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Title: TASTE RESPONSES IN COLUMBIAN BLACK-TAILED DEER
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Taste responses of the Columbian black-tailed deer,

Odocoileus hemionus columbianus (Richardson), were determined

by use of the two-choice preference test method, where the choices

were tap water and tap water-chemical solutions in ascending

concentrations.   The chemicals tested were: the sugars, glucose

and sucrose; the sodium salts of chloride (NaCl) and acetate (NaAc);

the acids, hydrochloric (HCl), acetic (HAc) and butyric (HBu); and

quinine sulfate (QSO_4), quinine monohydrochloride, and saccharin

(the non-sodium, crystalline form).

Animals used in the study consisted of twelve deer, half

bucks and half does, plus four Hampshire sheep as a control group

for comparison with previous work.   The deer, initially about five

months old, were penned by sex into four groups of three deer each.

The separately penned groups were fed ad libitum pelleted alfalfa

hay and Fischer's calf grower. Responses were determined by expressing the consumption of test fluid as percent intake of the total fluid consumed for a given time period.

The non-discrimination zone was derived by determining the normal variation, with tap water in both containers, around a theoretical mean intake of 50% from each container. To determine if there were differences in response due to sex both graphical analysis and a paired "t" test were used.

The chemical concentrations at the preference and rejection thresholds for deer were 57% and 43% of total fluid intake, respectively. For sheep the non-discrimination range was calculated to be from 44% to 56%.

Specific results are as follows:

1.   Deer demonstrated stronger preferences for sweet solutions than sheep. The average sensitivity levels of deer and sheep for glucose were at 0.0294 M and 0.1388 M, respectively. The average sensitivity level of deer for sucrose was at 0.00705 M and the sheep were too variable for determination.

2.   Deer preferred saccharin over a wide range of concentrations but to a much lesser degree than for the two sugars. Sheep were variable in response. The average sensitivity levels of deer and sheep for saccharin were at 0.0298 mM and 0.1024 mM, respectively.

3.   Deer strongly preferred sodium acetate but not sodium

chloride. Sheep were variable in response to both salts. The

average sensitivity levels of deer and sheep for sodium chloride

were at 0.1516 M and 0.2352 M, respectively. The average

sensitivity levels of deer and sheep for sodium acetate were at

0.0085 M and 0.0353 M, respectively.

4.   Deer exhibited a wide range of fairly strong preference for

acetic acid, but not for butyric and hydrochloric acid. Sheep

demonstrated distinct rejection trends for all three acids. Test

results with sodium acetate and acetic acid verified the strong

preference of deer for the acetate radical. The average sensitivity

levels of deer and sheep for acetic acid were at 0.0011 M and

0.1049 M, respectively. The average sensitivity levels of deer and

sheep for butyric acid were at 0.0100 M and 0.0014 M, respec-

tively. The average sensitivity levels of deer and sheep for

hydrochloric acid were at 0.0258 M and 0.0021 M, respectively.

Deer clearly rejected the volatile fatty acids (acetic and butyric

acid) at a higher pH than hydrochloric acid which has a less

objectionable smell.

5.   Definite sex differences were observed in the bitter taste

response of deer. Bucks demonstrated a marked preference for

bitter solutions while the does and sheep rejected them. The

average sensitivity levels of deer and sheep for quinine sulfate

were at 0.0386 mM and 0.1596 mM, respectively. The average

sensitivity levels of deer and sheep for quinine monohydrochloride

were at 0.0283 mM and 0.0204 mM, respectively.

6.   Among glucose, sodium chloride, acetic acid and the

quinine compounds, the quinine compounds are the most effective

taste stimulants (i. e., accepted at the lowest concentration).

Acetic acid is next in effectiveness, followed by sodium chloride and

glucose, respectively.

7.   Based on the sum of sensitivity levels of deer, sheep, goats

and calves in a sensitivity series for each of the primary taste

modalities, goats appear to be the most sensitive, followed by deer,

calves and finally by sheep.

8.   Species differences in taste responses appear to be a prod-

uct of the evolutionary process.

9.   Future studies of more ruminant species are requisite to a

basic understanding of taste responses and all of their applied

ramifications.

Taste Responses in Columbian Black-tailed Deer
(Odocoileus hemionus columbianus (Richardson)

by

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INTRODUCTION

This study is concerned with the determination of the taste responses of deer to certain chemicals representing the four primary taste sensations (sweet, bitter, salty and sour).

There are four main reasons why the determination of taste responses of animals are important. First, by accumulation of taste knowledge for a wide variety of species, it will eventually be possible to confidently state some of the fundamental mechanisms involved in this taste phenomenon. Currently, information on taste is limited to relatively few species. As a result, generalizations on fundamental mechanisms are plagued with exceptions to the rule.

Secondly, specific information on the taste responses of deer is needed as they are frequently in competition with domestic animals under range conditions, and are all too often involved in food crop, forest plantation and garden damage complaints. To develop effective repellents and attractants (attract away from crops) for preventing this damage the deer's means of sensory evaluation of food must be well understood. Reasons for forage preferences will hopefully become a worthwhile by-product.

Thirdly, the problem of deer management on winter ranges needs clarification regarding the correlation between food preferences and the nutrient level of the diet. The role of taste in an animal's sensory evaluation of food is a good method for gathering basic information to gain insight into this problem.

Fourthly, as pointed out by Goatcher (1968), taste in ruminant animals is likely to become of greater significance in the future. Increased demand for foods now utilized in livestock feeding will force livestock producers to use feeds of much lower palatability to achieve a favorable cost-price ratio. With the emphasis on higher production in domestic animals, it is necessary for animals to consume feed at their maximum capacity, and so, as a result, the sensory qualities of the feed assume greater importance. For while it is true that animals will usually eat enough of a feed of low palatability to sustain themselves, they may not eat enough to achieve satisfactory production levels. On the contrary, it might be desirable in some instances to limit intake (as in supplemental feeding) whereby advantage could be taken of the knowledge gained of the negative aspects of certain chemicals on intake (Goatcher, 1968).

The purpose of this study was to determine what concentrations of the various chemicals tested were necessary to initiate a response in deer; and, secondly, the direction (negative or positive

response) and magnitude of these responses. Effect of sex of immature deer on this response was also determined. The study was prompted by the apparent lack of any knowledge on taste reactions in this species and the availability of such data on other species such as cattle, sheep and goats. To achieve the stated purpose deer were subjected to increasing concentrations of various chemicals in water solution by use of the two choice preference test technique.

REVIEW OF LITERATURE

Literature Related to Taste Responses and Food
Preferences of Deer

After reviewing the current literature, it appeared that no work had been done on the taste responses of deer, or on any of the other means of sensory evaluation of food (olfaction, sight and touch). There has, however, been considerable work done in determining the food preferences of deer. Knowledge of the chemical composition of the preferred foods provides an indirect means of determining what chemicals initiate a positive taste response.

The many approaches used to study dietary preferences can be classified into three main criteria: (1) analyses of vegetation on feeding sites, (2) animal observation, and (3) collection of material from stomachs, esophageal fistulas, and feces.

Analyses of vegetetation on feeding sites can be done by tracking the animals and observing the browsed plants, and by checking utilization by animals in temporary and permanent sample plots. Deen (1938) disapproved of tracking as its accuracy depended upon the ability of the man to track animals and decide where they stopped to browse. Most range studies evaluate food preferences by determining the degree of use on each species in permanent and temporary plots (Allen, 1968; Crouch, 1966). Carhart (1944) used

both vegetation analyses and stomach content analyses and indicated

that the latter method was more exact and positive. Furthermore,

forage use data may be confounded by utilization by both domestic

livestock and big game animals (Cole, 1956); although this is not a

problem if livestock and game use the vegetation during different

seasons of the year (Dasmann, 1949) and if sampling is planned

accordingly.

Animal observations can be made from platforms, with

glasses or by stalking and following the animals. Much of this infor-

mation has been recorded as "deer minutes" per plant species

(Chatelain, 1947). Tribe (1950) favored continuous observation of

the grazing animal; however, most authorities (Buechner, 1950;

Cook, Blake and Call, 1963; Saunders, 1955) disapprove as distance

from the animal decreases accuracy and wary animals are difficult

to approach.

Collection of material from stomachs, esophageal fistulas,

and feces generally provide the most accurate means of determining

food preferences.

Analyses of stomach contents from killed or fistulated animals

have been reported in several studies (Allen, 1968; Anderson,

Snyder, and Brown, 1965; Chippendale, 1962, 1964; Leach, 1956;

Morris and Schwartz, 1957; Norris, 1943). A disadvantage of

stomach content analyses is that the differential digestibility of

plants precludes some plants from detection if only larger plant fragments are identified and a substantial time lapse has occured between eating and collection (Bergerud and Russell, 1964; Norris, 1943). With fistulated animals this problem can be minimized. Short (1962) noted several advantages with a fistulated white-tailed deer.

Although not applicable to game animals under range conditions, the esophageal fistula technique can provide very accurate determinations of dietary preferences of domestic species (Harker, Torell, and VanDyne, 1964; Heady and Torell, 1959; Torell, 1954).

Schrumpf (1968) developed the microscopic, cuticular identification technique of identifying plant residues in feces. Adams (1957), Dusi (1949), and Stewart (1967), who previously used feces analyses to determine dietary preferences, favored the method as feces can be collected at any time without killing an animal or hampering its activities, and feces can be easily stored.

To conclude this section, it can be said that in regard to preferences for the various range plants, no work has been done with deer to determine what mechanisms are involved in selecting the different plants (Herbel and Nelson, 1966; Powell and Box, 1966). All that is known of deer is that they utilize certain plants and generally choose plants of greater nutritional value (Anderson, Snyder, and Brown, 1965; Chatelain, 1947; Crouch, 1966).

Mechanisms of Sensory Evaluation of Food

Scott (1948) and Woods (1949a, 1949b) attribute three causal factors for the sensory evaluation of food. First, the effect of organic need on food choice relies on mechanisms which direct food-getting behavior in order to maintain a steady state with regard to any necessary food component (Hollander, 1955; Lepkovsky, 1948; Richter, 1947). This seems to be related to certain levels of innate nutritional wisdom. Second, in some cases it appears that food preferences are completely independent of organic need, specific foods being chosen because they apparently taste good to the animal. This may interfere with proper nutrition (Kare and Medway, 1959), or it may be used to induce animals to consume certain foodstuffs by improving its "palatability" (Young, 1948). The third approach attributes feeding habits to learning, as when feeding habits are developed through experience with foodstuffs that do, in fact, meet organic needs (Young, 1948).

To evaluate food, animals mainly rely on four mechanisms, or senses as they are called: 1) taste, 2) olfaction, 3) touch, and 4) sight (Bell, 1963; Cohen et al., 1957; Kalmbach, 1943; Landgren, 1957; Magnen, 1963; Murdoch, 1965; Neuhaus, 1963; Ray and Drake, 1959). Some chemicals such as strong acids and bases are apparently detected by their irritating qualities, but they are

insignificant in most natural foodstuffs (Biedler, 1958; Moncrieff,

1946). Innate nutritional wisdom, as previously indicated, is more

of a causal factor for the sensory evaluation of food, rather than a

mechanism in itself. Each of the mechanisms can achieve primary

importance depending upon the situation, but usually a combination

of all four mechanisms is thought to be involved.

Repellents and Attractants and Recent Interest
In a Deer's Mechanisms of Sensory Evaluation of Food

Interest in repellents and attractants for reducing or pre-

venting deer damage to crops, gardens and tree plantations has been

increasing for several years. As more people move into urban and

wooded residential situations where deer populations are commonly

high, the problem will increase (Mace, 1962). In 1957, deer were

reported as a special problem in 32 states, while 15 states were

still conducting research on crop damage (McDowell and Pillsbury,

1959). Oregon alone, in 1960-1961, reported over 1,000 deer

damage complaints (Stanton, 1962).

Repellents were the recommended treatment in more than

one-half the cases. Briefly, the term repellents refers to

materials which, when applied to seeds or vegetative parts, tend to

ward off or create an aversion through some odious or distasteful nature. A usable repellent must also be non-hazardous to man or wildlife, non-injurious to plants or soil, reasonably resistant to climatic factors, reasonable in cost, and applicable by normally available means to a wide variety of crops (Baumgartner and Powell, 1949; Champagne, 1953; Howard and Hjersman, 1951, 1952; Neff and Meanley, 1956; Thompson and Keener, 1951). Dietz and Tigner (1968) reported an additional use of repellents as an alternative to expensive and laborious fencing and caging of experimental plants and plots in range studies.

Other than "blood and bone meal" repellent, which is hung in sacks to repell by odor, most repellents are sprayed on the vegetation and evidently function by virtue of an undesirable taste and/or odor (Carpenter, 1967; Stanton, 1962). Among those that have been used as sprays are: Animal Repellent, Arasan, Diamond "L", ZAC or Improved ZIP, Magic Circle, Mapco, Nibonex, Selco TMTD, Tat-Go (Howard and Hjersman, 1951, 1952; Stanton, 1962).

Although most companies producing these commercial preparations select these chemicals by screening tests, they need more information on which odors and tastes repel or attract deer.

A new development stemming from the use of repellents is that of "attractants" to lure deer away from the object of concern.

Dasmann et al. (1967) successfully used molasses and sucrose —

in solution containers or sprayed on nearby brush — to prevent

conifer reproduction damage.

Functions and Characteristics of the Taste Response

Taste (or gustation) is the chemoreceptive sense by which

certain attributes of substances are ascertained by contact with

certain epithelial end organs (taste buds) occuring in the papillae on

the surface of the tongue.

Functions:

Functions of taste can logically be grouped into three main

categories: protection, identification, and motivation. The impor-

tance of identification and protection is most evident where a wide

range of plant life is available and the grazing animal must select,

to the best of its ability, the most nutritious foodstuffs from a variety

of feed components and be able to identify the toxic components to

protect itself (Arnold, 1966). Because taste is a powerful psychic

energizer it is indispensible in motivating feed intake when other

sources of motivating stimuli are absent (Teitelbaum and Epstein,

1963).

Physiological Characteristics:

In order for the chemical components of foodstuffs to be

sensed, solutions (saliva and food moisture) must bathe the taste

buds to allow for free movement of ions and molecules to and from

the receptors (taste buds). These receptors, distributed over the

tongue's surface, are in numbers characteristic for the species.

Microvilli projecting from the receptors offer specific sites for

taste stimuli which, when combined, cause the release of potassium,

depolarization, and initiation of electrical impulses in adjoining

nerve fibers. The signal for quantity is determined by the number

of receptor sites filled by taste stimuli which, in turn, determines

the magnitude of depolarization. The signal for quality is uncertain;

being due to either the summation of electrical events across several

fibers or to the activity in single neural channels. Taste impulses

pass through first order neurons carried by the chorda tympani and

glossopharyngeal nerves to the tractus solitarius. Second order

neurons extend on to the thalamus, and third order neurons then

radiate to the cerebral cortex (Beidler, 1954, 1966; Kitchell, 1961;

and Pfaffman, 1955, 1959).

Depending upon the chemical involved the general concensus

is that there are four basic tastes: sweet, bitter, salt, and sour

(Beidler, 1952; Bekesey, 1964a, 1964b; Kimura and Beidler, 1956;

Pfaffmann, 1955, 1956; Skramlik, 1963; Wenger, Jones and Jones, 1959). However, Kare and Ficken (1963) object to the use of the four classifications of tastes in studies with animals other than humans because they found that the type and strength of within taste group responses varied markedly with species. Although it appears that the four tastes may not be applicable to animals other than man, it has been pointed out by Goatcher (1968) that the concept provides a convenient frame of reference for comparison between species.

The water and alkaline tastes supported by some (Kloehn and Brogden, 1948; Pfaffmann, 1956) is disputed by others (Bell and Kitchell, 1966; Liljestrand and Zotterman, 1956; Moncrieff, 1946). It is generally felt that the water taste is the result of a hypotonic reaction, and the alkaline taste is a complex sensation due to the general stimulation of several different kinds of nerve endings.

Characteristics of the Chemistry of Taste

There is no single concept that can completely explain the stimulating properties of the chemicals within the four taste groups (Amerine, Pangborn and Roessler, 1965; Beidler, 1954, 1958; Fabian and Blum, 1943; Moncrieff, 1946). Goatcher (1968) gave a general description of the four types of taste substances as follows:

Sweet

The sweet taste is associated with an assortment
of non-ionized aliphatic hydroxy compounds such
as sugars, sugar derivatives, alcohols, and
glycols. Lead acetate and beryllium salts are
sweet as are the synthetic compounds saccharin,
dulcin (p-ethoxyphenylurea) and cyclamate.

Salty

Salt stimuli are exemplified by common salt,
sodium chloride. Both the anion and cation are
important to stimulation but the cation may have
the more important influence. Some salts, however,
produce both salty and bitter tastes (for example,
KBr and NH_4I), and some evoke mainly a bitter
taste (as with KI and CsCl). The bitter taste appears
to increase with molecular weight. Ionization is
necessary for characteristic stimulation, and
additivity between the different salts seems to exist.

Sour

The sour taste is produced by acids. Some of the
more common acids which cause a sour taste are
acetic, HCl and H_2SO_4. Picric acid is bitter as
well as sour and citric is sweet as well as sour.
Stimulation by mineral acids has been found to be
dependent primarily upon H^+ concentration, but with
respect to organic acids, the undissociated molecules,
which may be adsorbed to receptor cell surfaces, also
are significant. As has been observed many times,
at the same pH acetic acid is a stronger stimulus
than HCl, while at equi-molar concentration the
reverse is true. This greater stimulating power
of organic acids may be explained by a binding of
the undissociated acid units to receptor sites and
their consequent participation in stimulation.

Bitter

> The bitter and sweet taste are similar in that they
> are both evoked by a variety of compounds. Some
> of the more common bitter substances are quinine,
> brucine, tannins, caffeine, strychnine and magne-
> sium and ammonium salts. The bitter and sweet
> taste are often associated in that frequently the
> lower members of a homologous series will be
> sweet while the higher members will be bitter.
> For example, ethylene glycol is sweet while
> propylene glycol is only slightly sweet and
> hexamethylene glycol is bitter. The reverse
> may also be true: bitterness progressing to
> sweetness in a homologous series.

Species and Individual Differences in Taste Responses

Kare (1961) pointed out that "No pattern, chemical, physical,

nutritional or physiological, can be offered to explain the collective

comparative results" of different species. Many workers have

indicated that, within a species, individual variation is great but

represents a difference in degree while the differences between

species are absolute (Bell and Kitchell, 1966; Bernard and Kare,

1961; Ficken and Kare, 1961; Fisher, Pfaffmann and Brown, 1965;

Kare, Black and Allison, 1957; Kare, Pond and Campbell, 1965;

Lindenmaier and Kare, 1959). Although species differences in

taste have been studied by many there is still confusion on the subject, due in part to attempts to overgeneralize findings, but mainly to the fact that not enough is known about a suitable number of different species (Goodrum and Reid, 1962; Kare and Ficken, 1963). Domesticated animals, in general, seem to have less nutritional wisdom than wild species. Kare and Ficken (1963), Kare and Maller (1967), and Maller and Kare (1965) found that wild rats and jungle fowl, as opposed to tame ones, demonstrated behavior to be more complimentary to maintaining a steady caloric intake through free choice access to sucrose solutions. Big Sagebrush (Artemisia tridentata Nutt.) on certain winter ranges, although highly digestible and rich in protein and phosphorus (components usually deficient on winter ranges), is refused by cattle and sparingly accepted by sheep, while Mule deer and Antelope on the same areas often rely on it as a mainstay of their diet (Bissell and Strong, 1955; Esplin, Greaves and Stoddart, 1937; Ferrel and Leach, 1950). Maller (1967) sums it up well by pointing out that the differences in domesticated strains of wild animals, regarding their ability to select nutritious food, may be due to the fact that the wild animals cannot risk being guided solely by the palatability of a food. He further states that selective breeding that has taken place during the process of domestication may have changed the functions that taste serves in the detection, selection, and ingestion of nutrients.

Internal Characteristics That May Influence the Taste Response

There is general agreement among workers that taste sensitivity declines with age (Cicala and McMichael, 1964; Cohen and Gitman, 1959; Cooper, Bilash and Zubeck, 1959; Glanville, Kaplan and Fischer, 1964; Hilker, et al., 1967; Stubbs and Kare, 1958).

Although Cooper, Bilash and Zubeck (1959) found no sex differences in the taste sensitivity of people, more recent work by Glanville, Kaplan and Fischer (1964) demonstrated substantial sex differences of people in response to hydrochloric acid.

A relationship between body temperature and food and water intake in ruminants was reported by Brobeck (1960) and Conrad (1966). They found that a thermostatic mechanism serves mainly as an emergency mechanism which prevents intake of additional caloric supply and secures the extra supply of water necessary for urgent heat loss mechanisms when the body temperature reaches a critically high level. This would, no doubt, affect the intake of such calorie-rich chemicals as sucrose which could possibly be preferred more during cold weather due to its high caloric content.

At present the possibility of diurnal variations in acuity of the sense of taste is unresolved (Furchtgott and Friedman, 1960; Goetzl, Ahokas and Payne, 1950; Hammer, 1951; Irvin and Goetzl, 1952;

Janowitz and Grossman, 1949). Hammer (1951) suggested two possible reasons favoring diurnal variation; the physiological factors of fatigue and general body condition may influence sensory thresholds. Diurnal fluctuations in the environmental temperature may affect relative changes in the body temperature, which has been shown to affect food and water intake (Brobeck, 1960; Conrad, 1966).

In reviewing the work of others, Goatcher (1968) indicated that taste appears to mediate sugar intake at lower concentrations whereas at higher concentrations physiological conditions, such as the osmotic state, seem to be the mediator.

Previous experience with high concentrations of aversive chemicals can be expected to alter sensitivity to lower concentrations of the same chemical when reintroduced (Goatcher, 1968). Goatcher went on to point out that, on the other hand, Wagner's (1965) work indicated that experience apparently has no effect on preference when the chemical is not objectionable, as in the case of sugar.

It has been shown that several diseases may cause alterations in the taste response. Diseases usually associated with increased taste sensitivity to certain compounds include adrenal cortical insufficiency, adrenogenital syndrome and cystic fibrosis. Those usually associated with decreased taste sensitivity include familial dysaulonomia, hypogonadism and facial hypoplasia (Henkin, 1967). Henkin

also pointed out that the influence of heredity and hormones are intimately involved in several of the diseases.

As vitamin A seems to have a direct influence on the functioning of taste cells, its deficiency in the diet can drastically reduce taste sensitivity (Bernard, Halpern and Kare, 1961).

The ability of animals, deficient in certain nutrients, to select the needed nutrient often relies upon taste and/or smell (Richter, Holt and Barelare, 1937). The phenomenon of nutritional wisdom has been shown in a number of cases: reindeer for sea-water (Bell, 1963); rejection of the toxic sugar, xylose, by fowl (Kare and Medway, 1959); rats for the vitamin B complex (Harris et al., 1933); wild ruminants for salt (Russell and Duncan, 1956); and ruminants for phosphorous (Theiler, Green and Du Toit, 1924). On the other hand, different research has demonstrated the lack of nutritional wisdom: rats rejecting essential amino acids (Halpern, Bernard and Kare, 1961): lack of selection for nutrients by chicks (Kare and Scott, 1962). From these results it seems that the quality of nutritional wisdom depends upon the nutrient, the species of animal, and associated factors. In attempting to explain the inconsistency of nutritional wisdom, Harris et al. (1933) and Scott and Verney (1947) proposed that compensatory appetitive choices do not necessarily occur immediately following the development of a nutritional need and may be prevented from occurring at all, as in the

case of vitamin A which is apparently necessary for the proper

functioning of taste sensitivity (Bernard, Halpern and Kare, 1961).

Environmental Characteristics That May Influence the Taste Response:

Previous work indicates that there are at least two major

environmental factors — nature and temperature of the taste

medium — which may affect taste responses.

After reviewing the results of Machey (1958) and Mackey

and Valassi (1956), Goatcher (1968) postulated that the influence of

the nature of the taste media on taste sensitivity may be due to

several causes: a lessening of solubility of the stimuli, adsorption

of the taste substance to material in the media, and physical inter-

ference resulting in fewer taste molecules reaching receptors.

