6	6.0

[a] Percent intake

[b] Volume intake

[c] Values for periods 1 through 5 are for normal goat 6NSC, values for periods 6 through 10 are for normal goat 6 NHM.

Appendix Table 5. Consumption by two groups of sheep of water as an average of the percent taken from container A during the first ten hours and from container B during the second ten hours of 20-hour test periods, and corresponding volume intake in hundreds of milliliters.

	Period									
Animal	1	2	3	4	5	6	7	8	9	10
1S	43.5[a]	8.0	21.0	40.5	31.0	48.0	49.0	39.5	48.0	55.5
	14.5[b]	3.0	12.4	18.8	12.5	17.0	15.0	22.3	15.0	19.5
2S	56.0	50.0	58.0	56.0	56.0	46.0	46.0	46.0	50.0	49.5
	13.7	22.2	22.2	24.2	26.0	20.5	9.6	12.0	21.0	15.0
3S	19.0	48.5	2.5	33.5	38.5	47.0	51.5	58.5	62.5	17.5
	3.0	13.9	1.1	3.2	7.2	21.3	13.9	16.7	15.5	3.0
4[c]	81.5	24.5	85.0	60.0	61.5	46.5	49.5	50.0	64.5	62.5
	29.5	10.0	35.3	20.9	18.9	17.3	8.2	7.5	15.0	19.5
Means	50.0	32.8	41.6	47.5	46.8	46.9	49.0	49.5	56.6	46.2
	15.2	8.8	17.8	16.8	16.2	19.0	11.7	14.5	16.6	14.2
5S	37.0	60.5	37.0	43.0	50.0	72.0	65.0	41.0	56.0	70.0
	17.5	21.5	16.5	20.2	22.5	27.5	30.5	18.0	18.0	24.5
6S	84.5	65.5	33.0	73.0	30.5	57.0	47.5	53.5	12.5	55.5
	11.0	10.0	3.0	4.5	9.8	11.0	9.5	12.0	2.0	14.0
7S	40.0	22.0	44.5	74.5	32.0	52.5	59.5	56.0	45.0	40.0
	8.5	5.0	11.1	22.0	7.8	15.0	17.5	16.0	13.0	17.5
8S	73.5	63.0	51.0	48.0	54.5	46.5	60.5	63.5	86.0	35.0
	17.0	14.0	12.5	6.0	16.5	17.5	16.0	18.0	24.0	18.5
Means	58.8	52.8	41.4	59.6	41.8	57.0	58.1	53.5	49.9	50.1
	13.5	12.6	10.8	17.4	14.2	17.8	18.4	16.0	14.2	17.6
Grand Means	54.4	42.8	41.5	53.6	44.3	52.0	53.6	51.5	53.2	48.2
	14.4	10.7	14.3	17.1	15.2	18.4	15.0	15.2	15.4	15.9

[a] Percent intake

[b] Volume intake

[c] Values for periods 1 through 5 are for sheep 4S, values for periods 6 through 10 are for sheep 4SR.

Appendix Table 6. Consumption by two groups of cattle of water as an average of the percent taken from container A during the first ten hours and from container B during the second ten hours of 20-hour test periods, and corresponding volume intake in liters.

	Period									
Animal	1	2	3	4	5	6	7	8	9	10
1C	60.5[a]	69.0	6.0	61.0	59.5	78.0	45.5	40.5	18.0	18.5
	7.0[b]	6.7	1.0	8.7	16.0	5.1	12.8	12.5	6.2	6.8
2C	44.5	58.5	59.0	36.5	47.5	70.0	82.5	22.0	46.5	47.5
	8.3	11.9	9.3	7.3	6.4	5.9	11.2	7.3	15.4	15.1
3C	77.0	41.0	33.5	8.5	47.5	45.5	50.0	92.0	87.5	44.0
	8.4	10.6	5.3	2.1	7.2	13.3	7.0	18.9	25.5	16.5
4C	92.5	30.5	92.0	45.5	93.5	57.0	27.5	27.5	28.5	60.5
	11.0	4.3	13.4	8.2	16.0	12.8	2.7	9.3	13.3	17.6
Means	68.6	49.8	47.6	37.9	62.0	62.6	51.4	45.5	45.1	42.6
	8.7	8.4	7.2	6.6	11.4	9.3	8.4	12.0	14.8	14.0
5C	79.0	42.0	39.5	47.5	53.0	89.5	50.0	68.0	61.5	60.5
	5.2	8.9	14.6	9.2	11.6	23.3	16.0	22.6	15.6	16.1
6C	34.5	47.5	49.0	52.5	41.5	47.0	54.0	47.0	60.0	61.0
	7.2	9.8	8.9	11.2	5.1	12.0	16.0	14.7	15.6	15.2
7C	48.0	32.5	44.5	33.0	54.0	52.0	59.5	48.5	51.0	49.5
	7.7	11.2	8.2	5.5	15.3	12.0	15.6	12.9	13.3	13.8
8C	28.0	81.5	85.5	47.0	44.0	46.0	49.0	21.0	63.5	52.5
	6.6	21.2	16.6	10.8	10.3	9.2	12.4	5.6	16.5	15.2
Means	47.4	50.9	54.6	45.0	48.1	58.6	53.1	45.1	59.0	55.9
	6.8	12.8	12.1	9.2	10.6	14.1	15.0	14.0	15.2	15.1
Grand Means	58.0	50.4	50.4	40.4	55.0	60.6	52.2	45.3	52.0	49.2
	7.7	10.6	9.6	7.9	11.0	11.7	11.7	13.0	15.0	14.6

[a] Percent intake

[b] Volume intake

Appendix Table 7. Consumption by two groups of pygmy goats of sucrose solution as percent of total fluid intake and in hundreds of milliliters per two-day period.

