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Experiments were conducted to determine if any of four procedures for measuring taste responses of the pygmy goat permitted a more uniform response. The procedures consisted of a two-choice, free-choice preference test for 48 hr. (2CFC); a two-choice preference test with limited access to the test solution during a 48 hr. period (2CLA); a one-choice preference test in which the test solution was alternated with tap water every 24 hr. (1CFC); and a one-choice preference test in which limited access to the test solution or water was allowed for a 24 hr. test period (1CLA).

Studies were also conducted to observe the taste responses of pygmy goats when gymnemic acid (GymA), inosinic acid (InoA), or monosodium glutamate (MSG) was added in ascending concentrations to sucrose or quinine monohydrochloride (QHCl) solutions.

Observations were made on the taste responses of male and female calves to concentrations of 0.02%, 0.08%, 0.32%, or 1.25%

sodium chloride (NaCl), sodium sulfate (Na_2SO_4), sodium bicarbonate ($NaHCO_3$), sodium carbonate (Na_2CO_3), monobasic sodium phosphate (NaH_2PO_4), and dibasic sodium phosphate (Na_2HPO_4). Observations were made on similar concentrations of ammonium chloride (NH_4Cl), potassium chloride (KCl), calcium chloride ($CaCl_2$), magnesium chloride ($MgCl_2$), and manganese chloride ($MnCl_2$). In addition, responses were observed when 0.02%, 0.08%, 0.32% or 1.25% $NaHCO_3$, Na_2SO_4, or Na_2HPO_4 was offered in opposition to equal concentrations of NaCl. Observations were made on the responses to 5, 10, 20, 40 or 60 ppm concentrations of cupric chloride ($CuCl_2$), zinc chloride ($ZnCl_2$), molybdenum trioxide (MoO_3), and cobaltous chloride ($CoCl_2$).

Experimental animals were penned individually and fed a completely pelleted ration ad libitum. Trace mineralized salt was available free choice.

Responses were determined by expressing the intake of the test solution as percent of the total intake during the test period. Responses were measured during two 24 hr. test periods for the pygmies and two 8 hr. periods for the cattle. Using water as a basis for determination, a nondiscrimination zone was established. This zone represented percent intake ranging from 67% to 33% for pygmies; the corresponding zone for the cattle was 63% and 37%. For both species a preference threshold (PRT) was set at 80% intake, while the rejection threshold (RET) was set at 20% intake; these latter values were chosen arbitrarily.

None of the procedures for studying taste responses was found to be superior in reducing individual variation. Procedure 2CFC was utilized for subsequent studies.

The addition of 20, 40, or 100 ppm GymA to a 25% sucrose (adversive) solution caused the pygmies to show PRT responses. Additions of GymA to a 30% sucrose solution did not change the RET response. The addition of GymA to 1000 ppm QHCl did not change the RET response. However, additions of 10, 20, 60, 80, or 100 ppm GymA to a 200 ppm QHCl solution changed the response from rejection to nondiscrimination or weak preference. The results thus show that GymA probably reduces taste sensitivity to both sweet and bitter chemicals.

Addition of InoA from 50 to 500 ppm to a 0.08% sucrose solution did not change the response from nondiscrimination; when InoA was added to a 6.25 ppm QHCl solution, response was changed from nondiscrimination to rejection at 50 ppm and crossed the RET at 250 ppm, indicating an enhanced sensitivity to QHCl.

When MSG was added to a 0.08% sucrose solution the response remained nondiscriminatory until 500 ppm was reached; this elicited a weak rejection. When 50 ppm MSG was added to a 10% sucrose solution the response was changed from moderate preference to nondiscrimination. The response remained the same for all subsequent additions. The addition of 50 ppm MSG to a 30% sucrose solution caused a change in response from weak rejection to nondiscrimination. The response was changed to weak rejection at 250 ppm MSG, however 500 ppm caused a nondiscrimination response. The addition of 50 ppm MSG to a 100 ppm QHCl solution changed the taste response from moderate rejection to nondiscrimination. The response was not changed by subsequent additions of MSG. Additions of MSG from 50 to 500 ppm to a 6.25 ppm QHCl solution did not change the response from nondiscrimination. Thus, results with MSG indicate responses similar to that with GymA.

A concentration of 0.02% Na_2HPO_4, $NaHCO_3$ or Na_2SO_4 caused male calves to show taste sensitivity (point at which discrimination first occurred). Only $NaHCO_3$ caused female calves to show sensitivity at the 0.02% concentration. In males and females 0.32% Na_2CO_3 caused a RET response. No salt studied caused either sex to show a PRT response. The dibasic form of Na caused males and females to show the strongest response. Males and females were consistently different in their responses, however no trend toward preference or rejection was observed.

A concentration of 0.02% KCl, NH_4Cl, or $CaCl_2$ caused male calves to show sensitivity. Only $CaCl_2$ caused females to elicit sensitivity at this concentration. The males showed RET responses for 0.32% NH_4Cl, 1.25% KCl, 1.25% $MnCl_2$, and 1.25% $MgCl_2$. Only 0.32% NH_4Cl or 0.32% $CaCl_2$ caused females to elicit a RET response. Males and females were consistently different in their taste responses.

Responses to $NaHCO_3$, Na_2SO_4, or Na_2HPO_4 differed in the presence of NaCl from those observed with H_2O in a two-choice situation. Sex differences were also apparent. Males showed a RET response to a 1.25% Na_2SO_4; females showed a RET response at 0.32% Na_2SO_4 when in opposition to NaCl.

Female calves showed the strongest responses to the trace mineral solutions. A PRT response was shown at a concentration of 10 ppm $ZnCl_2$ and 60 ppm $CoCl_2$. A concentration of 60 ppm $CuCl_2$ caused females to show a RET response. Males showed moderate rejection to 40 ppm $CuCl_2$. Sex differences were observed.

Taste Responses of Pygmy Goats and Cattle

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Typed by Muriel Davis for Michael John Mehren

DEDICATION

To my wife, Diana, and my daughter, Yvette, this represents my best for you who are my very best.

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INTRODUCTION

As population growth continues, competition between man and ruminants for many feedstuffs is likely to become more intense. This has brought about widespread investigation into the role of the ruminant as a means for recycling waste products. If ruminants will be required to consume substances varying widely in chemical make-up, then information concerning the taste responses can be applied so that desired levels of consumption may be attained.

A review of the literature indicates that work on taste responses in ruminants has produced results from which generalizations are quite difficult due to the individual variation. Only one method of taste response evaluation has been employed. A trial comparing various preference testing techniques would seem to be of value.

Work conducted with humans indicates that several compounds exhibit taste-modifying properties. Three such compounds are gymnemic acid, inosinic acid, and monosodium glutamate. Gymnemic acid causes a transitory inhibition of the sweet and sour taste in humans. Inosinic acid has been found to improve the blend and flavor of food products; however its action is not uniform within a taste category (i.e., sweet). Monosodium glutamate enhances the flavor of certain foods when presented to humans. No studies have been reported in which these substances were provided to ruminants in the presence of relatively pure compounds representing a taste category such as sucrose or quinine. Information derived from taste response studies could be utilized to determine which category (sweet, salt, bitter or sour) a particular taste-modifier influences for ruminant species.

Information is available regarding the taste responses of ruminants to different salt solutions when the animals are in a deficient state, however little information is available regarding the taste responses of animals to different salts when on a nutritionally adequate diet. Information of this nature may lead to the discovery of the cause of preference or rejection of certain species of plants by ruminants.

Recent information indicates that, in humans and rats, metal ions may play a direct role in the sense of taste. This phenomenon may also occur in the ruminant. Information regarding the responses of ruminants to pure solutions of metal ions may be used to regulate or modify intake to the purpose for which the animal is being raised.

The purpose of this study was to determine which of four taste testing procedures was best suited for the pygmy goat. Observations were also made on the taste responses of the pygmy goat to sweet and bitter solutions when gymnemic acid, inosinic acid, or monosodium glutamate was added at increasing levels. Taste responses of male and female calves were observed when six sodium salts, six chloride solutions, and salts of copper, zinc, molybdenum and cobalt were offered. Differences in taste response due to sex were also determined.

LITERATURE REVIEW

Several experiments have been conducted at this station to observe the taste responses of ruminants. Species included in these studies were black-tailed deer, pygmy goat, normal goat, sheep, and cattle. Consequently, an extensive review of the literature concerning taste responses and interrelated factors has been compiled. The following presents a listing of the subjects reviewed and the author responsible.

Classification of Taste	Goatcher, 1969 Crawford, 1970 Rice, 1972
Sensory Interaction and Physiological Characteristics	Goatcher, 1969 Crawford, 1970 Rice, 1972
Interaction of Taste and the other Senses	Rice, 1972
Influence of Taste on Associative Learning	Rice, 1972
Environmental and Internal Factors Which May Influence the Taste Response	Goatcher, 1969 Crawford, 1970 Rice, 1972
Species and Individual Differences in Taste Responses	Goatcher, 1969 Crawford, 1970 Rice, 1972
Experimental Methods of Studying Taste Responses	Goatcher, 1969 Crawford, 1970

Taste Modifiers	Goatcher, 1970
Interaction of Tastes	Goatcher, 1970
Taste Thresholds	Goatcher, 1970
Mechanisms of Sensory Evaluation	Crawford, 1970
Functions of the Sense of Taste	Crawford, 1970

Due to the detailed nature of the reviews available, subjects that would normally be reviewed were summarized and updated if new information was available, rather than reiterating them.

Experimental Methods of Studying Taste Responses

Three different approaches have been employed in studying taste responses. Electrophysiological studies involve isolation of nerve fibers and recording an electrical impulse in response to a stimulus applied to the tongue. In general, this method may be correlated with a behavioral response. Another method involves measurement of a physiological response such as parotid gland flow rate. The third approach, which has been most widely used, is preference testing. The subject is given a choice between a test substance and water or another test substance. The amount of test solution taken is expressed as a percent of the total intake from both containers. The relative position of the fluids is then reversed during a second period in order to avoid positional or container bias.

Aldinger and Fitzgerald (1966) reported a single stimulus method of testing the palatability of baby pig rations. Two feeders per pen were used and a clock mechanism allowed continuous alternate feeding. Comparison with a free-choice selection and single stimulus method indicated that the coefficient of variation was reduced from 36.0% to 5.5% by the latter method. This method represented a modification of that first described by Weiner and Stellar (1951) for the rat.

Individual Variation in Taste Response

Individual variation has been related to physiological and environmental factors. Among the factors suggested are: blood glucose level, postingestive processes, degree of hunger, state of health, nutritional adequacy of diet and genetical influence which may be manifested through many physiological mechanisms. It is pointed out that individual variation within a species represents a difference in degree while variation among species is absolute.

Taste Modifiers

Work conducted with humans indicates that several compounds exhibit taste-modifying properties. Stocklin (1969) reported that gymnemic acid, a compound isolated from the leaves of the tropical plant *Gymnema sylvestre*, prevents the sweet as well as sour taste in humans. The inhibition persists for approximately two hours after chewing the leaves. Experiments conducted by Warren and Pfaffmann (1959) indicate that potassium gymnemate is the active principle. It was shown to have quantitatively equal effects on the sweet taste of threshold and suprathreshold concentrations of sucrose and sodium saccharin. Bartoshuk et al. (1969) have reported experiments which contradict earlier reports of the bitter-suppressing activity of gymnemic acid. These authors state that earlier reports were not a true suppression, but rather were a cross-adaptation between the bitter taste of the Gymnema sylvestre leaves and the extracts. Kurihara, Kurihara and Beidler (1969) reported that the A_1 extract of gymnemic acid suppressed the sweet taste of cyclamate, D-amino acids, beryllium chloride, and lead acetate, but did not suppress that of chloroform.

Inosinic acid is said to improve the blend, flavor, and fullness of food products and has the capacity to create the sensation of increased viscosity in liquid products (Kurtzman and Sjostrom, 1964). Inosinic acid is a hydrolytic product of adenosine monophosphate found in muscle and, as such, is classified as a nucleotide. These authors reported that inosinic acid did not elicit a uniform response within a taste group. For example, sucrose taste might be enhanced, while glucose taste was unaffected even though both are in the sweet category. Wagner, Titus, and Schade (1963) also reported the flavor modifying properties of the nucleotides. These authors state that phosphorylation at the 5' position of the ribose is essential for flavor enhancement. Three compounds meeting this criterion are inosinic acid, guanylic acid, and xanthylic acid.

Monosodium glutamate (MSG) is similar in action to inosinic acid in that it enhances the flavor of foods. Amerine, Pangborn, and Roessler (1965) have reviewed its properties with reference specifically to human nutrition. Studies by Hanson, Brushway, and Lineweaver (1960) and Norton, Tressler, and Forkas (1952) indicate that levels used in human foods are from 0.15% to 1.0%. Several studies have been reported in which MSG was added to the diet of domestic animals. Henson, Bogdonoff, and Thrasher (1962) reported that pigs preferred a pelleted ration containing 10% sucrose plus 0.1% MSG over one containing 10% sucrose only. This study was conducted on pigs two to six weeks of age. Klay (1964) also reported studies using pigs four to eight weeks of age. Pelleted or meal creep rations were fed containing sucrose and MSG in varying concentrations. The author concluded that MSG could be used as a partial substitute for sucrose in a creep ration for swine. Galgan and Russell (1964) reported studies in which MSG was added to rations for lambs. The lambs preferred rations containing MSG over the basal ration; gains also favored rations containing MSG.

Work conducted by Inglett *et al.* (1965) indicates that Miracle Fruit, a berry from the West African plant (*Synsepalum dulcificum*), has taste modifying properties. In humans, when placed in the mouth, substances having a sour taste are caused to have a sweet taste. However, the salty or the bitter taste was not affected. The authors also reported that the berry itself elicited no taste. Henning et al. (1969) and Kurihara et al. (1969), in separate experiments, reported that the sweetness-inducing principle of Miracle Fruit was a glycoprotein. Studies by Bartoshuk et al. (1969) indicated that Miracle Fruit did not alter the magnitude of the taste of citric acid, but rather changed the quality from sour to sweet and sour. The decrement in sour was compared to the decrement in sourness observed when sucrose was mixed with acid.

Forss (1969) has reported studies which indicate that lipids may modify taste sensation. The author cites work by Mackey (1958) in which the taste of caffeine, qüinine, and saccharin was more easily detected in water than in mineral oil by humans. The author further points out that flavor potential is much stronger in an aqueous medium than in an oil medium. Clapperton (1969) reported responses to the addition of 2% linseed oil fatty acids to the ration of sheep. The acids were added by soaking the feed with emulsions while the control ration was soaked in water. This addition increased feed intake by 40%. The author concluded that this addition doubled the amount of energy stored daily by the sheep. It would seem to be of interest to observe taste responses of ruminants to compounds causing a strong rejection in water in the presence of a vegetable oil. Perhaps unpalatable feeds could be utilized through additions of a certain amount or kind of lipid.

A compound known as sinapine has been isolated from crambe meal. This compound is an ester of sinapic acid and has been reported to be at least partly responsible for the unpalatability of crambe meal for ruminants (Nutrition Reviews, 1967). This compound offers interesting possibilities for limiting intake of livestock rations.

Blair and Fitzsimmons (1970) conducted a study with a compound reported to be the most bitter substance known. This compound, "bitrex" (2:6-xylylcarbamoyl methyl ammonium benzoate), was added to the diets of growing swine at levels ranging from 0.5 to 50 ppm. Voluntary feed intake or rate of gain was not depressed by additions of this compound.

Several workers have conducted studies to identify sweetening agents. Stevioside has been reported to be 300 times sweeter than sucrose (Bottle, 1964). This compound is an aglycoside that has been isolated from the leaves of a number of plants. Inglett and May (1968) have reported studies to identify tropical plants with unusual taste properties. The authors reported that a seed of a plant found in West Africa (*Thaumatococcus daniellii*) has a sweet taste and also causes sour materials to taste sweet for an hour after placing it in the mouth. These same authors (Inglett and May, 1969) reported that Serendipity berries from a plant (Dioscoreophyllum cumminsii) found in West Africa have intense sweetening properties. Their studies indicate that the berries are 800 to 1500 times sweeter than sucrose. Although positive identification has not been made, the substance responsible is thought to be a carbohydrate-type substance.

Another substance having potential as a sweetening agent has been synthesized from naringin, a flavonoid of grapefruit responsible for the bitter taste (Krbechek et al., 1968). This substance, known as neohesperidin dihydrochalcone, is 1000 to 1200 times sweeter than sucrose. These authors also reported another synthetic substance, homoneohesperidin dihydrochalcone, which was 900 to 1100 times sweeter than sucrose which was synthesized from the unripe fruit of the Seville orange. Since cattle, deer, and goats have shown preference for sweet substances, further work to observe responses to taste-modifying substances that influence the sweet taste seem justified.

Comparative Aspects of Taste Responses

Comparison of taste responses can be viewed in several different ways. A comparison of animals of varying ages within a species can be made; as well as one of similarly aged animals in different but related species. Comparison of similar compounds and their influence on the taste response within and among species would also seem to be of interest. The findings regarding interspecies comparison of taste responses have been stated quite concisely by Kare (1961), "No pattern, chemical, physical, nutritional, or physiological, can be offered to explain the collective comparative results." Differences due to age of the animal have been reported in several studies. The younger animals, in general, seem to have a higher sensitivity than do the older animals. Experiments conducted by Kare and Ficken (1963) were designed to observe the taste responses of the chicken to varying concentrations of many sodium salts and chloride solutions. The authors reported that no physical or chemical basis for preference or rejection could be determined. Toxicity was considered as a factor influencing preference since the chicks did reject some toxic salts. However, since some salts were lethal, toxicity could not be a consistent variable.

Denton and Sabine (1961) conducted studies to determine if sheep exhibited a selective appetite for sodium when the animals were maintained in a sodium-deficient state. These authors noted that sheep showed a clear preference for sodium bicarbonate over sodium chloride, potassium chloride or water. It was also reported that the sheep consumed only enough to balance that sodium lost. Pfaffmann (1963) also reported that sheep exhibited a preference for sodium salts over potassium chloride, ammonium chloride or calcium chloride when the animals were sodium deprived. However, Bott, Denton, and Weller (1965) reported that, when sheep were maintained on diets having 100 mEquiv/day of sodium and free access to water, no interest was shown for solutions of sodium chloride, sodium bicarbonate, potassium chloride, calcium chloride or magnesium chloride. Concentration or method of presentation of the solutions was not specified. Mitchell and Bell (1969) reported that breeds of sheep differ in their incidence of erythrocyte and hemoglobin types. In this context, the possibility that high potassium individuals and low potassium individuals might have different susceptibilities to salt deficit or salt excess seemed feasible and important. These authors noted that the low potassium sheep showed preference for sodium bicarbonate at approximately one-half the concentration that was employed before the high potassium sheep elicited preference. Even greater differences were observed for sodium chloride preferences. This investigation brings to light a factor that may tend to explain some of the differences observed within as well as among species and would seem to warrant further investigation.

In studying rabbits, Beidler (1963) reported a hypothesized difference in taste response between potassium chloride, potassium benzoate, and sodium chloride based on the relative number of anionic-cationic groups present at the taste bud membrane. The author indicated that this relationship between membrane anion and cation tends to explain the difference in taste responses within a species as well as among species.

Solms (1969) conducted experiments to determine the taste properties of amino acids, peptides, and proteins for humans. The amino acids elicited responses characterized as no taste, sweet, bitter and sulfurous. Peptides were most frequently classified as bitter tasting, while proteins often cause taste responses that are astringent in nature.

Studies reported by Bernard and Kare (1961) were conducted to observe electrophysiological recordings and behavioral responses of calves. Varying concentrations of acids, sugars, and salts were studied. The authors stated that no precise relationship between neural response and preference behavior was found. Subsequent studies by Bernard (1964) were conducted to investigate differences in electrophysiological response when stimulii were applied to anterior and posterior receptive fields of the gustatory nerves. Several sugars, acids, and salts were utilized. The author reported differences in response when the stimulus was applied to one or the other of the receptive fields. Bell and Kitchell (1966) employed goats, sheep, and calves to measure electrophysiological responses to two sugars as well as compounds representing the other taste categories. Sodium chloride elicited an electrical response at the lowest concentration in all three species, while the sweet substances were intermediate in their ability to elicit an electrophysiological response.

Workers at this station have reported several studies in which comparisons of similar chemical solutions have been made within species as well as among species. Goatcher and Church (1967) conducted studies in which taste responses of sheep to several sugars, acids, and sodium salts were observed. Subsequently, Goatcher and Church (1970 c, d) reported studies in which comparisons of sheep, pygmy goats, normal goats, and cattle were made using sucrose, sodium chloride, acetic acid, and quinine hydrochloride. Crawford and Church (1971) conducted experiments to compare the responses of sheep and deer to varying concentrations of several sugars, sodium salts, acids, and two different forms of quinine. The most recent study completed is that of Rice (1972). The author compared the responses of deer to several organic acids.

Influence of Sex on Taste Response

Several authors have reported differences in response due to the sex of the experimental subject. Due to the differences in response among varying age groups (Goatcher and Church, 1970e), comparisons of variation due to sex must be made at a similar age. In studies conducted with human subjects, Glanville, Kaplan, and Fisher (1964) observed sex differences in taste response. Wade and Zucker (1969) also observed response differences in the rat. In studies conducted with ruminant species, Crawford and Church (1971) reported that buck and doe deer responded differently to quinine sulfate, acetic acid, and sodium acetate. Rice (1972) conducted experiment with black-tailed deer, and found that bucks exhibited significantly different responses than does to extracts of bitterbrush, malic and succinic acid solutions, and an ethanol extract of douglas fir.

Although only a relatively few authors have conducted studies designed to observe differences due to sex, the differences noted seem to justify further studies to elucidate these responses and apply this knowledge in practical situations.

Influence of Trace Minerals on Taste Response

Henkin, Graziadei, and Bradley (1969) have discussed the role of metals in the taste response of humans. These authors report that taste acuity is decreased if the thiol level is high or if the copper or zinc level is low. The mechanism of action of thiols in decreasing taste acuity is not known. The role of the metal ions in the taste response has been hypothesized,

> Mechanisms controlling the preneural or initial events are assumed to regulate the flux of sapid substances (tastants) across the taste bud membrane by changes in the conformation of an hypothesized protein (gatekeeper protein) that lines the holes of the taste bud pore membrane. This control is partly exerted by an equilibrium between thiols and metal ions. Shifting this equilibrium alters the conformation of the gatekeeper protein causing it to open or close, thereby altering taste acuity by altering tastant flux.

Earlier studies with rats and humans conducted by Henkin and Bradley (1969) indicated that copper or zinc supplementation could overcome thiol-induced reduced taste acuity (hypogeusia). In a subsequent study with humans, disease-induced hypogeusia was returned to normal through oral administration of nickel. As in the previous study, administration of zinc also returned taste acuity to normal (Henkin and Bradley, 1970). The authors also noted that taste acuity returned to the pre-treatment state following the withdrawal of metal therapy.