Notwithstanding the lack of sufficient evidence to formulate

encompassing patterns on the effects of temperature on taste re-

sponses, it can still be said that temperature definitely does affect

taste responses (Beidler, 1954; Bekesy, 1964a: Yamashita, Yamada

and Sato, 1964).

The immediate surroundings of the animal's pen and, in particular, the related placement of the food or liquid containers within the pen may greatly influence preference behavior of the animal (Pick and Kare, 1962; Young, 1945, 1948). An animal's habits of movement within the pen (such as preferring to drink from the container nearest an opening to the outside or nearest the food) are the probable cause of a great deal of positional bias.

Pick and Kare (1962) demonstrated a container bias where visual cues of slight differences in the containers resulted in one being preferred over the other.

Experimental Methods of Studying Taste Responses

Three main methods, and some variations of these, have been used in studying taste responses. These methods are based either on the electrophysiology of nerves, on a physiological response, or on animal behavior.

Electrophysiological methods of studying taste, developed by Zotterman (1935), are based on differences in gustatory nerve activity as a result of stimulation of taste buds by gustatory substances (Iggo and Leek, 1965). In describing the process, Dukes (1955) indicated that nerve activity could be recorded by freeing an

end of a gustatory nerve, attaching it to suitable electrodes, and then observing the resulting electrical impulses on an oscilloscope. The electrophysiological method does not work equally as well for all four types of stimulants; some of them failing to initiate large discharges (Baldwin, Bell and Kitchell, 1959; Zotterman, 1935). Taste sensitivity as measured by electrophysiological responses agrees approximately with behavioral measurements, but it may not correspond with behavioral measurements as in the case of an induced change in the physiological state of the rat (Pfaffmann, 1957).

Use of the physiological response method has been based on flow rate of the parotid salivary gland as it is directly correlated with the stimulatory effectiveness of taste stimuli applied to the tongue (Chauncey and Shannon, 1960; Feller et al., 1965). Pfaffmann, Fisher and Frank (1965) pointed out that the physiological response method can complement the behavioral analyses by providing a means with which the behavioral test can be more critically analyzed.

Behavioral methods include the conditioned response and the preference test.

The conditioned response, first used by the Russian physiologist, Pavlov, consists of the formation of an association between two stimuli, one causing an observable reflex action, and

the other having its effects judged through the reflex action with which it has been associated (Koh and Teitelbaum, 1961; Young, 1945).

Behavioral preferences may be based upon immediate choice, rate of ingestion, or on quantity ingested.

The two-choice preference test is based on the quantity of chemical plus water consumed when offered with water only in a two-choice situation. The two choices, in identical containers, are reversed half way through a test to avoid positional bias. Container bias can be reduced by switching both containers with those of another pen. The immediate choice or rate of ingestion are based upon measurement in a two-choice situation and daily consumption from a single source is recorded with the test substance offered on alternate days (Young, 1948). The two-choice preference test has been used with man (Richter and Maclean, 1939), chimpanzees and monkeys (Patton and Ruch, 1944), rats (Patton and Ruch, 1944; Richter, 1939, 1941; Wedell, 1936), pigs (Kare, Pond and Campbell, 1965), sheep (Goatcher, 1968; Goatcher and Church, 1967), goats (Anderson and Jewell, 1957; Bell, 1959a), and cattle (Bell and Williams, 1959; Bernard and Kare, 1961; Stubbs and Kare, 1958).

EXPERIMENTAL PROCEDURE

The experimental animals used throughout these studies consisted of four groups of three Columbian Black-tailed deer (Odocoileus hemionus columbianus [Richardson]), each. Two of the groups were bucks and two of the groups were does. A control group of four Hampshire ewes was used for comparative purposes.

The deer were about five months old when the experiment was begun in October of 1968. Experimentation was terminated in July of 1969. Throughout most of the experimental period the separately penned groups of deer were fed pelleted and baled alfalfa hay and "Fischer's calf grower" ad libitum. For a short period during December and January the "Fischer's calf grower" was restricted to about one pound per animal per day, but due to inadequate consumption of alfalfa the deer became undernourished. After the loss of four deer in a short period, full feed of the calf grower was resumed and their condition was regained. Two deer were replaced leaving six bucks and four does for the remainder of the time.

Sheep were fed pelleted alfalfa hay and baled grass hay. Trace mineralized salt blocks were provided to all animals throughout the experimental period. The final diets were considered nutritionally adequate for the sheep and deer.

The pen consisted of two parts; a 3 m. x 4 m. roofed portion opening to a 3 m. x 16 m. outside portion. The pen walls were about 2 m. high. An inside alley way provided access to the inside portion of each pen. Feed and the solution containers were placed in corners of the inside portion of the pen next to the inside alley way. The solution containers were next to the alley gate. Bedding consisted of dried sawdust piled inside.

The taste testing procedure was essentially the same as the two-choice preference test developed by Bell (1959a) for the goat and used by Goatcher (1968) with sheep. Fluid was provided for each group in two identical containers. Plastic buckets of 8.5 liter capacity were used for each group of deer and galvanized buckets of 15.1 liter capacity were used for the group of sheep. This volume provided a sufficient amount of fluid in each container to meet each group's water requirement for at least 12 hours. At the start of each test run, one container was filled to weight with tap water and the other with tap water plus the test chemical. At the end of each of four, 12-hour time periods the containers and their contents were reweighed. The amount of test fluid consumed was expressed as a percent of the total fluid taken from both containers for all four periods. To avoid positional bias the position of the test fluid was reversed halfway through the test run. Because deer are considered

nocturnal feeders in their natural state, two full days, rather than one day of two 12-hour periods, had to be used to avoid the positional bias that may have resulted with one 12-hour night period. Randomized starting positions were used, and container bias was avoided by switching containers between pens at the end of each concentration. The final response point of the deer for a single concentration of a chemical consisted of the average percent intake of test fluid for each sex. The single group of sheep provided only one value for a final response point. This procedure was followed for each of the concentrations of the chemicals studied. Chemical concentrations comparable to those used for sheep, calves and goats (Bell, 1959a; Bell and Williams, 1959; Goatcher, 1968) were tested in ascending order. If a complete response curve was not obtained in this range, descending concentrations were used. Previous work with both ascending and descending concentrations has not yielded noticeably different results.

Each chemical was tested at all concentrations necessary to obtain a complete response curve except glucose, which would not go into solution, at 40%, and saccharin which was not available from chemical supply companies.

The chemicals studied in this manner were:

Sugars	Formula weights	Salts	Formula weights
Glucose	180.16	Sodium chloride	58.44
Sucrose	342.30	Sodium acetate	136.08

Acids	Formula weights	Miscellaneous	Formula weights
Hydrochloric	36.45	Quinine sulfate	782.96
Acetic	60.05	Quinine monohydro-	
Butyric	88.10	chloride	396.92
		Saccharin	183.19

Completion of the testing of a chemical was generally followed by a non-test period of two days before a new chemical was tested. Non-test breaks between tests of the chemical concentrations did not alter results as the test of each concentration stood independent of the others. The calendar dates of testing were as follows:

Chemical	Test Period
Glucose	10/29/68 - 11/28/68
Quinine sulfate	12/2/68 - 12/20/68
Sodium acetate	1/2/69 - 1/14/69
H_2O test for deer and sheep (to determine 95% confidence interval)	1/15/69 - 1/25/69
Sodium chloride	2/15/69 - 3/9/69

Sucrose	3/11/69 - 3/25/69
Acetic acid	3/27/69 - 4/30/69
Saccharin	5/2/69 - 5/24/69
Hydrochloric acid	5/27/69 - 6/8/69
Quinine monohydrochloride	6/10/69 - 6/22/69
Butyric acid	6/24/69 - 7/6/69

Chemicals of the same taste group were separated by calendar dates in the hopes of reducing possible seasonal effects.

For each chemical tested the mean responses of the deer to each of the concentrations were plotted graphically by sex in order to obtain a graph for either preference or rejection trends. The chemical concentrations at the preference and rejection thresholds for deer (i.e., where the test chemical comprised 57% and 43% of total fluid intake, respectively) were estimated from the graph. The 80% preference threshold and the 20% rejection threshold were also estimated from the graph. When preference or rejection trends were not apparent, the responses were assessed according to their position relative to the non-discrimination zone (the range between 43% and 57% of total fluid intake). For sheep the non-discrimination range was calculated to be from 44% to 56%. The non-discrimination zone was derived by determining the normal variation, with tap water in both containers, around a theoretical mean intake of 50%

from each container (Appendix Table II). Normal variation was calculated by a statistical analysis of the mean percent intake of all four groups. Although sex differences were elucidated primarily by graphical analysis, paired "t" tests were conducted for comparing the magnitude of sex difference with each test chemical. The paired "t" test involved only the data pertinent to the concentrations above the lowest concentration showing a response by either sex.

Although the sheep were used as a control group for comparison with previous work by Goatcher (1968), the new non-discrimination zone had to be calculated as in the case of the deer. Sheep responses were also plotted graphically to obtain a graph for both preference and rejection trends.

As the pH of the tap water may have varied from day to day (Goatcher, 1968), and because pH is related to the acid taste response (Fuerst and Kare, 1962) pH's of the acid solutions were determined by checking samples of the prepared test solutions with a Beckman pH meter.

Because time and facilities were limiting, the study of individual variation in the taste response of deer was assigned to another research project. The effects of individual variation have been shown to be nullified by plotting the response points of groups of animals and also by averaging the individual points of the same

members (Goatcher, 1968).

As the non-discrimination zone is based on a 95% confidence interval it follows that one out of twenty response points can be expected to be an artifact (e.g., a response point due to greater than normal variation rather than due to an accurate response). With this in mind, some response points must be disregarded, no matter how subjective the approach seems.

RESULTS

In general, it appeared that four groups of three deer, each, and the group of four sheep provided fairly consistent and reliable results. Condition of the deer throughout most of the experimental period was reasonably good, as judged by weight gain and general appearances. The diet of alfalfa plus limited "Fischer's calf grower" proved inadequate due to insufficient intake of alfalfa. Fischer's calf grower fed ad libitum with alfalfa proved adequate. Alfalfa intake increased noticeably during the months of May and June, especially for the bucks which were experiencing rapid antler development. The long pens provided adequate room for exercising which the deer would do during the morning and evening hours. When shut into the 3 m. x 4 m. inside portion, as when cleaning, some deer became very excited and frustrated as they would spin in circles and try to jump the walls. Sawdust bedding seemed most desirable as the deer defecated much less on it than on hay bedding. Sheep showed no such discretion for bedding.

At times rain water which collected in the outside portion of the pen was drunk by the deer, thus reducing fluid intake from the test solution containers. However, the problem would be presumed not to affect results as the preference method apparently operates

at any level of fluid intake.

Three types of bias were compensated for; positional bias, container bias, and starting position bias.

It was observed that positional bias for the solution containers was largely determined by the orientation of the two containers in the pen. The wary nature of the deer apparently caused them to prefer the container oriented nearest the door opening to the outside. By positioning the container holder at right angles to movement to and from the door, variation due to positional bias was greatly reduced. The differences were observed but unrecorded.

Although container bias was not observed, it was compensated for by switching the sets of containers to different pens at the end of each concentration.

Because placement of the treated containers on the same side at the beginning of each concentration biased the animals, the starting position was randomized according to a random numbers table.

Normal variation (in the absence of chemical treatments) around the theoretical mean intake of 50% from each container was determined by measuring the mean percent intake of water from container "T", in two positions (24 hours in each position), for all four groups of deer. The data were then statistically analyzed. Ten observations (a 48-hour period with container "T" on the right for

24 hours, and on the left for 24 hours) were made during the middle of the experimental period in January, 1969 (Appendix Table I).

A "t" test between the experimental mean and theoretical mena of 50% indicated the means were not significantly different (P> 0.05). A 95% confidence interval for the deer was applied to the theoretical mean as 50% $\pm$ 6.51%. For convenience the interval was rounded to an interval of from 43% to 57%. This normal variation from 43% to 57% could then be considered a non-discrimination reaction; that is, a reaction within this range could be expected 19 times out of 20 when water alone was presented in both test solution containers. The non-discrimination zone for sheep was determined in the same manner as for the deer, but for the sheep these values ranged from 44% to 56%.

The results of the deer and sheep taste responses to all chemicals tested are presented in Tables I and II. The taste response graphs of the chemicals have been summarized into tabular form as four thresholds. Preference and rejection thresholds border the non-discrimination zone while the 80% preference threshold and 20% rejection are more extreme responses. Sensitivity levels are also listed, although they may coincide with the preference or rejection thresholds depending upon whichever one is crossed first. The 80% preference threshold was crossed only

three times; by deer and sheep with glucose, and by deer, only, with

sucrose.   The 20% rejection threshold was crossed with all but two

of the chemicals tested——glucose and saccharin.   Inadequate

solubility of glucose and lack of a supply of saccharin prohibited

testing at higher concentrations to cross the 20% rejection threshold.

TABLE I. Threshold values of sheep and deer for the chemicals tested.

Chemical	Sensitivity Level[a] (mean of bucks & does)			80% Preference Threshold	Preference Threshold			Non-Discrimination	Rejection Threshold			20% Rejection Threshold		
Glucose														
Deer	0.529	g/100 ml	(0.0294 M)	2.50 - 20.00 g/100 ml	0.529	g/100 ml	(0.0294 M)	0.01 - 0.63 g/100 ml		---[b]			---	
Sheep	2.500	g/100 ml	(0.1388 M)	5.00 g/100 ml (0.2775 M)	2.500	g/100 ml	(0.1388 M)	0.01 - 1.25 g/100 ml	19.00	g/100 ml	(1.0546 M)		---	
Sucrose														
Deer	0.24	g/100 ml	(0.00705 M)	0.544 - 10.00 g/100 ml	0.24	g/100 ml	(0.00705 M)	0.01 - 0.16 g/100 ml	26.0	g/100 ml	(0.7595 M)	40.0	g/100 ml	(1.1685 M)
Sheep	3.77	g/100 ml	(0.1101 M)	---	3.77	g/100 ml	(0.1101 M)	0.01 - 2.50 g/100 ml	19.0	g/100 ml	(0.5550 M)	38.0	g/100 ml	(1.1101 M)
Saccharin														
Deer	0.547	mg/100 ml	(0.0298 M)	---	0.547	mg/100 ml	(0.0298 M)	0.312 mg/100 ml - 320 mg/100 ml		---			---	
Sheep	1.875	mg/100 ml	(0.1024 M)	---	1.875	mg/100 ml	(0.1024 M)	0.625 - 1.25 mg/100 ml; 20 - 320 mg/100 ml		---			---	
Sodium chloride														
Deer	0.886	g/100 ml	(0.1516 M)	---		---		0.01 - 0.02 g/100 ml; 0.16 - 0.63 g/100 ml	0.886	g/100 ml	(0.1516 M)	1,875	g/100 ml	(0.3208 M)
Sheep	1.375	g/100 ml	(0.2352 M)	---		---		0.01 - 1.25 g/100 ml	1.375	g/100 ml	(0.2352 M)	2.25	g/100 ml	(0.3850 M)
Sodium acetate														
Deer	0.115	g/100 ml	(0.0085 M)	---	0.115	g/100 ml	(0.0085 M)	0.01 g/100 ml	4.25	g/100 ml	(0.3123 M)	8.50	g/100 ml	(0.6246 M)
Sheep	0.48	g/100 ml	(0.0353 M)	---	0.48	g/100 ml	(0.0353 M)	0.01 - 0.16 g/100 ml	2.625	g/100 ml	(0.1929 M)	9.25	g/100 ml	(0.6797 M)
Acetic acid														
Deer	0.00675	ml/100 ml	(0.0011 M)	---	0.00675	ml/100 ml	(0.0011 M)	0.0006 - 0.005 ml/100 ml	0.448	ml/100 ml	(0.0746 M)	1.25	ml/100 ml	(0.2081 M)
Sheep	0.630	ml/100 ml	(0.1049 M)	---		---		0.0006 - 0.020 ml/100 ml	0.630	ml/100 ml	(0.1049 M)	3.00	ml/100 ml	(0.4995 M)
Butyric acid														
Deer	0.088	ml/100 ml	(0.0100 M)	---		---		0.0006 - 0.040 ml/100 ml	0.088	ml/100 ml	(0.0100 M)	0.40	ml/100 ml	(0.0454 M)
Sheep	0.012	ml/100 ml	(0.0014 M)	---		---		0.0006 - 0.010 ml/100 ml	0.012	ml/100 ml	(0.0014 M)	0.216	ml/100 ml	(0.0245 M)
Hydrochloric acid														
Deer	0.094	ml/100 ml	(0.0258 M)	---		---		0.0006 - 0.04 ml/100 ml	0.094	ml/100 ml	(0.0258 M)	0.416	ml/100 ml	(0.1141 M)
Sheep	0.0075	ml/100 ml	(0.0021 M)	---		---		0.0006 - 0.01 ml/100 ml	0.0075	ml/100 ml	(0.0021 M)	0.096	ml/100 ml	(0.0263 M)
Quinine mono-hydrochloride														
Deer	1.25	mg/100 ml	(0.0283 mM)	---	1.25	mg/100 ml	(0.0283 mM)	0.312 - 1.250 mg/100 ml	5.00	mg/100 ml	(0.1260 mM)	38.00	mg/100 ml	(0.9573 mM)
Sheep	0.81	mg/100 ml	(0.0204 mM)	---		---		0.312 - 0.625 mg/100 ml	0.813	mg/100 ml	(0.0204 mM)	20.00	mg/200 ml	(0.5038 mM)
Quinine sulfate														
Deer	3.03	mg/100 ml	(0.0386 mM)	---	3.03	mg/100 ml	(0.0386 mM)	1.250 - 10.000 mg/100 ml	12.00	mg/100 ml	(0.1532 mM)	52.00	mg/100 ml	(0.6641 mM)
Sheep	12.50	mg/100 ml	(0.1596 mM)	---		---		1.250 - 10.00 mg/100 ml	12.50	mg/100 ml	(0.1596 mM)	192.00	mg/100 ml	(2.452 mM)

[a] Sensitivity level may coincide with the preference or rejection thresholds depending upon whichever one is crossed first.

[b] Not demonstrated with concentrations tested.

TABLE II.   Sensitivity levels of buck and doe deer to the chemicals tested.

Chemical	Sensitivity Levels					
	Bucks		Does		Average	
Glucose	0.170 g/100 ml	(0.0094 M)	0.888 g/100 ml	(0.0493 M)	0.529 g/100 ml	(0.0294 M)
Sucrose	0.238 g/100 ml	(0.0070 M)	0.242 g/100 ml	(0.0071 M)	0.24 g/100 ml	(0.00705 M)
Saccharin	0.75 mg/100 ml	(0.0409 mM)	0.343 mg/100 ml	(0.0187 mM)	0.547 mg/100 ml	(0.0298 mM)
Sodium chloride	0.756 g/100 ml	(0.1294 M)	1.008 g/100 ml	(0.1725 M)	0.886 g/100 ml	(0.1516 M)
Sodium acetate	0.19 g/100 ml	(0.0140 M)	0.04 g/100 ml	(0.0029 M)	0.115 g/100 ml	(0.0085 M)
Acetic acid	0.005 ml/100 ml	(0.0008 M)	0.0085 ml/100 ml	(0.0014 M)	0.00675 ml/100 ml	(0.0011 M)
Butyric acid	0.07 ml/100 ml	(0.0079 M)	0.108 ml/100 ml	(0.0123 M)	0.088 ml/100 ml	(0.0100 M)
Hydro- chloric acid	0.028 ml/100 ml	(0.0077 M)	0.16 ml/100 ml	(0.0439 M)	0.094 ml/100 ml	(0.0258 M)
Quinine sulfate	2.00 mg/100 ml	(0.0255 mM)	4.05 mg/100 ml	(0.0511 mM)	3.03 mg/100 ml	(0.0386 mM)
Quinine monohydro- chloride	0.75 mg/100 ml	(0.0189 mM)	1.50 mg/100 ml	(0.0378 mM)	1.25 mg/100 ml	(0.0283 mM)

Sugars and Saccharin

Glucose (monosaccharide), sucrose (a disaccharide) and saccharin (an artificial sweetener) were studied. Deer demonstrated strong preferences for sweet solutions while the response of sheep was much less pronounced. Whereas the deer preferred a wide range of concentrations and greatly increased total fluid consumption, the sheep showed a very narrow preference range with no marked increase in consumption (Figures 1,2,3,4,5 and 6, Appendix Tables III, IV, V and XIII).

Deer demonstrated a response to glucose at a lower concentration than the sheep. The buck's sensitivity level for glucose was at 0.17% (0.0094 M), the doe's at 0.888% (0.0493 M) and the average for deer was at 0.529% (0.0294 M). The sensitivity level of sheep for glucose was at 2.50% (0.1388 M). Deer preferred glucose solutions including the highest concentration tested (20% solution). Over 90% of their fluid intake was of glucose solutions ranging from a concentration of 5% to 20% (Figure 1). Sheep intake surpassed the 80% preference threshold at only the 5% glucose solution. At a 20% solution the sheep rejected glucose (Figure 2).

Deer had the same strong preference for sucrose, except that they rejected it at a concentration of 40%. This was a higher concentration than could be tested with glucose due to its

lower solubility (Figure 3). Sheep demonstrated a narrow and weak preference for sucrose by preferring it (65% intake) at only the 10% concentration (Figure 4).

The buck's sensitivity level for sucrose was at 0.238% (0.0070 M), the doe's at 0.242% (0.0071 M), and the average for deer was at 0.24% (0.00705 M). Sheep were so variable at lower concentrations of sucrose that the sensitivity level could not be accurately estimated (Figure 4). The concentrations at the 20% rejection threshold were 40% and 38% for deer and sheep, respectively.

Deer preferred saccharin over a wide range of concentrations (from 0.625 mg/100 ml to 160.00 mg/100 ml solutions), but to a much lesser degree than the two sugars (Figures 1, 3 and 5). Sheep demonstrated a narrow and weak preference for saccharin by preferring it at only the 5 mg/100 ml (0.2729 mM) concentration (Figure 6).

The buck's sensitivity level for saccharin was at 0.750 mg/ 100 ml (0.0409 mM), the doe's at 0.3432 mg/100 ml (0.0187 mM) and the average for deer was at 0.5466 mg/100 ml (0.0298 mM). The sensitivity level of sheep for saccharin was at 1.875 mg/100 ml (0.1024 mM). A rejection trend for deer or sheep could not be established by higher concentrations of the saccharin compound

Figure 1. Taste responses of deer to ascending concentrations of glucose solution.

Figure 2. Taste responses of sheep to ascending concentrations of glucose solution.

Figure 3. Taste responses of deer to ascending concentrations of sucrose solution.

Figure 4. Taste responses of sheep to ascending concentrations of sucrose solution.

Figure 5. Taste responses of deer to ascending concentrations of saccharin solution.

Figure 6. Taste responses of sheep to ascending concentrations of saccharin solution.

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used as a supply was not available from any chemical company.

Salts

The salts studied were sodium chloride and sodium acetate
(Figures 7, 8, 9 and 10 and Appendix Tables VI and VII). Deer
exhibited much different taste responses to these salts. Sodium
chloride was rejected at concentrations from 0.04% to 0.16%, and
accepted in the non-discrimination zone from 0.16% to 0.63%, but
never preferred (Figure 7). Sodium acetate was preferred over
a wide range of concentrations, from 0.04% to 2.50% (Figure 9).
Sheep were rather variable in response to both salts. As with the
deer, sheep preferred sodium acetate over a wider range of con-
centrations than they did sodium chloride (Figures 8 and 10). Sheep
preferred sodium chloride at only the 0.16% concentration whereas
sodium acetate was preferred at a range of concentrations from
0.63% to 2.50%.

The buck's sensitivity level for sodium chloride was at
0.756% (0.1294 M), the doe's at 1.008% (0.1725 M) and the average
for deer was at 0.886% (0.1516 M). The sensitivity level of sheep
for sodium chloride was at 1.375% (0.2352 M). The concentrations
at the 20% rejection threshold were 1.875% and 2.25% for deer and
sheep, respectively.

Figure 7. Taste responses of deer to ascending concentrations of sodium chloride solution.