	Concentration of sucrose solution (g/100 ml)								
Animal	.08	.16	.32	.63	1.25	2.5	5	10	20
1P	62.5[a]	25.0	29.5	28.5	54.5	47.5	50.0	14.5	51.0
	8.0[b]	5.0	8.9	5.4	7.0	7.5	2.0	5.0	10.0
2P	54.0	70.0	50.0	50.0	50.0	50.0	82.0	86.5	55.0
	7.0	10.0	7.8	9.8	4.5	7.5	6.5	12.0	5.4
3P	50.0	22.0	50.0	39.0	53.5	62.5	65.5	99.9	51.5
	12.0	5.0	13.0	3.6	11.7	9.0	5.0	19.5	8.5
4P	33.5	32.0	40.5	44.0	86.0	97.5	90.0	89.5	87.5
	6.0	6.4	10.5	7.2	4.7	9.7	6.6	11.2	6.3
Means	50.0	37.2	42.5	40.4	61.0	64.4	71.9	72.6	61.2
	8.2	6.6	10.2	6.4	7.0	8.4	5.0	11.9	7.6
5P	51.5	59.5	50.0	55.0	60.5	49.0	68.0	52.0	72.5
	11.2	8.1	10.5	9.2	10.7	9.7	7.1	11.5	16.0
6P	50.0	6.0	95.5	71.5	39.5	99.9	88.5	70.5	19.5
	10.2	1.0	22.1	7.2	12.5	15.9	1.0	17.5	4.7
7P	51.5	45.0	51.5	49.0	43.5	56.0	54.0	92.5	27.0
	10.1	3.1	6.5	4.8	2.6	6.5	9.2	13.3	2.5
8P	50.0	75.5	49.5	53.0	48.5	50.5	68.0	61.5	87.5
	9.2	12.7	7.5	5.2	6.0	10.5	7.0	11.5	4.2
Means	50.8	46.5	61.6	57.1	48.0	63.9	69.6	69.1	51.6
	10.2	6.2	11.6	6.6	7.9	10.6	6.1	13.4	6.8
Grand Means	50.4	41.8	52.0	48.8	54.5	64.2	70.8	70.8	56.4
	9.2	6.4	10.9	6.5	7.4	9.5	5.6	12.6	7.2
	.7[c]	1.0	3.5	4.1	9.2	23.8	28.0	126.0	144.0

[a] Percent intake

[b] Volume intake

[c] Chemical intake, g/period

Appendix Table 8. Consumption by two groups of normal goats of sucrose solution as percent of total fluid intake and in hundreds of milliliters per two-day period.

	Concentration of sucrose solution (g/100 ml)								
Animal	.08	.16	.32	.63	1.25	2.5	5	10	20
1NAF	23.0[a]	33.0	50.0	65.0	50.0	50.0	45.5	85.0	95.5
	7.2[b]	17.5	7.2	12.4	14.3	15.5	11.0	20.5	18.5
2NAF	51.5	33.5	75.0	67.0	53.0	47.5	99.9	99.9	99.9
	15.0	7.4	9.0	7.8	16.2	7.0	9.5	17.0	10.4
3NAF	55.5	48.5	62.0	61.5	50.0	78.0	87.5	96.0	91.5
	16.3	10.6	10.1	10.8	16.0	16.7	11.6	18.5	13.5
4NAF	89.0	68.0	60.0	66.5	97.5	99.9	71.5	70.0	74.0
	18.4	10.6	9.6	7.0	25.0	26.0	9.7	14.0	10.0
Means	54.8	45.8	61.8	65.0	62.6	68.9	76.1	87.8	90.2
	14.2	9.0	9.0	9.5	17.9	16.3	10.4	17.5	13.1
5NSC	66.0	55.5	49.0	69.5	36.5	55.0	73.5	62.5	89.5
	17.2	7.8	7.0	10.0	6.5	11.0	10.0	8.5	25.5
6NSC	52.5	32.0	63.0	55.5	38.5	58.0	99.9	99.9	99.9
	13.0	8.0	15.6	12.2	8.0	12.1	21.5	17.0	19.5
7NAC	49.0	95.5	68.0	22.0	78.5	48.5	51.0	72.5	78.5
	13.6	16.8	11.9	5.5	22.3	7.5	1.0	11.0	17.2
8NAC	60.0	48.0	34.0	55.0	99.9	85.5	34.5	74.5	51.0
	18.0	13.5	10.5	19.0	38.5	43.0	5.2	16.0	20.5
Means	56.9	57.8	53.5	50.5	63.4	61.8	64.8	77.4	79.8
	15.4	11.5	11.2	11.6	18.8	18.4	9.4	13.1	20.7
Grand Means	55.8	51.8	57.6	57.7	63.0	65.4	70.4	82.6	85.0
	14.8	10.2	10.1	10.6	18.4	17.4	9.9	15.3	16.9
	1.2[c]	1.6	3.2	6.7	23.0	43.5	49.5	153.0	338.0

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[a] Percent intake

[b] Volume intake

[c] Chemical intake, g/period

Appendix Table 9. Consumption by two groups of sheep of sucrose solution as percent of total daily fluid intake and in hundreds of milliliters per day.