Several studies have been reported on the effects of trace mineral additions on the palatability of rations for ruminants. Voelker et al. (1969) conducted experiments to determine the effects of zinc supplementation.to lactating dairy cows on feed intake and milk production. Feed intake was not significantly influenced by the addition of zinc oxide to the rations. Steers were also fed rations containing supplemental zinc; no significant influences on consumption or feed efficiency were observed. O'Dell et al. (1970) indicated that, when nickel was added to a corn-soybean meal ration of male dairy calves, there was a definite reduction in palatability. Differences in influence were noted for the carbonate or chloride salt. The chloride salt had a much greater influence on palatability. Varela, Escriva, and Boza (1970) reported studies in which molybdenum was added to a barley and wheat straw diet for wether lambs. Molybdenum in the form of sodium molybdate was added at levels ranging from 2.27 to 10.27 ppm. Increasing molybdenum content of the diet significantly increased its acceptability. The authors also stated that a highly significant correlation existed between the amount of food ingested and ppm of molybdenum in the diet.

From the limited amount of information available, it seems apparent that trace minerals may well play a significant role in the taste response and as such may have a direct influence on the amount of a feedstuff or fluid an animal will consume. Further studies to describe the taste responses of ruminants to the metal ions seems to be warranted.

SECTION I

Experimental Procedure

The animals used in these experiments were 12 mature castrated male African pygmy goats (*Capra nana hircus*). Age of the animals was approximately two years; initial weight averaged 21.2 kg. The animals were individually penned and fed a completely pelleted ration consisting of 85% alfalfa hay, 10% barley, and 5% molasses. The ration was fed *ad libitum* and all animals were allowed free access to a trace-mineralized salt mixture.

Goatcher and Church (1970a) have presented a schematic relationship between taste thresholds and taste responses. This scheme was employed in the present study. The parameters determined for the pygmy goats are presented in figure 1.

Four methods of observing taste responses were studied. A 0.63% sodium chloride (NaCl) solution was used to determine taste response. In each of the methods studied, a single bucket contained sufficient fluid to allow the animal to consume all liquid desired from that container. Stainless steel containers were used, each having a four liter capacity. For all methods, the amount of test solution consumed was expressed as the percent of total fluid consumed from both containers for the test period. Twelve animals were subjected to

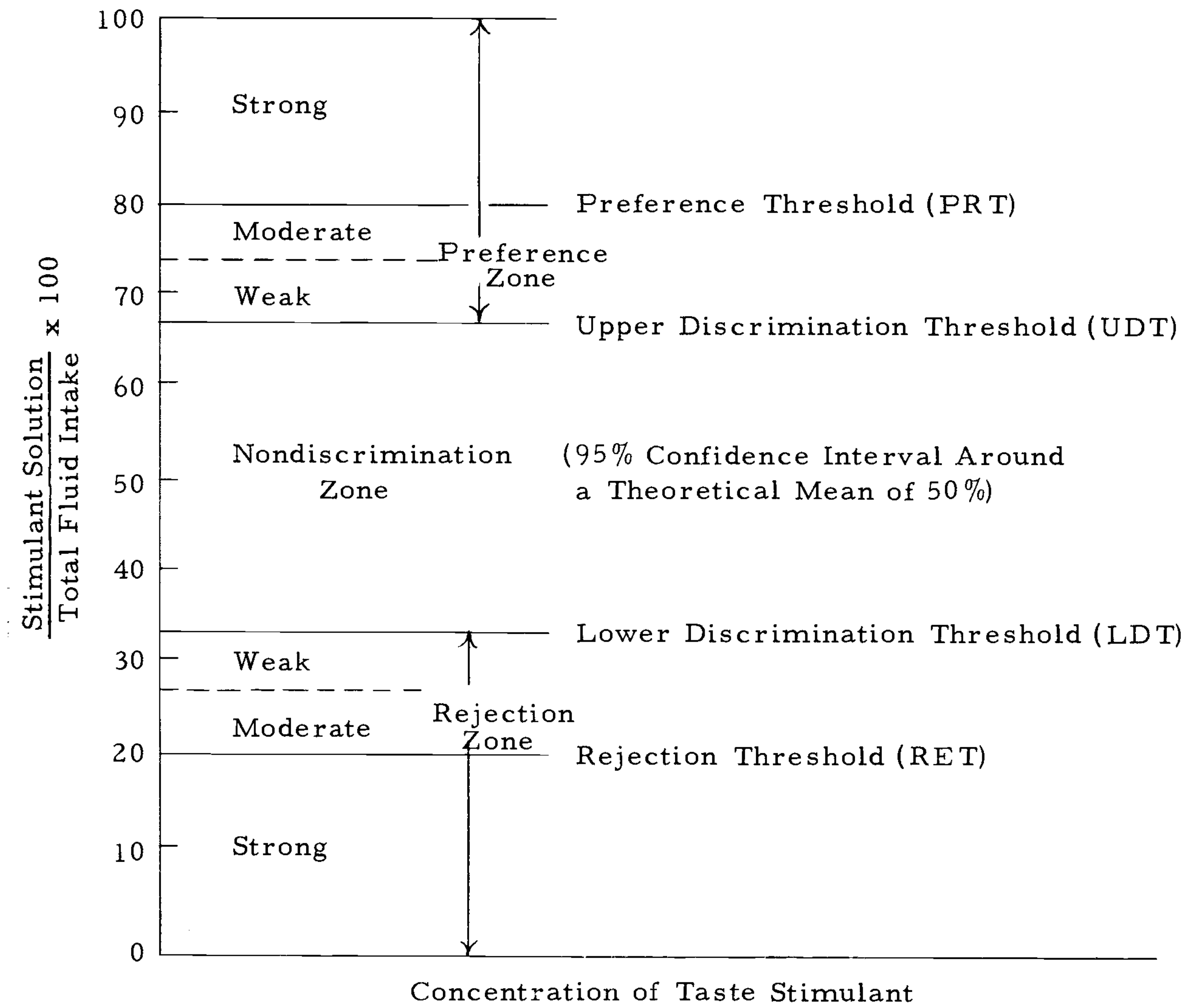


Figure 1. A schematic diagram of the relationships between pygmy goat taste thresholds and behavioral responses to taste stimulants.

each of four methods over four test periods. A given taste response represents the average of three animals.

The first method was designated two-choice, free choice (2CFC). This method has been described in detail previously by Goatcher and Church (1970a). Briefly, it consisted of a two-choice preference test for 48 hr. Buckets were refilled and positions were reversed after 24 hr.. One bucket contained tap water; the other contained tap water plus the test chemical. The second method has been designated two-choice, limited access (2CLA). This procedure was similar to the single stimulus method described by Aldinger (1968) for swine in which a 24 hr. period was divided into increments. In the present study testing was initiated one hour after feeding. The animals were allowed one hour to show a taste response. This period was followed by one of 2 hr. in which both fluid containers were removed from the pen. The succeeding period was one in which tap water only was available; this period was of 6 hr. duration. Finally all liquid was removed for a period of 15 hr.. Taste response was measured during the 1 hr. test period only. The third procedure studied was designated one-choice, free choice (1CFC). Each animal was given a test solution for a 24 hr. period. This was followed by a period of 24 hr. in which tap water was the only choice. The sequence was repeated twice. The fourth procedure has been designated the one-choice, limited access method (1CLA). The time sequence utilized was the same as that described previously for the 2CLA method. However, only one choice was offered to each animal. The sequence was repeated twice: that is, on day one, water only was the choice; on day two, test solution only; day three, water only; and day four, test solution only. Table 1 presents the time schedule used for the limited access studies.

Table 1. Time schedule used for limited access methods of studying the taste responses of pygmy goats to a 0.63% salt solution.

Time	Activity
7:30 a.m.	All animals fed
8:30 a.m.	Begin test period
9:30 a.m.	End test period; begin rest period
11:30 a.m.	End rest period; begin water-only period
5:30 p.m.	End water-only period; begin fluid deprivation period
8:30 a.m.	End fluid deprivation period; begin test period

Results and Discussion

Four methods of preference testing were studied using 12 castrated male pygmy goats in a latin square change-over with carry-over effects design (Patterson and Lucas, 1962). These authors describe this design as one "...in which each experimental unit receives a cyclical sequence of several treatments in successive periods..." The design was selected because it provides a comparison with high precision since the difference between experimental units is eliminated from experimental error. Previous work by Goatcher and Church (1970c) indicated that pygmy goats preferred a 0.63% NaCl solution to plain tap water. Of the substances studied by these authors, salt elicited the highest mean response. For these reasons this concentration was selected as the test chemical for studying the various preference determination methods.

Table 2 presents the analysis of variance for the methods studied. No significant differences ($P > .05$) existed among methods studied. Factors other than those controlled in the experiment accounted for the majority of the differences observed. Bell and Williams (1959) state that taste response is almost entirely under genetical control. Their observation was based on studies with monozygotic twin calves. Other factors influencing taste responses of domestic animals have been reviewed by Goatcher and Church (1970e). These include nature and temperature of the taste medium, visual and positional cues, age, disease, nutritional deficits, experience, sex, and psychological factors.

Figure 2 presents the mean values for the four methods studied during the testing periods. In the present study the animals did not show preference for the 0.63% NaCl solution that had been previously observed (Goatcher and Church, 1970c). However, in the previous study, the authors concluded that the pygmy goat consistently elicited the most variable taste response of the species studied. Responses

Table 2. Analysis of variance of four methods of studying taste response

Source	df	Mean Squares[a]
Total	47	.
Method	2	71.96
Animal x Method	9	584.84
Period	3	207.17
Period x Method	6	264.88
Unadjusted Direct	3	630.35
Direct x Method	6	240.22
Error	18	634.34

[a]None of the effects significant.

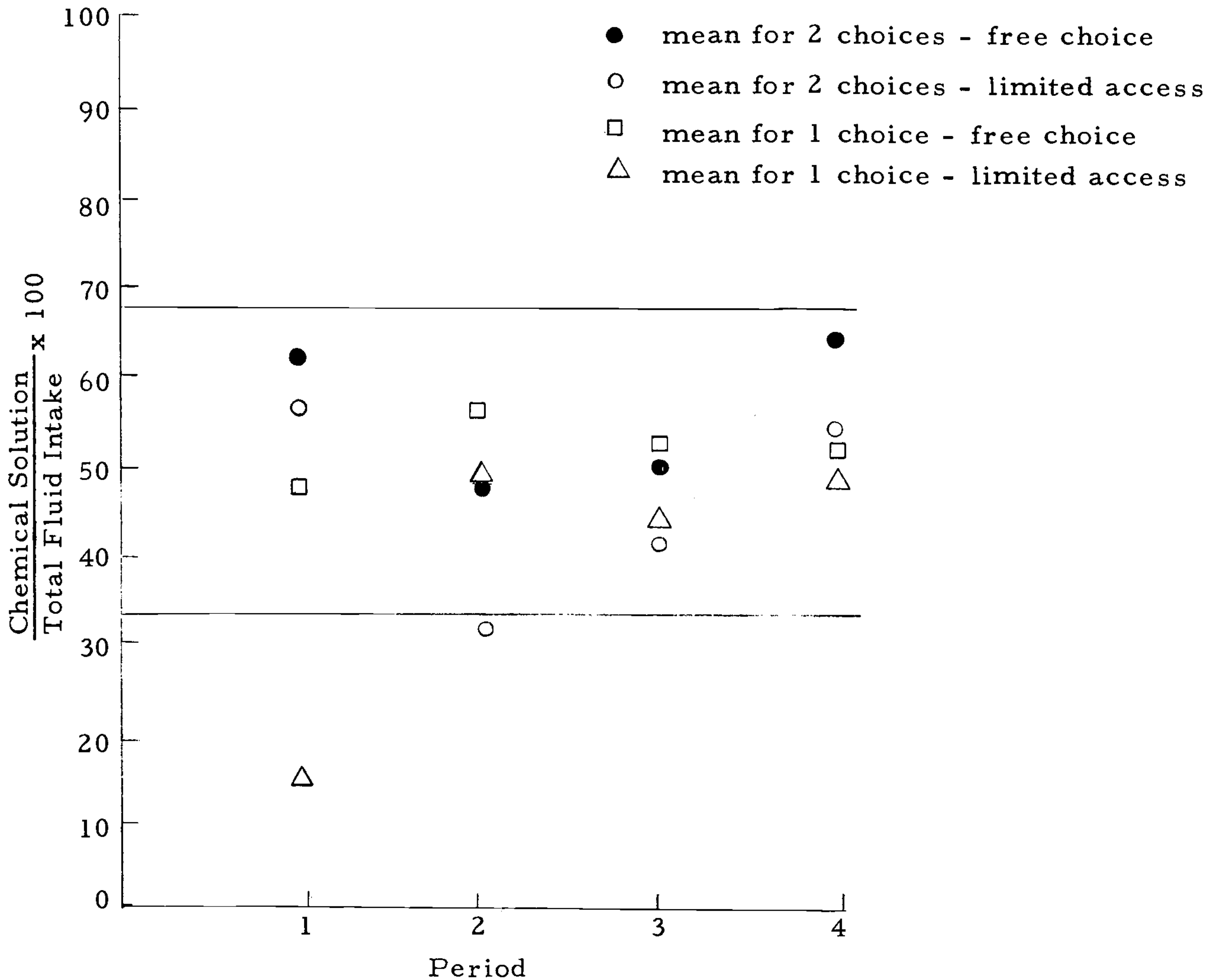


Figure 2. Average taste responses of pygmy goats to four taste response methods during four test periods.

were quite variable in the present study. In period one, the average intake of the salt solution ranged from 15% to 63.5% among the four methods.

Although differences among the methods studied were observed, the magnitude or consistancy was not sufficient to identify a superior method. None of the methods studied was able to effectively reduce individual variation. The method selected for subsequent study was that previously used at this station (2CFC). This method is in accord with the suggestions of Miller and Clifton (1964) for determining relatively palatability. The authors state that when more than two choices are offered, results may be biased estimates. Also, a short time period is desirable when substances are being tested simultaneously because animals tend to be quite uniform in their choices over a period of time. The method employed was essentially the same as that reported by Stubbs and Kare (1958) for cattle; Bell (1959a, b), Bell and Williams (1959), and Bell (1963) for domestic species. Kare, Pond and Campbell (1965) also used a similar method with swine and Goatcher and Church (1970c), sheep, pygmy goats, normal goats and cattle.

It is quite possible that the single stimulus method described by Aldinger (1968) or the modifications described previously might have elicited a more uniform response if variations in time intervals more suitable to the pygmy goat had been attempted. However, the initial results did not seem to justify the additional time for such investigations.

SECTION II

Experimental Procedure

The animals used in the second phase of this study were 12 mature castrated male African pygmy goats. These animals had been used in the previous studies. The animals were individually penned and fed a completely pelleted ration composed of 85% alfalfa hay, 10% barley, and 5% molasses. The ration was fed *ad libitum* and all animals were allowed free access to a trace-mineralized salt mixture. The method of measuring taste response was that designated 2CFC in the previous section. This method had been used previously at this station and described in detail by Goatcher and Church (1970a). Units of six animals each were given increasing concentrations of the test solutions. The taste response represents the average of six individuals over a two day period.

A highly purified form of gymnemic acid (GymA) was diluted in absolute ethyl alcohol at a concentration of 0.5 g GymA/100 ml alcohol. The GymA was added to 30% and 25% sucrose solutions, a 1000 ppm quinine monohydrochloride (QHCl) solution, and a 200 ppm QHCl solution. Taste responses were observed when the taste-modifying substance (GymA) was added to a sweet or bitter solution in opposition to a sweet or bitter solution of an approximately equal concentration containing no taste-modifier.

A highly purified form of inosinic acid (InoA) was diluted in tap water at a concentration of 20 g/100 ml. The InoA was added to a 0.08% sucrose solution and a 6.25 ppm QHCl solution. Taste responses were observed when a sweet or a bitter solution was placed in opposition to a sweet or a bitter solution plus InoA in the two-choice preference technique. Concentration of the two solutions tested at any one time was approximately equal.

A purified grade of monosodium glutamate (MSG) was added directly to 0.08%, 10%, and 30% sucrose solutions and 6.25 ppm and 100 ppm QHCl solutions. The testing procedure was similar to that described for the two previous taste-modifiers. Taste responses were observed when MSG was added to a sweet or bitter solution in opposition to a sweet or bitter solution of an approximately equal concentration containing no taste-modifier.

Results and Discussion

Twelve pygmy goats that had been used in the previous study were utilized to determine taste responses when taste modifying substances were added to sweet and bitter solutions. The first taste-modifier studied was GymA. Warren and Pfaffmann (1959) indicate that this substance was reported as a taste-modifier in 1847. It is derived from the leaves of the tropical plant *Gymnema sylvestre*, and, when chewed by humans, temporarily depresses the sensitivity to sweet and bitter substances.

GymA is quite insoluble in water. However, it is readily soluble in ethanol. This factor necessitated an experiment to determine if the amount of ethanol necessary to dissolve the GymA influenced the taste response. Figure 3 indicates that ethanol in the amount used brings about a non-discriminatory response when compared with plain tap water. Studies by Martin and Pangborn (1970) with human subjects indicate that ethyl alcohol did not significantly influence the taste intensity of quinine or sucrose solutions. Work reported by Goatcher and Church (1970a) indicates that sheep show a nondiscrimination response for concentrations of 10% ethanol when compared with tap water. However, the possibility of an interaction between ethanol and GymA which might influence the taste response cannot be completely eliminated.

The initial phases of the study with GymA were conducted using solutions containing 30% sucrose, which, when presented alone, caused a rejection response. When concentrations of GymA from 0. 05 to 3 ppm were added, reduction in total fluid intake was observed. The level of sucrose was reduced to 25% which resulted in a 28% intake (rejection). Results of the addition of increasing increments of GymA to the sucrose solutions are presented in figure 4. Except for levels of 10 and 50 ppm a definite preference was shown for solutions

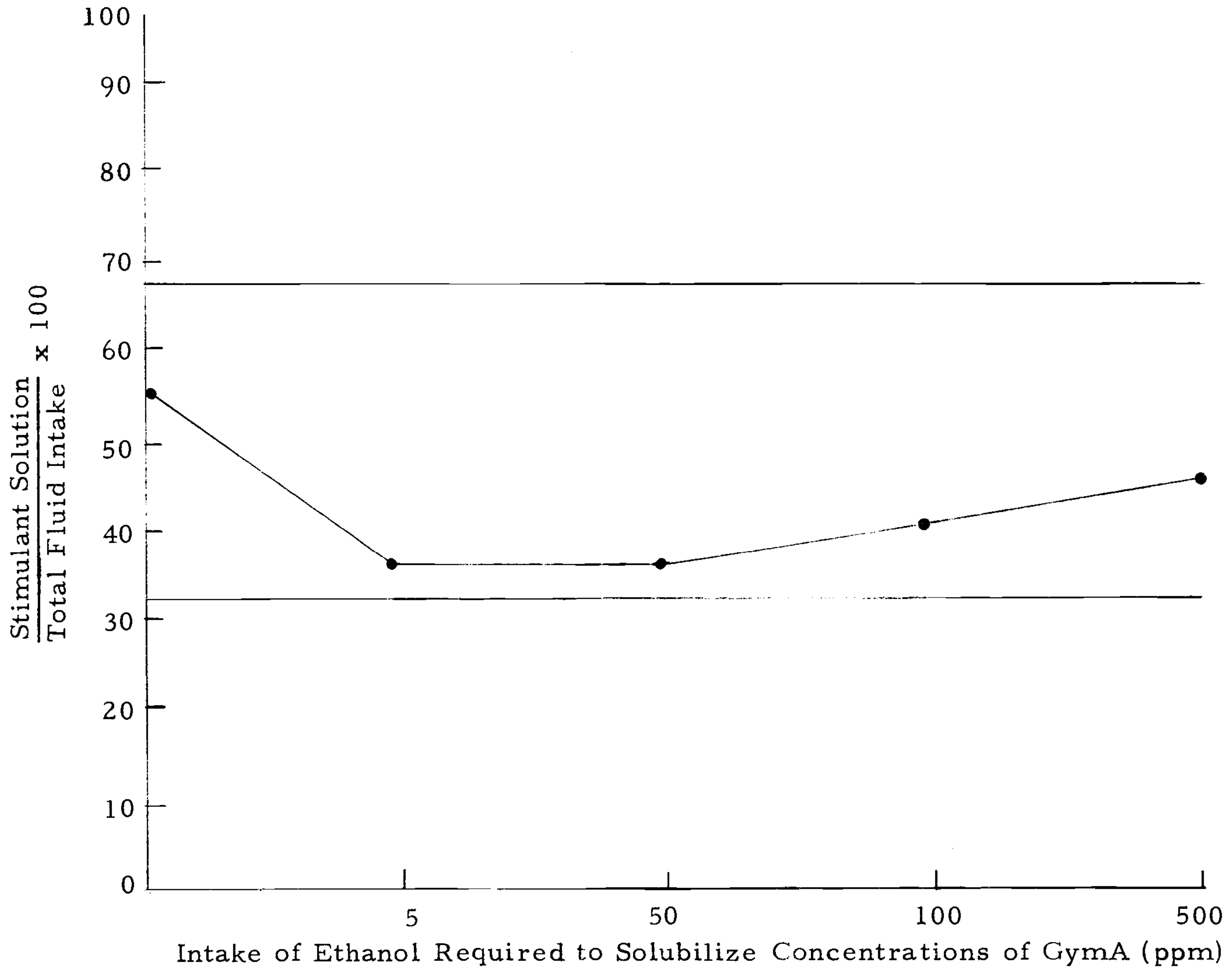


Figure 3. Average taste responses of pygmy goats to absolute ethyl alcohol in amounts used in studying GymA vs. tap water.