Figure 8.   Taste responses of sheep to ascending concentrations of sodium chloride solution.
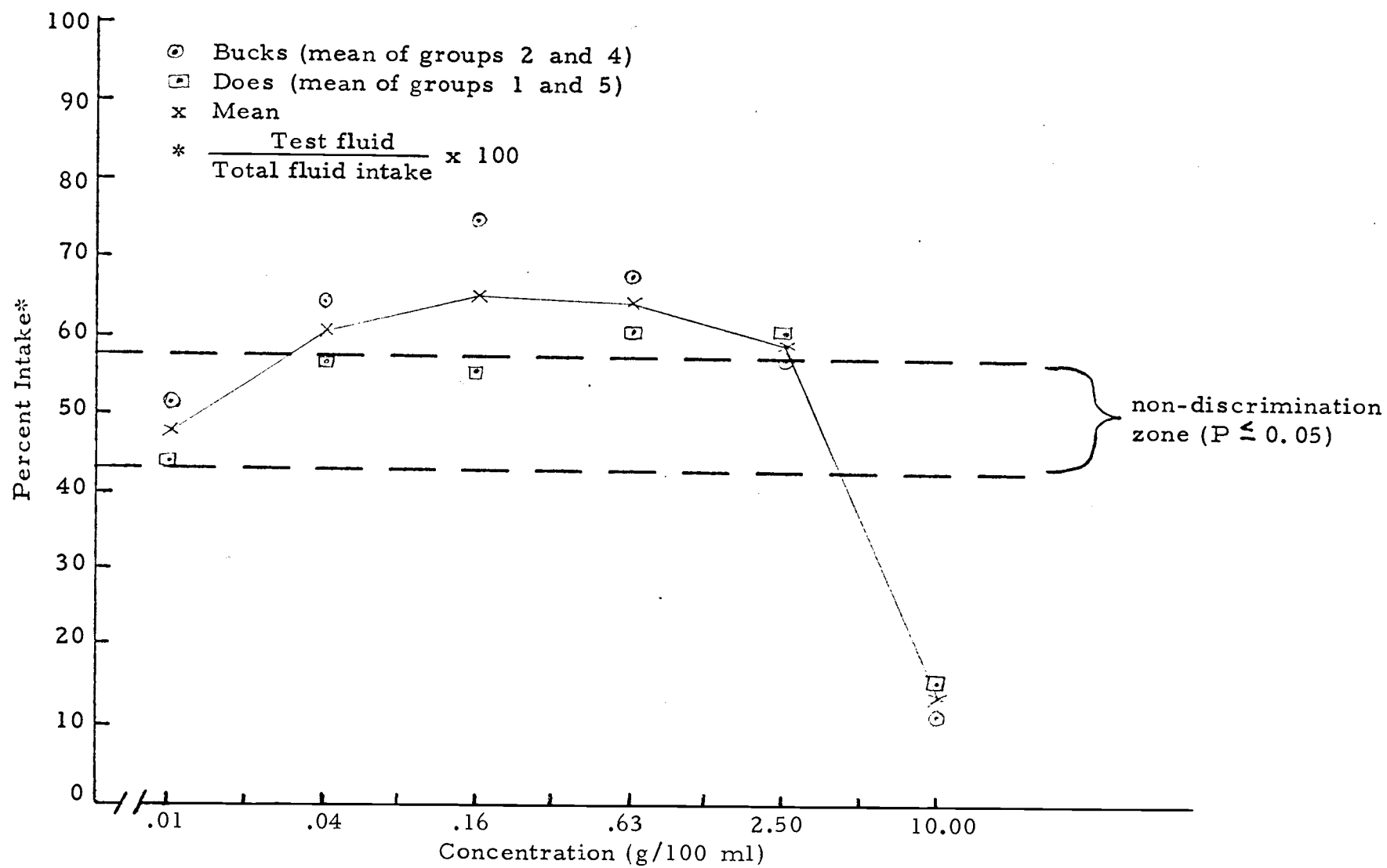
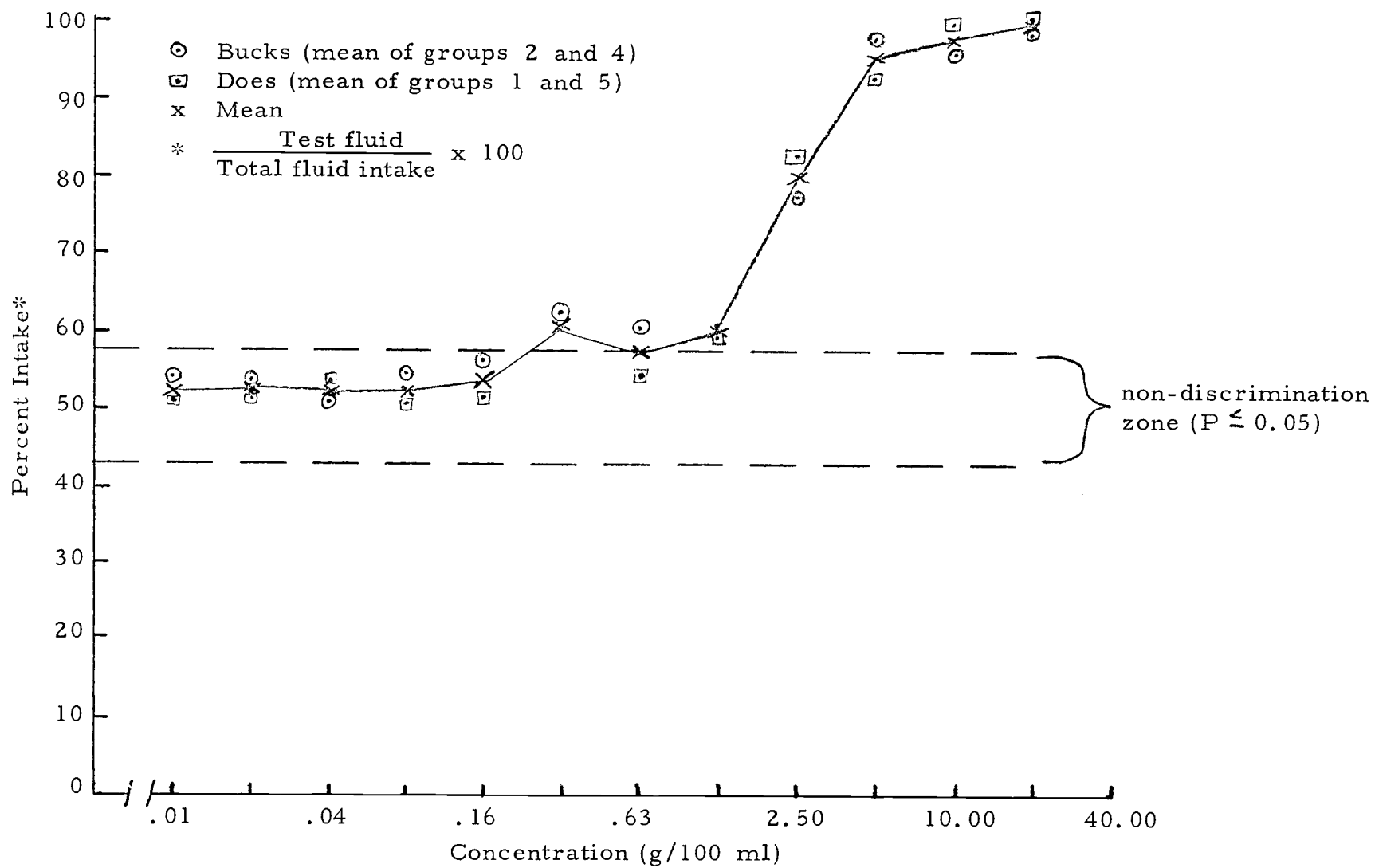Figure 9. Taste responses of deer to ascending concentrations of sodium acetate solution.
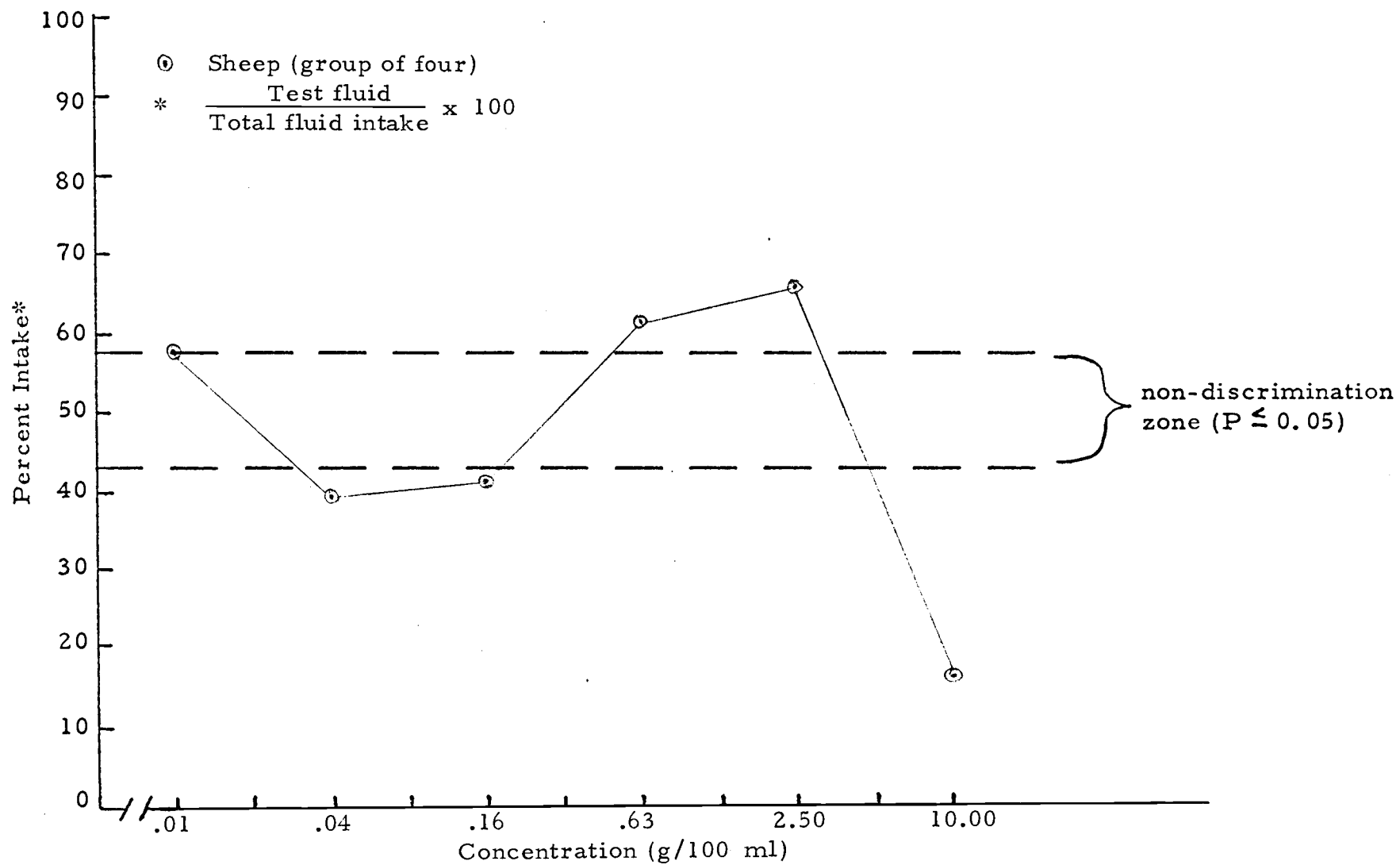
Figure 10. Taste responses of sheep to ascending concentrations of sodium acetate solution.

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The buck's sensitivity level for sodium acetate was at

0.04% (0.0029 M), the doe's at 0.19% (0.0140 M) and the average

for deer was at 0.115% (0.0085 M). The sensitivity level of sheep

for sodium acetate was at 0.48% (0.0353 M). The concentrations at

the 20% rejection threshold were 8.50% and 9.25% for deer and

sheep, respectively.

Acids

The acids studied were acetic, butyric and hydrochloric

(Figures 11, 12, 13, 14, 15 and 16 and Appendix Tables VII, IX and X).

Deer demonstrated a wide range of fairly strong preference for

acetic acid, but little or no preference for butyric and hydrochloric

acids. Acetic acid solutions were preferred from a concentration

of 0.01% to 0.160% (Figure 11). Butyric acid was only slightly

preferred at the concentrations of 0.0025% and 0.04% (Figure 13).

Hydrochloric acid was preferred only at the first concentration

tested 0.00063%, which may have been due to greater than normal

variations (Figure 15).