	Concentration of sucrose solution (g/100 ml)								
Animal	.08	.16	.32	.63	1.25	2.5	5	10	20
1S	34.5[a]	50.0	50.0	66.5	43.5	48.5	43.5	33.5	0
	15.0[b]	14.0	19.5	28.5	20.4	20.5	22.1	21.0	0
2S	53.0	38.0	44.5	40.0	50.0	47.0	50.0	48.5	53.5
	17.0	8.0	18.0	15.0	17.5	16.5	20.5	20.9	33.0
3S	60.0	50.5	48.0	80.0	56.5	66.5	3.5	0	0
	21.0	18.0	17.0	39.4	25.2	35.9	.7	0	0
4S	54.0	49.5	58.0	38.5	44.5	73.0	89.5	77.5	62.5
	18.0	16.5	18.0	16.3	18.6	36.5	38.0	38.0	38.0
Means	50.4	47.0	50.1	56.2	48.6	58.8	46.6	39.9	29.0
	17.8	14.1	18.1	24.9	20.4	27.4	20.3	20.0	17.8
5S	53.0	38.5	51.5	56.0	69.5	69.0	84.5	65.5	72.0
	21.0	17.2	21.3	26.0	27.3	27.0	38.0	40.5	36.4
6S	51.0	50.5	51.0	52.0	38.0	52.5	51.5	72.5	5.0
	12.0	18.1	14.0	15.5	10.7	14.5	20.5	23.0	1.0
7S	57.0	61.0	42.0	43.0	52.0	21.0	41.0	33.0	0
	13.0	15.5	11.2	7.5	10.1	5.5	16.7	11.5	0
8S	52.0	50.5	49.0	51.0	49.0	50.5	52.5	54.5	4.5
	8.5	18.7	10.8	11.9	10.7	16.7	16.5	20.5	1.5
Means	53.2	50.1	48.4	50.5	52.1	48.2	57.4	56.4	20.4
	13.6	17.4	14.3	15.2	14.7	15.9	22.9	23.9	9.7
Grand Means	51.8	48.6	49.2	53.4	50.4	53.5	52.0	48.2	24.7
	15.7	15.8	16.2	20.5	17.6	21.6	21.4	22.0	13.7
	1.3[c]	2.5	5.2	12.9	22.0	54.0	107.0	220.0	274.0

[a] Percent intake

[b] Volume intake

[c] Chemical intake, g/period

Appendix Table 10. Consumption by two groups of cattle of sucrose solution as percent of total daily fluid intake and in liters per day.

	Concentration of sucrose solution (g/100 ml)								
Animal	.08	.16	.32	.63	1.25	2.5	5	10	20
1C	61.5[a]	30.5	32.0	50.0	99.9	80.0	99.9	74.0	28.0
	8.3[b]	4.6	5.9	2.8	13.7	12.5	16.3	7.3	4.3
2C	38.0	49.5	11.0	37.5	72.5	99.9	89.0	77.5	39.5
	8.1	6.4	1.9	7.1	14.6	23.1	23.1	15.9	9.3
3C	35.0	39.0	94.5	59.0	80.0	81.5	87.0	94.5	37.5
	8.0	7.4	13.9	9.1	16.7	23.1	18.2	11.4	3.5
4C	44.0	79.5	43.5	69.5	81.5	77.0	90.0	74.5	20.0
	14.2	10.2	6.6	13.1	16.1	15.4	20.3	11.1	5.5
Means	44.6	49.6	45.2	54.0	83.5	84.6	91.5	80.1	31.2
	9.9	7.2	7.1	8.3	15.3	18.5	19.5	11.4	5.6
5C	44.0	31.0	36.5	50.0	47.5	85.5	90.5	85.5	18.5
	12.0	3.2	8.2	12.4	13.9	26.0	28.0	18.9	5.8
6C	51.5	88.5	57.5	62.5	86.0	96.5	99.0	96.0	15.0
	6.5	14.2	12.5	12.1	15.1	28.0	28.1	16.7	1.7
7C	51.0	5.0	51.0	49.0	51.5	86.0	98.5	53.5	87.0
	10.9	1.1	6.1	5.9	7.6	19.6	27.9	10.5	14.5
8C	51.5	70.5	33.0	42.0	46.5	71.5	78.0	20.5	28.5
	9.2	18.0	5.4	6.9	7.5	12.7	14.8	3.8	4.1
Means	49.5	48.8	44.5	50.9	57.9	84.9	91.5	63.9	37.2
	9.6	9.1	8.0	9.3	11.0	21.6	24.7	12.5	6.5
Grand Means	47.0	49.2	44.8	52.4	70.7	84.8	91.5	72.0	34.2
	9.8	8.2	7.6	8.8	13.2	20.0	22.1	12.0	6.0
	7.8[c]	13.1	24.3	55.4	165.0	500.0	1105.0	1200.0	1200.0

[a] Percent intake

[b] Volume intake

[c] Chemical intake, g/period

Appendix Table 11. Consumption by two groups of pygmy goats of sodium chloride solution as percent of total fluid intake and in hundreds of milliliters per two-day period.

	Concentration of sodium chloride solution (g/100 ml)									
Animal	.02	.04	.08	.16	.32	.63	1.25	2.5	5	10
1P	37.0[a]	28.0	60.0	68.0	81.0	56.0	41.5	26.0	12.5	0
	6.3[b]	5.0	5.0	7.0	10.5	12.0	15.0	2.0	1.0	0
2P	71.0	64.5	44.5	82.0	35.5	72.5	50.0	38.0	17.0	5.5
	12.0	5.2	3.8	9.8	5.8	18.7	15.0	4.8	1.0	.8
3P	50.0	50.0	29.0	89.5	62.5	92.0	83.0	26.0	7.0	0
	10.2	6.1	2.0	8.3	8.0	19.7	22.0	2.5	.5	0
4P	78.5	69.0	81.0	50.0	64.5	83.5	36.0	33.0	17.0	12.0
	13.0	3.0	6.0	6.9	5.8	17.3	11.5	3.5	.5	2.4
Means	59.1	52.9	53.6	72.4	60.9	76.0	52.6	30.7	13.4	4.4
	10.4	4.8	4.2	8.0	7.5	16.9	15.9	3.2	.8	.8
5P	37.0	6.0	96.0	36.5	35.0	95.0	53.0	22.5	10.0	4.5
	4.7	.4	12.5	5.5	7.5	14.0	11.5	5.2	1.2	.7
6P	74.0	94.5	48.5	96.5	96.0	97.5	55.5	2.0	2.0	10.0
	9.2	12.0	3.2	18.0	10.0	15.5	9.0	.4	.4	1.2
7P	52.0	49.5	50.5	73.5	96.5	98.0	94.0	50.0	6.0	0
	8.2	6.2	4.2	7.7	11.5	16.5	14.0	10.2	.7	0
8P	49.0	49.5	49.5	50.5	50.0	74.0	89.0	2.0	4.5	2.0
	14.0	5.2	4.7	9.2	9.5	12.0	21.0	.4	.7	.4
Means	53.0	49.9	61.1	64.2	69.4	91.8	72.9	19.1	5.6	4.1
	9.0	6.0	6.2	10.1	9.6	14.5	13.9	4.0	.8	.6
Grand Means	56.0	51.4	57.4	68.3	65.2	83.6	62.8	24.9	9.5	4.2
	9.7	5.4	5.2	9.0	8.6	15.7	14.9	3.6	.8	.6
	.2[c]	.2	.4	1.4	2.8	9.9	18.6	9.0	4.0	6.0

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[a] Percent intake

[b] Volume intake

[c] Chemical intake, g/period

Appendix Table 12. Consumption by two groups of normal goats of sodium chloride solution as percent of total fluid intake and in hundreds of milliliters per two-day period.