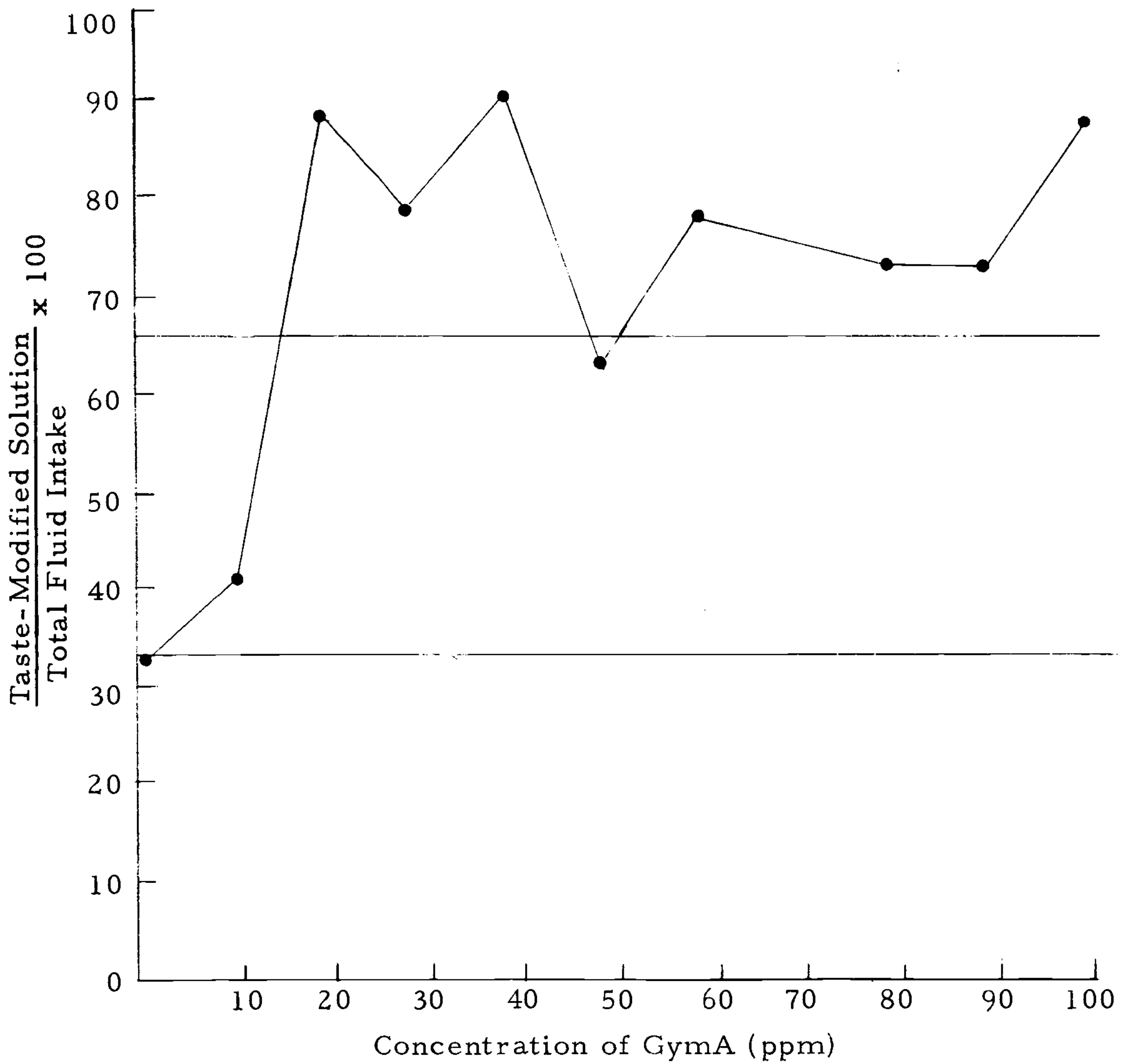


Figure 4. Average taste responses of pygmy goats to 25% sucrose vs. 25% sucrose and increasing increments of GymA.

containing GymA. Levels of 20, 40 and 100 ppm elicited strong preference responses. The data indicate that GymA modifies a sucrose solution through an unknown mechanism altering the taste response from mild rejection to strong preference. If the results on 50 ppm GymA are ignored, levels above 20 ppm GymA do not appear to have an added advantage.

GymA was also added to QHCl solutions. Previous work by Goatcher and Church (1970d) indicated that 800 ppm QHCl approached the rejection threshold for the pygmy goat. An attempt was made to study the influence of GymA added to 1000 ppm solutions. However, responses were not changed by the taste-modifier. The level of QHCl was reduced to 200 ppm; at this level a moderate rejection response was observed. Figure 5 presents the results of this experiment. With the exception of 40 ppm GymA, the taste response was altered from rejection to nondiscrimination. Levels above 10 ppm did not produce any additional effect. It is quite possible that the response to 40 ppm was due to an environmental factor such as change of weather, or a new batch of feed. Many studies at this station indicate that factors such as these may account for some of the aberrant responses observed. These results indicate that GymA also influences the taste response to a bitter solution. Perhaps the mechanism is similar to that of the human in which the bitter taste is depressed.

For both the sweet and bitter solutions, the addition of GymA

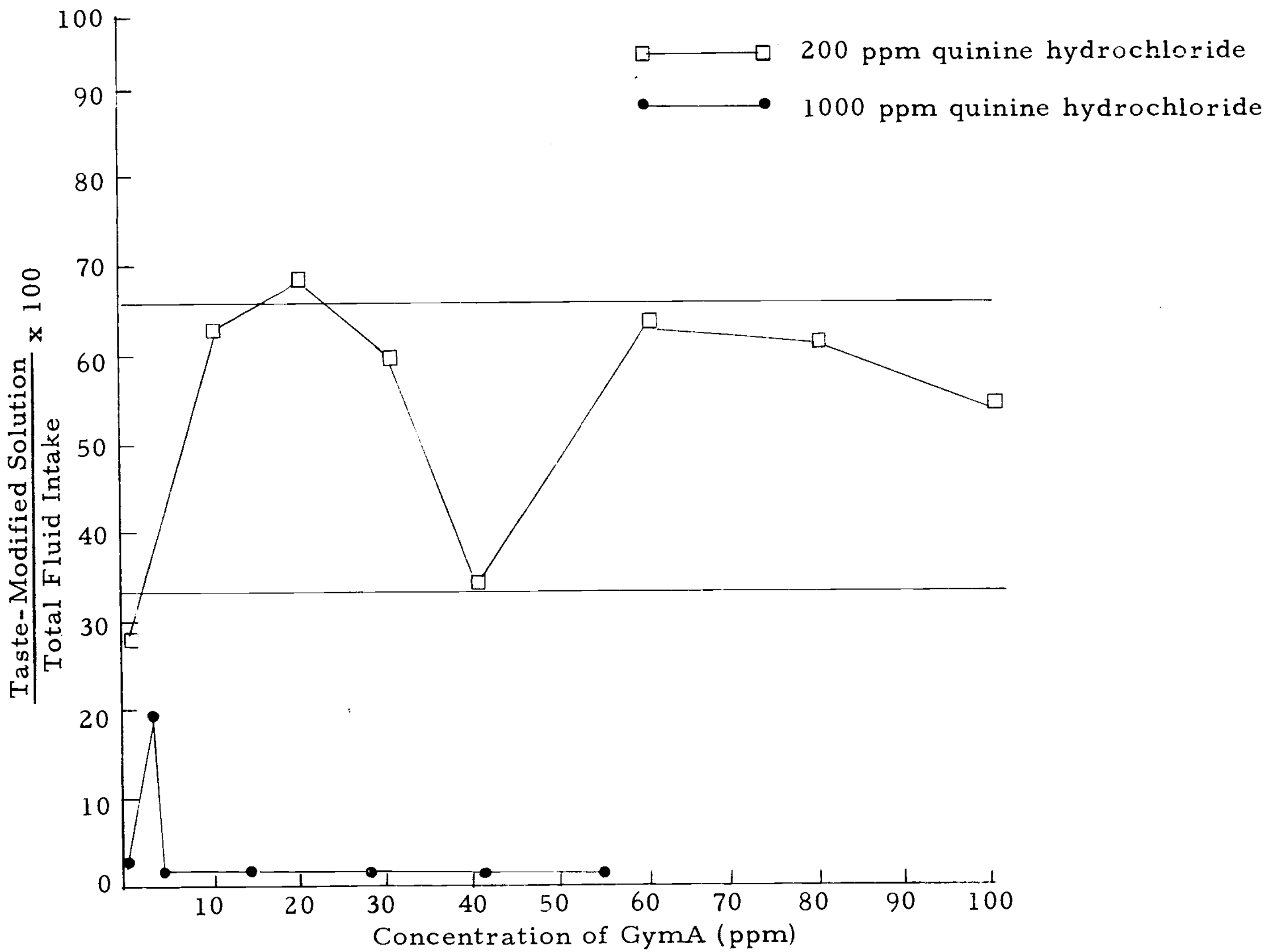


Figure 5. Average taste responses of pygmy goats to solutions containing 200 ppm or 1000 ppm QHCl and increasing increments of GymA.

beyond a certain concentration was without effect on the taste response. This is in agreement with work reported on human subjects by Warren and Pfaffmann (1959). These authors reported that the inhibition by potassium gymnemate is not proportional to its concentration, but levels off at higher concentrations.

The action of InoA is different that that of GymA. Work by Kurtzman and Sjostrom (1964) indicates that InoA acts as a flavor enhancer. These authors also state that InoA does not seem to affect the basic tastes in any consistent manner. On the assumption that this mechanism might also apply to ruminants, concentrations of sucrose and quinine were selected that elicit the nondiscrimination response by pygmy goats. Goatcher and Church (1970c) reported this level to be 0.08% sucrose. Figure 6 presents the results of this experiment. In the present study, as reported in previous work, 0.08% sucrose caused a nondiscrimination response. However, the addition of InoA up to 500 ppm did not alter the response. A limited supply of InoA precluded the use of higher levels of InoA or different concentrations of sucrose.

A concentration of 6.25 ppm QHCl was selected to determine the effects of added InoA. This concentration was found by Goatcher and Church (1970d) to elicit a nondiscrimination response. This was also apparent in the present study (figure 7). The addition of 5 ppm InoA did not alter the taste response. However, a level of 50 ppm

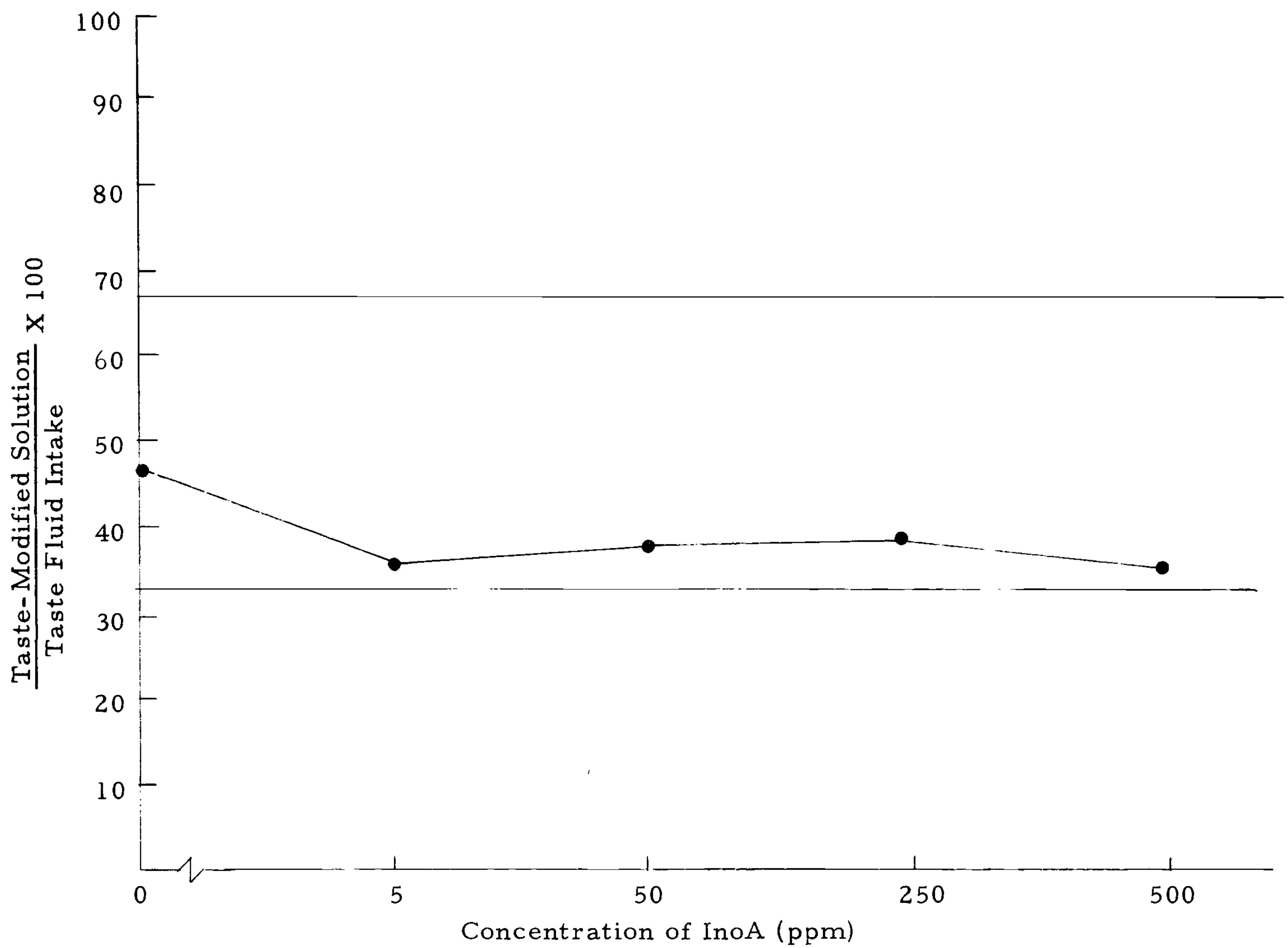


Figure 6. Average taste responses of pygmy goats to 0.08% sucrose vs. 0.08% sucrose and increasing increments of InoA.

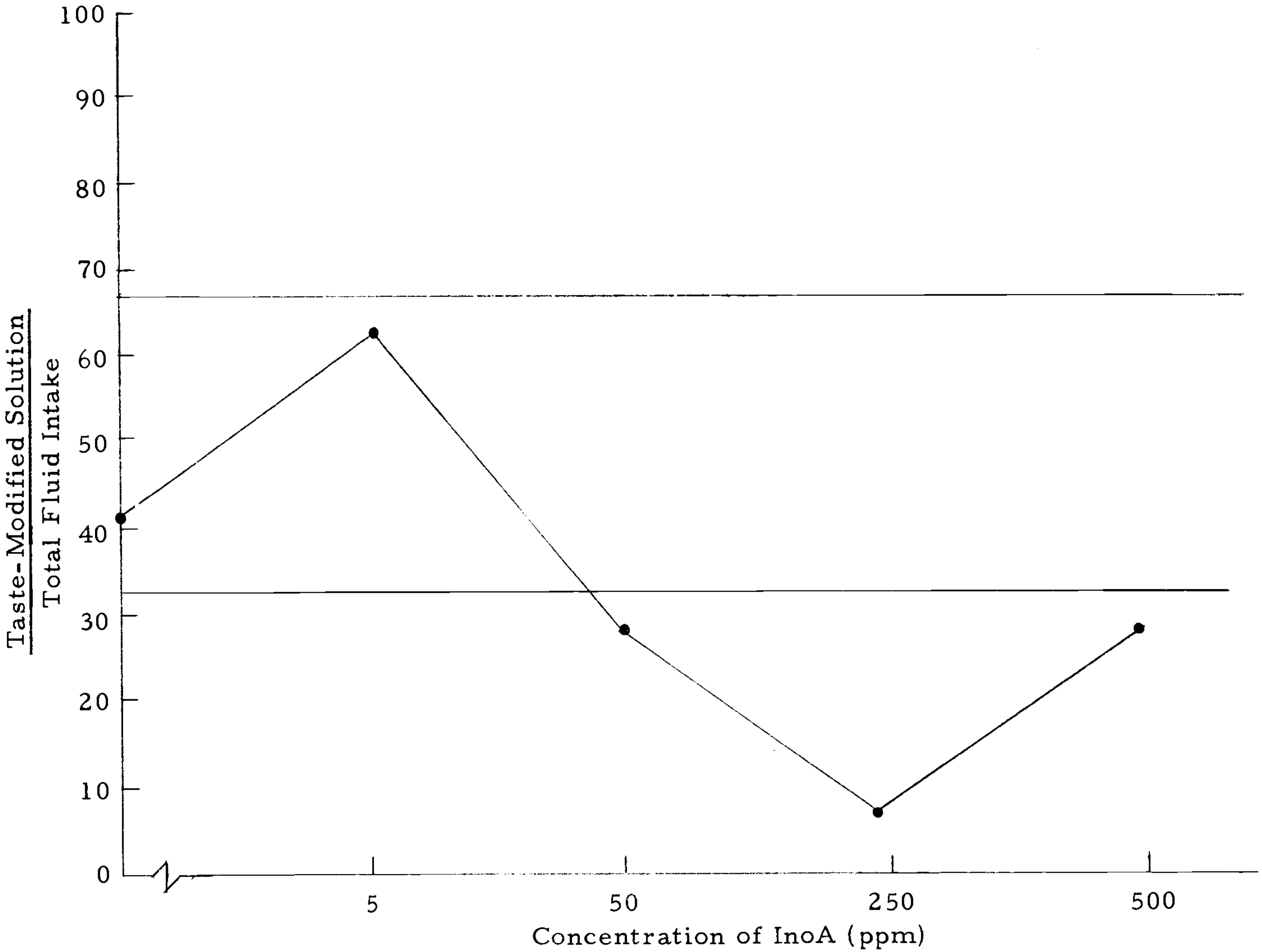


Figure 7. Average taste responses of pygmy goats to 6.25 ppm QHCl vs. 6.25 ppm QHCl and increasing increments of InoA.

caused a mild rejection, while a level of 250 ppm caused a strong rejection. The intake of the 6.25 ppm QHCl solution with 50 ppm InoA was 29.4%, while that of 200 ppm QHCl alone was 27.5%. The data indicate that InoA may enhance the flavor of QHCl.

Similar to InoA, MSG has been utilized for flavor enhancement with humans. Three concentrations of sucrose were used with the pygmy goats. The range was from 0.08% (nondiscrimination) to 10% (preference) to 30% (rejection). The results of the influence of concentrations of 5 to 500 ppm MSG on the response to all concentrations of sucrose are presented in figure 8. As may be noted, only 500 ppm MSG altered the taste response to 0.08%, bringing about a mild rejection. All levels of MSG resulted in change from a preference to a nondiscrimination response when added to a 10% sucrose solution. When 30% sucrose was utilized, except for 250 ppm MSG, the response was altered from rejection to nondiscrimination. Apparently, when MSG is added to sucrose solutions, taste acuity is depressed. Taste responses of preference and rejection were changed to nondiscrimination. While a sucrose solution eliciting a nondiscriminatory response was unchanged. No previous studies have been reported in which MSG was added to pure chemicals in an aqueous media for ruminants. However, Waldern and Van Dyk (1971) reported a study in which MSG was added to a calf starter. The authors reported a transitory increase in feed consumption followed by a period of rejection.

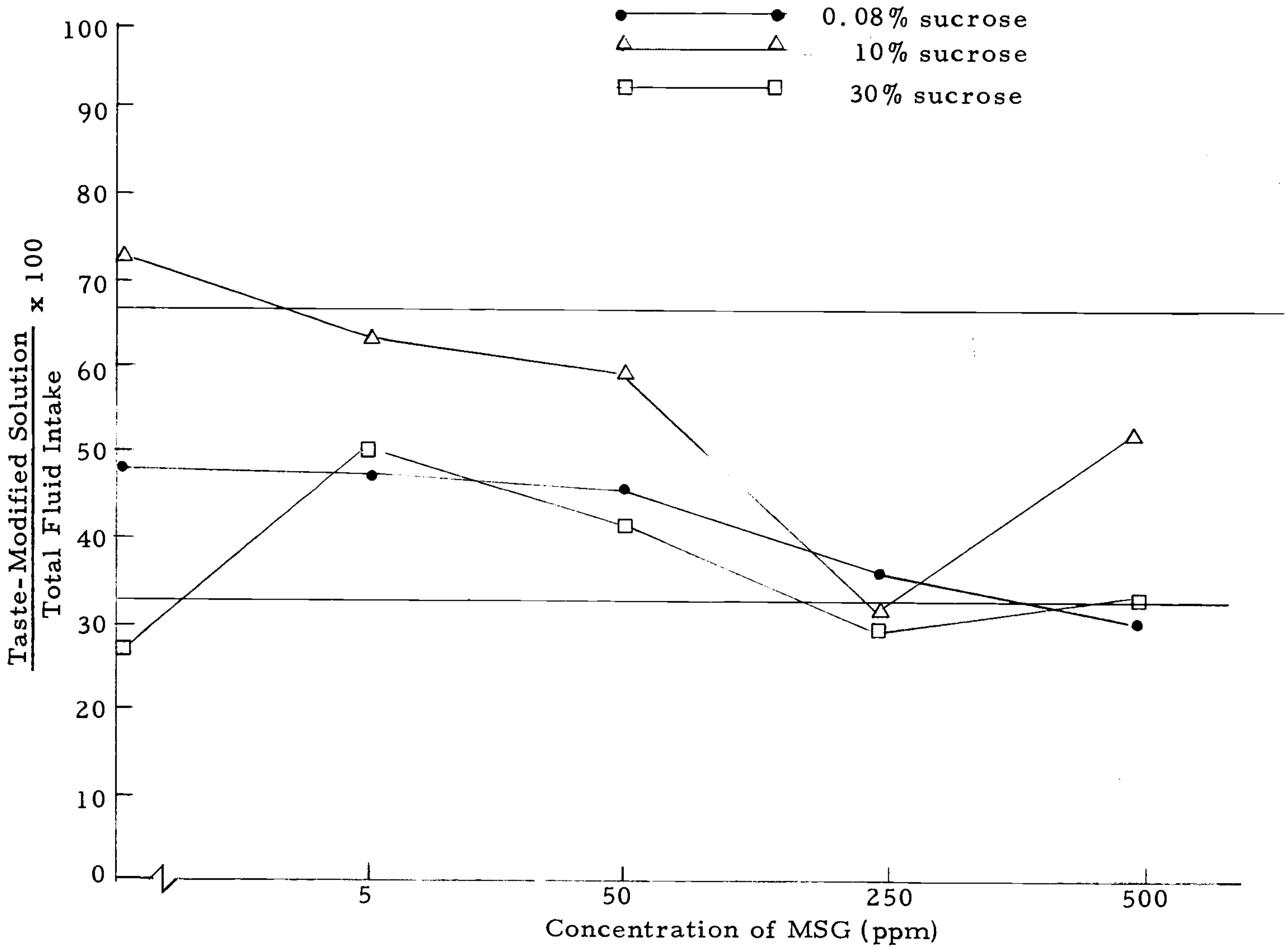


Figure 8. Average taste responses of pygmy goats to solutions containing 0.08%, 10%, or 30% sucrose and increasing increments of MSG.

The effects of MSG on the taste response to bitter solutions was also studied. When MSG was added to a 6.25 ppm (nondiscrimination) QHCl solution the responses were not altered. However, when MSG was added to a 100 ppm (rejection) QHCl solution, the taste response was changed to nondiscrimination (figure 9). These data indicate that the bitter taste was depressed.