Sheep demonstrated distinct rejection trends for all three

acids (Figures 12, 14 and 16). The only response indicating pre-

ference occurred at 0.005% acetic acid solution. This may have

been due to greater than normal variation (Figure 12). Although
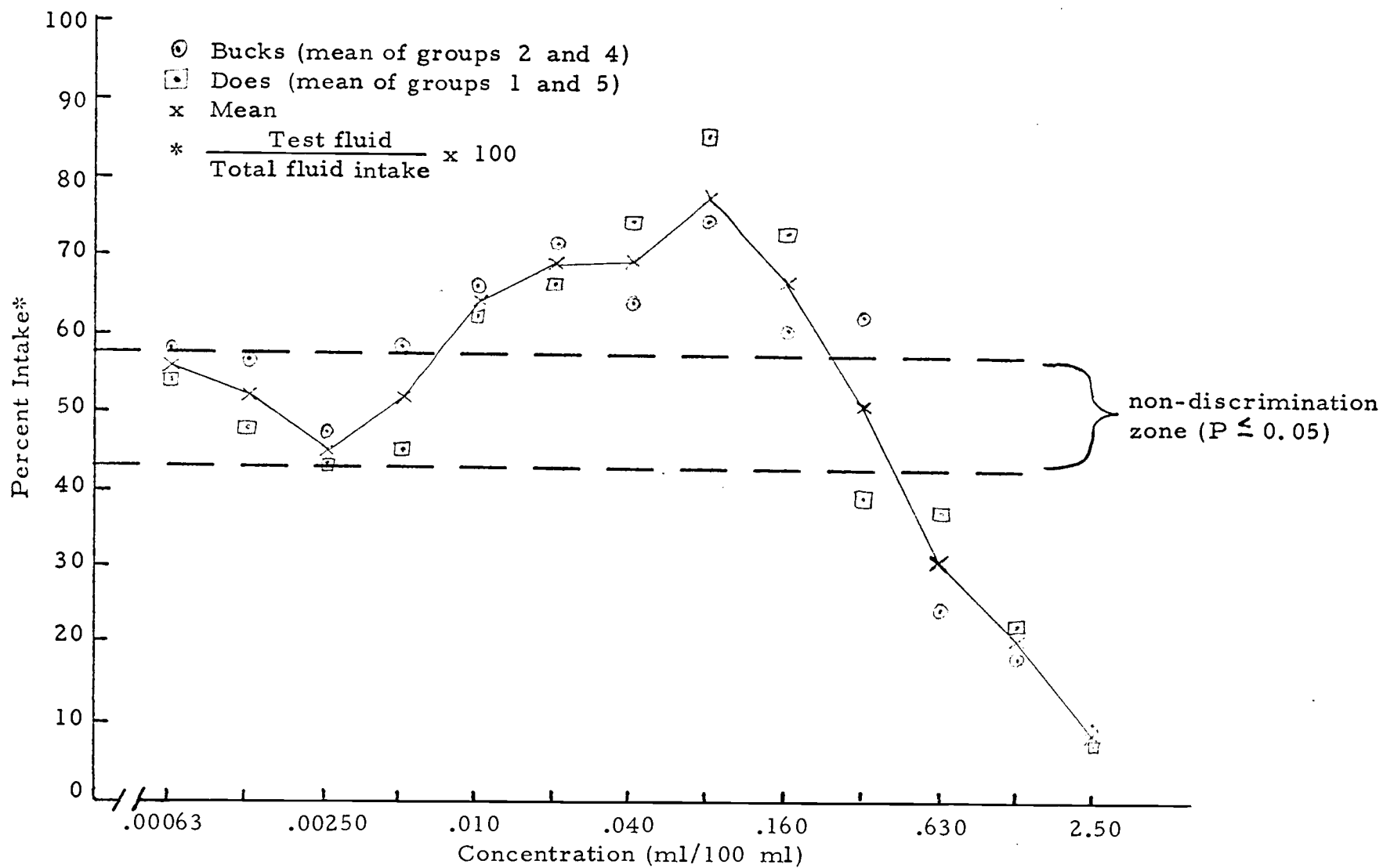
Figure 11. Taste responses of deer to ascending concentrations of acetic acid solution.
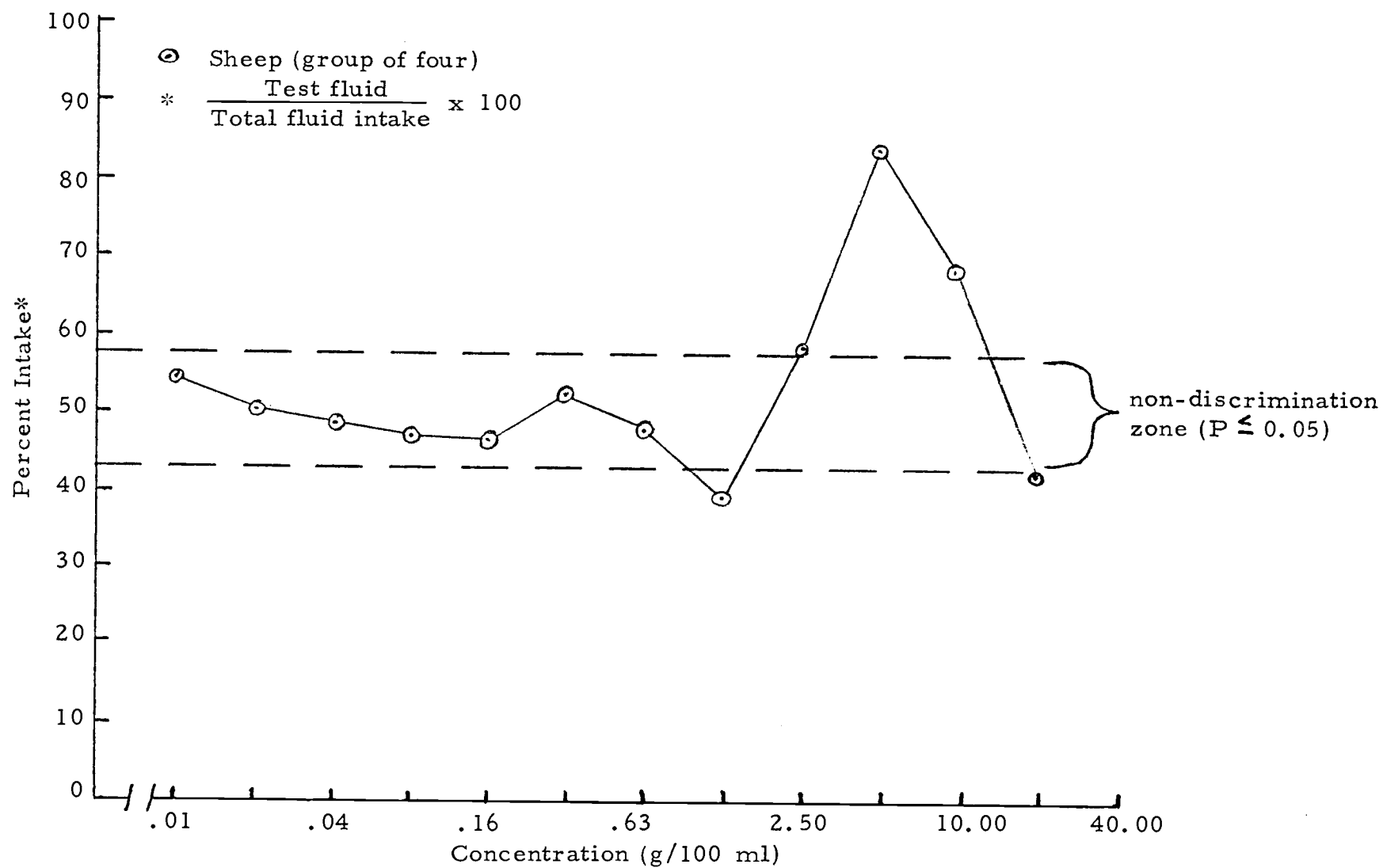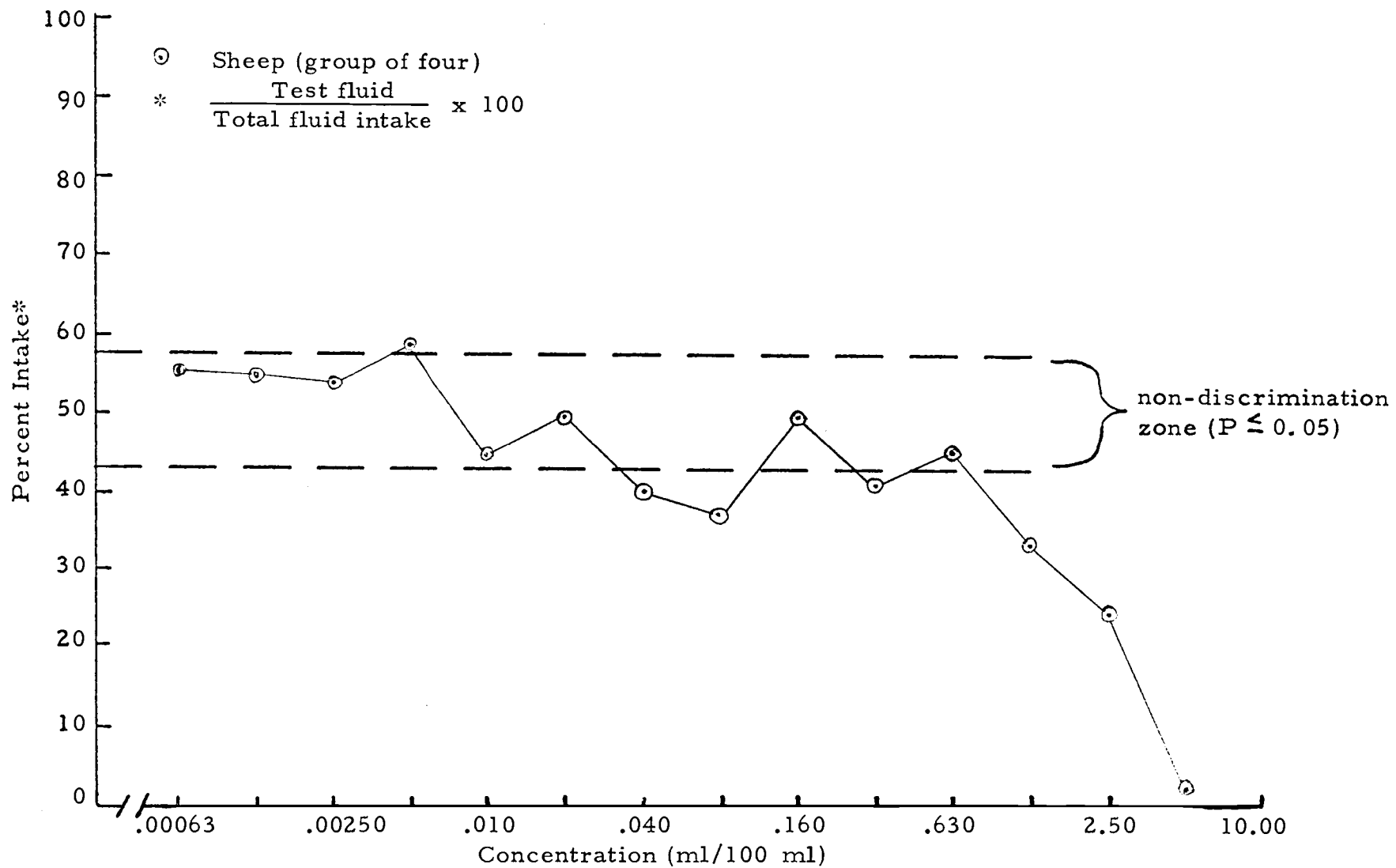
Figure 12. Taste responses of sheep to ascending concentrations of acetic acid solution.
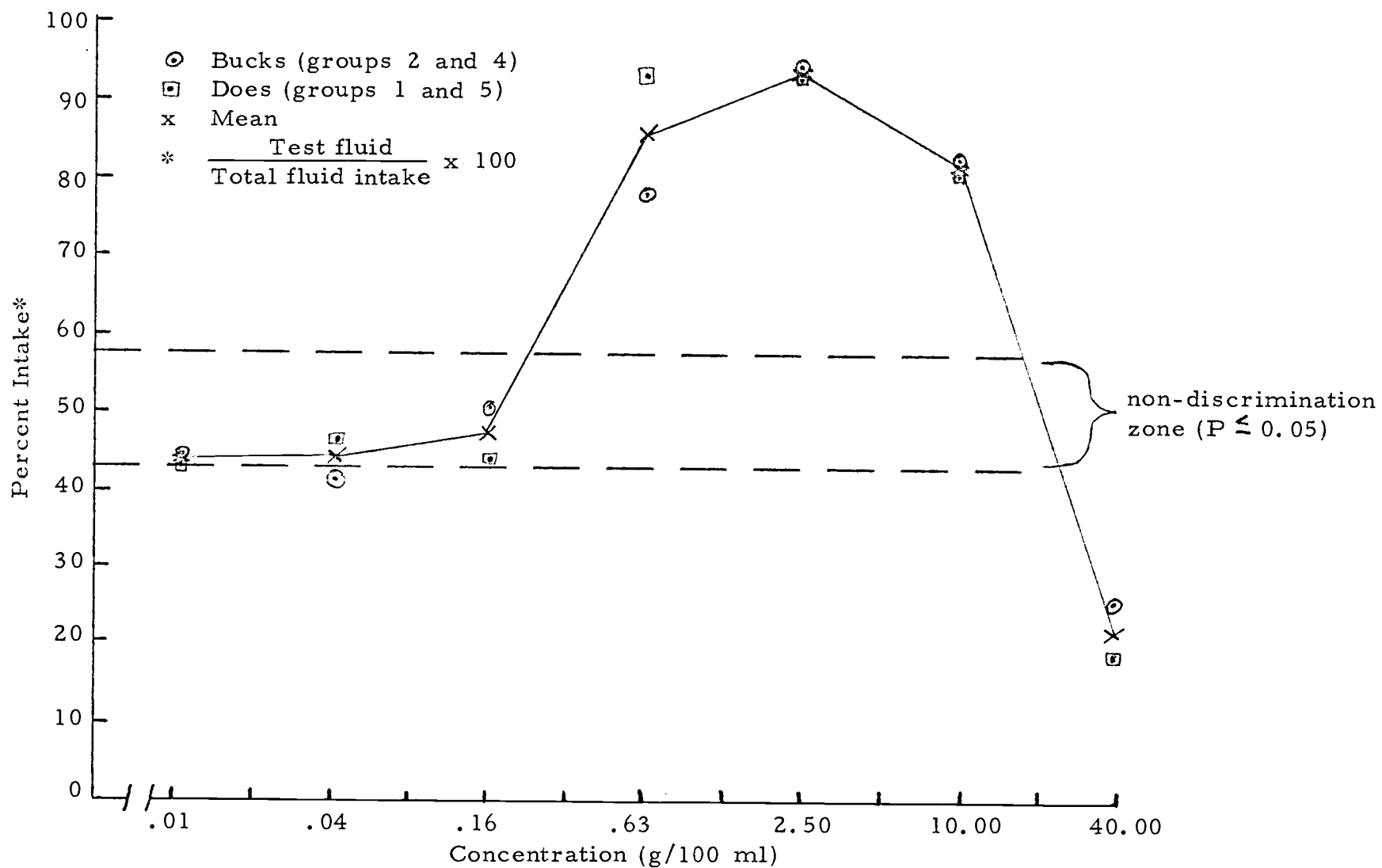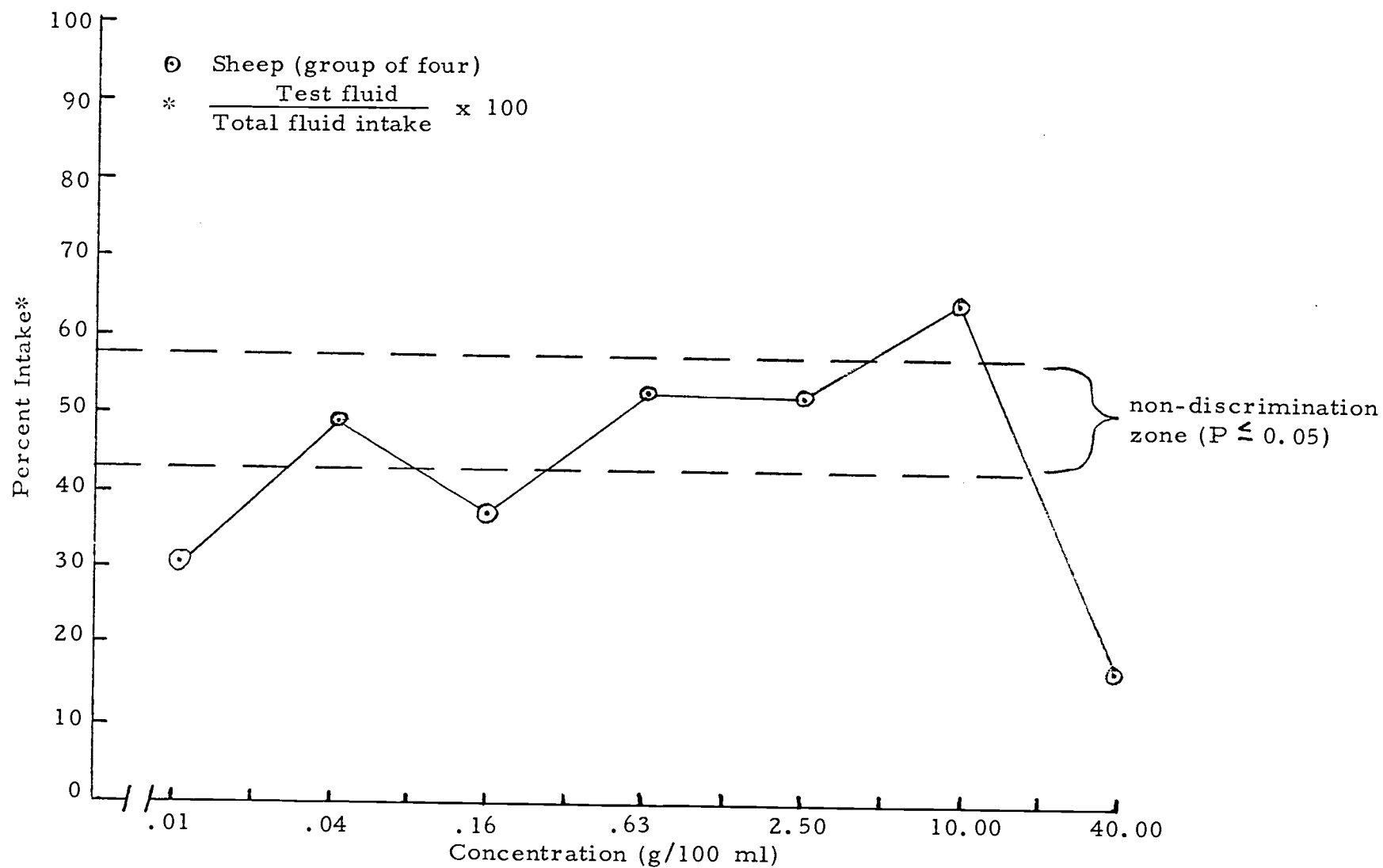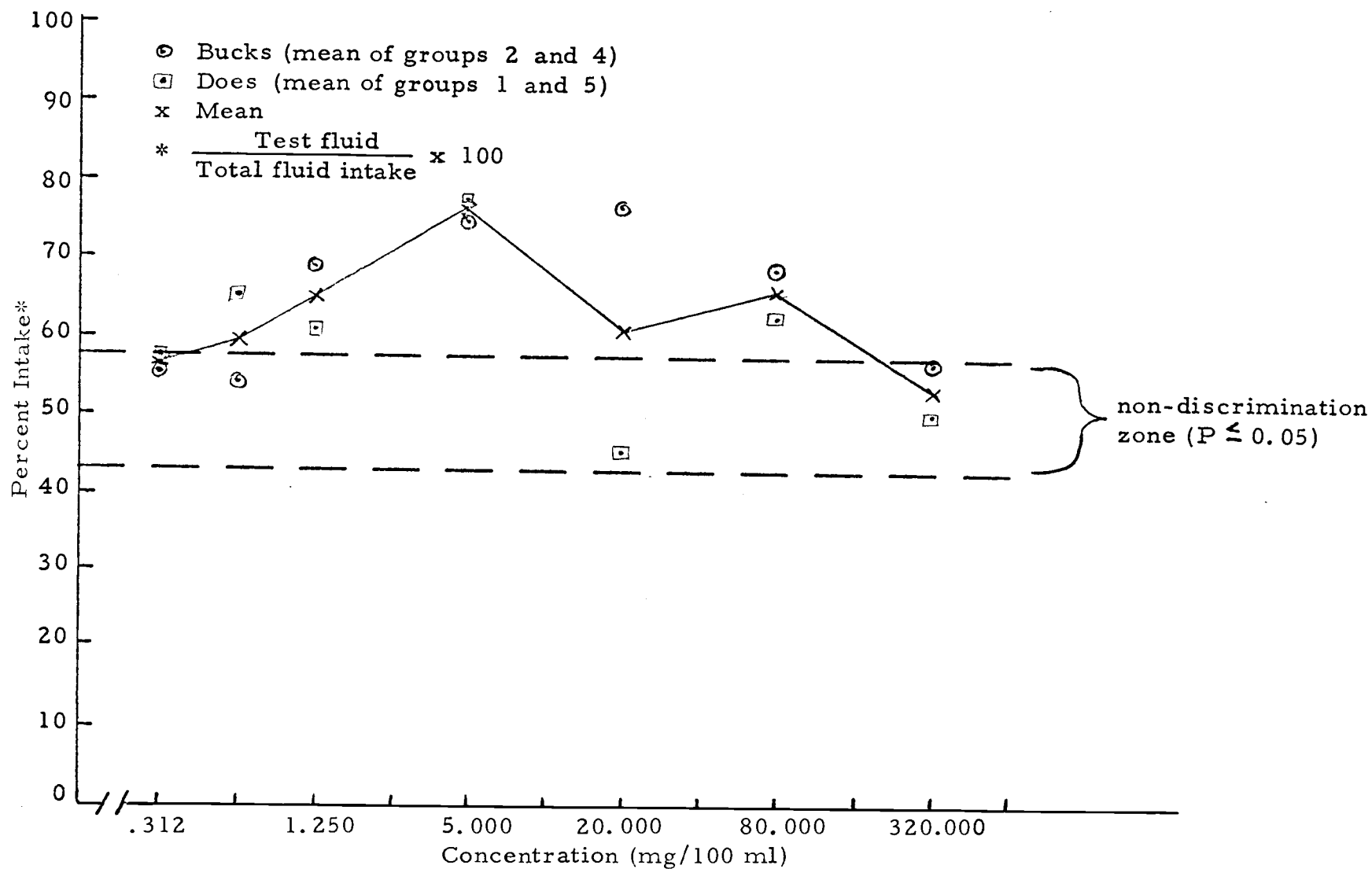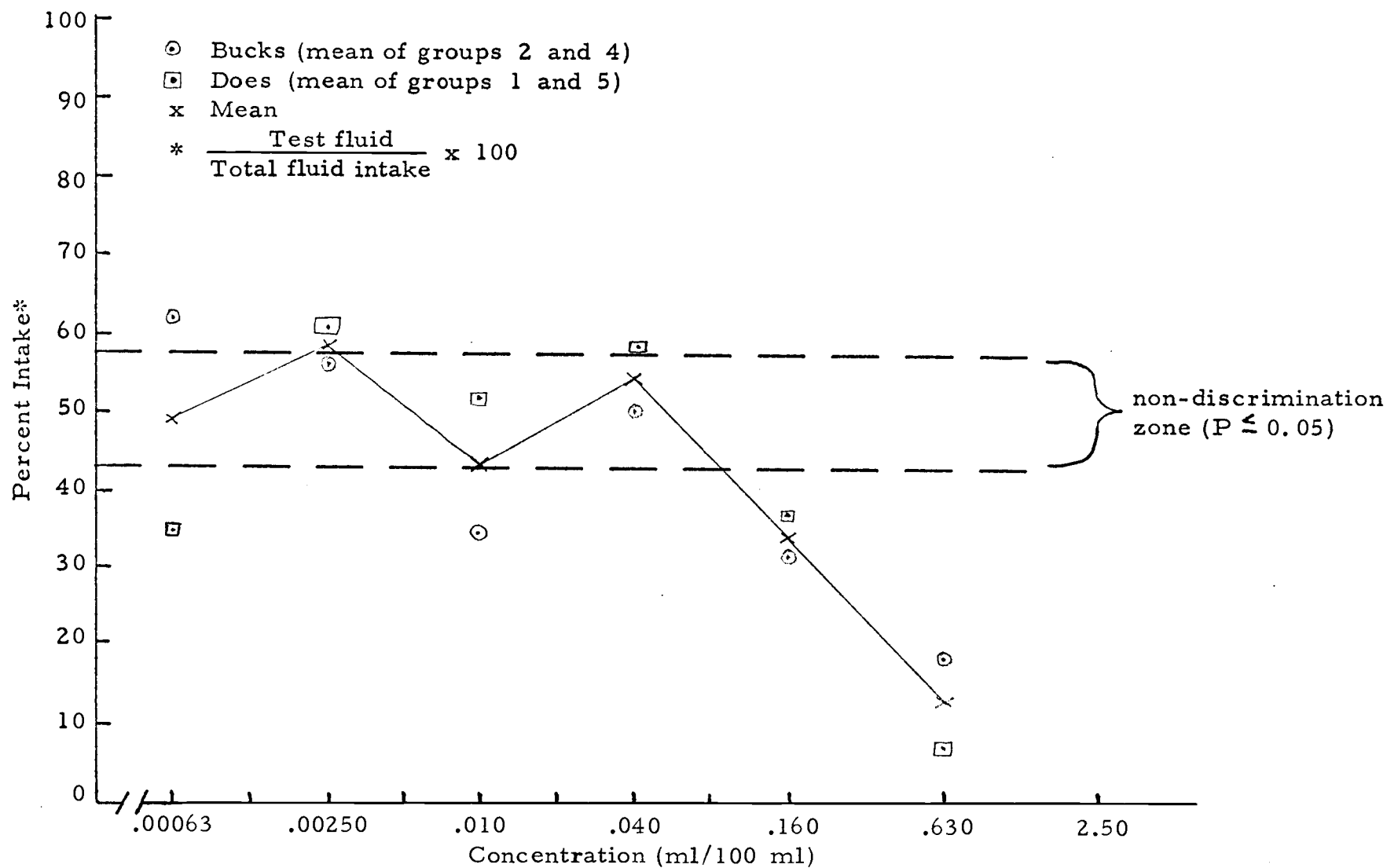
Figure 13. Taste responses of deer to ascending concentrations of butyric acid solution.
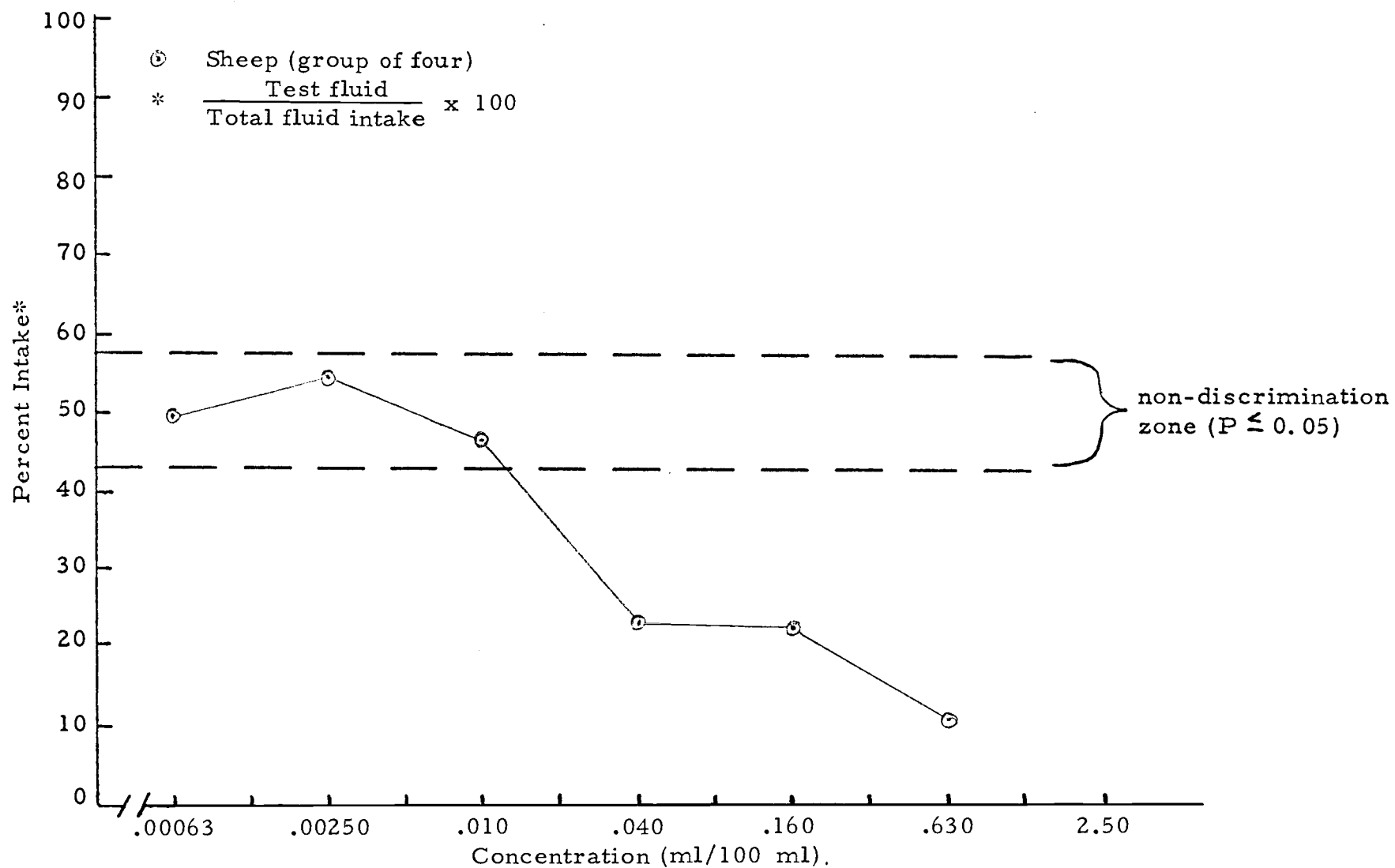
Figure 14. Taste responses of sheep to ascending concentrations of butyric acid solution.