	Concentration of sodium chloride solution (g/100 ml)									
Animal	.02	.04	.08	.16	.32	.63	1.25	2.5	5	10
1NAF	79.5[a]	73.5	66.0	53.5	50.0	25.0	60.0	43.5	16.0	9.5
	24.5[b]	15.0	16.6	13.7	11.0	5.3	8.5	6.5	1.5	2.3
2NAF	48.0	80.0	4.0	57.0	90.0	50.0	99.0	79.0	3.0	5.0
	14.4	13.0	1.0	12.0	13.2	10.7	7.0	3.7	1.0	2.0
3NAF	16.0	11.5	54.5	80.0	51.0	79.0	22.0	27.0	10.0	0
	3.7	2.8	10.5	14.9	15.0	9.8	4.0	2.0	1.0	0
4NAF	55.0	79.0	86.0	83.5	51.5	71.0	20.0	14.5	62.5	0
	16.4	20.2	16.2	15.3	10.3	8.5	1.0	.8	1.0	0
Means	49.6	61.0	52.6	68.5	60.6	56.2	50.2	41.0	22.9	3.6
	14.8	12.8	10.3	14.0	12.4	8.6	5.1	3.2	1.1	1.1
5NSC	50.0	52.0	26.0	63.5	24.5	29.5	3.5	2.5	3.5	2.5
	10.5	15.0	11.0	18.0	5.5	3.5	1.0	1.0	1.0	.5
6NHM	33.5	72.0	41.5	83.0	71.5	50.0	24.0	7.5	3.0	4.5
	9.5	12.5	12.5	22.5	21.0	14.0	9.5	3.0	1.0	1.0
7NAC	70.0	69.5	56.0	37.0	49.5	38.0	13.5	11.0	4.0	0
	15.0	14.0	12.0	10.5	9.0	12.0	2.5	3.5	1.5	0
8NAC	50.0	50.0	44.5	30.5	47.0	42.0	7.5	4.5	2.0	2.5
	24.5	19.5	15.0	6.5	4.5	7.5	2.5	1.5	.5	.5
Means	50.9	60.9	42.0	53.5	48.1	39.9	12.1	6.4	3.1	2.4
	14.9	15.2	12.6	14.4	10.0	9.2	3.9	2.2	1.0	.5
Grand Means	50.2	61.0	47.3	61.0	54.4	48.0	31.2	23.7	13.0	3.0
	15.8	15.0	11.4	14.2	11.2	8.9	4.5	2.7	1.0	.8
	.3[c]	.6	.9	2.3	3.6	5.6	5.6	6.8	5.0	8.0

[a] Percent intake

[b] Volume intake

[c] Chemical intake, g/period

Appendix Table 13. Consumption by two groups of sheep of sodium chloride solution as percent of total daily fluid intake and in hundreds of milliliters per day.

Animal	Concentration of sodium chloride solution (g/100 ml)								
	.02	.04	.08	.16	.32	.63	1.25	2.5	5
1S	63.5[a]	34.0	43.0	48.5	49.0	49.0	22.0	2.0	3.5
	24.5[b]	18.7	24.4	20.5	24.5	27.7	14.0	.3	1.5
2S	50.0	27.0	60.5	55.0	50.0	50.0	42.0	27.5	14.0
	18.5	17.4	22.6	19.6	18.0	18.4	18.0	3.5	6.5
3S	37.0	50.0	59.0	57.5	24.5	47.5	7.5	8.0	6.0
	1.2	.5	18.2	9.0	6.2	20.0	.8	2.0	1.0
4S	62.0	57.5	66.5	63.5	51.0	52.0	68.0	28.5	5.0
	9.9	18.1	24.3	30.7	18.7	24.0	31.5	19.0	2.0
Means	53.1	42.1	57.2	54.6	43.6	49.6	34.9	16.5	7.1
	13.5	13.7	22.4	20.0	16.8	22.5	16.1	6.2	2.8
5S	57.0	50.0	53.5	68.0	54.0	74.0	58.0	49.0	31.5
	13.8	10.5	27.7	25.5	25.0	33.0	38.8	36.5	17.5
6S	57.0	6.5	25.0	4.0	50.5	82.0	35.0	23.0	3.5
	8.5	1.5	23.8	2.6	16.5	17.0	18.8	4.3	1.0
7S	82.0	82.0	73.5	49.0	35.5	39.0	45.5	12.5	3.5
	5.0	20.0	34.2	25.4	8.5	5.5	14.5	3.5	1.0
8S	26.5	94.0	48.5	51.0	49.5	38.0	50.5	26.5	7.5
	15.5	14.5	25.5	35.0	10.5	1.8	16.5	1.0	2.5
Means	55.6	58.1	50.1	43.0	47.4	58.2	47.2	27.8	11.5
	10.7	11.6	27.8	24.6	15.1	14.3	22.2	11.3	5.5
Grand Means	54.4	50.1	53.6	48.8	45.5	53.9	41.0	22.2	9.3
	12.1	12.6	25.1	22.3	16.0	18.4	19.2	8.8	4.2
	.2[c]	.5	2.0	3.6	5.1	11.6	24.0	22.0	21.0

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[a] Percent intake

[b] Volume intake

[c] Chemical intake, g/period

Appendix Table 14. Consumption by two groups of cattle of sodium chloride solution as percent of total daily fluid intake and in liters per day.