Table 3 presents a summary of the effects of the taste-modifiers on the responses of the pygmy goats. The addition of GymA to sweet and bitter solutions eliciting a rejection response caused pygmy goats to show a change in taste response. The response to a sweet solution was one of preference when GymA was added at levels above 10 ppm, except at the 50 ppm level, which caused a nondiscriminatory response. At the highest bitter concentration studied, GymA did not change the taste response from one of strong rejection. At a lesser bitter concentration the taste response was changed from rejection to nondiscrimination at concentrations of GymA ranging from 10 ppm to 100 ppm.

InoA is classified as a substance that enhances flavor in humans (Norton, Tressler, and Forkas, 1952; Kurtzman and Sjostrom, 1964). When added to a sweet solution causing a nondiscriminatory response by the pygmy goats, no change in response was observed at concentrations of InoA ranging from 5 to 500 ppm. However, when InoA was added to a bitter solution eliciting a nondiscriminatory response

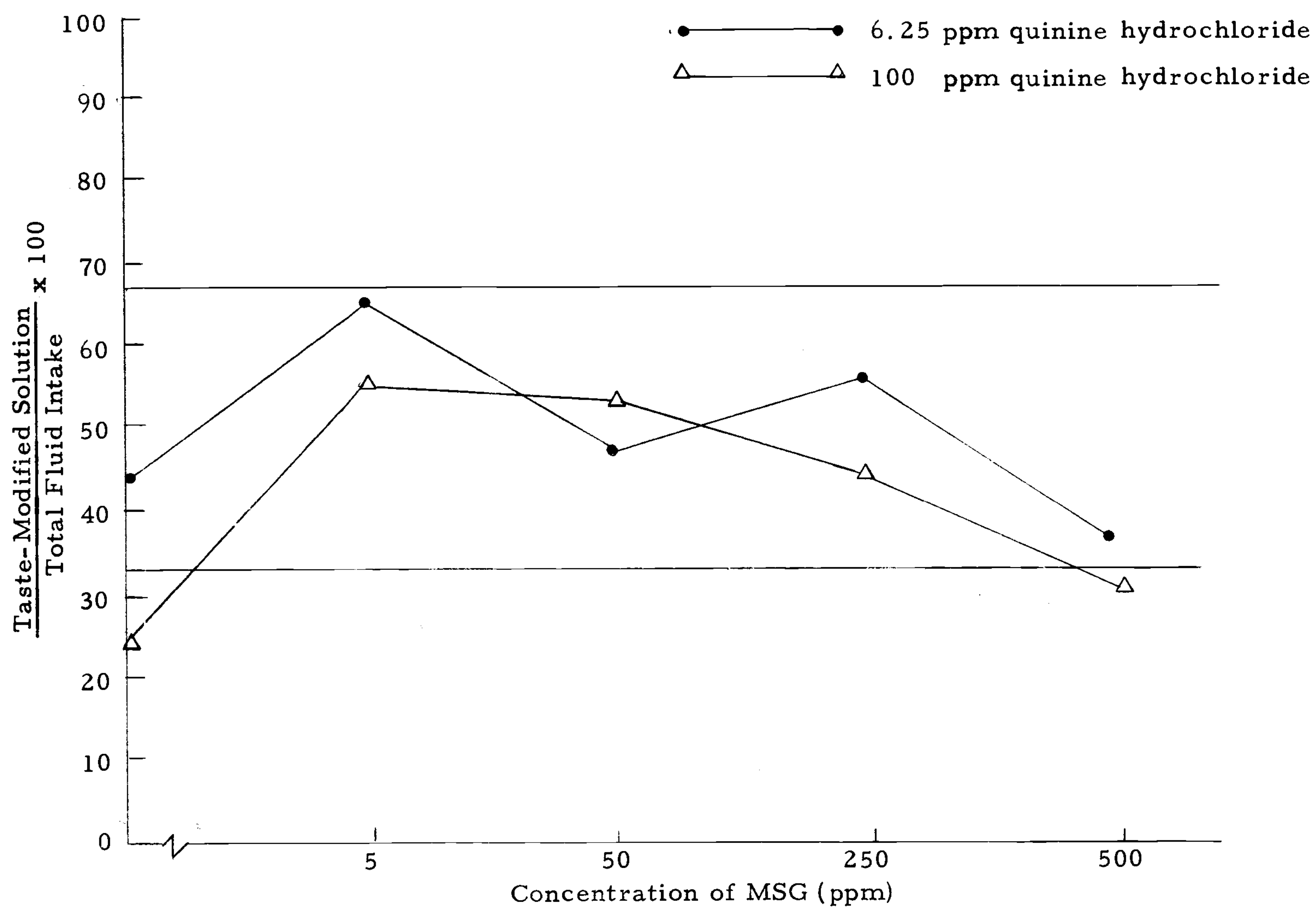


Figure 9. Average taste responses of pygmy goats to solutions containing 6.25 ppm or 100 ppm QHCl and increasing increments of MSG.

levels of 50, 250, and 500 ppm changed the responses of pygmy goats to rejection.

Table 3. Taste sensitivity of pygmy goats for sweet or bitter solutions in the presence of a taste-modifier in relation to pure sweet or bitter solutions.

Solutions	Taste-Modifier		
	GymA	InoA	MSG
	Sensitivity Change[a]		
High Sucrose	reduced	---	reduced
Medium Sucrose	---	---	reduced
Low Sucrose	---	none	none
High Quinine	none	---	---
Medium Quinine	reduced	---	---
Low Quinine	---	enhanced	none

[a]Sensitivity change indicated when average taste response shifted from a given response zone to a different response zone.

MSG is similar in nature to InoA in its action on taste responses of humans (Norton, Tressler, and Forkas, 1952; Kurtzman and Sjostrom, 1964). When MSG was added to a sweet solution causing a preference response by pygmy goats the taste response was changed to nondiscrimination by the lowest level of MSG employed. Addition of MSG to a sweet solution causing a nondiscriminatory response did not alter the response until a concentration of 500 ppm MSG was reached. At that level the response was mild rejection. Addition of

MSG to a sweet solution eliciting a rejection response caused a change in response to nondiscrimination at 5 ppm and a subsequent change back to a rejection response at a level of 250 ppm.

MSG additions did not change the responses of pygmy goats to a bitter solution causing a nondiscriminatory response. However, additions of MSG to a bitter solution causing a rejection response brought about nondiscriminatory responses at the lowest level studied (5 ppm) and only the highest concentration of MSG (500 ppm) caused a return to the rejection response.

SECTION III

Experimental Procedure

Two groups of Holstein calves were utilized in observing taste responses to various salt solutions and trace-mineral solutions. Group 1 consisted of six male calves and six female calves. The average initial weight of the males was 128 kg, while the females averaged 163 kg, following a 100 day test period, the males averaged 191 kg, while the females averaged 220 kg. The calves employed in this study ranged in age from ten weeks to six months.

The animals were individually penned and fed a completely pelleted ration ad libitum; a trace-mineralized salt mixture was also available free-choice. The ration consisted of 85% alfalfa hay, 10% barley, and 5% molasses.

The taste testing procedure was the same as that described previously by Goatcher and Church (1970c) for cattle, except that 10 liter plastic buckets were substituted for plastic-coated galvanized buckets, and the test period was reduced from 10 hr. to 8 hr. Figure 10 presents the parameters of the taste responses determined for the two groups of cattle used in the present study (adapted from Goatcher and Church, 1970a). Units of three animals of each sex were offered increasing concentrations of the test solution. Taste response represented the average of three animals over two 8 hr. test periods.

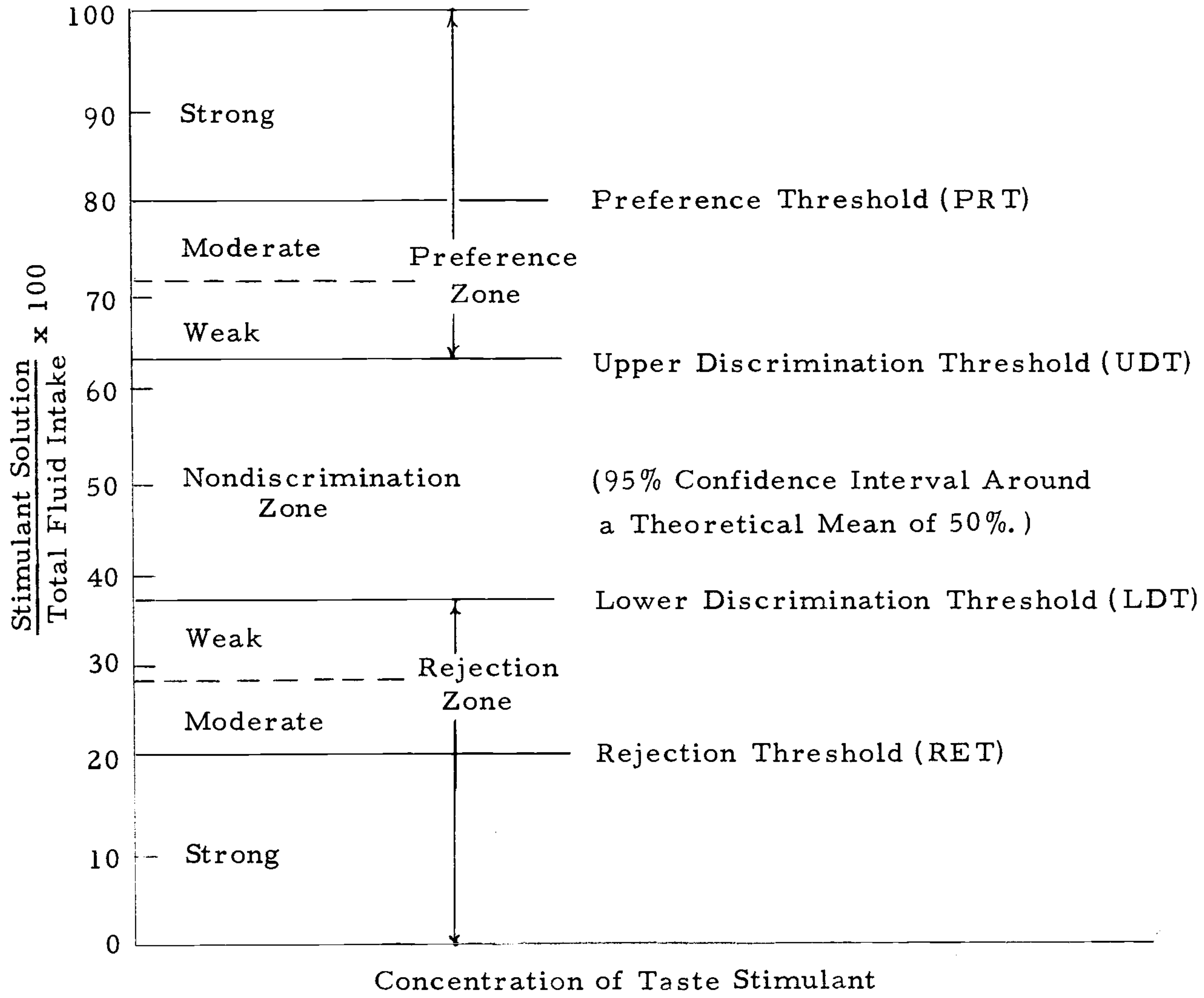


Figure 10. A schematic diagram of the relationships between cattle taste thresholds and behavioral responses to taste stimulants.

Salts used to observe taste response were technical grade, except in a few cases where reagent grade was used.

Group 2 was comprised of different male and female Holstein calves. The average initial weight of the males was 108 kg; the females weighed 113 kg; following a 59 day test period the average final weight of the males was 167 kg while the females weighed 156 kg. The calves used in the study ranged in age from four to seven months. Rations, facilities, and response-group sizes were similar to Group 1. The preference determination procedure was similar, except that salts were presented in opposition to each other, rather than separately in opposition to tap water. Salts were technical grade. The trace-mineral salts used were all reagent grade.

Results and Discussion

Sodium salts and chloride solutions were tested at concentrations ranging from 0.02% to 1.25%. The data for the taste responses of the male calves to increasing levels of sodium salts are presented in table 4. Of the salts studied, three elicited sensitivity (point at which discrimination first occurred) at 0.02% concentration. They were dibasic sodium phosphate (Na_2HPO_4), sodium bicarbonate ($NaHCO_3$), and sodium sulfate (Na_2SO_4). The sensitivity point described does not constitute the minimum concentration that would elicit a response, but rather the lowest concentration at which a response was observed in the present study. Sodium carbonate (Na_2CO_3) first brought about a discriminatory response at the 0.32% level while monobasic sodium phosphate (NaH_2PO_4) brought about a response at the highest concentration studied (1.25%). The animals apparently did not discriminate NaCl at the concentrations employed as all responses were in the zone of nondiscrimination. In a study reported by Bell and Williams (1959) the mean responses for calves remained in the nondiscrimination zone until a concentration of 1.25% NaCl was attained. Only Na_2CO_3 caused a response crossing the RET. This occurred at concentrations of 0.32% and 1.25%. None of the sodium salts studied caused a response that crossed the PRT. However, the 0.08% and 1.25% concentration of Na_2SO_4 showed a moderate preference response. It is interesting to note that the most marked responses occurred when sodium was in the dibasic form (Na_2CO_3 and Na_2SO_4).

Responses of the female calves to the sodium salt solutions are presented in table 5. $NaHCO_3$ elicited sensitivity at the 0.02% concentration. A concentration of 0.08% caused the female calves to show sensitivity for NaCl, Na_2CO_3, and Na_2HPO_4. The salt requiring the highest concentration (1.25%) before sensitivity was observed was NaH_2PO_4. In male and female calves $NaHCO_3$ caused sensitivity at the 0.02% concentration. A similar trend was apparent in the case of NaH_2PO_4; sensitivity was not shown until a concentration

Table 4. Average taste responses of male calves to ascending concentrations of sodium salt solutions

Item	Taste Response[a]						
	Rejection Zone			Nondiscrimination Zone	Preference		
	RET	Mod.	Weak		Weak	Mod.	PRT
	concentration[b]						
NaCl				0.02			
					0.08		
				0.32			
				1.25			
Na_2CO_3				0.02			
					0.08		
	0.32						
	1.25						
Na_2HPO_4				0.02			
			0.08				
					0.32		
					1.25		
$NaHCO_3$					0.02		
					0.08		
				0.32			
			1.25				
NaH_2PO_4				0.02			
				0.08			
				0.32			
		1.25					
Na_2SO_4				0.02			
				0.08			
				0.32			
				1.25			

[a] $\frac{\text{Chemical solution}}{\text{Total fluid intake}} \times 100.$

[b] g/100 ml.

Table 5. Average taste responses of female calves to ascending concentrations of sodium solutions

Item	Taste Response[a]						
	Rejection Zone			Nondiscrimination Zone	Preference Zone		
	RET	Mod.	Weak		Weak	Mod.	PRT
	concentration[b]						
NaCl				0.02			
				0.08			
				0.32			
				1.25			
Na_2CO_3				0.02			
				0.08			
	0.32						
	1.25						
Na_2HPO_4		0.02					
				0.08			
			0.32				
				1.25			
$NaHCO_3$		0.02					
				0.08			
					0.32		
				1.25			
NaH_2PO_4				0.02			
				0.08			
				0.32			
		1.25					
Na_2SO_4		0.02					
						0.08	
				0.32			
						1.25	

[a] $\frac{\text{Chemical solution}}{\text{Total fluid intake}} \times 100$.

[b] g/100 ml.

of 1.25% was attained for both male and females. The female calves apparently were much more sensitive to NaCl as a weak preference response was observed at a concentration of 0.08% while the male calves showed a nondiscrimination response through all concentrations. In previous work at this station, Goatcher and Church (1970c) reported that heifer calves showed a rejection response for NaCl at concentrations above 0.16%. However, in studies reported by Bell and Williams (1959), the mean responses for calves remained in the nondiscrimination zone until a concentration of 1.25% was reached.

Similar to the male calves, only 0.32% and 1.25% Na_2CO_3 caused a response by the females that crossed the RET. Also, sodium in the dibasic form elicited the strongest response (Na_2CO_3 at concentrations of 0.32% and 1.25%) in the females.

In a study reported by Goatcher (1970) using female calves, acceptance and rejection thresholds were similar for sodium chloride and sodium acetate, while sodium propionate and sodium butyrate had lower thresholds. The author suggested that the difference may have been due to smell. However, differences in sensitivity among sodium salts in the present study does not appear to be related to smell.

As mentioned previously, sex has been reported to have an influence on the taste response. Table 6 indicates those salts and concentrations at which a difference in taste response was observed between the male and female calves.

Table 6. Sodium salts and concentrations at which mean taste responses of male and female calves differed.

Item	Concentration[a] 0.02 M	0.02 F	0.08 M	0.08 F	0.32 M	0.32 F	1.25 M	1.25 F
	Percent Intake[b]							
NaCl	--[c]	--	43.1	68.4	--	--	--	--
Na_2CO_3	--	--	56.9	64.3	--	--	--	--
Na_2HPO_4	28.8	56.9	39.1	32.4	36.1	71.1	50.6	67.1
$NaHCO_3$	23.4	70.0	49.5	71.2	71.1	51.5	58.9	35.1
NaH_2PO_4	--	--	--	--	--	--	--	--
Na_2SO_4	28.1	42.8	76.2	46.0	--	--	75.4	46.1

[a] g/100 ml.

[b] $\frac{\text{Chemical Solution}}{\text{Total fluid intake}} \times 100.$

[c] Response of both sexes in same taste response zone.

No consistent differences in taste response were observed between the male and female calves. Female calves showed a weak preference for 0.08% NaCl while the males showed nondiscrimination. The female calves also showed a weak preference for 0.08% Na_2CO_3 while the males showed a nondiscriminatory response. At the lowest concentration (0.02%) of Na_2HPO_4 tested the male calves showed a weak rejection response while the female did not discriminate this level from tap water. At the next higher concentration, 0.08%, the males changed to a nondiscriminatory response while the females changed to one of rejection. At a concentration of

0.32%, the female calves showed a weak preference while males showed a weak rejection . At the highest concentration employed in this study (1.25%), the females showed a weak preference while the males showed a nondiscrimination. The $NaHCO_3$ also elicited several responses that were very diverse. At the 0.02% concentration, the males showed a moderate rejection while the females showed a weak preference. At the 0.08% level, males showed a nondiscrimination while the females continued to show a weak preference. When higher concentrations were studied, the responses of the females went from nondiscrimination to weak rejection while the males went from weak preference to nondiscrimination. Studies reported by Bell (1959b) indicate that goats showed a marked preference for a 1% $NaHCO_3$ solution, while species differences in taste responses have been reported by Goatcher and Church (1970c). The responses to NaH_2PO_4 for both sexes remained in the same taste response zone for all concentrations studied. At the 0.02% concentration of Na_2SO_4 the male calves showed a moderate rejection. The females showed a nondiscrimination response. When the concentration was increased to 0.08%, the females continued to show a nondiscrimination response, however, the males showed a moderate preference. At the highest concentration, 1.25%, the males and females showed responses similar to those observed at the 0.08% concentration.

The data indicate that generalizations on the taste responses of cattle are very difficult. Marked differences exist between the responses of the male and the female to sodium salt solutions. In work with deer, Rice (1972) observed similar trends with plant extracts. The author reported that, when five extracts were studied, females showed a greater sensitivity two times; the same sensitivity twice; the less sensitivity once when compared to males. In the present study, females showed more sensitivity two times, less sensitivity two times, and sensitivity equal to the males two times. Direction of response also varied between the males and the females; a concentration of 0.02% $NaHCO_3$ elicited a weak preference in the females while the male calves showed a moderate rejection.

The chloride solutions were tested at the same concentrations as the sodium salts. Six solutions were employed in the study. Table 7 presents the data on taste responses of male calves. The males showed sensitivity to potassium chloride (KCl), ammonium chloride (NH_4Cl), and calcium chloride ($CaCl_2$) at the 0.02% level. Sensitivity to manganese chloride ($MnCl_2$) was exhibited at the 0.32% concentration while magnesium chloride ($MgCl_2$) responses were not apparent until a concentration of 1.25% had been attained. The majority of the responses, in which a distinction was apparent between the salt and tap water, were rejection in nature. Four salts caused responses that crossed the RET. NH_4Cl caused such a response at the lowest concentration (0.32%), while the other salts--KCl, $MnCl_2$, and

Table 7. Average taste responses of male calves to ascending concentrations of chloride solutions.

Item	Taste Response[a]						
	Rejection Zone			Nondiscrimination Zone	Preference Zone		
	RET	Mod.	Weak		Weak	Mod.	PRT
	concentration[b]						
NaCl				0.02			
				0.08			
				0.32			
				1.25			
KCl		0.02					
				0.08			
				0.32			
	1.25						
NH_4Cl					0.02		
				0.08			
	0.32						
		1.25					
$MnCl_2$				0.02			
				0.08			
			0.32				
	1.25						
$MgCl_2$				0.02			
				0.08			
				0.32			
	1.25						
$CaCl_2$		0.02					
			0.08				
		0.32					
		1.25					

[a] $\frac{\text{Chemical solution}}{\text{Total fluid intake}} \times 100.$

[b] g/100 ml.

$MgCl_2$--did not cause a strong rejection until the 1.25% concentration was reached. It is quite possible that such a response would have been detected at a concentration more closely approximating 0.32%, however, the purpose of this study was not to establish minimum sensitivity concentrations, but rather to observe taste responses not reported previously. While NH_4Cl caused a strong rejection at the lowest concentration, it was the only chloride salt studied for which a preference response was elicited. A weak preference was shown at the 0.02% concentration.

The responses of the female calves to the chloride solutions are presented in table 8. Sensitivity to $CaCl_2$ was shown at the 0.02% concentration. This was followed by sensitivity to NaCl at 0.08%. NH_4Cl and $MnCl_2$ caused a sensitivity at the 0.32% concentration. While no distinction from tap water was elicited for KCl or $MgCl_2$ until the 1.25% concentration was attained. Two solutions caused responses that crossed the RET. These were NH_4Cl and $CaCl_2$, both at a concentration of 0.32%. Two solutions also caused a weak preference response. NaCl was preferred at the 0.08% concentration; $MnCl_2$ was preferred at the 0.32% concentration.

The females differed markedly from the males in their taste responses to the chloride solutions. Both sexes showed sensitivity to $CaCl_2$ at the 0.02% concentration. However, where the males showed sensitivity to KCl and NH_4Cl at the 0.02% concentration the

Table 8. Average taste responses of female calves to ascending concentrations of chloride solutions

Item	Taste Response[a]						
	Rejection Zone			Nondiscrimination Zone	Preference Zone		
	RET	Mod.	Weak		Weak	Mod.	PRT
	concentration[b]						
NaCl				0.02			
					0.08		
				0.32			
				1.25			
KCl				0.02			
				0.08			
				0.32			
		1.25					
NH_4Cl				0.02			
				0.08			
	0.32						
		1.25					
$MnCl_2$				0.02			
				0.08			
					0.32		
			1.25				
$MgCl_2$				0.02			
				0.08			
				0.32			
		1.25					
$CaCl_2$		0.02					
				0.08			
	0.32						
			1.25				

[a] $\frac{\text{Chemical solution}}{\text{Total fluid intake}} \times 100.$

[b] g/100 ml.

females showed sensitivity at 1.25% and 0.32% respectively. Both sexes showed sensitivity to $MnCl_2$ and $MgCl_2$ at the same concentration (0.32% and 1.25%, respectively). KCl caused a response that crossed the RET in the males but not in the females. A concentration of 0.32% NH_4Cl caused a strong rejection response (RET) in both sexes. $MnCl_2$ and $MgCl_2$ showed responses crossing the RET in the males at the 1.25% concentration; the females showed a rejection response, but to a lesser degree. The females showed RET responses to 0.32% $CaCl_2$ while the males showed only moderate rejection. Preference responses differed between the males and females. Only the 0.02% concentration of NH_4Cl caused a weak preference response by the males. However, 0.08% NaCl and 0.32% $MnCl_2$ caused weak preference responses by the females.