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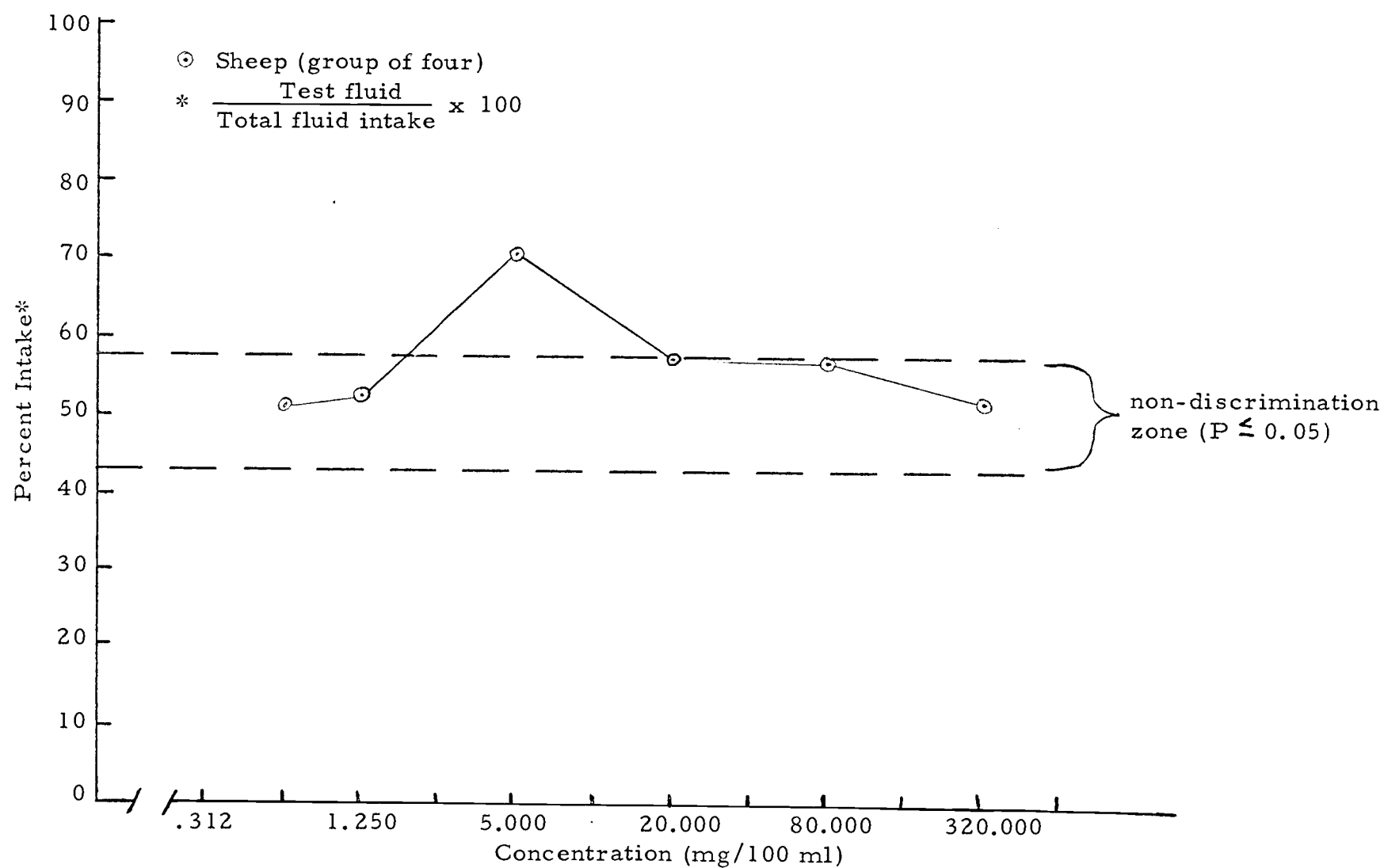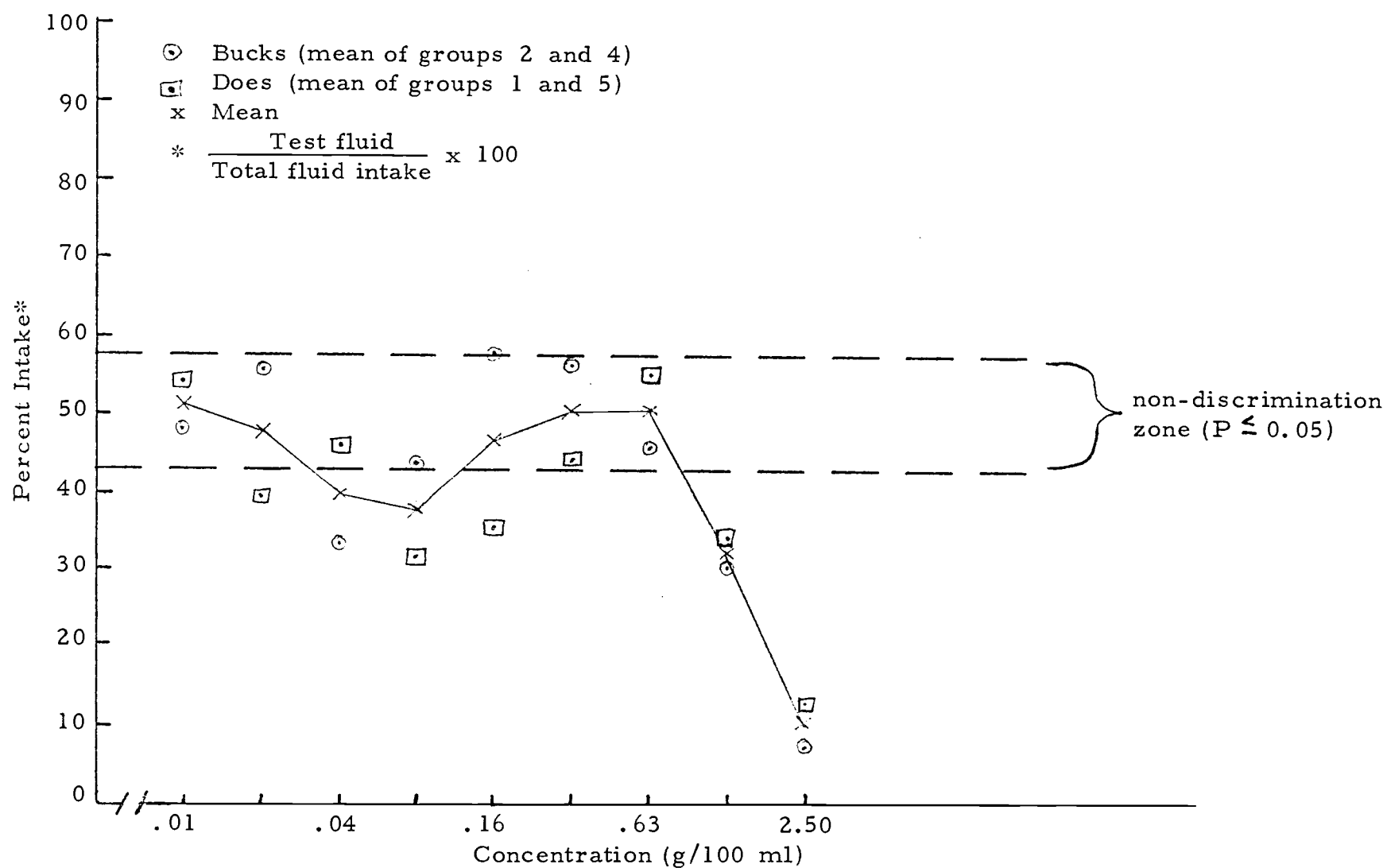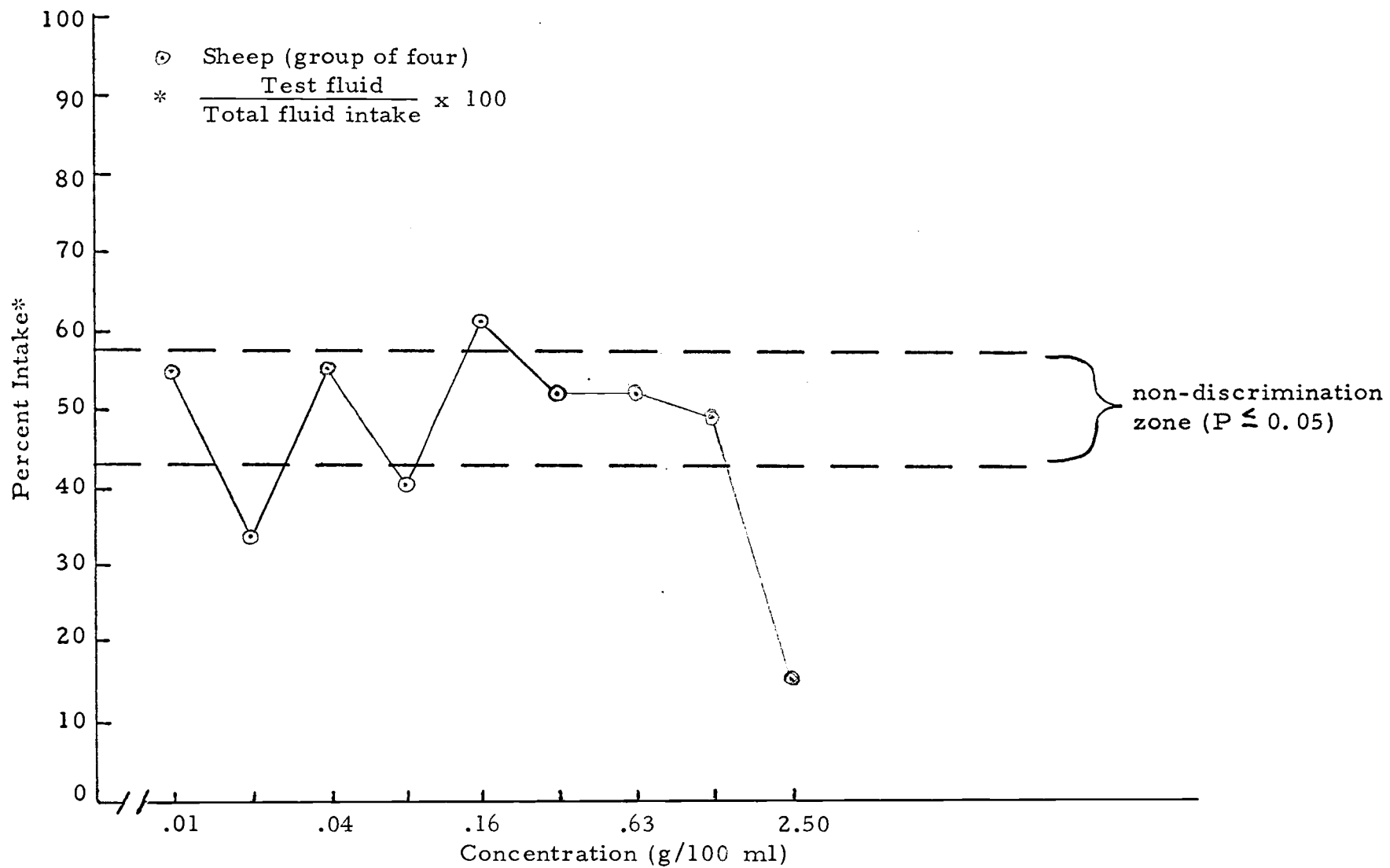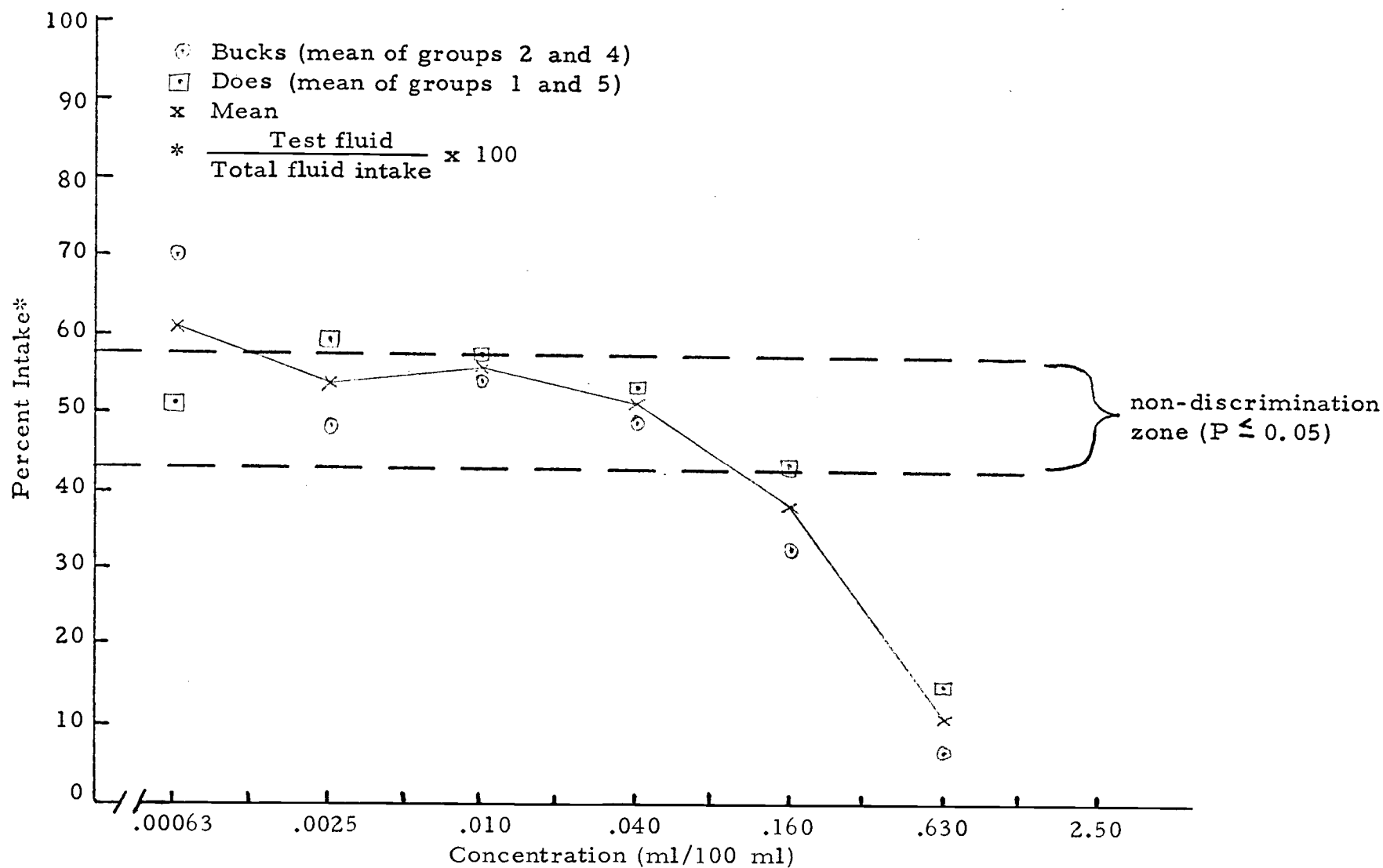Figure 15. Taste responses of deer to ascending concentrations of hydrochloric acid solution.
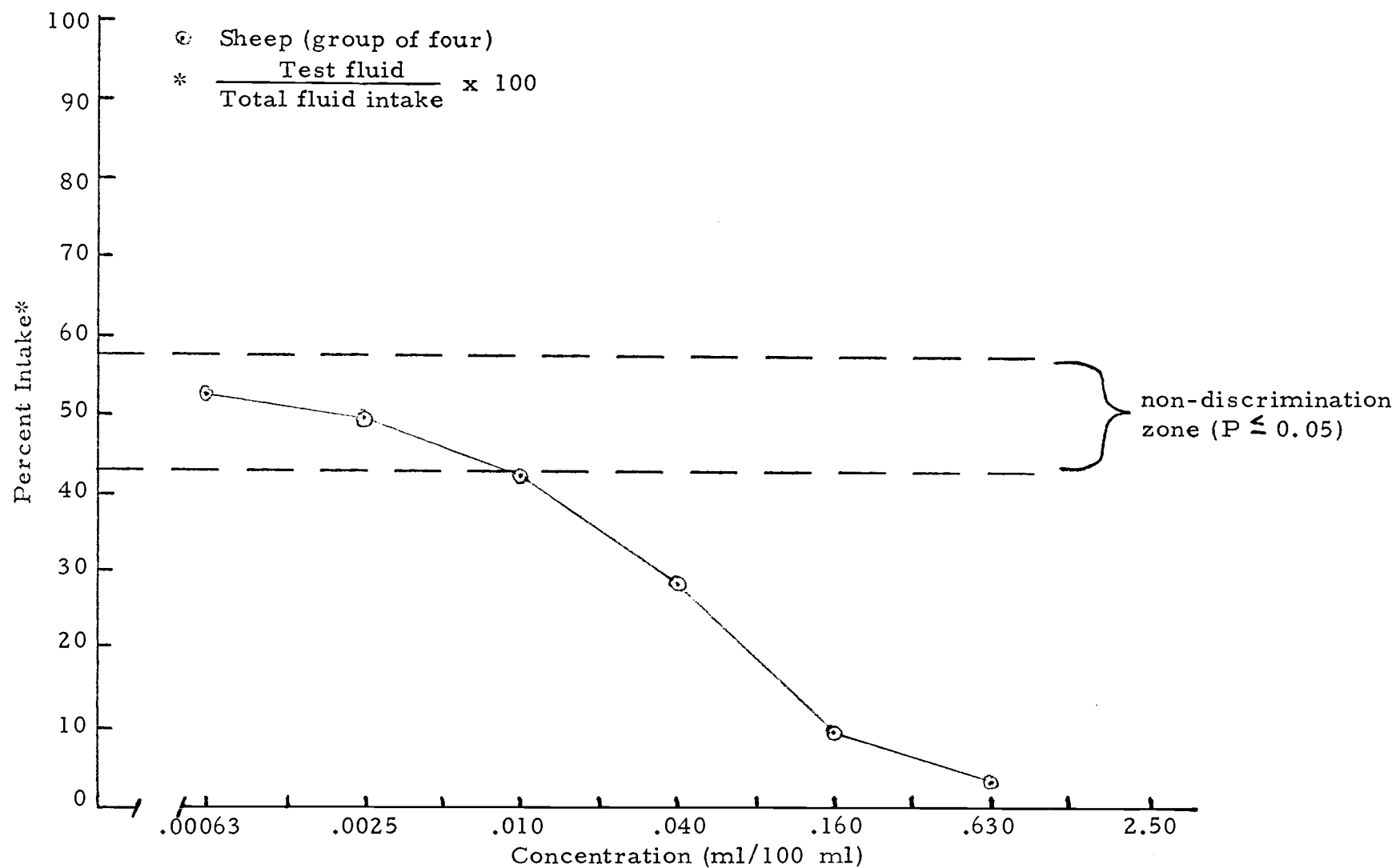
Figure 16. Taste responses of sheep to ascending concentrations of hydrochloric acid solution.

sheep did not prefer acetic acid to any marked degree, they did accept it in the non-discrimination zone for a wide range of concentrations (from 0.00063% to 0.630%).

The buck's sensitivity level for acetic acid was at 0.005% (0.0008 M), the doe's at 0.0085% (0.0014 M) and the average for deer was at 0.00675% (0.0011 M). The sensitivity level of sheep for acetic acid at the rejection threshold was at 0.630% (0.1049 M). The concentrations at the 20% rejection threshold were 1.25% and 3.00% for deer and sheep, respectively.

The buck's sensitivity level for butyric acid was at 0.07% (0.0079 M), the does at 0.108% (0.0123 M) and the average for deer was at 0.088% (0.0100 M). The sensitivity level of sheep for butyric acid was at 0.012% (0.0014 M). The concentrations at the 20% rejection threshold were 0.40% and 0.216% for deer and sheep, respectively.

The buck's sensitivity level for hydrochloric acid was at 0.028% (0.0077 M), the doe's at 0.16% (0.0439 M) and the average for deer was at 0.094% (0.0258 M). The sensitivity level of sheep for hydrochloric acid was at 0.0075% (0.0021 M). The concentrations at the 20% rejection threshold were 0.416% and 0.096% for deer and sheep, respectively.