	Concentration of sodium chloride solution (g/100 ml)						
Animal	.02	.04	.08	.16	.32	.63	1.25
1C	49.5[a]	25.0	53.5	3.5	2.5	24.0	2.0
	4.9[b]	3.1	8.8	.3	.2	2.9	.2
2C	42.0	31.5	58.0	41.0	56.5	47.0	2.0
	7.7	6.2	7.0	9.1	11.9	12.5	.3
3C	49.0	1.5	1.5	20.5	72.0	10.5	10.0
	5.2	2.2	.2	2.0	9.2	1.5	1.9
4C	22.0	76.0	11.5	53.0	7.5	37.0	12.5
	5.4	8.8	2.5	8.6	1.1	10.9	2.0
Means	40.6	33.5	31.1	29.5	34.6	29.6	6.6
	5.8	5.1	4.6	5.0	5.6	7.0	1.1
5C	65.0	52.0	47.5	16.0	1.0	43.0	2.5
	13.1	14.7	10.0	3.6	.2	13.6	.4
6C	66.0	71.5	62.5	52.5	17.5	11.5	6.0
	10.4	12.2	15.5	11.1	3.8	2.2	1.4
7C	10.5	48.5	51.5	50.0	50.0	50.5	43.5
	.9	13.1	9.8	10.4	7.8	15.8	11.0
8C	51.0	73.0	48.0	62.5	8.0	5.5	1.0
	9.3	13.1	10.4	14.7	1.6	1.1	.2
Means	48.1	61.2	52.4	45.2	19.1	27.6	13.2
	8.4	13.3	11.4	10.0	3.4	8.2	3.2
Grand Means	44.4	47.4	41.8	37.4	26.8	28.6	9.9
	7.1	9.2	8.0	7.5	4.5	7.6	2.2
	1.4[c]	3.7	6.4	12.0	14.4	47.9	27.5

[a] Percent intake

[b] Volume intake

[c] Chemical intake, g/period

Appendix Table 15. Consumption by two groups of pygmy goats of acetic acid solution as percent of total fluid intake and in hundreds of milliliters per two-day period.

	Concentration of acetic acid solution (ml/100 ml)								
Animal	.005	.01	.02	.04	.08	.16	.32	.63	1.25
1P	37.5[a]	50.0	51.5	66.0	63.5	43.0	42.5	21.5	0
	7.6[b]	7.4	9.9	10.5	12.3	7.5	5.6	3.0	0
2P	49.5	30.0	45.0	49.5	30.5	20.5	60.0	43.0	0
	9.0	5.5	7.9	7.8	7.1	3.0	11.3	6.0	0
3P	46.5	44.5	80.5	26.0	74.0	57.0	53.5	27.0	2.5
	5.3	5.9	14.5	4.4	12.0	8.5	8.0	1.6	.4
4P	20.0	65.5	8.5	45.5	50.5	3.5	6.5	0	0
	2.7	7.3	1.0	3.1	7.4	.4	.8	0	0
Means	38.4	47.5	46.4	46.7	54.6	31.0	40.6	22.9	.6
	6.2	6.5	8.3	6.4	9.7	4.8	6.4	2.6	.1
5P	84.0	94.5	97.5	97.0	96.5	51.5	97.5	50.0	78.5
	17.0	11.5	15.5	15.0	18.5	9.5	16.5	10.7	12.0
6P	50.0	47.5	47.0	97.5	61.5	81.5	74.0	90.5	29.0
	13.5	7.0	10.7	14.0	12.5	16.0	12.0	9.0	3.7
7P	96.5	51.5	66.5	96.0	96.0	96.5	93.5	93.5	94.0
	11.0	8.7	9.5	15.5	11.0	18.5	14.5	19.0	15.5
8P	72.0	87.0	70.0	96.0	92.0	89.0	94.5	65.0	49.5
	4.0	10.5	7.5	16.0	16.0	18.0	16.5	9.0	6.5
Means	75.6	70.1	70.2	96.6	86.5	79.6	89.9	74.8	62.8
	11.4	9.4	10.8	15.1	14.5	15.5	14.9	11.9	9.4
Grand Means	62.9	58.8	58.3	71.6	70.6	55.3	65.2	48.8	31.7
	8.8	8.0	9.6	10.8	12.1	10.2	10.6	7.2	4.8
	.04[c]	.08	.19	.43	.97	1.63	3.39	4.54	6.00
pH	5.3	4.8	4.4	3.9	3.6	3.3	3.1	2.9	2.7

[a] Percent intake

[b] Volume intake

[c] Chemical intake, ml/period

Appendix Table 16. Consumption by two groups of normal goats of acetic acid solution as percent of total fluid intake and in hundreds of milliliters per two-day period.

	Concentration of acetic acid solution (ml/100 ml)								
Animal	.005	.01	.02	.04	.08	.16	.32	.63	1.25
1NAF	20.5[a]	75.5	13.0	57.5	52.5	29.5	37.0	36.5	5.5
	17.2[b]	19.5	3.2	17.3	5.3	13.0	19.7	13.3	2.0
2NAF	73.5	52.5	44.5	32.5	98.5	80.5	.5	0	0
	16.1	8.0	4.4	13.5	17.2	15.1	.1	0	0
3NAF	17.5	50.5	73.0	33.0	45.5	40.0	53.5	19.5	16.0
	11.2	2.0	11.5	14.6	10.1	4.0	8.9	5.9	2.9
4NAF	42.0	50.0	75.0	5.0	1.0	23.5	1.5	0	0
	12.8	5.4	17.1	1.8	.3	3.6	.4	0	0
Means	38.4	57.1	51.4	30.5	49.5	43.4	23.1	14.0	5.4
	14.3	8.7	9.0	11.8	8.2	8.9	7.3	4.8	1.2
5NSC	38.5	55.0	48.0	57.5	56.0	58.5	80.5	75.0	25.5
	7.0	20.0	20.0	20.5	21.5	22.0	14.0	36.0	13.0
6NHM	53.5	63.0	34.0	43.5	32.5	29.0	46.5	52.0	8.5
	19.0	29.0	15.0	16.5	13.5	15.5	20.0	13.5	4.0
7NAC	57.5	16.5	45.5	3.0	4.0	2.5	4.0	0	10.0
	15.0	4.5	14.0	1.0	1.5	1.0	1.5	0	1.0
8NAC	61.0	60.5	64.0	28.5	20.5	26.0	3.0	25.0	0
	17.0	22.0	22.0	10.0	9.0	16.0	1.0	7.5	0
Means	52.6	48.8	47.9	33.1	28.2	29.0	33.5	38.0	11.0
	14.5	18.9	17.8	12.0	11.4	13.6	9.1	14.2	4.5
Grand Means	45.5	53.0	49.6	31.8	38.8	36.2	28.3	26.0	8.2
	14.4	13.8	13.4	11.9	9.8	11.2	8.2	9.5	2.8
	.07[c]	.14	.27	.48	.78	1.79	2.62	5.98	3.5
pH	5.3	4.8	4.4	3.9	3.6	3.3	3.1	2.9	2.7