Differences in taste responses of the male and female calves to the chloride solutions are presented in table 9.

Except for the responses to 0.02% NH_4Cl, the male calves consistently imbibed less of the chloride solutions than the females. This implies a greater sensitivity since the majority of responses were rejection. Examples of these differences are exhibited in the responses to 1.25% $MnCl_2$ and $MgCl_2$. Greater distinction may also be observed in the responses to KCl at the 0.02% concentration. The only exception to this trend observed was in the 0.08% NaCl; the females showed weak preference while the males showed nondiscrimination.

Table 9. Chloride solutions and concentrations at which mean taste responses of male and female calves differed.

Item	Concentration[a]							
	0.02		0.08		0.32		1.25	
	M	F	M	F	M	F	M	F
	Percent Intake[b]							
NaCl	--[c]	--	43.1	68.4	--	--	--	--
KCl	27.6	46.3	--	--	--	--	18.2	21.2
NH_4Cl	67.9	59.4	--	--	--	--	--	--
$MnCl_2$	--	--	--	--	35.5	65.9	3.6	32.4
$MgCl_2$	--	--	--	--	--	--	7.0	25.5
$CaCl_2$	24.3	29.3	35.3	48.0	--	--	22.6	29.6

[a] g/100 ml.

[b] $\frac{\text{Chemical solution}}{\text{Total fluid intake}} \times 100$.

[c] Response of both sexes in the same taste response zone.

Taste responses were also observed when male and female calves were given a choice between NaCl and another sodium salt in a two-choice preference situation. Equal concentrations of both salts were studied over a range of four concentrations. Taste response data are presented in table 10.

When NaCl and $NaHCO_3$ were presented in opposition, responses of males and females were quite similar until a concentration of 1.25% was reached. At that level, males showed a nondiscriminatory response while females showed a response closely approaching PRT for NaCl. When NaCl and Na_2SO_4 were studied, variations in response between males and females were observed at all

Table 10. Average taste responses of male and female calves when given a choice between NaCl and a selected sodium salt in equal concentrations

Item	Concentration[a]							
	0.02		0.08		0.32		1.25	
	M	F	M	F	M	F	M	F
	Percent Intake[b]							
NaCl vs $NaHCO_3$	48.8	53.7	53.6	52.9	74.4	70.8	46.8	79.6
NaCl vs Na_2SO_4	48.3	67.3	46.4	29.9	67.0	86.5	97.0	62.2
NaCl vs Na_2HPO_4	54.2	67.8	70.3	31.5	69.6	42.1	64.9	27.8

[a] g/100 ml.

[b] $\frac{\text{NaCl solution}}{\text{Total fluid intake}} \times 100.$

concentrations. Males showed nondiscrimination responses at concentrations of 0.02% and 0.08%. Females showed a weak preference for NaCl at 0.02% and a weak preference for Na_2SO_4 at 0.08% concentration. At levels of 0.32% and 1.25% the male responses changed from nondiscrimination to weak preference and PRT for NaCl respectively. At those concentrations the responses of the females moved in the opposite direction; the 0.32% response crossed the PRT for NaCl while the 1.25% concentration elicited nondiscrimination. When NaCl was compared with Na_2HPO_4, the male calves showed nondiscrimination at the 0.02% concentration and a weak preference for NaCl at the higher concentrations. Conversely, the females showed a preference for NaCl at the 0.02% concentration, moderate preference for Na_2HPO_4 at 0.08% and nondiscrimination at the 0.32% level. A moderate preference for Na_2HPO_4 was again shown at the 1.25% concentration.

The male calves showed nondiscrimination responses between NaCl and either $NaHCO_3$, Na_2SO_4, or Na_2HPO_4 at the 0.02% concentration. However, the females showed a weak preference for NaCl over either Na_2HPO_4 or $NaHCO_3$ at that concentration. When the concentrations were increased to 0.08%, the males showed a weak preference for NaCl over Na_2HPO_4 and nondiscrimination between the other salts. The females also preferred NaCl over Na_2HPO_4. NaCl was also preferred to Na_2SO_4 while a nondiscrimination response was shown with $NaHCO_3$. At the 0.32% concentration males preferred NaCl throughout. Females showed responses crossing the PRT for NaCl over Na_2SO_4, a weak preference for NaCl over $NaHCO_3$ and indifference for Na_2HPO_4. At the highest concentration studied, 1.25%, males showed a PRT response for NaCl over Na_2SO_4, a weak preference for NaCl over Na_2HPO_4 and indifference to $NaHCO_3$. However, the females showed moderate preference for NaCl over $NaHCO_3$, nondiscrimination for Na_2SO_4 and weak preference for Na_2HPO_4 over NaCl.

In studies reported by Goatcher and Church (1970a), 5% sucrose was preferred over tap water by sheep, however, when 5% sucrose and 5% maltose were offered in opposition a nondiscriminatory response was observed. In the present study the taste responses of male and female calves to three sodium salts were compared when in the presence of tap water or NaCl. The data are presented in table 11.

Table 11. Average taste responses of male and female calves to three sodium salts in the presence of water or NaCl.

Item	Concentration[a]							
	0.02		0.08		0.32		1.25	
	M	F	M	F	M	F	M	F
	Percent Intake							
$NaHCO_3$ vs. H_2O[b]	23.4	70.0	49.5	71.2	71.7	51.5	58.9	35.1
H_2O vs. NaCl[c]	51.2	46.3	46.4	47.1	25.6	29.2	53.2	20.4
Na_2SO_4 vs. H_2O	28.1	42.8	76.2	46.0	53.8	54.6	75.4	46.1
H_2O vs. NaCl	51.7	32.7	53.6	70.1	33.0	13.5	13.5	37.8
Na_2HPO_4 vs. H_2O	28.8	56.9	39.1	32.4	36.1	71.1	50.6	67.1
H_2O vs. NaCl	45.8	32.2	29.7	68.5	30.4	57.9	35.1	72.2

[a] g/100 ml.

[b] $\frac{\text{Selected salt solution}}{\text{Total fluid intake}} \times 100.$

[c] $\frac{\text{Selected Na salt solution}}{\text{Total selected Na salt solution and NaCl intake}} \times 100.$

Comparison of the taste responses reveals that differences for male and female calves are apparent when $NaHCO_3$, Na_2SO_4, and Na_2HPO_4, are offered with water or NaCl in a two-choice situation. However, no trend is apparent. Calves did not show a consistent preference or rejection response for any of the salts studied when the choice was changed from H_2O to NaCl. Sex differences in taste response were quite apparent. In only three cases were the responses of the males and females in the same discrimination zone when the salts were present with NaCl. These were the 0.02%, 0.08% and 0.32% concentrations of $NaHCO_3$ vs. NaCl. All other combinations elicited a difference in response. When salts were in opposition to H_2O, only in two cases were the responses of the males and females, those being the 0.32% Na_2SO_4 and the 1.25% Na_2HPO_4. It is of interest to note that males and females each showed a response crossing the RET. Both were elicted by Na_2SO_4; the females at a concentration of 0.32% and the males at 1.25%.

Taste responses of male and female calves were observed using four "trace mineral" salts. The salts were presented in ascending concentrations ranging from 5 ppm to 60 ppm and offered in opposition to water in a two-choice situation. The results of that experiment are presented in table 12.

Table 12. Average taste responses of male and female calves to various trace mineral solutions

Item	Concentration[a] 5 M	5 F	10 M	10 F	20 M	20 F	40 M	40 F	60 M	60 F
	Percent Intake[b]									
$ZnCl_2$			64.0	89.6	61.6	44.0	52.1	57.5	61.7	38.1
$CoCl_2$			68.0	69.5	29.0	60.6	52.9	26.7	46.4	83.3
MoO_3	53.6	70.5	41.8	29.6						
$CuCl_2$			46.0	50.8	32.5	51.3	22.6	36.2	30.2	16.0

[a] ppm total salt.

[b] $\frac{\text{Chemical solution}}{\text{Total fluid intake}}$ X 100.

The female calves elicited the strongest responses to the trace mineral solutions. Concentration of 10 ppm $ZnCl_2$ caused females to show a response crossing the PRT. Likewise, 60 ppm $CoCl_2$ showed a 83.3% intake above the PRT. The highest concentration, 60 ppm, of $CuCl_2$ caused a response crossing the RET by the females. Males did not exhibit responses of that magnitude; however, a concentration of 40 ppm $CuCl_2$ caused males to show a moderate rejection response (22.6% intake). No easily identifiable trends were elicited by either sex.

In studies reported by Henkin and Bradley (1969) Cu and Zn returned taste acuity to normal in humans and rats after previous alteration by administration of thiol-containing drugs that resulted in decreased sensitivity. Although direct comparison is not warranted, it is interesting to note that the female calves showed the strongest preference response, 89.6% intake, for the 10 ppm $ZnCl_2$ solution and the strongest rejection, 16.0% intake, for the 60 ppm $CuCl_2$ solution. Males showed the strongest rejection response to 40 ppm $CuCl_2$. No marked preference was exhibited by the males for any of the trace mineral solutions offered.

Responses of males and females varied as observed in the previous studies, however, no distinct pattern emerged. Responses in which discrimination was shown were uniformly divided between lower (5, 10 and 20 ppm) and higher (40, 60 ppm) concentrations. However, preference responses occurred more frequently at lower concentrations, and rejection responses were more frequently observed at the higher concentrations.

The study was terminated prematurely due to the death of two of the experimental animals. Necropsy failed to elucidate the cause of death, however, no relationship between death and experimental treatments was established.

LITERATURE CITED

Aldinger, S. M. 1968. Conducting palatability trials in swine. Feedstuffs. 40:18.

________ and M. F. Fitzgerald. 1966. New method of testing palatability of baby pig rations. J. Anim. Sci. 25:887. (Abstr.).

Amerine, M. A., R. M. Pangborn, E. B. Roessler. 1965. Principles of Sensory Evaluation of Food. Academic Press, New York.

Anonymous. 1967. Sweetening agents. Nutr. Rev. 25:93.

Bartoshuk, L. M., G. P. Dateo, D. J. Vandenbelt, R. L. Buttrick and L. Long, Jr. 1969. Effects of Gymnema sylvestre and Synsepalum dulcificum on taste in man. In C. Pfaffmann (Ed.) Olfaction and Taste. III. Rockefeller Univ. Press, New York.

Beidler, L. M. 1963. Dynamics of taste cells. In. Y. Zotterman (Ed.) Olfaction and Taste. I. Pergamon, London.

Bell, F. R. 1959a. The sense of taste in domesticated animals. Vet. Rec. 71:1071.

__________________. 1959b. Preference thresholds for taste discrimination in goats. J. Agr. Sci. 52:125.

__________________. 1963. Alkaline taste in goats assessed by the preference test technique. J. Comp. Physiol. Psychol. 56:174.

________ and R. L. Kitchell. 1966. Taste reception in the goat, sheep and calf. J. Physiol. 183:145.

________ and H. L. Williams. 1959. Threshold value for taste in monozygotic twin calves. Nature. 183:345.

Bernard, R. A. 1964. An electrophysiological study of taste reception in peripheral nerves of the calf. Amer. J. Physiol. 206:827.

________ and M. R. Kare. 1961. Neural and behavioral taste responses in the calf. J. Anim. Sci. 20:965.

Blair, R. and J. Fitzsimmons. 1970. A note on the voluntary feed intake and growth of pigs given diets containing an extremely bitter compound. Anim. Prod. 12:529.

Bott, E., D.A. Denton and S. Weller. 1965. The innate appetite for salt exhibited by Na-deficient sheep. In T. Hayashi (Ed.) Olfaction and Taste. II. Pergamon, London.

Bottle, R.T. 1964. Synthetic sweetening agents. Mnftrng. Chem. 35:60.

Clapperton, J.L. 1969. The effect of adding certain fatty acids on the voluntary food intake of sheep. Proc. Nutr. Soc. 28:57A.

Crawford, J.C. 1970. Taste responses in Columbian black-tailed deer. M.S. Thesis. Oregon State University, Corvallis.

_______ and D.C. Church. 1971. Response of black-tailed deer to various chemical taste stimulii. J. Wildlife Mgmt. 35:210.

Denton, D.A. and J.R. Sabine. 1961. The selective appetite for Na^+ deficient sheep. J. Physiol. 157:97.

Forss, D.A. 1969. Role of lipids in flavors. Agr. Food Chem. 17:681.

Galgan, W.M. and T.S. Russell. 1964. Use of DYNA-FERM and monosodium glutamate in rations for lambs. Res. Prog. Wash. Agr. Exp. Sta. Circ. p. 27. (Nutr. Abstr. and Rev. 1970. No. 1765).

Glanville, E.V., A.R. Kaplan and R. Fisher. 1964. Age, sex, and taste sensitivity. J. Gerontol. 19:474.

Goatcher, W.D. 1969. Taste responses in sheep. M.S. Thesis. Oregon State University, Corvallis.

___________. 1970. A comparison of taste responses in pygmy goats, normal goats, sheep, and cattle. Ph.D. Thesis. Oregon State University, Corvallis.

_______ and D.C. Church. 1967. Taste reactions in sheep. Proc. West. Sec. Amer. Soc. Anim. Sci. 18:315.

Goatcher, W. D. and D. C. Church. 1970a. Taste responses in ruminants. I. Reactions of sheep to sugars, saccharin, ethanol, and salts. J. Anim. Sci. 30:777.

__________. 1970b. Taste responses in ruminants. II. Reactions of sheep to acids, quinine, urea, and sodium hydroxide. J. Anim. Sci. 30:784.

__________. 1970c. Taste responses in ruminants. III. Reactions of pygmy goats, normal goats, sheep and cattle to sucrose and sodium chloride. J. Anim. Sci. 31:364.

__________. 1970d. Taste responses in ruminants. IV. Reaction of pygmy goats, normal goats, sheep and cattle to acetic acid and quinine hydrochloride. J. Anim. Sci. 31:373.

__________. 1970e. Review of some nutritional aspects of the sense of taste. J. Anim. Sci. 31:973.

Hanson, J. L., M. H. Brushway and H. Lineweaver. 1960. Monosodium glutamate studies. I. Factors affecting detection of and preferences for added glutamate in food. Food Technol. 14:320.

Henkin, R. I. and D. F. Bradley. 1969. Regulation of taste acuity by thiols and metal ions. Proc. Natl. Acad. Sci. 62:30.

__________. 1970. Hypogeusia corrected by Ni^{++} and Zn^{++}. Life Sci. 9:701.

Henkin, R., P. G. Graziadei, and D. F. Bradley. 1969. The molecular basis of taste and its disorders. Annal. of Internal Med. 71:791.

Henning, G. J., J. N. Brouwer, J. Van Der Wel, and A. Francke. 1969. Miraculin, the sweetness-inducing principle from miracle fruit. In C. Pfaffmann (Ed.) Olfaction and Taste. III. Rockefeller Univ. Press, New York.

Henson, J. N., P. D. Bogdonoff, and G. M. Thrasher. 1962. Levels of monosodium glutamate in pig starter preference. J. Anim. Sci. 21:999.

Inglett, G. E., B. Dowling, J. J. Albrecht, and F. A. Holgan. 1965. Taste-modifying properties of Miracle Fruit (*Synsepalum dulcificum*). J. Agr. Food Chem. 13:284.

Inglett, G. E. and J. F. May. 1968. Tropical plants with unusual taste properties. Econ. Bot. 22: 326.

________________. Serendipity berries - source of a new intense sweetener. J. Food Sci. 34: 408.

Kare, M. R. 1961. Comparative aspects of the sense of taste. In M. R. Kare and P. B. Halpern (Eds.) Physiological and Behavioral Aspects of Taste. Univ. Chicago Press, Chicago.

________ and M. S. Ficken. 1963. Comparative studies on sense of taste. In T. Hayashi (Ed.) Olfaction and Taste. II. Pergamon, London.

________, W. C. Pond and J. Campbell. 1965. Observations on the taste reactions in pigs. Anim. Behav. 13:265.

Klay, R. F. 1964. Monosodium glutamate in pig creep rations. J. Anim. Sci. 23: 598.

Krbchek, L., G. Inglett, M. Holik, B. Dowling, and R. Wagner. 1968. Synthesis of potential sweetening agents. J. Agr. Food Chem. 16: 109.

Kurihara, K., Y. Kurihara and L. M. Beidler. 1969. Isolation and mechanism of taste modifiers; taste-modifying protein and gymnemic acids. In C. Pfaffmann (Ed.) Olfaction and Taste. III. Rockefeller Univ. Press, New York.

Kurtzman, C. H. and L. B. Sjostrom. 1964. The flavor-modifying properties of disodium inosinate. Food Technol. 18: 1467.

Mackey, A.O. 1958. Discernment of taste substances as affected by solvent medium. Food Res. 23: 580.

Martin, S. and R. M. Pangborn. 1970. Taste interaction of ethyl alcohol with sweet, salty, sour and bitter compounds. J. Sci. Food Agr. 21: 653.

Miller, W. J. and C. M. Clifton. 1964. Influence of experimental design on results of palatability studies. J. Dairy Sci. 47: 927.

Mitchell, A. R. and F. R. Bell. 1969. Spontaneous sodium appetite and red-cell type in sheep. In C. Pfaffmann (Ed.) Olfaction and Taste. III. Rockefeller Univ. Press, New York.

Norton, K. B., D. K. Tressler, and L. D. Forkas. 1952. The use of monosodium glutamate in frozen foods. Food Technol. 6:405.

O'Dell, G. D., W. J. Miller, S. L. Moore and W. A. King. 1970. Effect of nickel as the chloride and the carbonate on palatability of cattle feed. J. Dairy Sci. 53:1266.

Patterson, H. D. and H. L. Lucas. 1962. Change-over designs. North Carolina Agric. Exp. Sta. Tech. Bull. 147.

Pfaffmann, C. 1963. Taste stimulation and preference behavior. In Y. Zotterman (Ed.) Olfaction and Taste. I. Pergamon, London.

Rice, P. R. 1972. Taste reactions in Columbian black-tailed deer. M. S. Thesis. Oregon State University, Corvallis.

Solms, J. 1969. The taste of amino acids, peptides, and proteins. J. Agr. Food Chem. 17:686.

Stocklin, W. 1969. Chemistry and physiological properties of gymnemic acid, the antisaccharine principle of the leaves of Gymnema sylvestre. Agr. Food Chem. 17:704.

Stubbs, O. J. and M. R. Kare. 1958. Taste preferences of cattle. J. Anim. Sci. 17:1162 (Abstr.).

Varela, G., J. J. Escriva, and J. Boza. 1970. Influence of the addition of molybdenum on the digestibility and palatability of a diet for sheep. Proc. Nutr. Soc. 29:381.

Voelker, H. H., N. A. Jorgensen, G. P. Mohanty and M. J. Owens. 1969. Effects of zinc supplementation to dairy cattle rations. J. Dairy Sci. 52:929. (Abstr.).

Wade, G. N. and I. Zucker. 1969. Taste preferences of female rats: modification of neonatal hormones, food deprivation and prior experience. Physiol. Behav. 4:935.

Wagner, J. R., D. S. Titus and J. E. Schade. 1963. New opportunities for flavor modification. Food Technol. 7:52.

Waldern, D. E. and R. D. Van Dyk. 1971. Effect of monosodium glutamate in starter rations on feed consumption and performance of early weaned calves. J. Dairy Sci. 54:1.

Warren, R. M. and C. Pfaffmann. 1959. Suppression of sweet sensitivity by potassium gymnemate. J. Appl. Physiol. 14:40.

Weiner, L. H. and E. Stellar. 1951. Salt preference of the rat determined by single-stimulus method. J. Comp. Physiol. Psychol. 44:394.

APPENDIX

Appendix Table 1. Taste response of pygmy goats to four methods of preference testing.

Period	Method 2CFC	2CLA	1CFC	1CLA
	Percent Intake[a]			
1	83.8	35.8	13.0	42.9
	49.0	84.7	64.1	2.6
	54.8	50.1	64.9	0.9
Means	62.5	56.9	47.3	15.5
2	45.8	47.0	52.4	50.2
	68.4	10.2	62.8	22.6
	82.7	50.5	27.8	33.3
Means	65.6	32.1	47.7	35.4
3	55.3	27.9	52.7	27.8
	99.1	47.6	32.5	52.3
	62.8	40.5	7.1	50.4
Means	72.4	41.0	30.8	43.5
4	66.5	50.9	78.8	57.1
	32.8	76.3	32.5	52.3
	49.9	44.3	60.8	49.3
Means	49.7	53.6	57.4	52.9

[a] $\frac{\text{Chemical solution}}{\text{Total fluid intake}} \times 100$; an 0.63% NaCl solution was used as test solution in oppostion to tap water.

Appendix Table 2. Consumption by pygmy goats of absolue ethanol in amounts necessary to solubilize GymA as a percent of total fluid intake per two-day period.