The role of pH and smell in stimulating a response to acids was also analyzed (Figures 17, 18, 19, 20, 21 and 22, and Tables III, IV and V). Deer clearly demonstrated that the volatile fatty acids
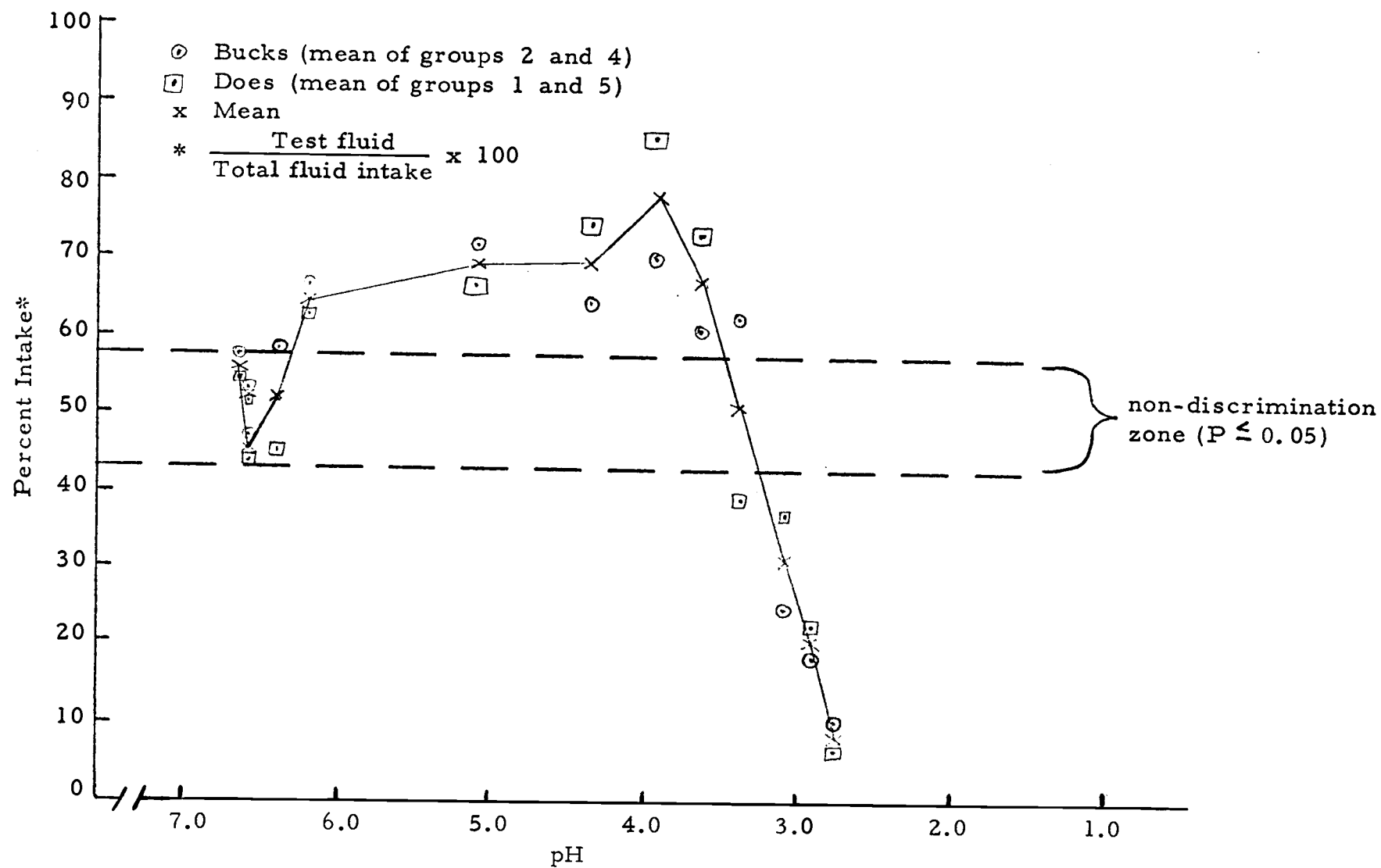
Figure 17. Taste responses of deer to descending pH of acetic acid solution.
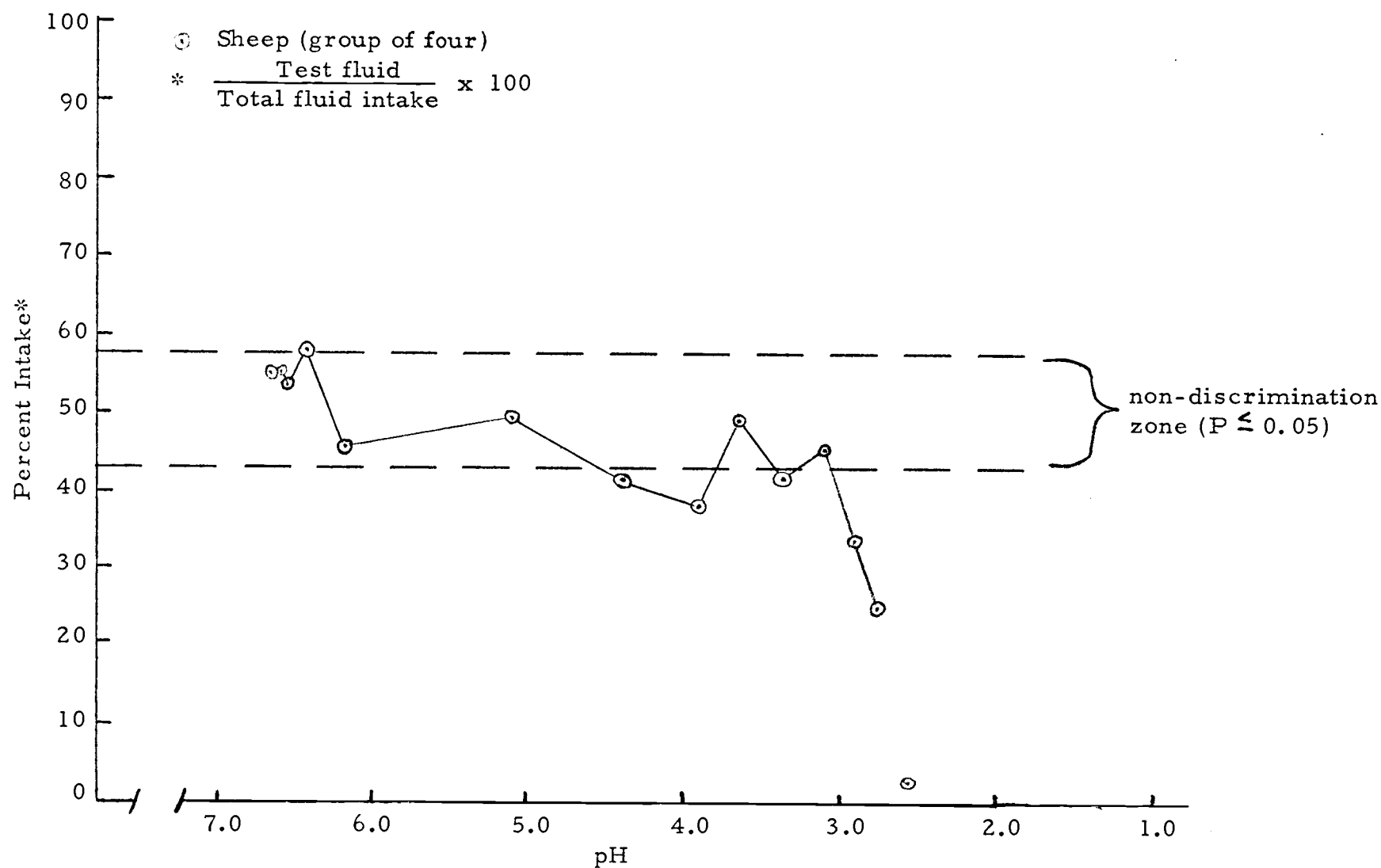
Figure 18. Taste responses of sheep to descending pH of acetic acid solution.
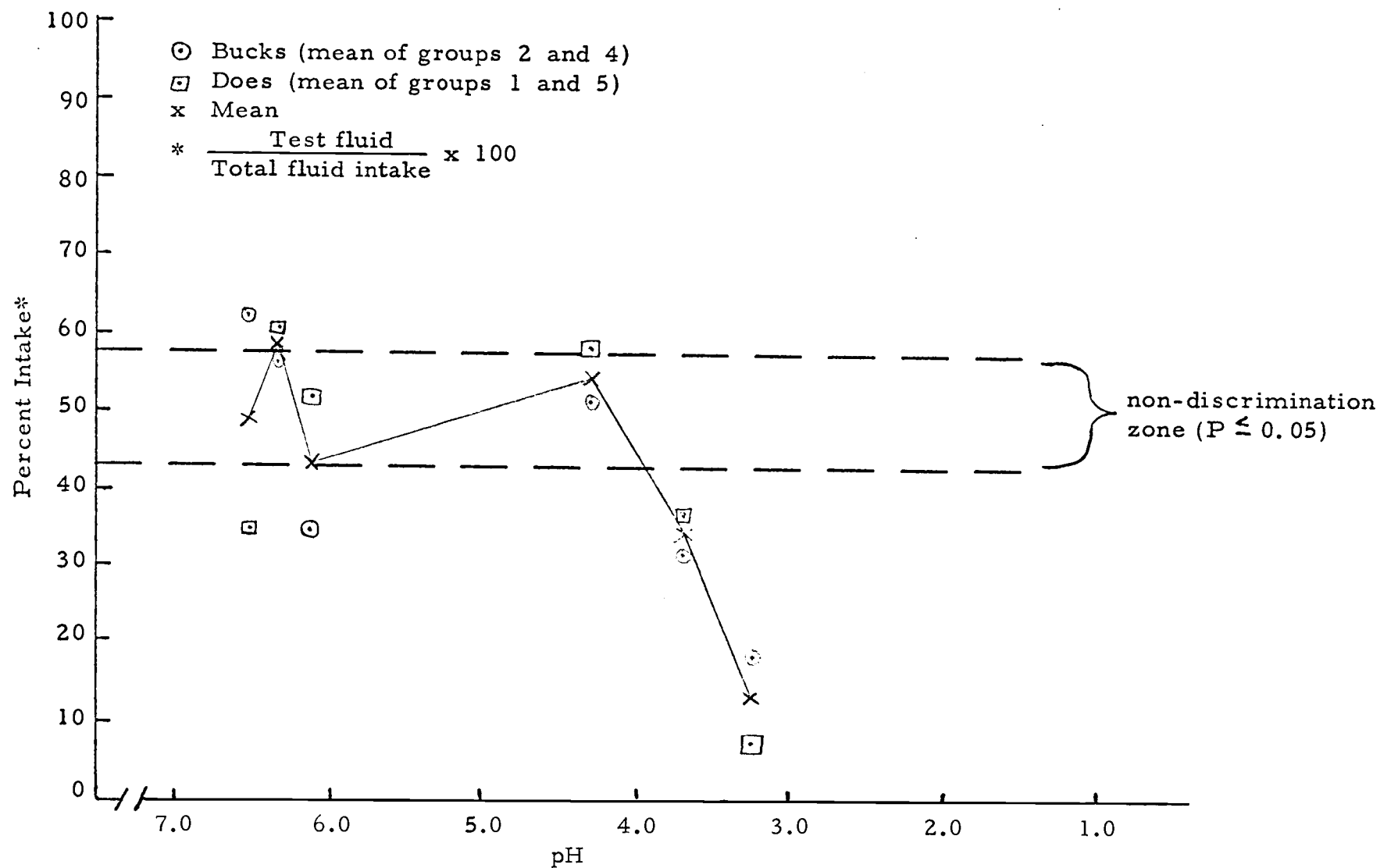
Figure 19. Taste responses of deer to descending pH of butyric acid solution.
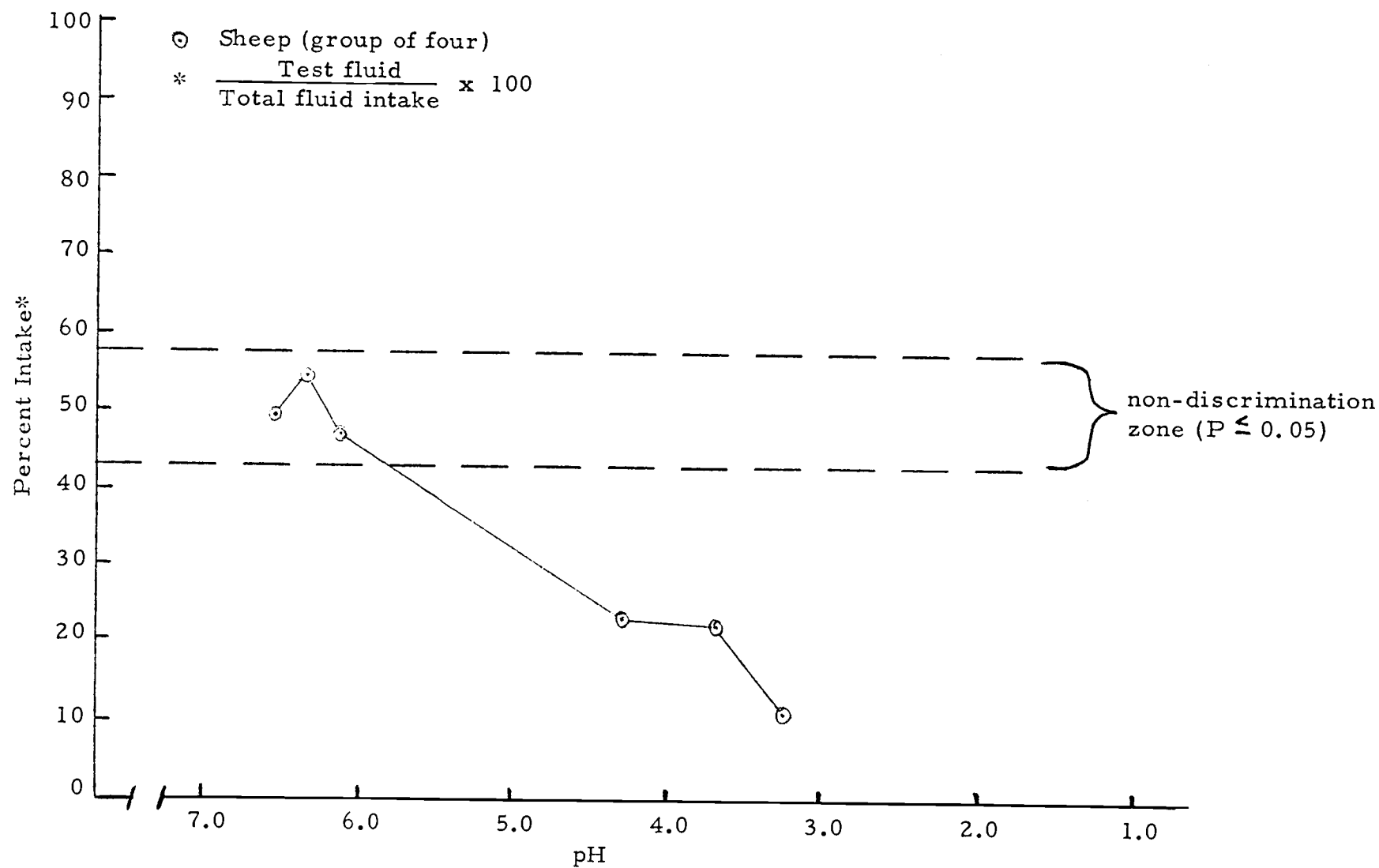
Figure 20. Taste responses of sheep to descending pH of butyric acid solution.
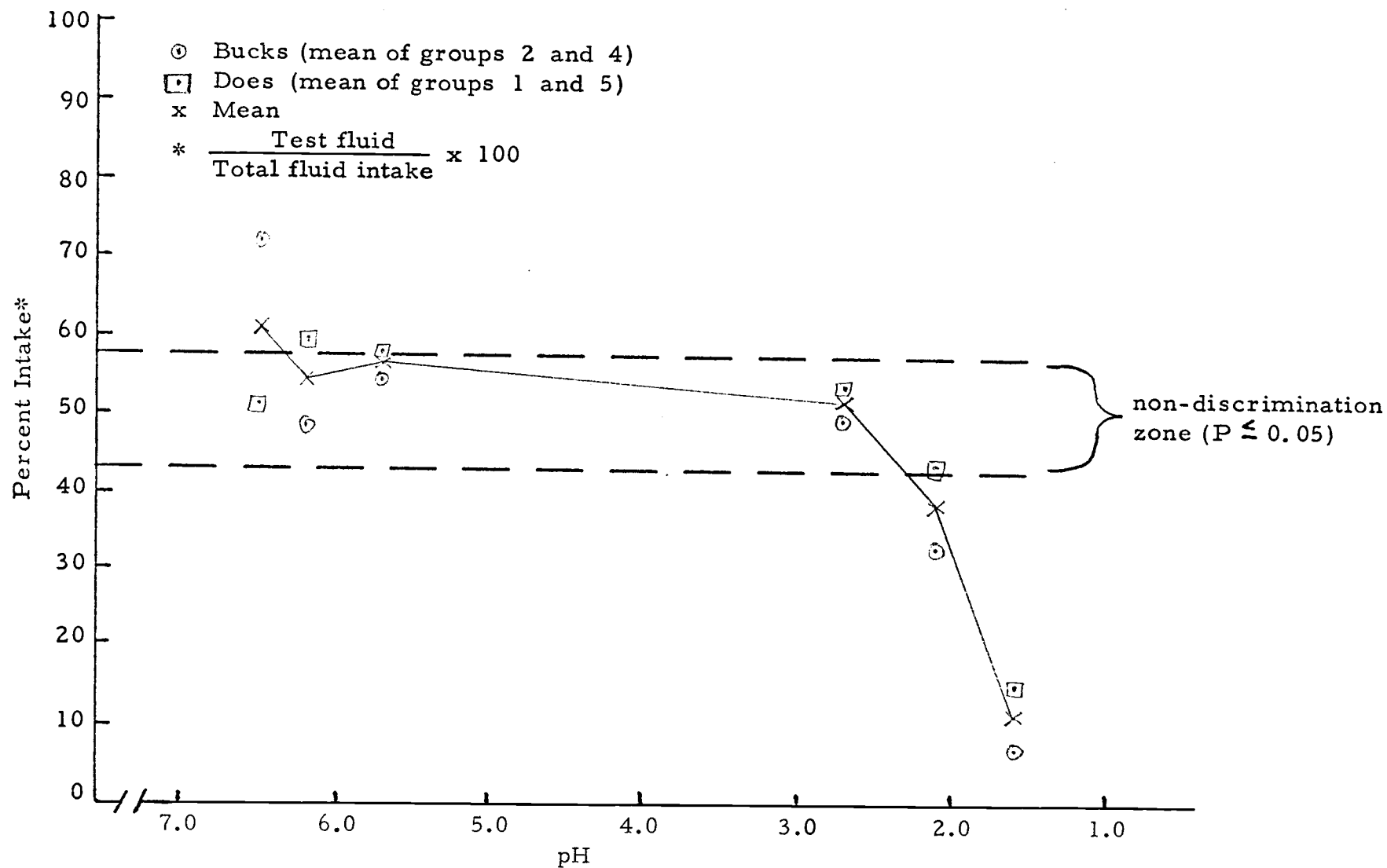
Figure 21. Taste responses of deer to descending pH of hydrochloric acid solution.
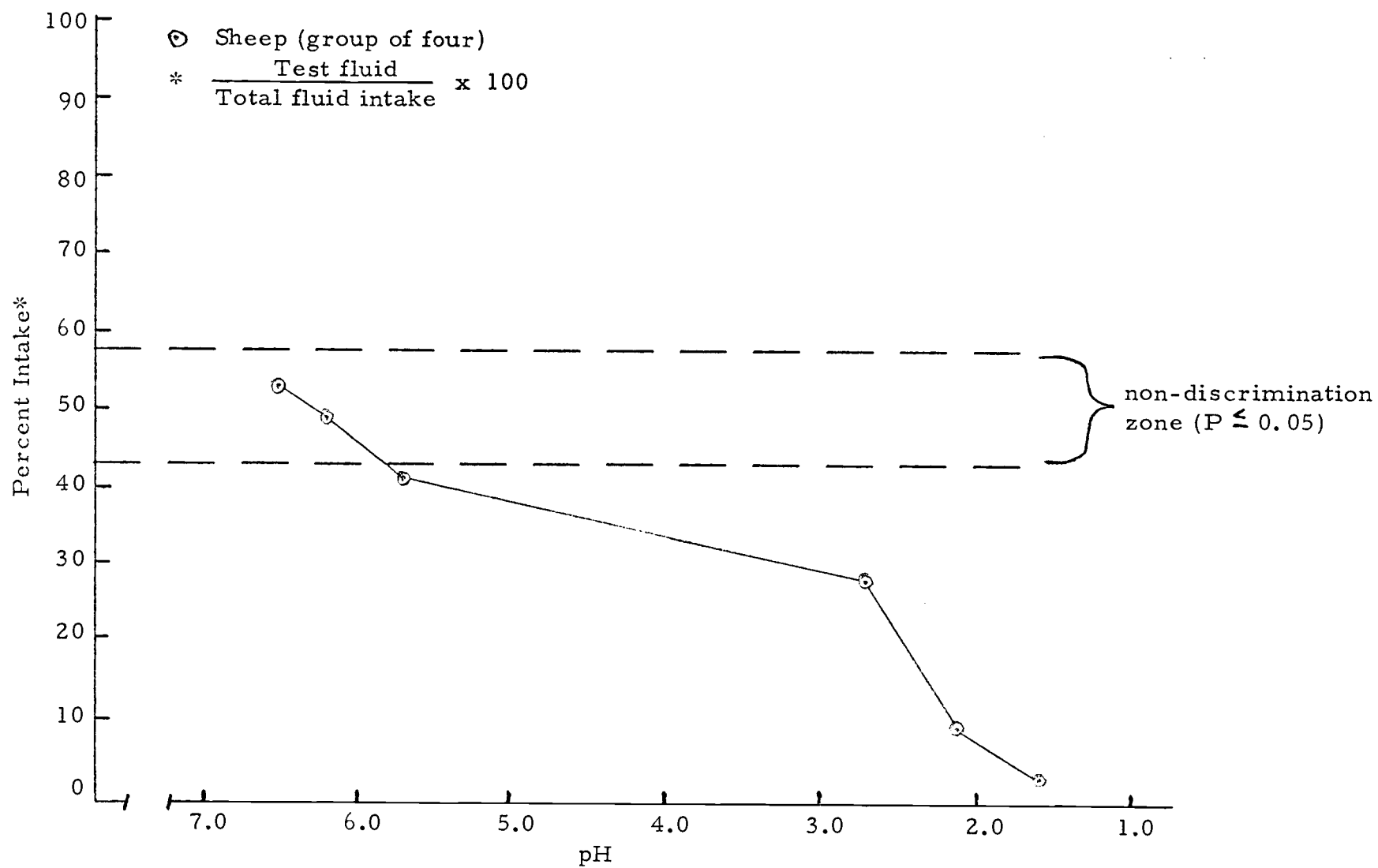
Figure 22. Taste responses of sheep to descending pH of hydrochloric acid solution.

TABLE III.   Sensitivity level for descending pH of acetic acid solution by sheep and deer.[a]

Species	pH of solution
Deer	
Does	6.25
Bucks	6.43
Sheep	3.10

[a] Sensitivity is defined as the first solution of descending pH that will evoke a response (positive or negative) outside of the non-discrimination zone.

TABLE IV.   Sensitivity level for descending pH of butyric acid solution by sheep and deer.[a]

Species	pH of solution
Deer	
Does	6.55
Bucks	6.25
Sheep	5.90

[a] Sensitivity is defined as the first solution of descending pH that will evoke a response (positive or negative) outside of the non-discrimination zone.

TABLE V.   Sensitivity level for descending pH of hydrochloric acid solution by sheep and deer.[a]

Species	pH of solution
Deer	
Does	2.15
Bucks	2.50
Sheep	5.83

[a] Sensitivity is defined as the first solution of descending pH that will evoke a response (positive or negative) outside of the non-discrimination zone.

(acetic and butyric) were rejected at a higher pH (3.25 for acetic

acid, and 3.95 for butyric acid) than hydrochloric acid (2.35) which

has a less noticeable odor (Figures 17,19 and 21). Sheep did not

demonstrate this relationship (Figures 18, 20 and 22). In the case

of sheep, butyric and hydrochloric acid were rejected at a higher

pH (5.90 for butyric, and 5.70 for hydrochloric) than acetic acid

(3.07). This species difference may be partly explained by the wide

and strong preference of deer for the acetate radical, compared to

the narrow and weak preference of sheep. Species differences in

sense of smell may also be a factor. Analysis of the sodium acetate

and acetic acid graphs for these two species (Figures 9, 10, 11,and

12) reveals this relationship.

Quinine Sulfate and Quinine Monohydrochloride

The two bitter compounds tested were quinine sulfate and

quinine monohydrochloride. Quinine dihydrochloride, which was

used in other research to test the bitter taste response of calves and

goats, was not available from any chemical supply company, so

direct comparisons with precisely the same compound among sheep,

deer, calves and goats were not possible. However, a comparison

of the trends in the graphs of the different species was possible, so

they have been discussed in the discussion section. Comparisons of

the bitter taste responses toward all three quinine compounds have

also been made on the basis of molar concentrations.

Deer demonstrated a marked sex difference in the bitter

taste response. Only the bucks preferred the bitter solutions, while

does and sheep rejected them (Figures 23,24,25 and 26 and Appendix

Tables XI and XII). The rejection trends were similar for bucks,

does and sheep; the differences being in the concentrations that were

preferred by bucks and either accepted or rejected by the does and sheep, and the more gradual rejection by sheep.

The buck's sensitivity level for quinine sulfate was at 2.00 mg/100 ml (0.0255 mM), the doe's 4.05 mg/100 ml (0.0511 mM) and the average for deer was at 3.03 mg/100 ml (0.0386 mM). The sensitivity level of sheep for quinine sulfate was at 12.50 mg/100 ml (0.1596 mM). The concentrations at the 20% rejection threshold were 52.00 mg/100 ml and 192.00 mg/100 ml for deer and sheep, respectively.

The buck's sensitivity level for quinine monohydrochloride was at 0.75 mg/100 ml (0.0189 mM), the doe's at 1.50 mg/100 ml (0.0378 mM) and the average for deer was at 1.25 mg/100 ml (0.0283 mM). The sensitivity level of sheep for quinine mono-hydrochloride was at 0.81 mg/100 ml (0.0204 mM). The concentrations at the 20% rejection threshold were 38.00 mg/100 ml and 20.00 mg/100 ml for deer and sheep, respectively.

Sex Differences

To determine if there were sex differences in deer both graphical analysis and the paired "t" test were used. Definite sex differences were observed in their bitter taste response. Large paired "t" values were recorded with both quinine compounds, and the graphs demonstrated the buck's marked preference, and high tolerance of bitter solutions, compared to the doe's definite rejection and low tolerance (Figures 23 and 25, and Appendix Tables XI and XII). Paired "t" values, determining sex differences in the taste responses of deer to the chemicals tested, are listed in Table VI.

TABLE VI.   Paired "t" values to determine sex differences in the taste responses of deer to the chemicals tested.

Chemical	Paired "t" value	d. f.
Sugars:		
Glucose	0.0073	6
Sucrose	0.4587	5
Salts:		
Sodium chloride	0.5286	7
Sodium acetate	0.3612	4
Acids:		
Hydrochloric	0.6246	5
Acetic	0.0430	10
Butyric	0.0501	5
Miscellaneous:		
Quinine sulfate	1.5467[a]	6
Quinine monohydrochloride	1.1320	3
Saccharin	1.0215	5
Sensitivity levels of all chemicals	0.2936	9
Water test (deer)	0.8442	4

[a] Significantly different at the 20% level of probability.

Although a large paired "t" value was recorded for saccharin, the graph does not indicate any definite sex difference (Figure 5 and Appendix Table V).

Does were less sensitive to the bitter taste than bucks. When does did sense the compound they assumed a rejection trend while

the bucks assumed a preference trend through moderate concentra-
tions. Bucks preferred quinine sulfate at concentrations from 2.50
to 10 mg/100 ml, and quinine monohydrochloride from 1.25 to 5.00
mg/100 ml. Does either showed no discrimination or rejected these
concentrations.

Because only Hampshire ewes were used, no test of sex
differences for sheep was possible.

Species differences between the deer and sheep in the study
were ascertained by both graphical analysis and a paired "t" test
over all sensitivity levels of all chemicals tested. The paired "t"
test indicated the sheep and deer were significantly different at
$P \leq 0.20$. Graphical analysis indicated absolute differences in that
the shape of the graphs were different. In general deer demonstra-
ted preference trends for certain chemical concentrations while
the sheep usually demonstrated rejection trends upon response to
the chemical in solution.