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[a] Percent intake

[b] Volume intake

[c] Chemical intake, ml/period

Appendix Table 17. Consumption by two groups of sheep of acetic acid solution as percent of total daily fluid intake and in hundreds of milliliters per day.

	Concentration of acetic acid solution (ml/100 ml)									
Animal	.005	.01	.02	.04	.08	.16	.32	.63	1.25	2.5
1S	48.0[a]	47.0	50.0	69.0	99.9	96.5	77.0	73.0	17.5	3.0
	19.5[b]	14.7	18.4	27.3	31.3	31.6	37.0	30.5	5.3	1.0
2S	36.5	43.0	86.5	59.0	89.5	74.0	42.0	18.5	1.0	1.5
	15.0	15.0	32.0	25.3	31.9	30.0	16.2	7.0	.4	.5
3S	26.5	80.0	86.0	89.5	99.9	50.5	3.0	7.5	2.5	0
	8.0	14.2	25.2	29.7	18.7	24.8	1.0	2.2	1.0	0
4SR	65.5	70.5	81.0	87.5	83.5	59.5	9.0	14.0	52.0	2.0
	16.2	23.2	25.1	28.6	22.2	15.1	17.0	5.1	18.5	.5
Means	44.1	60.1	75.9	76.2	93.2	70.1	32.8	28.2	18.2	1.6
	14.7	16.8	25.2	27.7	26.0	25.4	17.8	11.2	6.3	.5
5S	57.0	44.5	53.5	48.0	37.5	22.0	11.0	9.0	10.0	1.0
	27.5	27.5	32.0	21.5	20.0	13.5	5.5	4.8	5.0	.5
6S	48.5	50.0	57.5	60.5	29.0	12.5	3.5	5.5	4.5	3.0
	16.5	17.5	22.0	22.0	11.5	3.0	1.0	1.4	2.1	1.0
7S	14.5	12.0	56.0	4.0	6.0	3.5	4.0	6.0	3.0	1.5
	5.5	4.5	8.5	1.0	1.0	1.0	.5	1.1	.7	.5
8S	95.0	51.0	21.5	44.0	16.0	3.0	8.5	3.0	1.0	1.5
	29.0	18.0	6.5	6.0	3.5	1.0	.5	.7	.8	.3
Means	53.8	39.4	47.0	39.1	22.1	10.2	6.8	5.9	4.6	1.8
	19.6	16.9	17.2	12.6	9.0	4.6	1.9	2.0	2.2	.6
Grand Means	49.0	49.8	61.4	57.6	57.6	40.2	19.8	17.0	11.4	1.7
	17.2	16.8	21.2	20.2	17.5	15.0	9.8	6.6	4.2	.6
	.09[c]	.17	.42	.81	1.40	2.40	3.14	4.16	5.25	1.50
pH	5.3	4.8	4.4	3.9	3.6	3.3	3.1	2.9	2.7	2.5

[a] Percent intake

[b] Volume intake

[c] Chemical intake, ml/period

Appendix Table 18. Consumption by two groups of cattle of acetic acid solution as percent of total daily fluid intake and in liters per day.

	Concentration of acetic acid solution (ml/100 ml)						
Animal	.005	.01	.02	.04	.08	.16	.32
1C	57.0[a]	70.5	87.5	79.5	7.5	5.0	8.0
	11.7[b]	13.6	11.6	12.6	1.2	1.0	1.3
2C	52.0	69.5	79.5	90.5	43.0	9.0	1.5
	12.8	19.0	19.2	21.6	9.8	2.4	.4
3C	66.0	38.0	81.5	73.0	0	2.0	8.5
	16.2	9.0	18.8	18.4	0	.4	1.0
4C	46.0	55.5	87.0	61.0	40.0	4.5	6.0
	11.3	11.0	21.8	13.8	9.6	1.0	1.9
Means	55.2	58.4	83.9	76.0	22.6	5.1	4.8
	13.0	13.2	17.8	16.6	5.2	1.2	1.1
5C	26.0	58.5	59.5	76.5	95.5	86.5	44.0
	6.7	17.9	15.2	19.8	26.2	26.9	14.0
6C	60.0	71.0	71.5	73.0	58.5	17.0	35.0
	18.1	13.8	20.1	22.4	13.2	4.2	9.7
7C	11.5	54.0	51.5	33.0	49.5	55.5	37.5
	1.9	7.4	11.5	9.6	9.6	12.9	7.0
8C	26.0	62.5	67.0	36.0	20.0	5.5	7.0
	5.8	11.1	13.6	10.6	3.7	.6	1.1
Means	30.9	61.5	62.4	54.6	55.9	41.1	30.9
	8.1	12.6	15.1	15.6	13.2	11.2	8.0
Grand Means	43.0	60.0	73.2	65.3	39.2	23.1	18.4
	10.6	12.9	16.4	16.1	9.2	6.2	4.6
	.53[c]	1.29	3.28	6.44	7.36	9.92	14.72
pH	5.3	4.8	4.4	3.9	3.6	3.3	3.1

[a] Percent intake

[b] Volume intake

[c] Chemical intake, ml/period

Appendix Table 19. Consumption by two groups of pygmy goats of quinine hydrochloride solution as percent of total fluid intake and in hundreds of milliliters per two-day period.