Animal	GymA Equivalent[a]							
	5		50		100		500	
	D_1	D_2	D_1	D_2	D_1	D_2	D_1	D_2
2	4.4	99.4			23.7	65.3		
3	1.8	98.5			0.0	83.7		
4	0.0	0.0			0.0	2.2		
5	85.2	1.5			97.8	39.4		
6	70.2	1.9			98.9	0.3		
2 day average means	36.3				41.1			
8			5.2	99.1			36.1	99.1
9			0.7	45.8			78.9	41.7
10			0.5	99.5			67.4	68.0
11			2.8	1.4			20.7	1.0
12			90.5	17.6			56.4	4.8
2 day average means			36.3				47.4	

[a] ppm

Appendix Table 3. Consumption by pygmy goats of 25% sucrose plus increasing increments of GymA as a percent of total fluid intake per two-day period.

	parts per million of GymA[a]																	
Animal	10		20		30		40		50		60		80		90		100	
	D_1	D_2	D_1	D_2	D_1	D_2	D_1	D_2	D_1	D_2	D_1	D_2	D_1	D_2	D_1	D_2	D_1	D_2
1					18.7	96.9			08.0	96.8	10.7	94.3			39.2	94.1	92.1	99.5
3					99.0	25.1			29.8	92.0	98.2	17.8			75.0	67.2	64.4	93.8
5					87.3	98.9			22.5	99.3	64.7	90.3			65.6	98.0	33.9	94.7
7					24.1	98.1			50.2	79.2	96.1	99.8			01.5	99.9	96.5	99.4
9					99.1	98.1			36.8	97.7	100.0	23.0			81.3	63.0	99.2	99.3
11					97.6	97.8			70.0	96.1	57.1	94.1			96.6	98.7	97.9	97.5
1-day means					71.0	85.8			36.2	93.5	71.1	69.9			59.9	86.8	80.7	97.4
2-day average means					78.3				64.9		70.5				73.5		89.0	
13	46.2	51.4	95.9	88.4			97.7	93.8			98.6	98.0	94.9	16.0				
15	95.1	99.9	97.9	70.6			95.2	90.0			96.7	99.2	98.9	99.4				
17	97.1	03.9	28.7	98.0			36.8	99.6			36.2	70.6	97.6	98.3				
19	22.4	52.9	99.6	99.4			99.8	99.4			99.3	83.6	92.4	10.3				
21	41.2	03.7	87.8	96.8			87.5	96.7			97.1	90.4	91.2	97.6				
23	29.3	15.5	97.0	87.5			96.9	95.3			90.1	66.0	60.7	32.5				
1-day means	55.2	37.9	84.5	90.1			85.5	95.8			86.3	84.6	89.3	59.0				
2-day average means	46.6		87.3				90.6				85.5		74.2					

[a]Average consumption in the absence of GymA was 32.1%.

Appendix Table 4. Consumption by pygmy goats of 1000 ppm of quinine hydrochloride plus increasing increments of GymA as a percent of total fluid intake per two-day period.

Animal	parts per million of GymA[a]											
	1.74		3.5		13.9		27.8		41.6		55.6	
	D_1	D_2	D_1	D_2	D_1	D_2	D_1	D_2	D_1	D_2	D_1	D_2
1	2.3	1.5	1.0	0.0					0.0	1.0		
2	52.5	56.0	0.0	0.0					0.0	0.0		
5	01.0	1.0	0.0	0.0					0.0	0.0		
7					0.0	0.0	0.0	0.0			1.0	1.0
9					0.0	0.0	0.0	0.0			1.0	0.0
11					1.0	0.0	1.0	0.0			2.0	0.0
1-day meand	18.6	19.5	0.3	0.0	0.3	0.0	0.3	0.0	0.0	0.3	1.33	0.3
2-day average means	19.1		0.15		0.15		0.15		0.15		.82	

[a]Average consumption in the absence of GymA was 2.8%.

Appendix Table 5. Consumption by pygmy goats of 200 ppm of quinine hydrochloride plus increasing increments of GymA as a percent of total fluid intake per two-day period.

Animal	parts per million of GymA[a]													
	10		20		30		40		60		80		100	
	D_1	D_2	D_1	D_2	D_1	D_2	D_1	D_2	D_1	D_2	D_1	D_2	D_1	D_2
1	51.8	26.0	98.2	58.2	96.0	100.0			99.4	100.0				
	49.5	99.5	99.7	98.8	87.3	77.3			89.5	62.8				
5	99.7	100.0	99.5	100.0	99.1	100.0			100.0	100.0				
7	20.5	0.2	60.1	97.4	56.8	100.0			76.8	92.5				
9	98.9	98.7	62.1	2.0	0.6	0.0			0.0	0.0				
11	57.6	52.0	41.5	7.4	4.1	0.0			43.4	0.0				
1-day means	63.0	62.7	76.9	60.6	57.3	62.9			68.2	59.2				
2-day average means	62.9		68.7		60.1				63.7					
13							98.4	0.0			99.4	0.0	100.0	99.3
15							0.5	13.5			98.4	100.0	43.8	0.1
17							0.1	9.3			19.6	75.6	5.9	0.0
19							98.4	1.6			60.7	46.1	87.0	99.2
21							99.0	45.0			99.5	0.1	----	----
23							31.0	2.1			41.2	98.5	52.3	54.9
1-day mean							54.6	11.9			69.8	53.4	57.8	50.7
2-day average means							33.3				61.6		54.3	

[a]Average consumption in the absence of GymA was 28.8%.

Appendix Table 6. Consumption by pygmy goats of 0.08% sucrose plus increasing increments of InoA as a percent of total fluid intake.

Animal	parts per million of InoA[a]							
	5		50		250		500	
	D_1	D_2	D_1	D_2	D_1	D_2	D_1	D_2
1	0.9	78.2			15.4	99.5		
3	47.3	68.5			81.6	41.3		
5	5.8	100.0			47.0	10.9		
7	0.5	32.4			0.4	100.0		
9	50.0	0.6			2.9	0.6		
11	18.0	30.5			71.4	1.3		
13			98.2	0.0			99.4	50.0
15			0.8	10.1			0.0	1.7
17			2.1	48.0			0.0	5.3
19			98.2	36.2			99.1	0.8
21			86.5	33.3			93.1	68.1
23			12.2	17.0			0.5	4.1
1-day means	20.4	51.7	49.7	24.1	36.5	42.3	48.7	21.7
2-day average mean	36.1		36.9		39.4		35.2	

[a]Average consumption in the absence of InoA was 47.2%.

Appendix Table 7. Consumption by pygmy goats of 6.25 ppm quinine hydrochloride plus increasing increments of InoA as a percent of total fluid intake.

Animal	parts per million InoA[a]							
	5		50		250		500	
	D_1	D_2	D_1	D_2	D_1	D_2	D_1	D_2
5							38.2	83.4
7							2.9	98.5
9							1.0	23.3
11							36.4	13.0
13							1.1	0.8
15	74.7	99.0	2.1	75.0	0.5	1.1		
17	60.5	98.0	5.9	90.8	0.6	8.4		
19	0.2	99.6	5.0	100.0	0.0	90.8		
21	1.4	99.1	5.4	1.4	0.9	0.8		
23	3.5	87.8	3.2	5.3	24.0	0.6		
1-day mean	28.1	96.7	4.3	54.5	5.2	20.3	15.9	43.8
2-day average mean	62.4		29.4		12.8		29.9	

[a]Average consumption in the absence of InoA was 41.9%.

Appendix Table 8. Consumption by pygmy goats of 0.08% sucrose plus increasing increments of MSG as a percent of total fluid intake.

Animal	parts per million MSG[a]							
	5		50		250		500	
	D_1	D_2	D_1	D_2	D_1	D_2	D_1	D_2
1					54.3	99.7		
2	93.8	20.0			7.6	34.5		
3	12.5	66.7			47.8	4.8		
4	87.0	44.4			29.7	58.8		
5	72.7	55.3			2.1	0.3		
6	33.3	0.6			29.9	70.3		
1-day mean	59.9	37.4			28.6	44.7		
2-day average mean	48.7				36.7			
7							50.0	100.0
8			37.5	50.0			2.6	99.1
9			95.7	22.2			49.5	0.2
10			1.1	99.3			0.6	50.6
11			67.5	1.1			9.7	0.5
12			89.2	1.3			12.1	0.9
1-day mean			58.2	34.8			20.8	41.9
2-day average mean			46.5				31.4	

[a]Average consumption in the absence of MSG was 48.0%.

Appendix Table 9. Consumption by pygmy goats of 10% sucrose plus increasing increments of MSG as a percent of total fluid intake.

Animal	parts per million of MSG[a]							
	5		50		250		500	
	D_1	D_2	D_1	D_2	D_1	D_2	D_1	D_2
1	23.5	100.0			1.0	78.6		
3	56.2	50.7			47.3	44.0		
5	35.2	87.0			11.8	98.4		
7	27.0	97.4			56.9	35.7		
9	97.8	88.2			3.8	1.0		
11	50.0	57.1			12.5	3.3		
13			11.1	100.0			42.9	50.0
15			80.6	98.3			9.1	97.8
17			62.6	1.7			81.8	29.3
19			24.0	100.0			0.5	92.4
21			18.7	99.2			23.8	95.1
23			81.3	41.0			83.6	19.5
1-day mean	48.3	80.1	46.4	73.4	22.2	43.5	40.3	64.0
2-day average mean	64.2		59.9		32.9		52.2	

[a]Average consumption in the absence of MSG was 72.5%.

Appendix Table 10. Consumption by pygmy goats of 30% sucrose plus increasing increments of MSG as a percent of total fluid intake.

Animal	parts per million MSG[a]							
	5		50		250		500	
	D_1	D_2	D_1	D_2	D_1	D_2	D_1	D_2
1	37.3	94.7			1.7	20.0		
3	46.7	50.7			43.2	7.8		
5	18.7	98.2			25.9	99.6		
7	23.4	48.0			5.7	44.3		
9	24.2	33.3			8.0	5.8		
11	78.9	47.3			88.9	2.8		
15			3.8	91.2			4.6	36.4
17			47.6	15.6			78.3	0.4
19			1.4	94.0			0.9	87.5
21			----	----			22.5	4.3
23			50.0	23.1			74.6	22.0
1-day mean	38.2	62.0	25.7	56.0	28.9	30.1	36.2	30.1
2-day average mean	50.1		41.0		29.5		33.2	

[a]Average consumption in the absence of MSG was 27.9%.

Appendix Table 11. Consumption by pygmy goats of 6.25 ppm quinine hydrochloride plus increasing increments of MSG as a percent of total fluid intake.

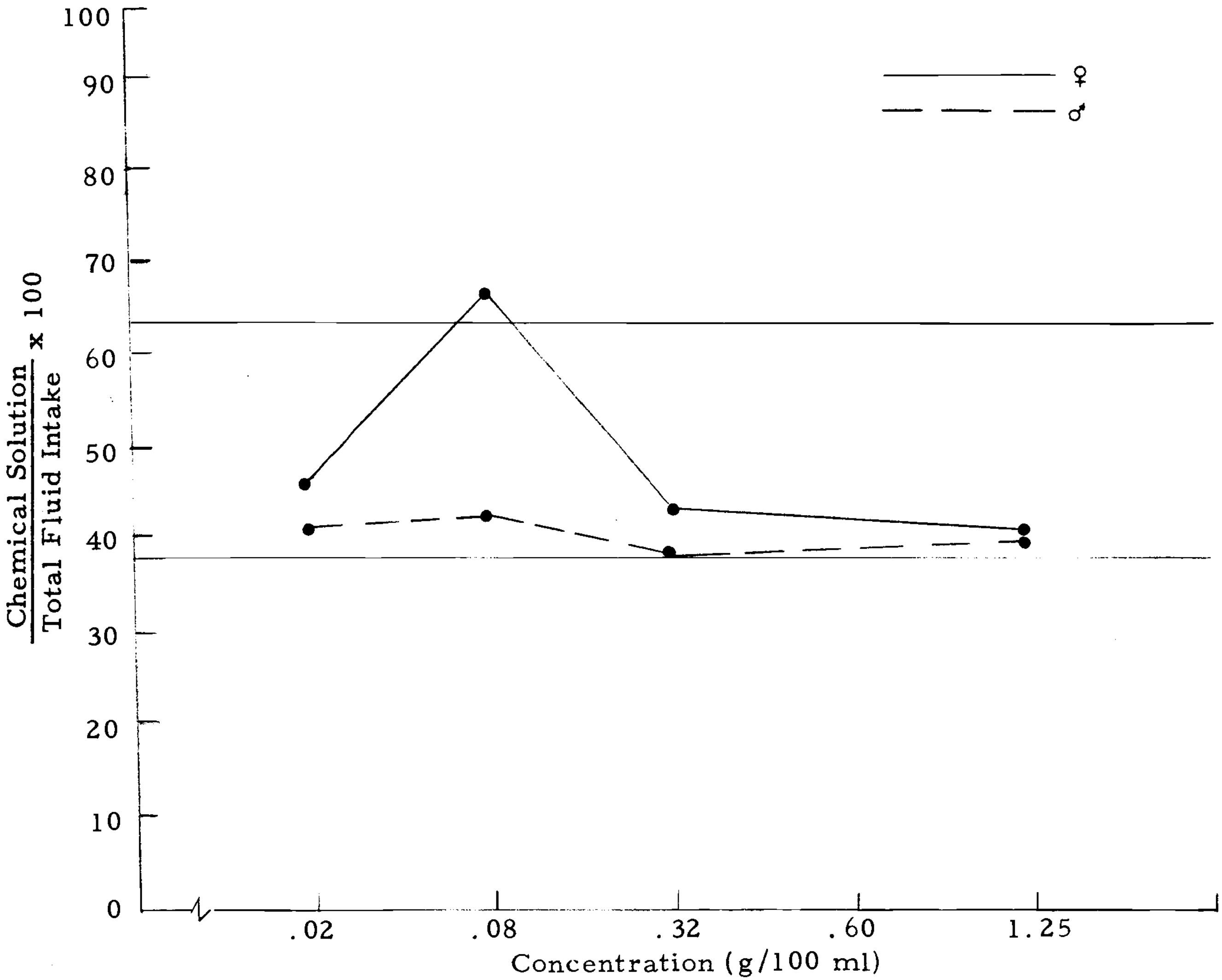
Animal	parts per million of MSG[a]							
	5		50		250		500	
	D_1	D_2	D_1	D_2	D_1	D_2	D_1	D_2
1	14.4	99.1			16.2	99.1		
3	49.0	93.2			53.0	100.0		
5	1.5	99.2			42.5	99.0		
7	30.2	98.3			24.3	26.9		
9	89.6	98.7			1.1	77.8		
11	79.4	28.9			65.5	68.9		
15			1.1	99.2			1.0	44.4
17			62.2	74.7			71.8	7.1
19			1.6	98.7			0.4	81.8
21			30.8	1.7			72.2	0.8
23			98.4	0.7			80.2	12.3
1-day mean	44.0	86.2	38.8	55.0	33.8	78.6	45.1	29.3
2-day average mean	65.1		46.9		56.2		37.2	

[a]Average consumption in the absence of MSG was 43.2%.

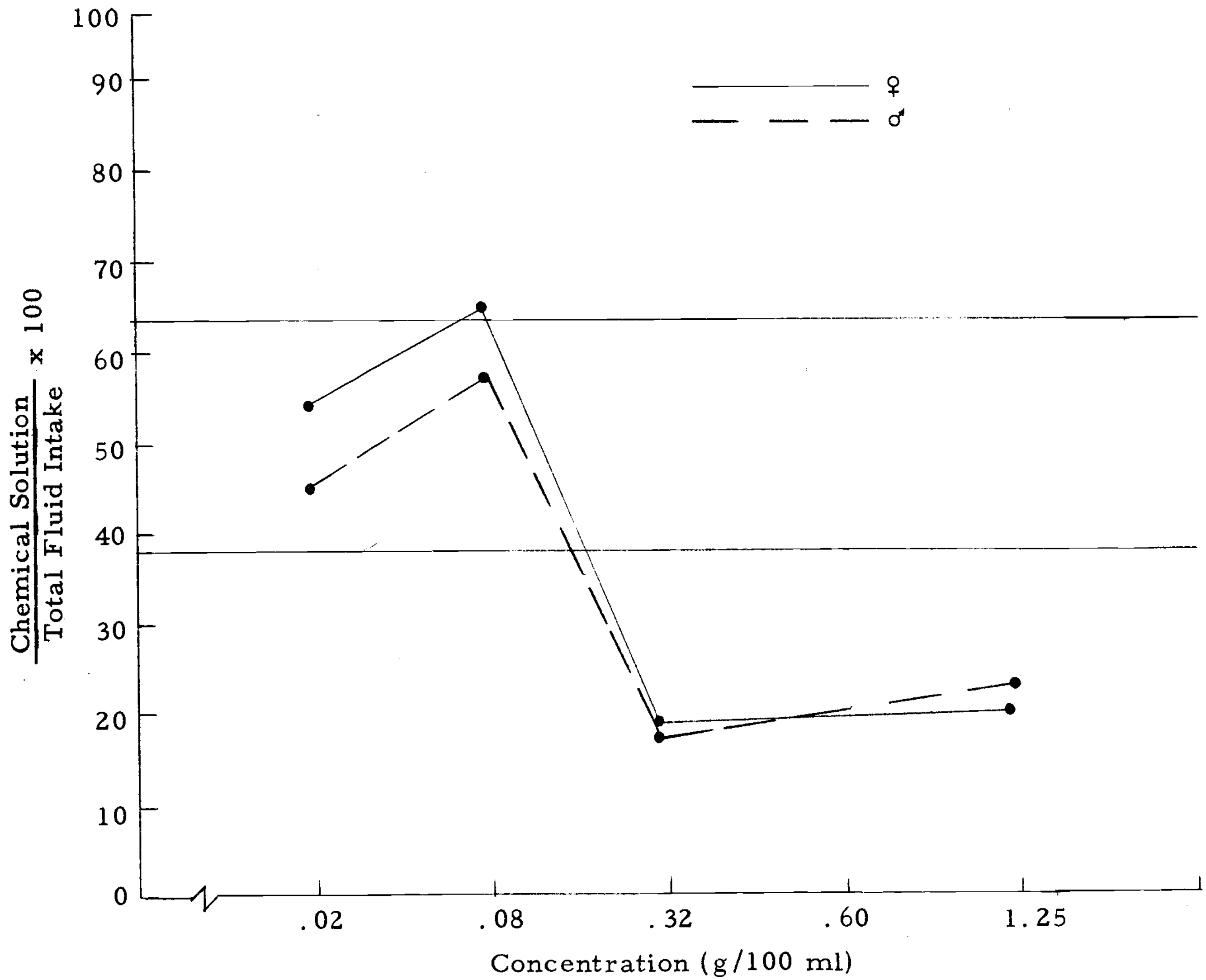
Appendix Table 12. Consumption by pygmy goats of 100 ppm quinine hydrochloride plus increasing increments of MSG as a percent of total fluid intake.

Animal	parts per million of MSG[a]							
	5		50		250		500	
	D_1	D_2	D_1	D_2	D_1	D_2	D_1	D_2
1	46.4	46.4			91.9	30.1		
3	20.5	20.18			41.2	33.0		
5	37.4	89.4			1.5	99.3		
7	25.0	99.8			65.7	74.5		
9	----	----			1.4	14.5		
11	71.9	99.7			76.8	1.0		
13			83.9	49.3			98.6	95.7
15			5.4	99.6			21.5	2.7
17			92.5	39.8			66.8	10.6
19			1.3	89.7			1.0	1.1
21			97.7	0.9			49.3	1.6
23			65.2	8.1			30.6	1.1
1-day mean	40.2	71.2	57.7	47.9	46.4	42.1	44.6	18.8
2-day average means	55.7		52.8		44.2		31.7	

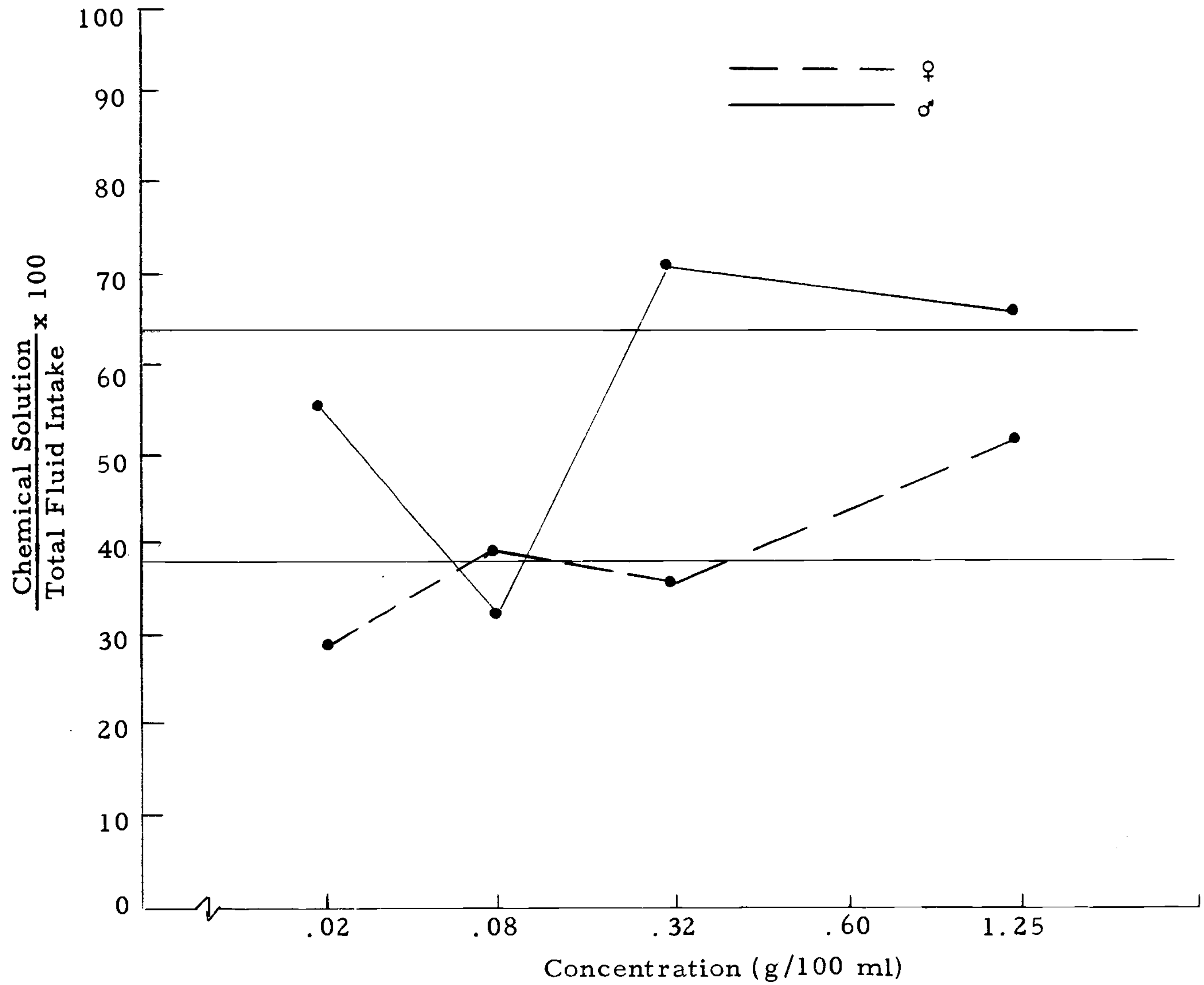
[a]Average consumption in the absence of MSG was 24.0%.



Appendix Figure 1. Average taste responses of male and female calves to increasing concentrations of NaCl.