A review of Appendix Tables III through XII illustrates the
greater effect of individual variation in the small groups. As
indicated in the experimental procedure section, individual variation
can be nullified by testing large groups or averaging the response of
several individuals. By the same token, averages between small
groups gives a better estimate of the taste response of the species.
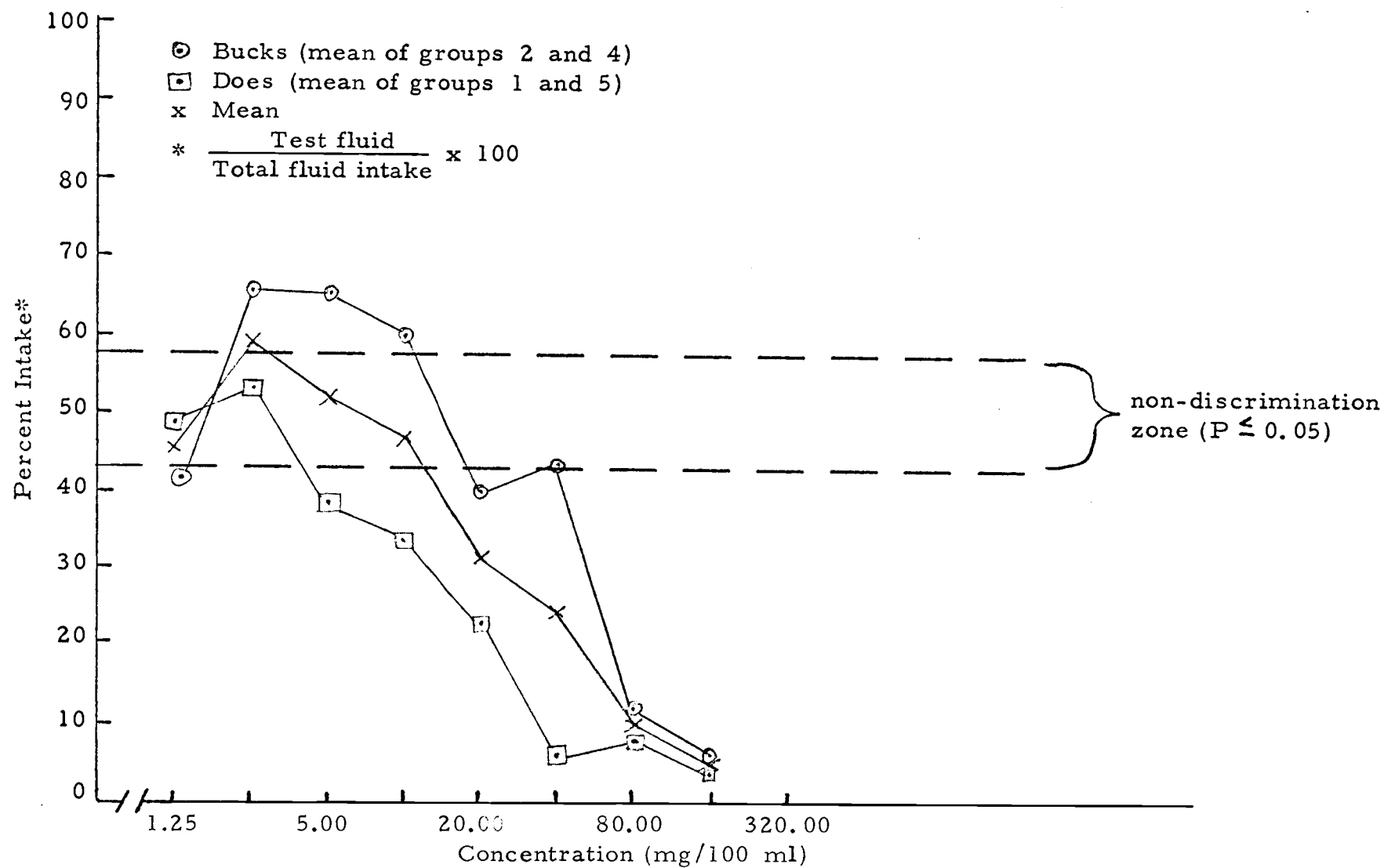
Figure 23. Taste responses of deer to ascending concentrations of quinine sulfate solution.
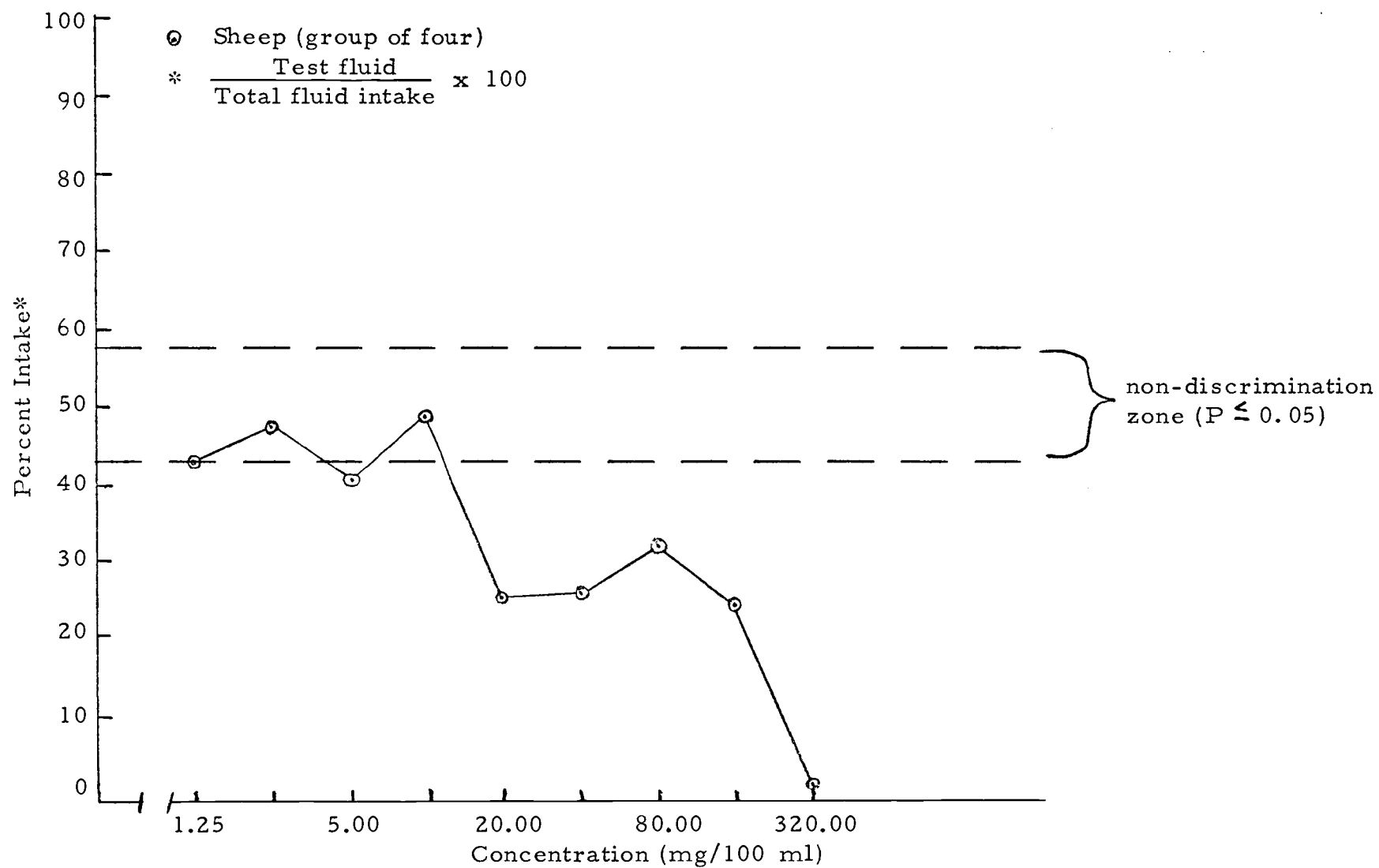
Figure 24. Taste responses of sheep to ascending concentrations of quinine sulfate solution.
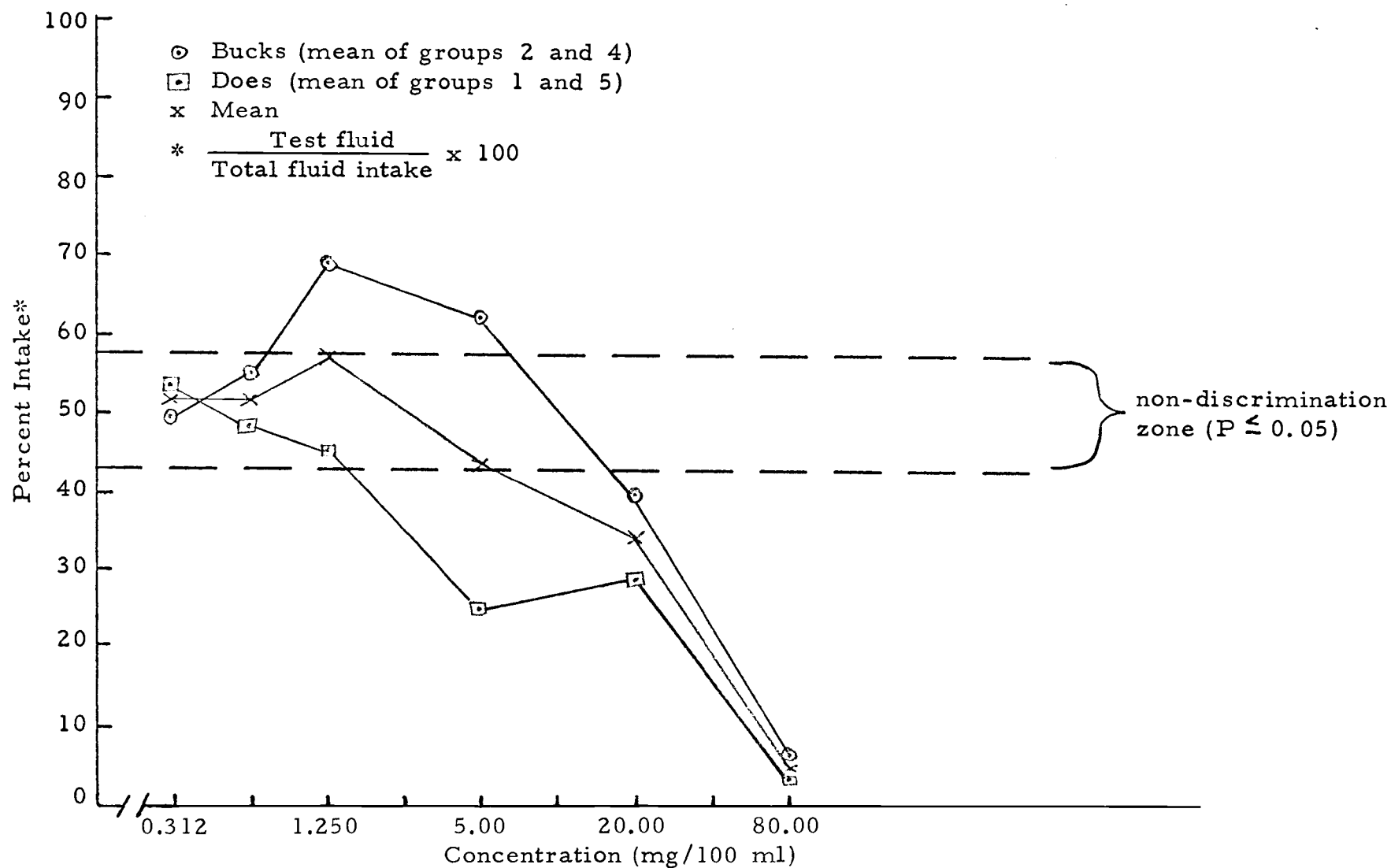
Figure 25. Taste responses of deer to ascending concentrations of quinine monohydrochloride solution.
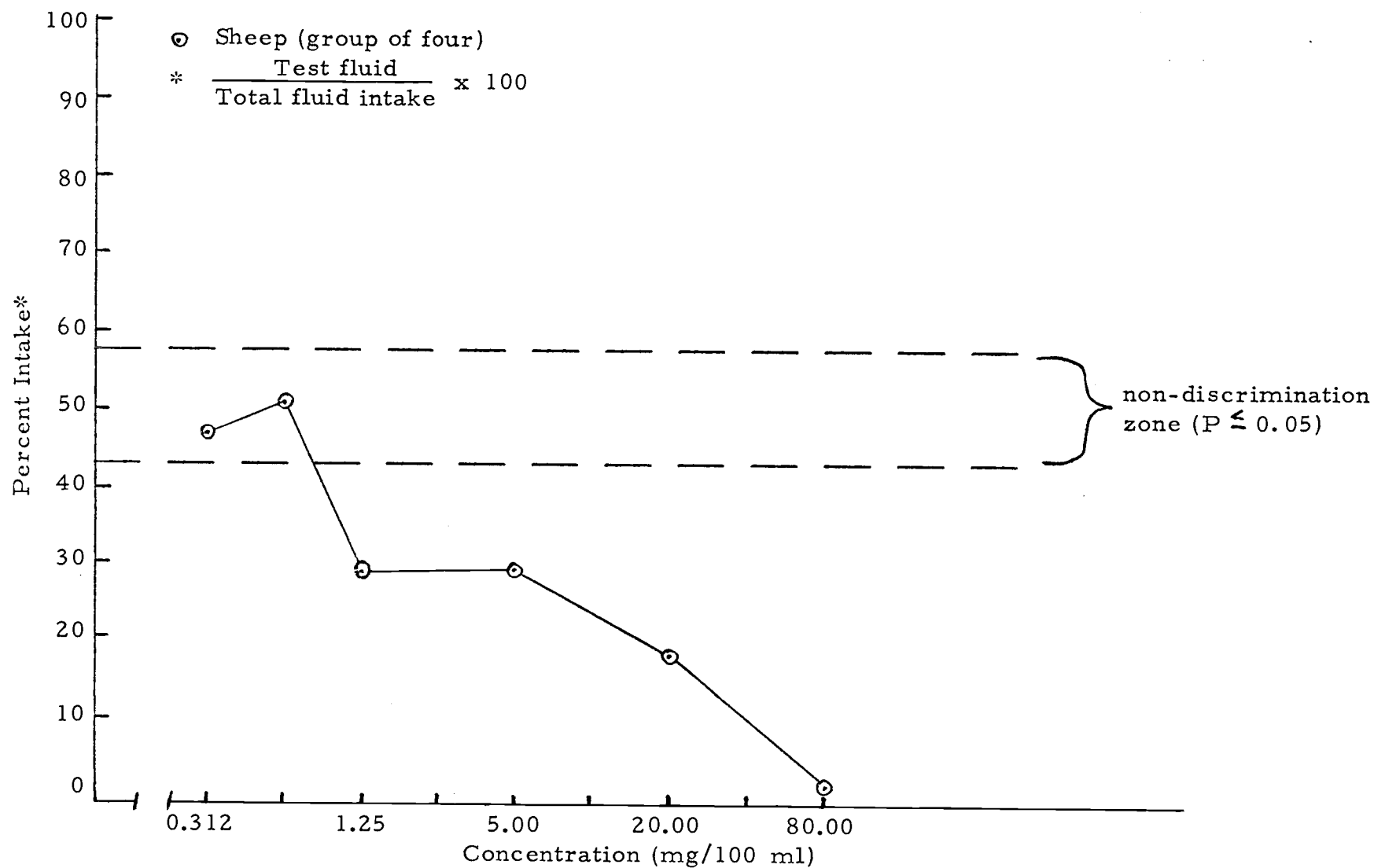
Figure 26. Taste responses of sheep to ascending concentrations of quinine monohydrochloride solution.

DISCUSSION

A major difficulty in comparing the taste responses of ani-
mals is that of determining what criteria should be used for com-
parison. In previous work comparisons between species have been
based on acceptance (the lower limit of the non-discrimination zone)
and/or the 20 percent rejection thresholds. As long as there are
no preference trends these criteria are suitable. But, when pre-
ference exists, the preference threshold (the upper limit of
the non-discrimination zone) should be used. The necessity of using
such a threshold is substantiated by Bell's (1959a) work, which showed
that goats demonstrated positive preference responses to the differ-
ent chemicals at lower concentrations than are required to cause the
acceptance threshold to be crossed. The need for using preference
thresholds is further substantiated by results on the deer which also
demonstrate positive preference responses.

Because the upper limit of the non-discrimination is called
the "preference threshold, " it should logically follow that the lower
limit of the non-discrimination zone--previously referred to as the
acceptance threshold--should be called the "rejection threshold, "
as a response below it indicates rejection. For these reasons, the
preference and rejection thresholds (meaning the upper and lower

limit of the non-discrimination zone, respectively) are used in this

study, to indicate sensitivity as the lowest concentration which will

evoke a response outside of the non-discrimination zone.

Rogers, Hartke and Kitchell (1965) pointed out another pro-

blem in using the acceptance category. They said that,

> ." . . it is in the acceptance category where it is not
> possible to determine whether the animal does not
> discriminate because he cannot perceive the ingre-
> dients or whether he can perceive the ingredients but
> does not discriminate because he is not motivated to
> discriminate."

Although one might think that the more sophisticated electrophysio-

logical responses would indicate whether the animal could, or could

not, perceive an ingredient without being motivated, this is evidently

not the case. When studying the responses of sheep to glucose,

NaCl, HAc and quinine dihydrochloride, Bell and Kitchell (1966)

found that, with the exception of NaCl, appreciably greater con-

centrations were involved in eliciting electrophysiological responses

than in inducing the preference behavior. The opposite case was

true for NaCl.

A major problem incurred in comparing the bitter taste re-

sponses of deer to goats, sheep and calves, is that different forms

of quinine have been used. Due to lack of available supplies of qui-

nine dihydrochloride only quinine monohydrochloride and quinine

sulfate were tested in this study. The fact that previous tests with

sheep were conducted with quinine monohydrochloride, and those with calves and goats were conducted with quinine dihydrochloride, makes comparison difficult as all three quinine compounds may have differing degrees of bitterness at equimolar concentrations. Future comparison of the bitter taste in deer, goats, sheep and calves should be tested using the same quinine compound.

Use of the sheep as a control group for comparison with previous work done at this experiment station indicated that the reported taste responses of deer are comparable. Comparison of the sensitivity levels as reported in the two studies (this paper and Goatcher, 1968) indicates similar values except for saccharin and quinine monohydrochloride (Appendix Table XIV), which may have been due to greater than normal variation in either, or both of the cases. Graphical analysis of the two studies also indicates that the results are quite similar.

The high sweet threshold of deer is quite similar to goats (Bell, 1959b) and calves (Bell and Williams, 1959) but unlike the sweet response of sheep which demonstrate little preference for sweet solutions. From this, it is apparent that deer demonstrate a "sweet tooth," the almost universal characteristic of higher animals. A practical application capitalizing upon the "sweet tooth" of deer would be the use of attractants for preventing crop damage. Das-

mann <u>et</u> <u>al.</u> (1967) successfully used sweet solutions to draw deer

away from young trees. Results with the sheep confirm Goatcher's

(1968) findings, demonstrating little preference for sweet tasting

substances.

As a note of interest, it was observed that the great con-

sumption of high-sugar solutions did not result in any digestive

disturbances in the deer. The opposite is often the case with many

animals. Rapid digestion of the deer or the stepwise increase in

sugar concentrations may be two reasons the deer did not suffer

digestive disturbances.

For deer, sucrose was a more effective taste stimulant than

glucose, at any given molar concentration. Due to extreme varia-

bility in the taste response of sheep to sucrose, a comparison

between glucose and sucrose is not possible.

Whereas deer demonstrated strong preferences for sugars,

up to a concentration of about 20%, they demonstrated only moderate

preference for saccharin. Response to saccharin was of interest in

that it was not rejected, by either sheep or deer, up to the highest

concentration tested (320.00 mg/100 ml). Kare and Ficken (1963)

indicated that this was also the case for calves which seemed indif-

ferent to saccharin up to about 250.00 mg/100 ml, the highest con-

centration tested. Goatcher (1968), on the other hand, reported

that sheep rejected saccharin at about 50 mg/100 ml. Apparently saccharin is an effective stimulant of the sweet taste at lower concentrations, but loses its stimulating effectiveness at higher concentrations.

Extreme differences in the taste responses of deer to salts (sodium chloride and sodium acetate) is apparently due to its preference for the acetate radical. Results with acetic acid indicate preference over a wide range of concentrations similar to the results with sodium acetate. Sheep failed to elicit a strong preference for the acetate radical in either the salt or acid form, although some preference was shown for the acetate.

Based on sensitivity levels, sodium chloride served as a more effective stimulant for deer and sodium acetate was more effective for sheep. Goatcher (1968) pointed out that smell may account for the response to salts of fatty acids such as sodium acetate.

Like the deer, calves demonstrate no preference for sodium chloride. Goats, unlike either deer, calves or sheep, prefer sodium chloride, from a concentration of 0.08% to 1.25%.

Strong preference for the acetate radical was well demonstrated by the deer when they showed fairly strong preference for acetic acid, and little or no preference for butyric acid and hydrochloric acid. Sheep demonstrated distinct rejection trends for all

three acids.

Goats were similar to deer in their response to acetic acid, while calves were more like sheep in that they demonstrated little or no preference for acetic acid.

Results with deer clearly indicated the role of pH and smell in stimulating a response to acids. Butyric and acetic acid, two volatile fatty acids with a noticeable smell, were rejected at a much higher pH than hydrochloric acid. Apparently smell is more important than pH in eliciting the fatty acid response, while pH is more important for hydrochloric acid (Tables III, IV and V).

On the basis of molar concentration, butyric acid was the most effective, hydrochloric acid second, and acetic acid least effective in eliciting a rejection response in both sheep and deer.

The bitter taste response of sheep was similar to the does as neither demonstrated a preference——only acceptance or rejection. Bucks indicated a definite preference for both quinine compounds tested (quinine sulfate and quinine monohydrochloride), thus substantiating the sex difference.

The definite sex difference observed for the bitter taste response of deer may be of consequence in studies on the food habits of bucks and does. Results of this study indicate that the buck's bitter taste preference may cause them to prefer shoots and leaves

of browse, which are normally quite bitter, much more than the

does, who showed no preference for bitter solutions. Although pre-

vious food habit studies of deer have not demonstrated noticeable

sex differences there may be reason for investigating this possibility.

It is well known that adult bucks prefer different habitat than does

during a good share of the year, but it is not known why they do.

The presence of certain bitter tasting browse may be more attractive

to bucks thus holding them in an area while the does move on. If

this were the case, it may provide a useful tool for managing migra-

tory deer herds. One could seed certain browse species——prefer-

red by bucks——in an area to retain bucks because of the differential

in taste preferences. To aid in the selection of such plants, one

might be able to use the buck's preferred bitter solution concentra-

tions (from 0.0025% to 0.0005%) as a criteria for selecting plants

with a similar content of bitter extracts.

The bitter taste response of goats was most nearly like that

of the buck deer as they too preferred moderate concentrations of

quinine solutions. Goats preferred quinine solutions from a con-

centration of 1.56 mg/100 ml to 10.00 mg/100 ml. Calves were

most similar to sheep and doe deer as they demonstrated only

acceptance or rejection.

On the basis of molar concentration, quinine sulfate was

more effective than quinine monohydrochloride for stimulating the bitter taste response in both sheep and deer.

Arrangement of sensitivity levels of the chemicals representing the four primary taste modalities into sensitivity series for each of the species (Table VII) enables one to reliably compare the effectiveness of taste stimulation of each. The sensitivity series clearly indicate that quinine compounds are the most effective taste stimulants. Acetic acid is next in effectiveness, followed by sodium chloride and glucose, respectively.

Comparative sensitivity of different ruminant species is well demonstrated by arranging the species in a series (Table VIII) based on the sensitivity levels for each of the chemicals representing the four primary taste modalities (Tables IX, X, XI and XII). For the sweet taste, goats were most sensitive, calves second, deer third and sheep fourth. For the salty taste, goats were most sensitive, deer second, calves third and sheep fourth. For the sour taste, calves were most sensitive, deer second, goats third and sheep fourth. For the bitter taste, deer were most sensitive, calves second, goats third and sheep fourth.

From this it would seem that sheep are the least sensitive of the four species being compared. Regarding deer, goats and calves, one cannot justifiably say any of these is more sensitive than the

TABLE VII.   Trend and sensitivity series of sheep, deer, goats and calves to glucose, sodium chloride, acetic acid and quinine compounds, the chemicals representing the four primary taste modalities.

Species	Trend[a] and Sensitivity series[b]			
Deer[c]	Trend	preference	preference	preference rejection
	Sensitivity series	quinine compounds > acetic acid >		glucose > sodium chloride
Goats[d]	Trend	preference	preference	preference preference
	Sensitivity series	quinine compounds > acetic acid >		glucose > sodium chloride
Sheep[e]	Trend	rejection	rejection	preference rejection
	Sensitivity series	quinine compounds > acetic acid >		glucose > sodium chloride
Calves[f]	Trend	rejection	rejection	preference rejection
	Sensitivity series	quinine compounds > acetic acid >		glucose > sodium chloride

[a] Trend refers to the taste response at the sensitivity level (e. g. , whether the response assumed a preference or rejection trend).

[b] Sensitivity series is defined as the series of sensitivity levels of the chemicals arranged in order of decreasing sensitivity or increasing molar concentration required to elucidate a response.

[c] This paper.

[d] Bell (1959b).

[e] This paper.

[f] Bell and Williams (1959).

TABLE VIII. Comparative sensitivity of sheep, deer, goats and calves to glucose, sodium chloride, acetic acid and quinine compounds, the chemicals representing the four primary taste modalities.

Taste	Comparative sensitivity[a]
Sweet (glucose)	goats[b] > calves[c] > deer[d] > sheep[e]
Salty (sodium chloride)	goats > deer > calves > sheep
Sour (acetic acid)	calves > deer > goats > sheep
Bitter (quinine compounds)	deer > calves > goats > sheep

[a] Comparative sensitivity is arranged by species, from the most sensitive at the left to the least sensitive species at the right.

[b] Bell (1959b)

[c] Bell and Williams (1959)

[d] This paper

[e] This paper

TABLE IX.   Sensitivity level for sweet taste by deer, sheep, goats and calves (glucose, g/100 ml).[a]

Species	Minimum Concentration		Author(s)
Deer			
Does	0.888	(0.0493 M)	This paper
Bucks	0.170	(0.0094 M)	This paper
Average	0.529	(0.0294 M)	This paper
Goats	0.08	(0.0044 M)	Bell (1959b)
Calves	1.57	(0.0871 M)	Bell and Williams (1959)
Sheep	2.50	(0.1388 M)	This paper
	2.44	(0.1354 M)	Goatcher (1968)

[a] Sensitivity is defined as the lowest concentration that will evoke a response (positive or negative) outside of the non-discrimination zone. It is estimated from the taste response graphs.

TABLE X.   Sensitivity level for salt taste by deer, sheep, goats and calves (sodium chloride, g/100 ml).[a]

Species		Minimum Concentration		Author(s)
Deer				
	Does	1.008	(0.1725 M)	This paper
	Bucks	0.756	(0.1294 M)	This paper
	Average	0.886	(0.1516 M)	This paper
Goats		0.05	(0.0086 M)	Bell (1959b)
Calves		0.91	(0.1557 M)	Bell and Williams (1959)
Sheep		1.375	(0.2352 M)	This paper
		0.256	(0.0438 M)	Goatcher (1968)

[a] Sensitivity is defined as the lowest concentration that will evoke a response (positive or negative) outside of the non-discrimination zone. It is estimated from the taste response graphs.

TABLE XI.   Sensitivity level for sour taste by deer, sheep, goats and calves (acetic acid, ml/100 ml).[a]

Species	Minimum Concentration		Author (s)
Deer			
Does	0.0085	(0.0014 M)	This paper
Bucks	0.0050	(0.0008 M)	This paper
Average	0.00675	(0.0011 M)	This paper
Goats	0.020	(0.0033 M)	Bell (1959b)
Calves	0.003	(0.0005 M)	Bell and Williams (1959)
Sheep	0.630	(0.1049 M)	This paper
	0.013	(0.0022 M)	Goatcher (1968)

[a] Sensitivity is defined as the lowest concentration that will evoke a response (positive or negative) outside of the non-discrimination zone. It is estimated from the taste response graphs.

TABLE XII. Sensitivity level for bitter taste by deer, sheep, goats and calves (quinine compounds, mg/100 ml).[a]

Species		Compound	Minimum	Concentration	Author(s)
Deer					
	Does	Quinine sulfate	4.05	(0.0517 mM)	This paper
	Bucks	Quinine sulfate	2.00	(0.0255 mM)	This paper
	Average	Quinine sulfate	3.025	(0.0386 mM)	This paper
	Does	Quinine monohydrochloride	1.50	(0.0378 mM)	This paper
	Bucks	Quinine monohydrochloride	0.75	(0.0189 mM)	This paper
	Average	Quinine monohydrochloride	1.125	(0.0283 mM)	This paper
Goats		Quinine dihydrochloride	2.34	(0.0589 mM)	Bell (1959b)
Sheep		Quinine sulfate	12.50	(0.1596 mM)	This paper
		Quinine monohydrochloride	0.81	(0.0204 mM)	This paper
		Quinine monohydrochloride	27.70	(0.6978 mM)	Goatcher (1968)
Calves		Quinine dihydrochloride	1.54	(0.0388 mM)	Bell and Williams (1959)

[a] Sensitivity is defined as the lowest concentration that will evoke a response (positive or negative) outside of the non-discrimination zone. It is estimated from the taste response graphs.

others; only that they are more or less sensitive than the others depending upon the taste modality concerned. If the molar values of the sensitivity levels of each species (Tables IX, X, XI and XII) are added up numerically the sums are as follows: goats (.0164), deer (0.1878), calves (0.2433) and sheep (0.4790). On this basis goats appear to be the most sensitive, followed by deer, calves and finally by sheep.