	Concentration of quinine hydrochloride solution (mg/100 ml)							
Animal	.63	1.25	2.5	5	10	20	40	80
1P	63.5[a]	57.5	84.5	61.5	28.0	39.5	63.5	34.5
	9.9[b]	8.8	11.0	6.8	2.5	8.5	15.0	8.0
2P	46.5	61.5	43.0	30.5	34.0	11.0	0	7.0
	6.1	8.7	6.0	2.8	4.7	2.0	0	.5
3P	66.5	74.5	62.5	38.5	48.5	22.0	5.0	4.0
	12.5	10.5	9.8	5.0	10.3	5.5	1.5	.5
4P	64.0	74.0	53.5	27.0	10.0	2.5	2.5	0
	11.2	13.7	7.2	3.7	1.5	.5	.5	0
Means	60.1	66.9	60.9	39.4	30.1	18.8	17.8	11.4
	9.9	10.4	8.5	4.6	4.8	4.1	4.2	2.2
5P	83.5	32.5	46.0	44.0	17.0	82.5	32.5	85.0
	14.5	9.5	11.0	12.0	4.2	14.0	8.5	13.0
6P	79.5	67.0	70.5	9.0	43.5	7.5	12.0	6.5
	12.0	13.5	14.0	1.2	3.7	.7	2.5	.7
7P	50.0	50.0	50.5	49.0	91.0	49.5	42.5	72.5
	8.0	7.5	9.0	5.2	15.5	10.2	5.2	10.2
8P	76.0	86.5	36.0	43.5	86.5	50.0	62.5	25.5
	13.0	15.0	10.2	5.0	15.0	9.2	13.5	6.5
Means	72.2	59.0	50.8	36.4	59.5	47.4	37.4	47.4
	11.9	11.4	11.0	5.8	9.6	8.5	7.4	7.6
Grand Means	66.2	63.0	55.8	37.9	44.8	33.1	27.6	29.4
	10.9	10.9	9.8	5.2	7.2	6.3	5.8	4.9
	6.9[c]	13.6	24.5	26.0	72.0	126.0	232.0	392.0

[a] Percent intake

[b] Volume intake

[c] Chemical intake, mg/period

Appendix Table 20. Consumption by two groups of normal goats of quinine hydrochloride solution as percent of total fluid intake and in hundreds of milliliters per two-day period.

Animal	Concentration of quinine hydrochloride solution (mg/100 ml)							
	.63	1.25	2.5	5	10	20	40	80
1NAF	55.5[a]	77.0	82.5	48.5	30.5	59.5	51.5	17.5
	19.3[b]	26.2	18.4	15.5	10.2	21.0	26.0	5.5
2NAF	63.0	99.9	68.5	65.0	82.0	3.5	9.5	4.5
	17.6	14.4	10.0	8.0	9.0	1.0	2.5	.8
3NAF	50.0	87.0	51.0	32.5	32.0	57.0	45.0	19.0
	15.6	14.6	10.4	2.5	8.5	18.0	9.5	4.5
4NAF	80.5	70.5	98.5	27.5	67.5	72.0	0	0
	17.3	13.6	14.6	17.3	22.0	21.5	0	0
Means	62.2	83.6	75.1	43.4	53.0	48.0	26.5	10.2
	17.4	17.2	13.4	10.8	12.4	15.5	9.6	2.7
5NSC	55.5	51.0	48.0	38.5	26.5	51.0	41.0	47.0
	23.0	26.5	26.5	24.0	12.0	23.5	24.0	17.0
6NHM	73.5	46.5	42.5	49.0	43.5	45.0	26.5	37.5
	31.0	24.5	24.0	31.5	29.0	20.5	15.0	22.0
7NAC	46.0	46.0	47.0	21.0	4.0	6.0	2.5	3.0
	19.0	25.5	22.5	10.0	1.5	1.5	1.0	1.0
8NAC	66.0	50.5	46.5	62.0	57.5	55.0	21.0	2.0
	36.5	32.0	32.0	32.0	33.0	22.0	15.0	1.0
Means	60.2	48.5	46.0	42.6	32.9	39.2	22.8	22.4
	27.4	27.1	26.2	24.4	18.9	16.9	13.8	10.2
Grand Means	61.2	66.0	60.6	43.0	43.0	43.6	24.6	16.3
	22.4	22.2	19.8	17.6	15.6	16.2	11.7	6.4
	14.1[c]	27.8	49.5	88.0	156.0	324.0	468.0	512.0

[a] Percent intake

[b] Volume intake

[c] Chemical intake, mg/period

Appendix Table 21. Consumption by two groups of sheep of quinine hydrochloride solution as percent of total daily fluid intake and in hundreds of milliliters per day.

	Concentration of quinine hydrochloride solution (mg/100 ml)						
Animal	.63	1.25	2.5	5	10	20	40
1S	71.0[a]	52.0	15.5	1.5	3.0	1.0	1.0
	18.4[b]	20.8	5.5	1.0	1.0	.1	.2
2S	67.0	50.0	63.5	2.5	4.5	2.5	1.0
	20.0	12.0	23.6	1.0	1.4	.8	.3
3S	25.5	50.0	47.0	3.5	.5	2.5	0
	6.9	22.8	16.8	1.0	.1	.8	0
4SR	53.5	40.0	50.5	37.5	22.0	6.0	2.5
	6.8	19.9	12.7	11.3	5.2	1.0	.9
Means	54.2	48.0	44.1	11.2	7.5	3.0	1.1
	13.0	18.9	14.6	3.6	1.9	.7	.4
5S	61.5	35.5	23.0	22.0	68.5	5.0	2.5
	31.5	17.5	9.5	6.5	32.0	1.5	.8
6S	43.0	50.0	48.5	49.0	62.0	49.5	6.0
	3.0	14.5	7.5	10.5	27.0	10.5	1.1
7S	23.5	44.0	66.5	10.0	57.0	49.0	11.5
	8.5	17.0	11.5	2.5	25.0	9.5	1.5
8S	39.5	32.0	50.5	51.0	64.5	39.5	12.5
	15.0	17.0	6.0	11.5	15.5	3.5	2.0
Means	41.9	40.4	47.1	33.0	63.0	35.8	6.8
	14.5	16.5	8.6	7.8	24.9	6.2	1.4
Grand Means	48.0	44.2	45.6	22.1	35.2	19.4	4.0
	13.8	17.7	11.6	5.7	13.4	3.4	.9
	8.7[c]	22.1	29.0	28.5	134.0	68.0	36.0