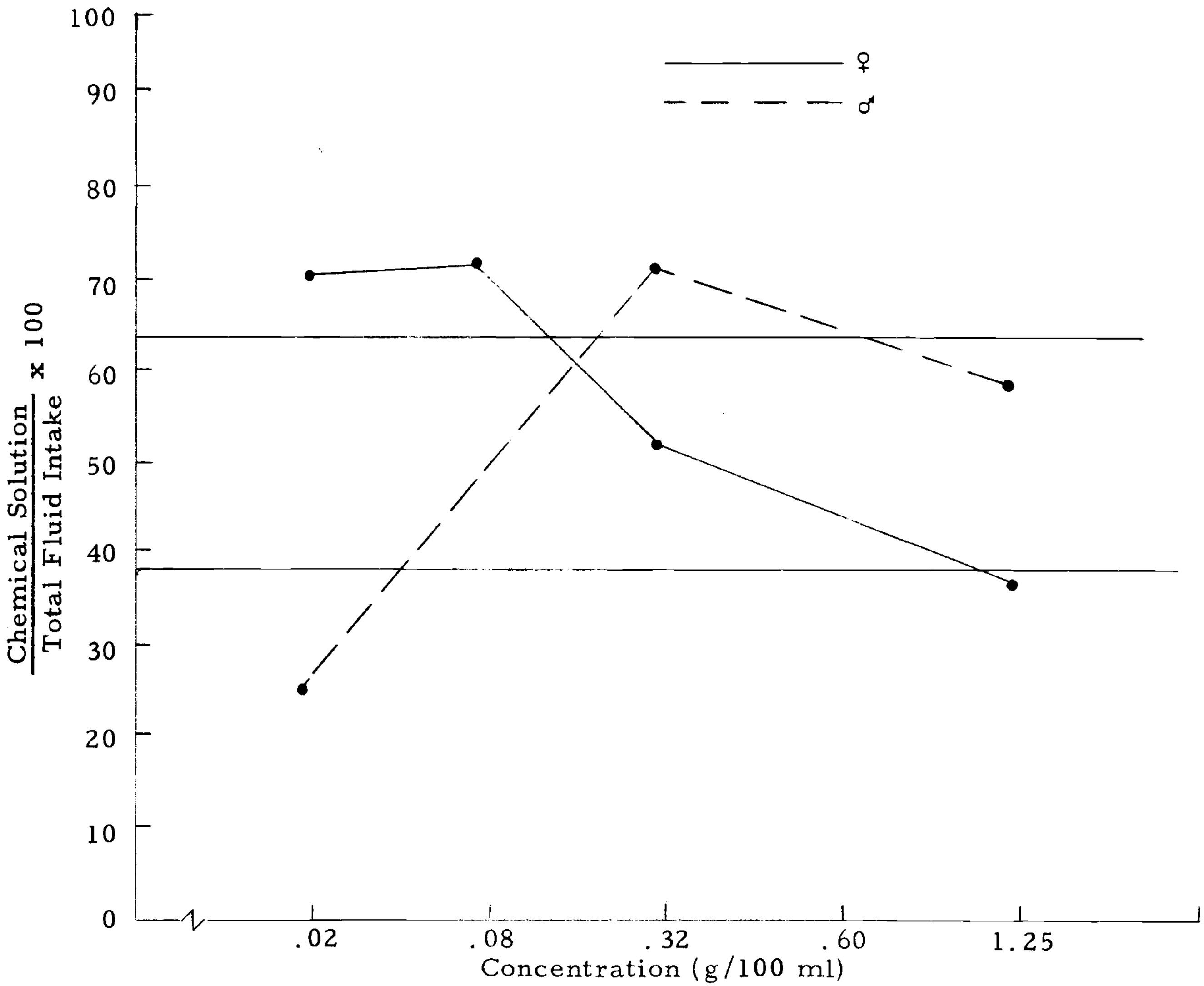


Appendix Figure 2. Average taste responses of male and female calves to increasing concentrations of Na_2CO_3.

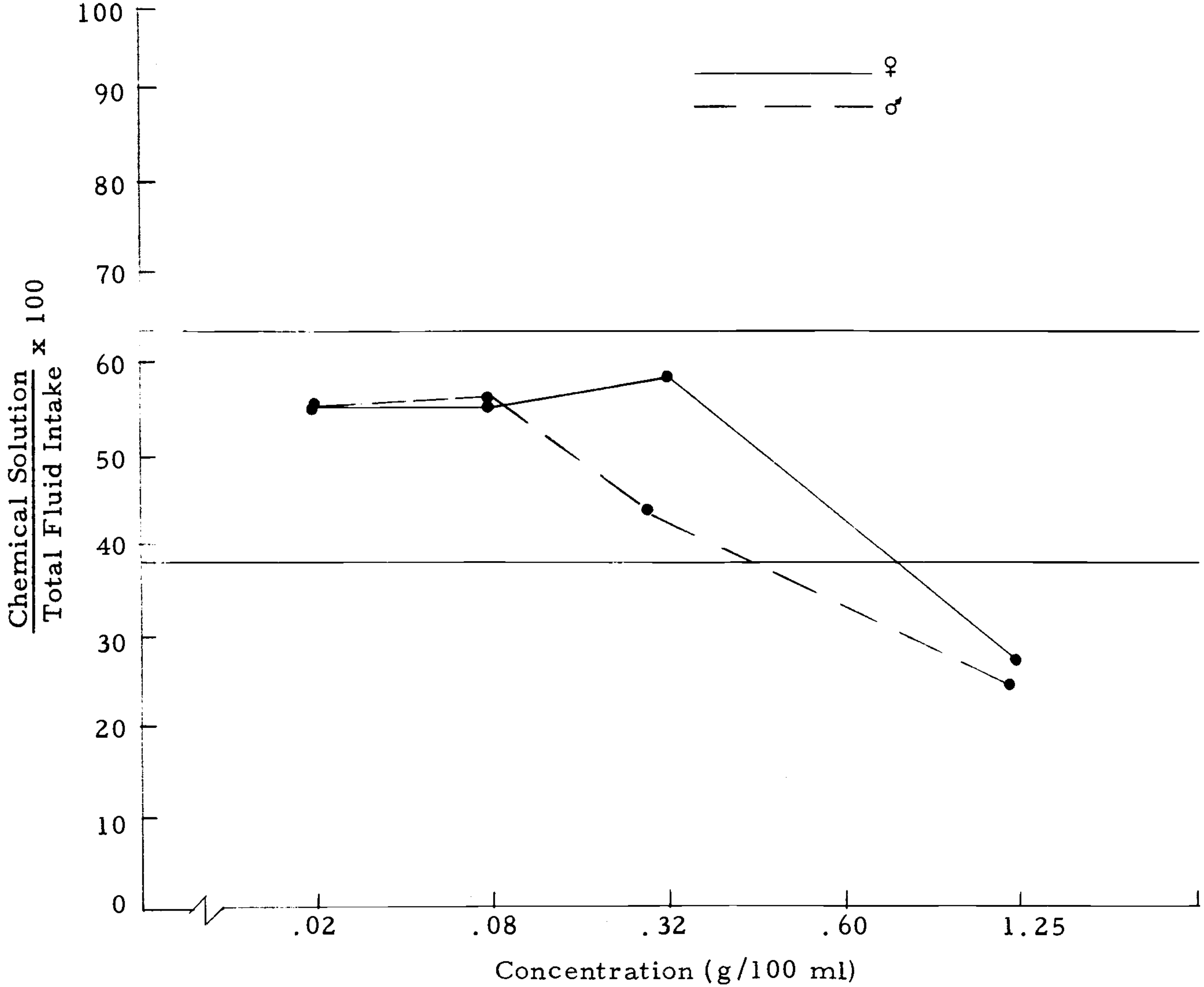


Appendix Figure 3. Average taste responses of male and female calves to increasing concentrations of Na_2HPO_4.

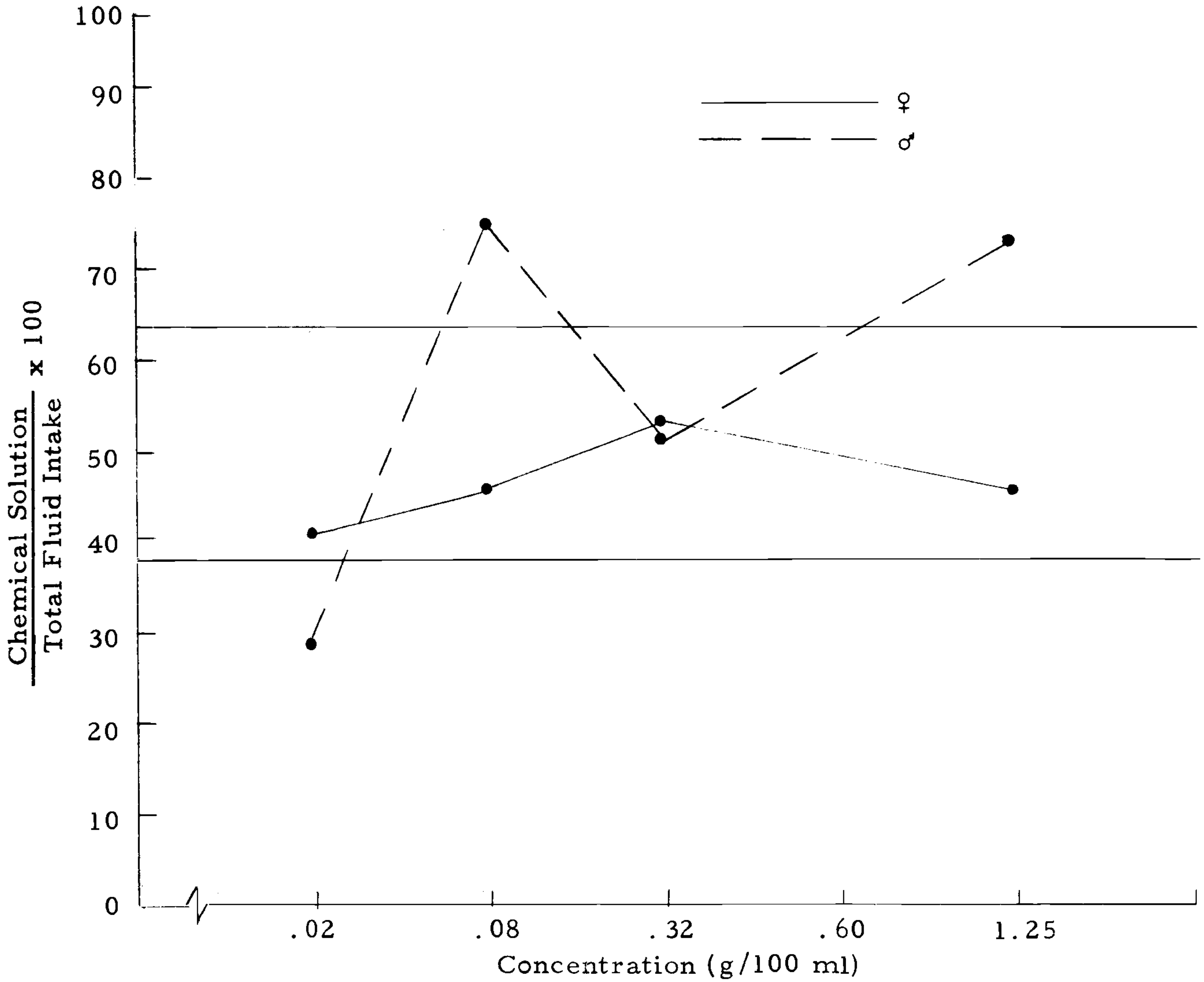
85



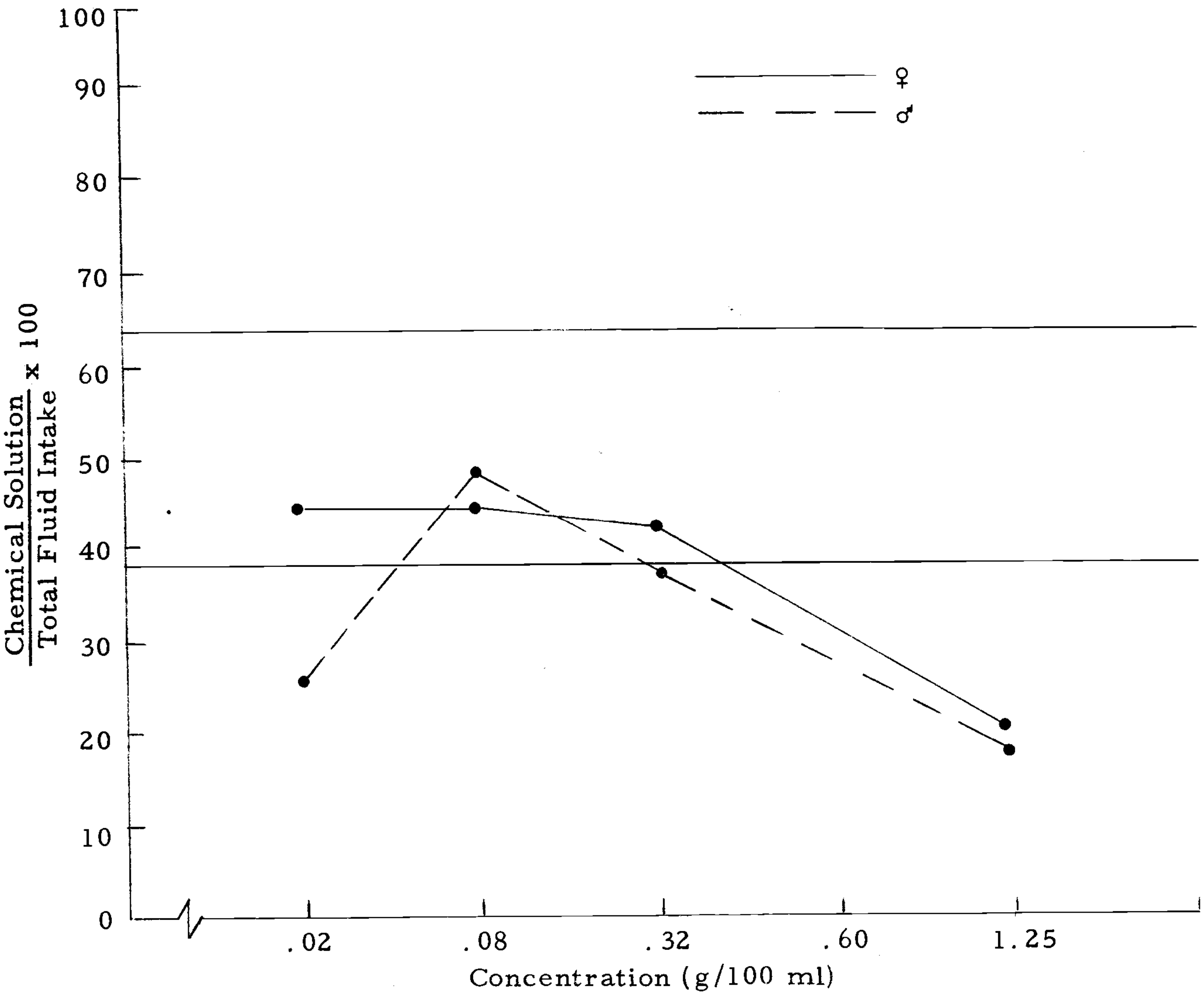
Appendix Figure 4. Average taste responses of male and female calves to increasing concentrations of $NaHCO_3$.



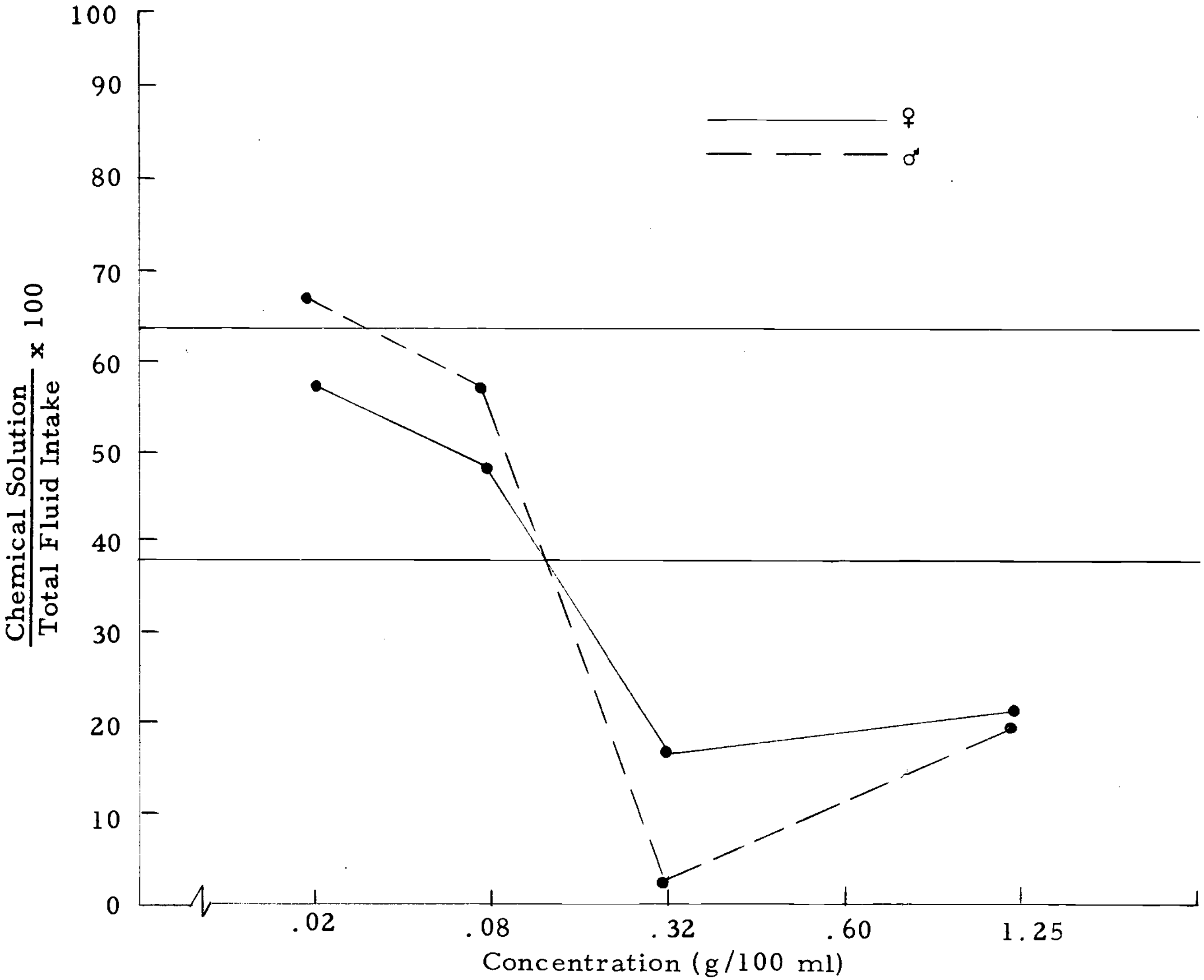
Appendix Figure 5. Average taste responses of male and female calves to increasing concentrations of NaH_2PO_4.



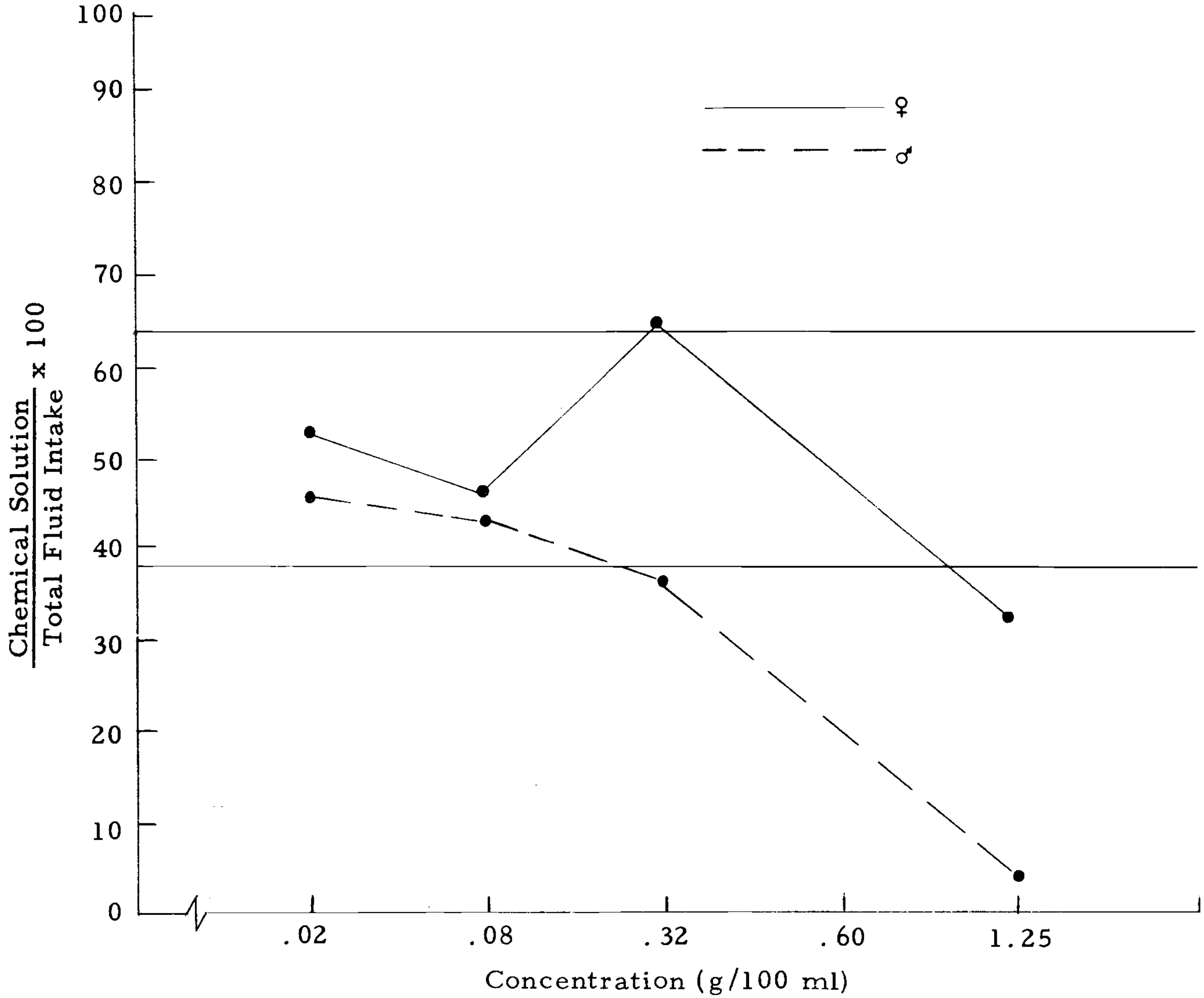
Appendix Figure 6. Average taste responses of male and female calves to increasing concentrations of Na_2SO_4.