If one accepts this classification of sensitivity, he must ask why it is so! Kare and Ficken (1963), in discussing species differences in taste, state that "one should consider the function of taste in different animals, since it is on this aspect that natural selection is acting." They went on to say that, "It is reasonable to ascribe to it a role in the regulation of ingestion of nutrients and possibly the avoidance of toxic substances."

As man's domestication of ruminant animals has not been toward the selection of 'picky eaters,' he may have unwittingly bred out the species' taste sensitivity. More than 200 modern breeds of sheep attest to their extreme domestication by way of selective breeding. Compared to cattle and goats, sheep have been domesticated for a much longer period of time, thus making it seem reasonable to accept the 'series placement' classification of sensitivity.

Another point made by Kare and Ficken (1963) is that "the taste system in a particular species would be adapted through the evolutionary process to its metabolic and dietary requirements." Bell (1959a) stated essentially the same thing when he pointed out that the marked differences between the bitter taste responses in ruminant species can possibly be explained by the contrast in grazing behavior, natural habits and food of these species. The deer and goats' preference for bitter tastes and sour tastes (acetic acid for both and sodium acetate for deer) may be an evolutionary adaptation. Being browsing animals feeding on shoots or leaves, which are normally quite bitter, and wild fruits, which are normally quite sour, has enabled them to adapt to high bitter and sour taste thresholds.

One cannot freely generalize upon the taste responses of different species — especially from those based upon human experience. However, the acquisition of knowledge about the taste responses of many different species is requisite to a basic understanding of taste responses and all of their applied ramifications. Future studies of ruminant taste responses should explore the taste responses of wild ruminants and different classes and sexes of domestic livestock. Responses of these animals to plant extracts and chemicals of combined taste modalities should reveal much useful information.

SUMMARY AND CONCLUSIONS

Four groups of three deer, each, were used to obtain data
on the taste responses of black-tailed deer. Weight gain and general
appearance of the deer throughout most of the experimental period
indicated that the diet (alfalfa and Fischer's calf grower) and the pen-
ned arrangement were adequate for maintaining health of the
animals.

It was observed that positional bias for the solution contain-
ers was largely determined by the orientation of the containers in
the pen as this was dependent upon the pattern of animal movement
in the pen. Container bias and starting position bias must also be
considered.

Taste responses of the deer were determined by use of the
two-choice preference test method, where the choices were tap
water and tap water-chemical solutions in ascending concentrations.
The chemicals tested were: the sugars, glucose and sucrose; the
sodium salts of chloride (NaCl), acetate (NaAc); the acids, hydro-
chloric (HCl), acetic (HAc), butyric (HBu); and quinine sulfate
(QSO_4), quinine monohydrochloride, and saccharin.

Animals used in the study consisted of twelve deer, half bucks
and half does, plus four female Hampshire sheep as a control group

for comparison with previous work at this experiment station. The deer, initially about five months old, were penned by sex into four groups of three deer each.

Throughout most of the experimental period the separately penned groups were fed alfalfa (pelleted and baled) and "Fischer's calf grower" ad libitum which proved quite adequate. Responses were determined by expressing the consumption of test fluid as percent intake of the total fluid consumed for a given time period.

For each chemical tested the mean responses of bucks and does were plotted graphically to obtain a graph of the preference or rejection trends. The chemical concentrations at the preference and rejection thresholds (e.g., where the test chemical comprised 57% and 43% of total fluid intake, respectively) were estimated from the graph.

The non-discrimination zone was derived by determining the normal variation, with tap water in both containers around a theoretical mean intake of 50% from each container. Although sex differences were elucidated primarily by graphical analysis, paired "t" tests were conducted for comparing the magnitude of sex difference with each test chemical.

Deer demonstrated stronger preferences for sweet solutions than sheep. The buck's sensitivity level for glucose was at 0.0094 M,

the doe's at 0.0493 M and the average for deer was at 0.0294 M. The sensitivity level of sheep for glucose was at 0.1388 M. The buck's sensitivity level for sucrose was at 0.0070 M, the doe's at 0.0070 M, and the average for deer was at 0.00705 M. Sheep were so variable at lower concentrations of sucrose that the sensitivity level could not be estimated.

Deer preferred saccharin over a wide range of concentrations, but to a much lesser degree than the two sugars. Sheep were rather indifferent to saccharin. The buck's sensitivity level for saccharin was at 0.0409 mM, the doe's at 0.0187 mM, and the average for deer was at 0.0298 mM. The sensitivity level of sheep for saccharin was at 0.1024 mM.

Deer exhibited much different taste responses to sodium chloride and sodium acetate. Sodium chloride solutions were rejected while sodium acetate was preferred over a wide range of concentrations. Sheep were rather variable in response to both salts. The buck's sensitivity level for sodium chloride was at 0.1294 M, the doe's at 0.1725 M and the average for deer was at 0.1516 M. The sensitivity level of sheep for sodium chloride was at 0.2352 M. The buck's sensitivity level for sodium acetate was at 0.0140 M, the doe's at 0.0029 M and the average for deer was at 0.0085 M. The sensitivity level of sheep for sodium acetate was at 0.0353 M.

Deer demonstrated a wide range of fairly strong preference for acetic acid, but little or no preference for butyric and hydrochloric acids. Sheep demonstrated distinct rejection trends for all three acids. The combination of results from tests with sodium acetate and acetic acid verified the deer's strong preference for the acetate radical. The buck's sensitivity level for acetic acid was at 0.0008 M, the doe's at 0.0014 M and the average for deer was at 0.0011 M. The sensitivity level of sheep for acetic acid was at 0.1049 M. The buck's sensitivity level for butyric acid was at 0.0079 M, the doe's at 0.0123 M and the average for deer was at 0.0100 M. The sensitivity level of sheep for butyric acid was at 0.0014 M. The buck's sensitivity level for hydrochloric acid was at 0.0077 M, the doe's at 0.0439 M and the average for deer was at 0.0258 M. The sensitivity level of sheep for hydrochloric acid was at 0.0021 M. Deer clearly demonstrated that the volatile fatty acids (acetic and butyric) were rejected at a higher pH than hydrochloric acid which has a less noticeable smell.

Deer demonstrated a marked sex difference in the bitter taste response. Only the bucks preferred the bitter solutions, while does and sheep rejected the quinine sulfate and quinine monohydrochloride solutions. The buck's sensitivity level for quinine sulfate was at 0.0255 mM, the doe's at 0.0511 mM and the average for deer was at

0.0386 mM. The sensitivity level of sheep for quinine sulfate was at

0.0159 mM. The buck's sensitivity level for quinine monohydro-

chloride was at 0.0189 mM, the doe's at 0.0378 mM and the average

for the deer was at 0.0283 mM. The sensitivity level of sheep for

quinine monohydrochloride was at 0.0204 mM.

Among glucose, sodium chloride, acetic acid and the

quinine compounds, the quinine compounds are the most effective

taste stimulants (i. e., accepted at the lowest concentrations).

Acetic acid is next in effectiveness, followed by sodium chloride and

glucose respectively.

Based on the sum of sensitivity levels of deer, sheep, goats

and calves in a sensitivity series for each of the primary taste

modalities, goats appear to be the most sensitive, followed by deer,

calves and finally by sheep.

When one analyzes species differences in taste responses he

must consider the animals adaptation through the evolutionary pro-

cess to its metabolic and dietary requirements. The degree of

domestication apparently has a strong bearing on the animals adapta-

tion and resultant sensitivity.

Future studies of more ruminant species, classes and sexes

are requisite to a basic understanding of taste responses and all of

their applied ramifications.

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APPENDICES

Appendix Table I.   Various statistical formulas used in the study.

Statistical analysis for determining normal variation

N = number of observations

d. f. = N-1 = degrees of freedom

Σx = sum of all observations

$\bar{x}$ = mean of all observations

$\Sigma(x)^2$ = sum of the squares of all observations

$(\Sigma x)^2$ = sum of all observations squared

$(\Sigma x)^2/N$ = correction factor

$\Sigma(x)^2 - (\Sigma x)^2/N$ = SSx = sum of squares of x

$SSx/N-1 = s^2$ = variance

$\sqrt{s^2/N} = s\bar{x}$ = standard error of the mean

95% confidence interval = $\bar{x} \pm s\bar{x}t._{05}$

$t = \dfrac{\bar{x} - 50\%}{s\bar{x}}$

Paired "t" test

Observations restricted to concentrations in response range

N_1 = N of bucks and N_2 = N of does

$\bar{x}_1$ = $\bar{x}$ of bucks and $\bar{x}_2$ = $\bar{x}$ of does

SSx_1 = SSx of bucks and SSx_2 = SSx of does

$sp^2 = \dfrac{SSx_1 + SSx_2}{(N_1 - 1) + (N_2 - 1)}$ = pooled variance (of paired observations)

$s\bar{d}p = \sqrt{\dfrac{2\,sp^2}{N}}$ = standard error of the difference
of the paired observations

$t = \dfrac{\bar{x}_1 - \bar{x}_2}{s\bar{d}p}$ = significance (the computed t value)

APPENDIX TABLE II.   Mean percent intake of water from container "T", in two positions (24 hours in each position), for all four groups of deer.

Observation[a]	Percent intake from container "T"
1	54. 20
2	42. 43
3	51. 22
4	67. 75
5	61. 20
$\sum X$	276. 80
$\bar{X}$	55. 36[b]

$s\bar{x}$ = 3. 0548
Computed "t" = 1. 7546

[a] An observation consisted of a 48-hour period with container "T" on the right for 24 hours, and on the left for 24 hours.

[b] Not significantly different from a theoretical mean of 50% at the 5% level of probability as determined by a "t" test between the experimental mean, and theoretical mean of 50%.

APPENDIX TABLE III.   Taste responses of sheep and deer to ascending concentrations of glucose solution. [a]

Conc. g/100 ml.	Bucks			Does			Deer Grand Mean	Sheep Group of four
	Grp. 2	Grp. 4	Mean	Grp. 1	Grp. 5	Mean		
.01	56.33	50.43	53.38	57.87	42.96	50.42	51.90	54.02
.02	54.63	50.94	52.79	52.47	51.45	51.96	52.37	50.10
.04	52.14	47.87	50.01	51.19	54.60	52.90	51.45	48.20
.08	63.29	44.09	53.69	52.03	48.52	50.28	51.99	46.88
.16	60.26	51.10	55.68	52.07	50.55	51.31	53.50	46.08
.32	57.58	63.73	60.66	59.44	61.04	60.24	60.45	52.26
.63	56.24	63.55	59.90	60.86	46.75	53.80	56.85	47.64
1.25	54.58	63.88	59.23	65.34	55.17	60.26	59.75	39.59
2.50	84.44	68.93	76.69	76.10	88.43	82.31	79.50	57.29
5.00	96.31	98.74	97.53	89.33	95.17	92.25	94.89	80.38
10.00	91.63	98.41	95.02	98.62	99.60	99.26	97.14	68.15
20.00	98.09	98.39	98.24	99.89	99.47	99.68	98.96	41.74

[a] Taste responses expressed as the percent of total fluid intake represented by test fluid intake,

$$\frac{\text{Test fluid}}{\text{Total fluid intake}} \times 100$$

APPENDIX TABLE IV. Taste responses of sheep and deer to ascending concentrations of sucrose solution. [a]

Conc. g/100 ml	Bucks			Does			Deer Grand Mean	Sheep Group of four
	Grp. 2	Grp. 4	Mean	Grp. 1	Grp. 5	Mean		
.01	46.04	41.41	43.73	49.41	38.19	43.80	43.77	32.02
.04	42.99	40.36	41.68	48.92	44.78	46.85	44.27	47.59
.16	45.72	55.93	50.83	33.61	55.02	44.32	47.57	37.80
.63	68.60	88.79	78.70	96.95	91.24	93.95	86.32	52.40
2.50	99.30	90.97	95.14	92.95	97.55	95.25	95.19	57.74
10.00	86.17	78.69	82.43	81.77	83.09	82.13	82.28	64.81
40.00	29.38	20.78	25.08	22.94	15.16	19.05	22.07	17.50

[a] Taste responses expressed as the percent of total fluid intake represented by test fluid intake,

$$\frac{\text{Test fluid}}{\text{Total fluid intake}} \times 100$$

APPENDIX TABLE V. Taste responses of sheep and deer to ascending concentrations of saccharin solution.[a]

Conc. mg/100 ml	Bucks			Does			Deer Grand Mean	Sheep Group of four
	Grp. 2	Grp. 4	Mean	Grp. 1	Grp. 5	Mean		
0.312	57.24	53.49	55.37	33.69	79.50	56.60	55.98	---[b]
0.625	47.62	60.40	54.01	63.45	67.90	65.68	59.85	50.37
1.25	72.41	66.07	69.24	56.71	65.99	61.35	65.30	51.64
5.0	85.36	65.27	75.32	86.23	70.20	78.22	76.77	70.12
20.0	80.28	73.64	76.96	36.00	56.03	45.02	60.99	56.87
80.0	76.10	61.30	68.70	56.60	73.91	62.76	65.73	56.35
320.0	59.06	53.98	56.52	30.63	68.60	49.62	53.07	51.11

[a] Taste responses expressed as the percent of total fluid intake represented by test fluid intake,

$$\frac{\text{Test fluid}}{\text{Total fluid intake}} \times 100$$

[b] Missing data are concentrations not needed to obtain a complete taste response graph for the animal concerned.

APPENDIX TABLE VI.   Taste responses of sheep and deer to ascending concentrations of sodium chloride solution.[a]

| Conc. g/100 ml | Bucks | | | Does | | | Deer Grand Mean | Sheep Group of four |
	Grp. 2	Grp. 4	Mean	Grp. 1	Grp. 5	Mean		
.01	28.66	67.71	48.19	48.71	59.59	54.15	51.17	53.81
.02	46.48	65.10	55.79	24.62	54.46	39.54	47.67	34.03
.04	18.25	48.29	33.27	41.78	50.36	46.07	39.67	53.44
.08	46.38	40.88	43.63	25.73	37.51	31.62	37.63	40.69
.16	65.25	53.54	57.90	26.69	43.64	35.16	46.53	59.76
.32	66.93	45.70	56.32	41.10	47.07	44.09	50.20	51.81
.63	36.16	55.09	45.92	48.18	62.062	55.12	50.52	51.28
1.25	37.16	23.61	30.39	24.98	43.44	34.21	32.30	48.21
2.50	8.40	6.21	7.31	5.27	20.61	12.94	10.12	13.72

[a]Taste responses expressed as the percent of total fluid intake represented by test fluid intake,

$$\frac{\text{Test fluid}}{\text{Total fluid intake}} \times 100$$

APPENDIX TABLE VII. Taste responses of sheep and deer to ascending concentrations of sodium acetate solution.[a]

Conc. g/100 ml	Bucks			Does			Deer Grand Mean	Sheep Group of four
	Grp. 2	Grp. 4	Mean	Grp. 1	Grp. 5	Mean		
.01	51.64	50.56	51.10	41.74	44.95	43.35	47.23	55.97
.04	63.45	65.54	64.50	46.55	67.88	57.22	60.86	39.97
.16	56.69	93.81	75.25	25.59	85.44	55.52	65.49	41.97
.63	61.16	75.21	68.19	56.26	66.00	61.13	64.66	60.47
2.50	72.49	42.76	57.63	51.64	70.24	60.94	59.28	64.91
10.00	13.23	8.29	10.76	15.28	15.69	15.49	13.13	16.61

[a]Taste responses expressed as the percent of total fluid intake represented by test fluid intake,

$$\frac{\text{Test fluid}}{\text{Total fluid intake}} \times 100$$

APPENDIX TABLE VIII.   Taste response of sheep and deer to ascending concentrations of acetic acid solution.[a]

Conc. ml/100 ml	pH	Bucks Grp. 2	Grp. 4	Mean	Does Grp. 1	Grp. 5	Mean	Deer Grand Mean	Sheep Group of four
0.00063	6.65	58.81	55.59	57.20	56.75	51.19	53.97	55.59	54.65
0.00125	6.61	53.75	58.85	56.30	49.30	45.92	47.61	51.96	54.27
0.00250	6.60	48.72	45.09	46.91	45.44	39.96	42.70	44.80	52.72
0.00500	6.40	50.55	66.01	58.28	47.81	41.69	44.75	51.52	57.79
0.01000	6.20	64.10	68.98	66.54	67.79	57.64	62.72	64.63	45.26
0.02000	5.10	72.78	70.79	71.79	66.72	66.61	66.67	69.23	49.21
0.04000	4.35	61.67	66.84	64.26	69.74	79.93	74.84	69.55	41.92
0.08000	3.92	72.43	67.62	70.03	78.76	93.27	86.02	78.02	38.53
0.16000	3.63	66.19	54.95	60.57	70.96	75.50	73.23	66.90	48.15
0.32000	3.38	56.61	67.83	62.22	28.44	42.82	38.63	50.43	42.37
0.63000	3.09	12.29	35.81	24.05	4.88	68.69	36.76	30.41	44.10
1.25000	2.90	11.48	24.92	18.20	2.52	41.60	22.06	20.13	34.02
2.50000	2.75	7.13	8.73	7.93	0.00	14.28	7.14	7.54	24.98
5.00000	2.55	---[b]	---	---	---	---	---	---	1.93

[a]Taste response expressed as the percent of total fluid intake represented by test fluid intake,

$$\frac{\text{Test fluid}}{\text{Total fluid intake}} \times 100$$

[b]Missing data are concentrations not needed to obtain a complete taste response graph for the animal concerned.

APPENDIX TABLE IX.   Taste responses of sheep and deer to ascending concentrations of butyric acid solution. [a]

Conc. ml/100 ml	pH	Buck Grp. 2	Buck Grp. 4	Mean	Does Grp. 1	Does Grp. 5	Mean	Deer Grand Mean	Sheep Group of four
0.00063	6.55	72.22	52.24	62.23	13.54	55.82	34.68	48.46	49.01
0.00250	6.35	56.32	56.32	56.32	61.16	60.31	60.74	58.53	54.39
0.01000	6.13	50.65	17.45	34.05	53.75	49.91	51.83	42.94	46.62
0.04000	4.30	44.32	55.99	50.16	26.55	90.04	58.30	54.23	22.75
0.16000	3.70	10.50	51.70	31.10	2.74	70.36	36.55	33.83	21.98
0.63000	3.25	1.84	34.05	17.95	0.58	12.34	6.46	12.20	10.56

[a] Taste responses expressed as the percent of total fluid intake represented by test fluid intake,

$$\frac{\text{Test fluid}}{\text{Total fluid intake}} \times 100$$

APPENDIX TABLE X.   Taste responses of sheep and deer to ascending concentrations of hydrochloric acid solution.[a]

Conc. ml/100 ml	pH	Bucks Grp. 2	Grp. 4	Mean	Does Grp. 1	Grp. 5	Mean	Deer Grand Mean	Sheep Group of four
0.00063	6.50	77.04	63.40	70.22	45.07	57.30	51.19	60.71	52.62
0.00250	6.20	45.24	51.35	48.30	63.00	55.94	59.47	53.88	49.43
0.01000	5.70	47.72	61.00	54.36	49.59	66.18	57.89	56.13	42.06
0.04000	2.72	52.52	46.05	49.29	10.70	96.37	53.54	51.41	28.77
0.16000	2.13	33.78	31.06	32.42	6.35	79.69	43.02	37.72	9.64
0.63000	1.60	5.44	6.81	6.13	4.79	24.41	14.60	10.36	3.05

[a]Taste responses expressed as the percent of total fluid intake represented by test fluid intake,

$$\frac{\text{Test fluid}}{\text{Total fluid intake}} \times 100$$

APPENDIX TABLE XI.   Taste responses of sheep and deer to ascending concentrations of quinine monohydrochloride solution. [a]

Conc. mg/100 m	Bucks			Does			Deer Grand Mean	Sheep Group of four
	Grp. 2	Grp. 4	Mean	Grp. 1	Grp. 5	Mean		
0.312	45.74	53.16	49.45	55.46	51.20	53.33	51.39	46.31
0.625	49.73	60.27	55.00	54.84	41.42	48.13	51.57	51.20
1.250	98.20	40.12	69.16	39.65	50.28	44.92	57.04	29.10
5.000	62.80	61.88	62.34	3.49	44.97	24.23	43.29	29.91
20.000	35.88	42.45	39.17	1.53	54.84	28.19	33.68	19.07
80.000	1.09	9.61	5.35	1.43	3.38	2.41	3.88	1.27

[a] Taste responses expressed as the percent of total fluid intake represented by test fluid intake,

$$\frac{\text{Test fluid}}{\text{Total fluid intake}} \times 100$$

APPENDIX TABLE XII. Taste responses of sheep and deer to ascending concentrations of quinine sulfate solution.[a]

Conc. mg/100 ml	Bucks			Does			Deer Grand Mean	Sheep Group of four
	Grp. 2	Grp. 4	Mean	Grp. 1	Grp. 5	Mean		
1.25	43.24	39.72	41.48	52.39	44.97	48.68	45.08	43.90
2.50	59.88	72.16	66.02	69.96	36.08	53.02	59.52	47.73
5.00	64.17	67.04	65.61	25.62	50.78	38.20	51.91	41.69
10.00	44.11	75.88	60.00	40.76	26.17	33.47	46.73	49.56
20.00	21.40	58.20	39.80	17.74	27.28	22.51	31.15	25.99
40.00	27.27	58.93	43.10	7.28	3.50	5.39	24.25	26.49
80.00	0.00	22.71	11.36	10.91	3.78	7.35	9.36	32.56
160.00	1.31	10.02	5.66	1.14	5.09	3.12	4.39	25.24
320.00	---[b]	---	---	---	---	---	---	1.03

[a] Taste responses expressed as the percent of total fluid intake represented by test fluid intake,

$$\frac{\text{Test fluid}}{\text{Total fluid intake}} \times 100$$

[b] Missing data are concentrations not needed to obtain a complete taste response graph for the animal concerned.

APPENDIX TABLE XIII. Total fluid consumption (Kgs) and percent treated solution consumption of glucose (g/100 ml) by sheep and deer.[a]

Conc. g/100 ml	Deer (total of 12 animals)		Sheep (total of 4 animals)	
	Total fluid cons.	% treated solu.	Total fluid cons.	%treated solu.
.01	84.79 Kgs.	51.90	53.97 Kgs.	54.02
.02	90.45	52.37	46.98	50.10
.04	86.69	51.45	32.80	48.20
.08	79.00	51.99	39.57	46.88
.16	88.08	53.50	52.13	46.08
.32	81.80	60.45	47.98	52.26
.63	83.73	56.85	43.37	47.64
1.25	81.79	59.75	42.83	39.59
2.50	71.61	79,50	49.94	57.29
5.00	109.48	94.89	41.13	80.38
10.00	104.56	97.14	53.61	68.15
20.00	110.45	98.96	32.10	41.74

[a]Fluid consumption is based on the same 48-hour period during which each glucose solution was tested.

APPENDIX TABLE XIV.   Sensitivity levels for comparing differences in the taste response of sheep as reported in two separate studies.

Chemical	This paper		Goatcher (1968)	
	Sensitivity levels			
Glucose	2.500	g/100 ml	2.44	g/100 ml
Sucrose	3.770	g/100 ml	3.375	g/100 ml
Saccharin	1.875	mg/100 ml	50.000	mg/100 ml
Sodium chloride	1.375	g/100 ml	0.256	g/100 ml
Sodium acetate	0.480	g/100 ml	0.12	g/100 ml
Acetic acid	0.630	ml/100 ml	0.013	ml/100 ml
Butyric acid	0.012	ml/100 ml	0.00625	ml/100 ml
Hydrochloric acid	0.0075	ml/100 ml	0.00445	ml/100 ml
Quinine monohydrochloride	0.8125	mg/100 ml	27.7000	mg/100 ml