[a] Percent intake

[b] Volume intake

[c] Chemical intake, mg/period

Appendix Table 22. Consumption by two groups of cattle of quinine hydrochloride solution as percent of total daily fluid intake and in liters per day.

	Concentration of quinine hydrochloride solution (mg/100 ml)						
Animal	.63	1.25	2.5	5	10	20	40
1C	37.5[a]	24.5	1.0	70.5	1.5	4.0	1.0
	11.5[b]	4.1	.2	18.4	.4	.8	.1
2C	55.5	81.5	38.0	43.5	12.0	3.5	2.0
	15.3	20.8	7.3	11.7	3.0	.6	.5
3C	22.5	85.5	28.0	31.5	45.0	7.0	2.0
	5.4	21.5	8.0	9.3	10.7	1.7	.3
4C	53.5	14.5	54.5	38.0	9.0	1.5	1.0
	14.1	3.6	11.9	8.3	2.4	.2	.1
Means	42.2	51.5	30.4	45.9	16.9	4.0	1.5
	11.6	12.5	6.8	11.9	4.1	.8	.5
5C	52.0	26.5	38.0	24.0	55.0	26.5	1.5
	17.3	7.0	10.8	5.6	13.6	4.9	.2
6C	60.5	40.0	58.5	47.5	32.0	8.5	2.5
	20.5	10.2	14.7	11.1	8.1	1.1	.2
7C	51.0	50.0	52.5	54.5	51.0	48.5	1.0
	12.3	10.2	11.1	11.5	11.1	9.3	.1
8C	47.5	61.5	43.0	16.0	8.5	6.0	2.5
	10.8	13.6	8.8	2.4	1.1	.6	.4
Means	52.8	44.5	48.0	35.5	36.6	22.4	1.9
	15.2	10.2	11.4	7.6	8.5	4.0	.2
Grand Means	47.5	48.0	39.2	40.7	26.8	13.2	1.7
	13.4	11.4	9.1	9.8	6.3	2.4	.3
	84.4[c]	142.5	227.5	490.0	630.0	480.0	12.0

[a] Percent intake

[b] Volume intake

[c] Chemical intake, mg/period

Appendix Table 23. Consumption by two groups of sheep of molasses solution as percent of total daily fluid intake and in hundreds of milliliters per day.

	Concentration of molasses solution (g/100 ml)	
Animal	2.08	8.33
1S	50.0[a]	58.0
	12.0[b]	29.5
2S	50.5	97.0
	12.5	43.0
3S	99.0	96.0
	35.0	33.0
4SR	0	20.5
	0	6.5
Means	49.9	67.9
	14.9	28.0
5S	19.0	20.5
	9.0	11.5
6S	64.5	4.5
	22.0	1.0
7S	16.0	4.0
	5.5	1.0
8S	97.0	14.0
	34.0	3.5
Means	49.1	10.8
	17.6	4.2
Grand Means	49.5	39.4
	16.2	16.1
	20.2[c]	80.5

[a] Percent intake

[b] Volume intake

[c] Molasses intake, g/period

Appendix Table 24. Consumption by two groups of cattle of molasses solution as percent of total daily fluid intake and in liters per day.

Animal	Concentration of molasses solution (g/100 ml) 2.08	 8.33
1C	99.5[a]	89.5
	22.7[b]	27.2
2C	84.5	79.5
	27.2	27.2
3C	75.0	91.5
	23.0	27.2
4C	84.5	84.5
	21.9	27.2
Means	85.9	86.2
	23.7	27.2
5C	88.5	56.5
	27.0	19.2
6C	58.0	40.5
	9.2	.2
7C	94.0	44.5
	26.8	25.6
8C	69.5	30.0
	18.3	5.5
Means	77.5	42.9
	20.3	12.6
Grand Means	81.7	64.6
	22.0	19.9
	275.0[c]	995.0

[a] Percent intake

[b] Volume intake

[c] Molasses intake, g/period

Appendix Table 25. Statistical analysis of sheep and cattle responses to two concentrations of molasses.

		Animal Species			
		Sheep (S)		Cattle (C)	
Item	Molasses Conc:	2.08% (L)	8.33%(H)	2.08%(L)	8.33% (H)
Variance		1,178.20	1,337.24	160.68	526.15
S.D., %		34.32	36.57	12.68	22.94
Mean, %		49.51	39.31	81.69	64.56
F-value[a]					
SL vs. CL[b]		7.326[g]			
SL vs. SH		1.135[e]			
SL vs. CH		2.238[e]			
CL vs. SH		8.318[g]			
CL vs. CH		3.273[e]			
SH vs. CH		2.541[e]			
t-value[c]		.040[e]	.827[e]	7.069[h]	1.795[f]
t-value[d]					
SL vs. CL		2.487[g]			
SH vs. CH		1.654[f]			
SL vs. SH		.127[e]			
CL vs. CH		1.848[g]			

[a] A test of whether group variances differ from each other.

[b] S = sheep, C = cattle, L = 2.08%, H = 8.33%.

[c] A test of whether group means differ from a theoretical mean of 50%.

[d] A test for differences between concentrations within animal types and between animal types within concentrations.

[e] $(P > .10)$ probability level.

[f] $(P < .10)$ probability level.

[g] $(P < .05)$ probability level.

[h] $(P < .01)$ probability level.