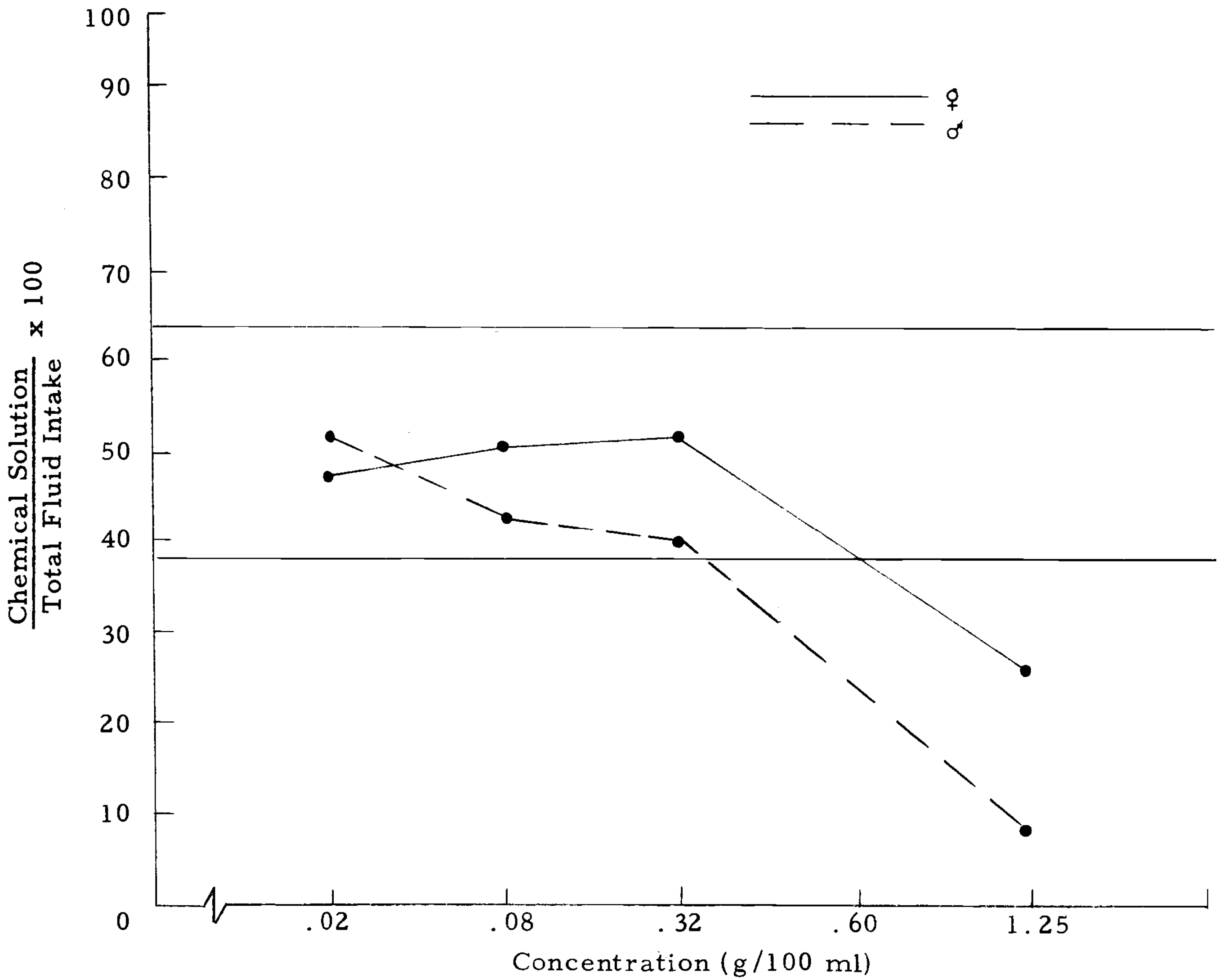
Appendix Figure 7. Average taste responses of male and female calves to increasing concentrations of KCl.



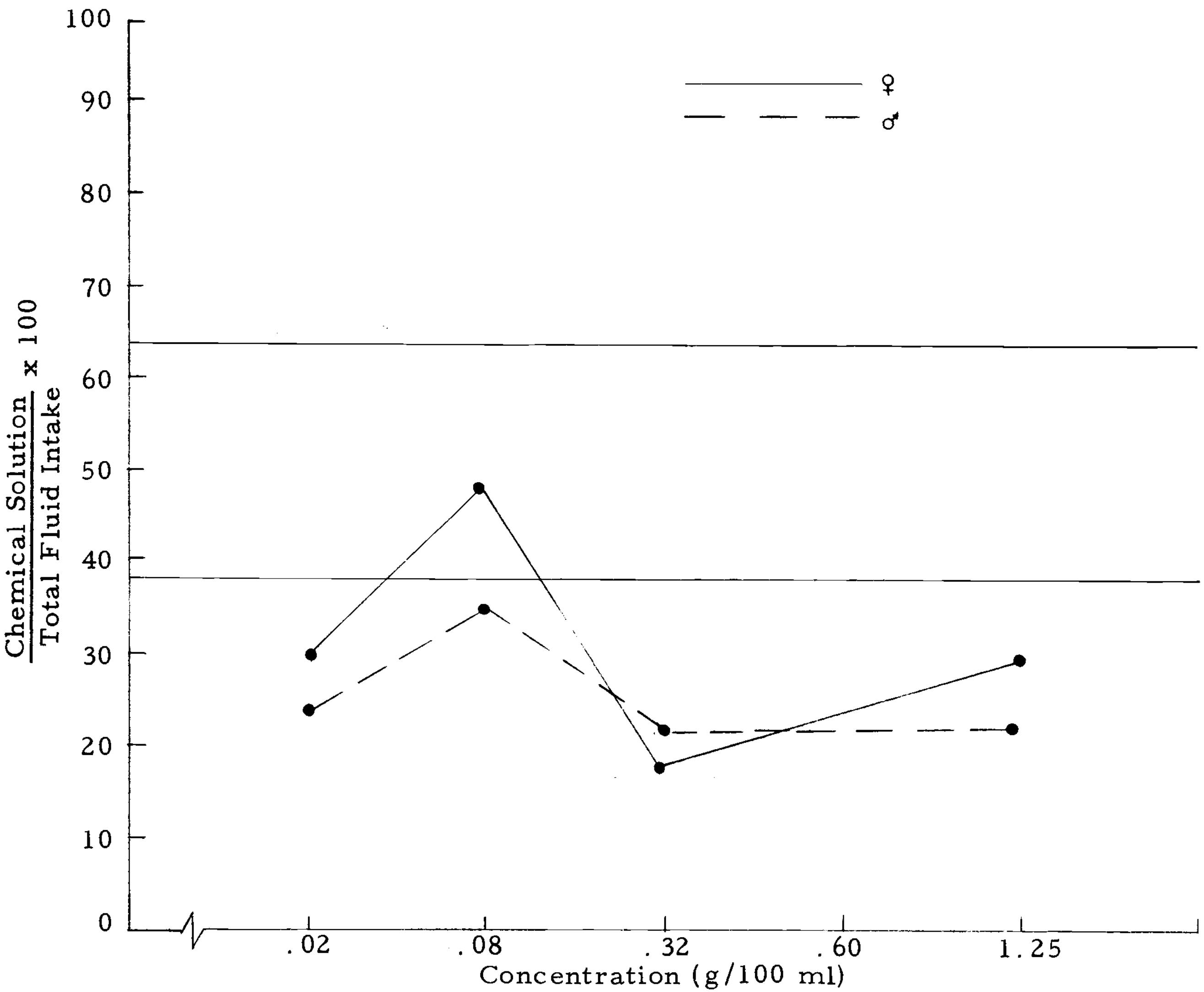
Appendix Figure 8. Average taste responses of male and female calves to increasing concentrations of NH_4Cl.



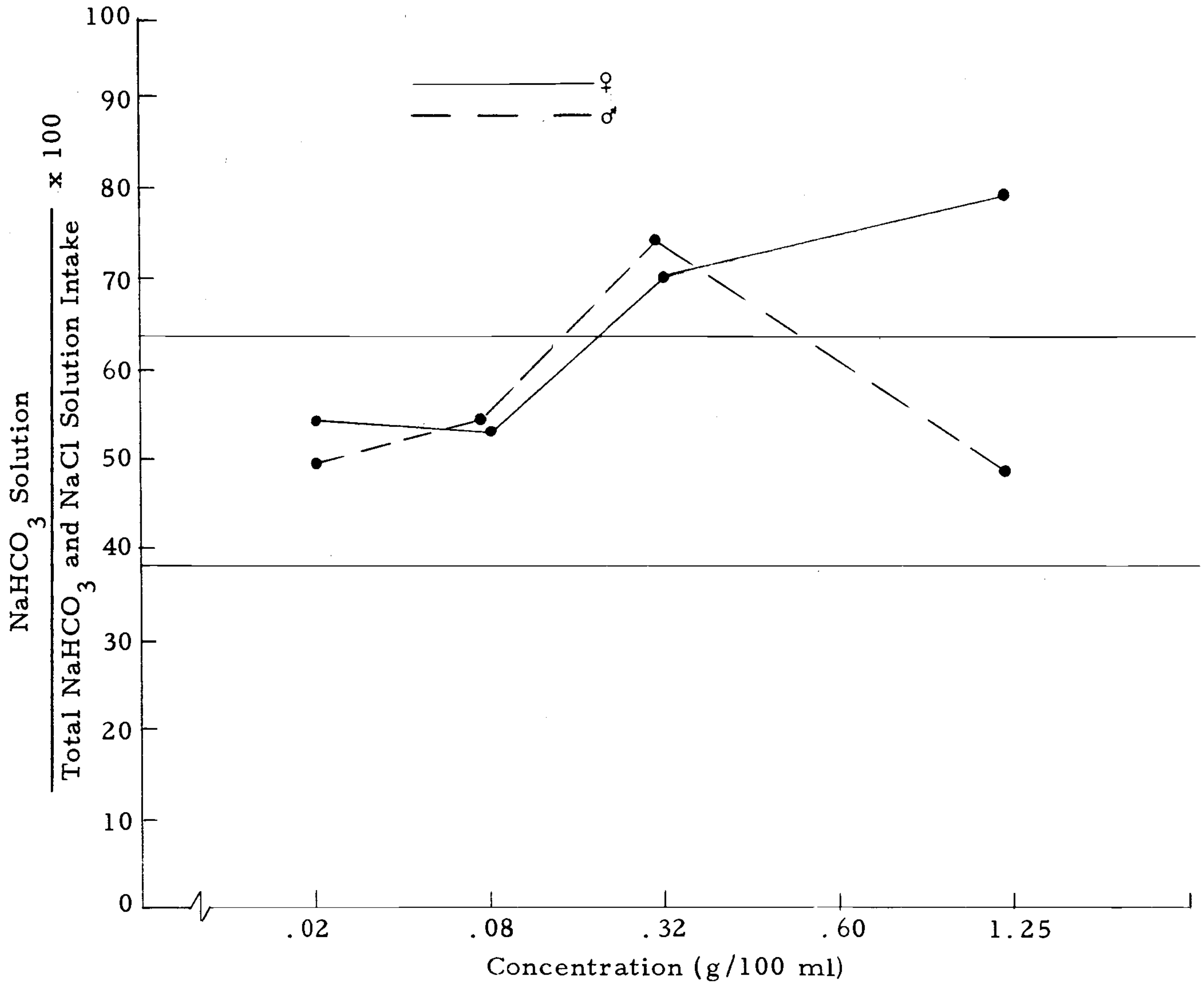
Appendix Figure 9. Average taste responses of male and female calves to increasing concentrations of $MnCl_2$.



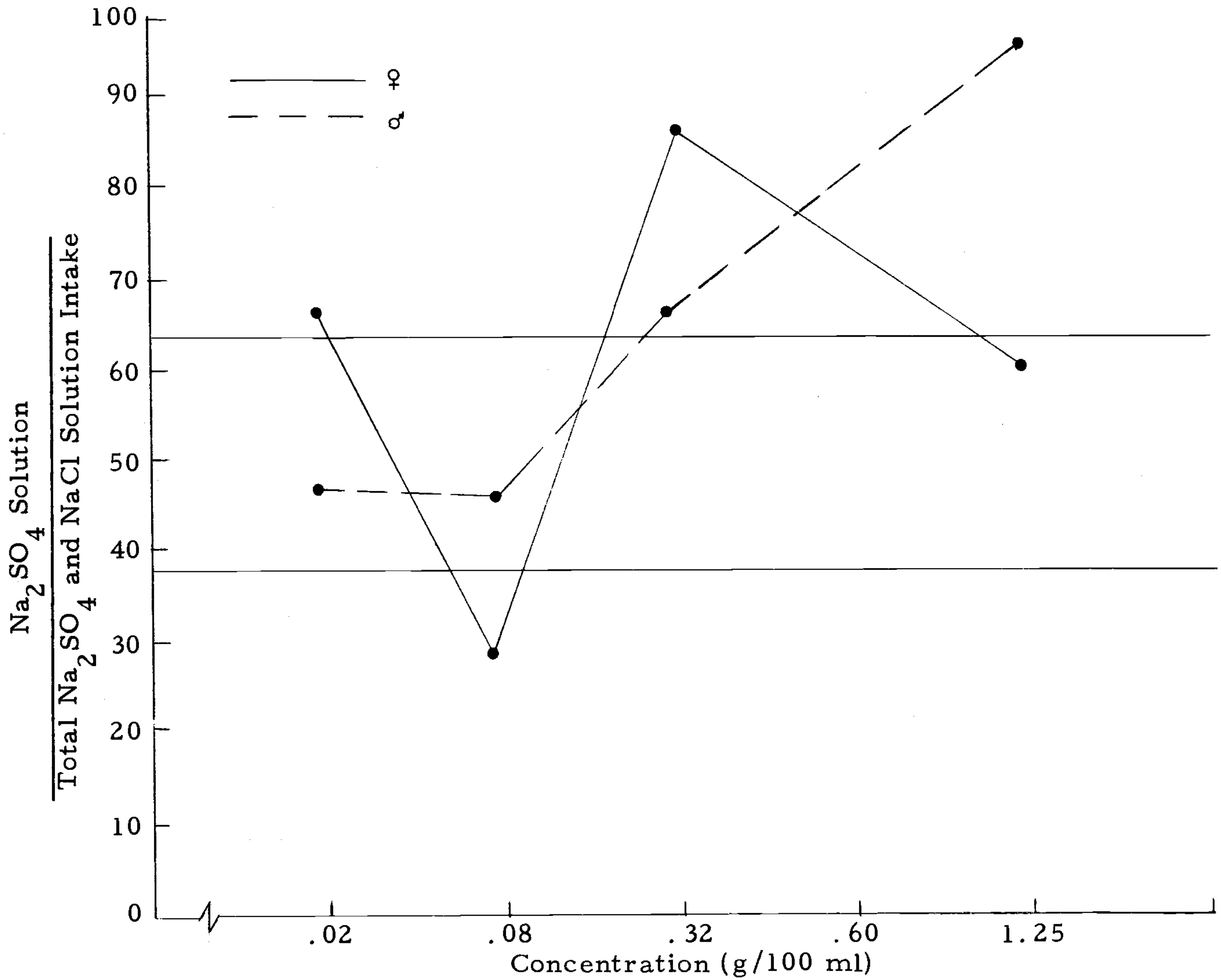
Appendix Figure 10. Average taste responses of male and female calves to increasing concentrations of $MgCl_2$.



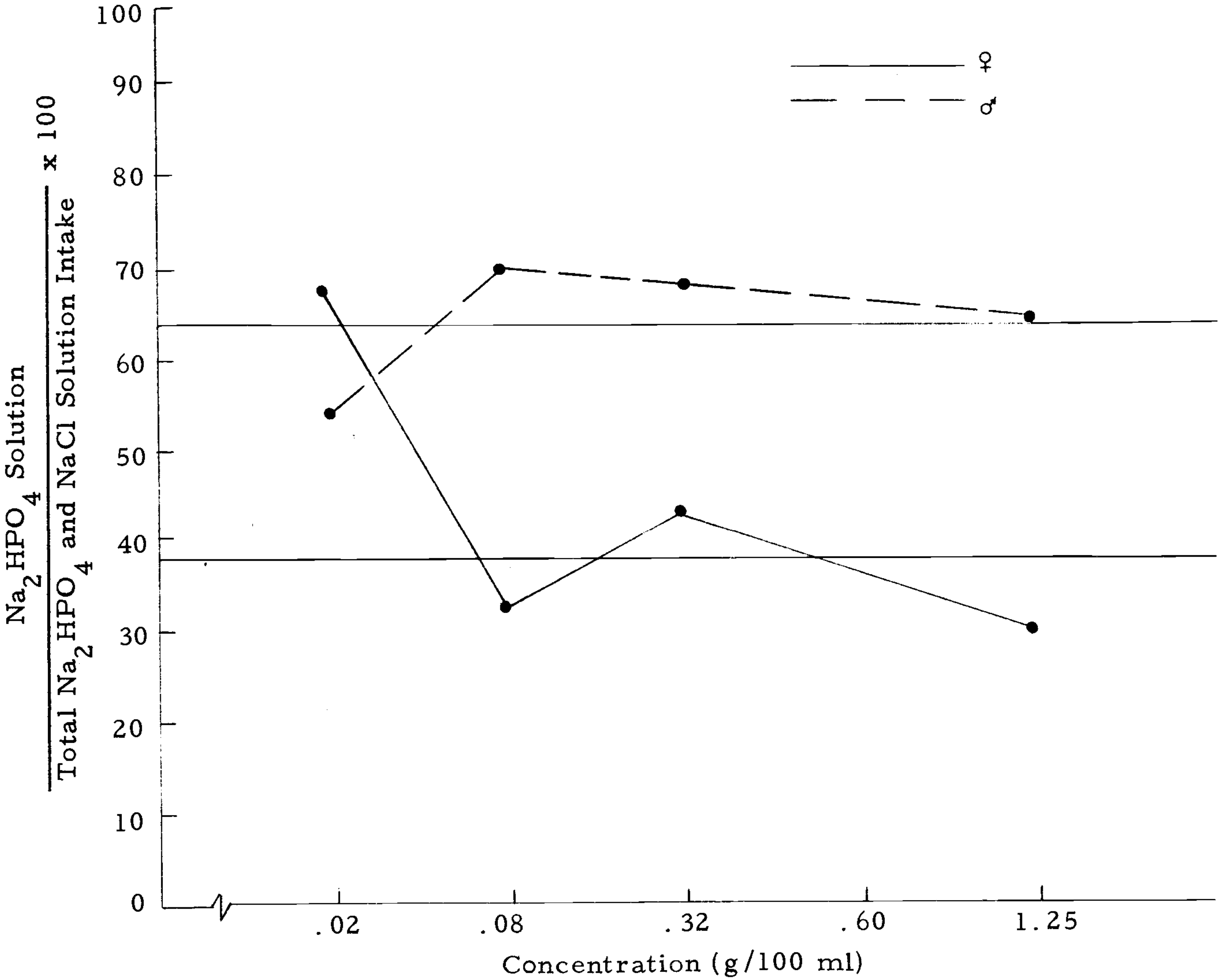
Appendix Figure 11. Average taste responses of male and female calves to increasing concentrations of $CaCl_2$.



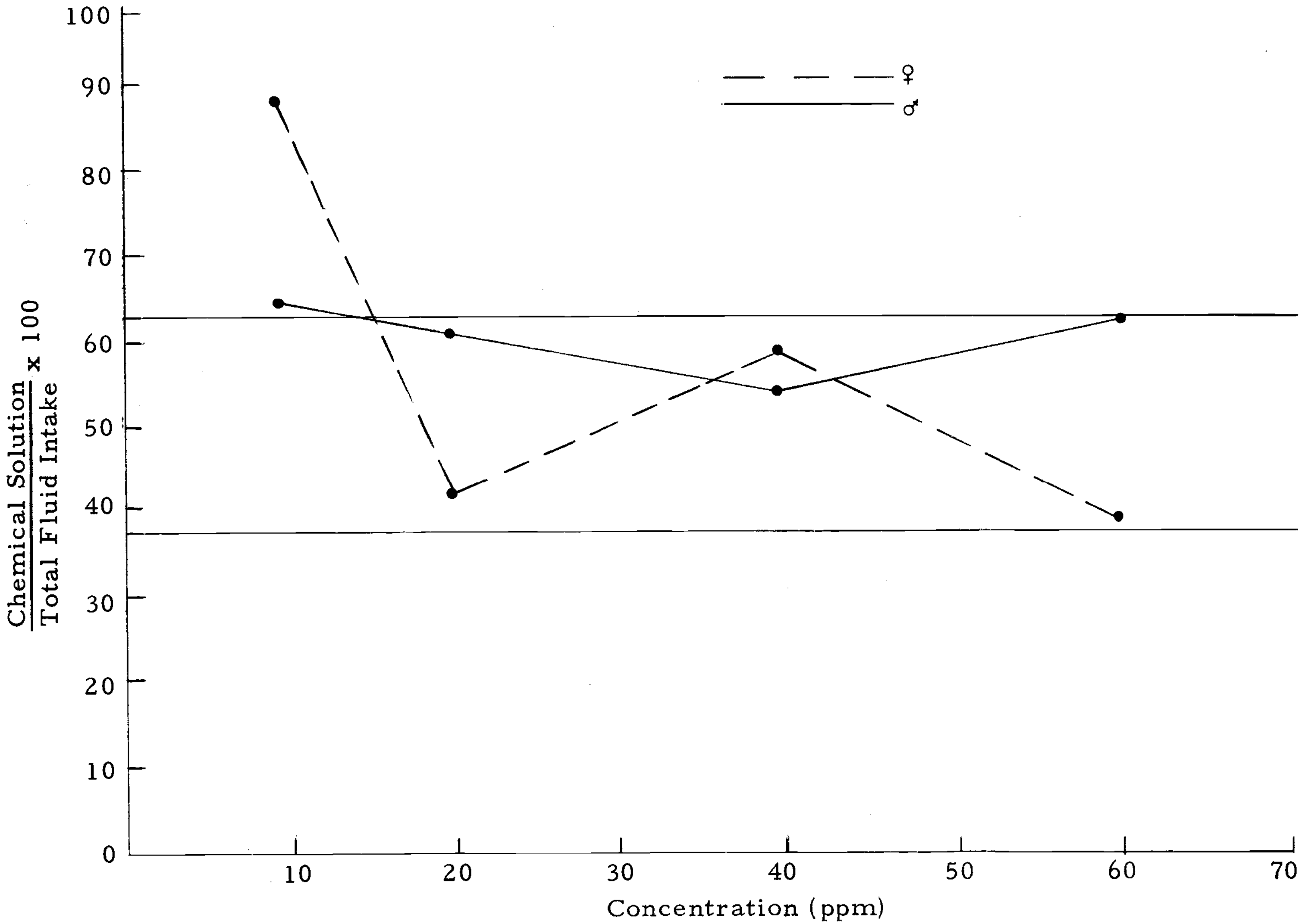
Appendix Figure 12. Average taste responses of male and female calves to increasing concentrations of NaCl vs. $NaHCO_3$.



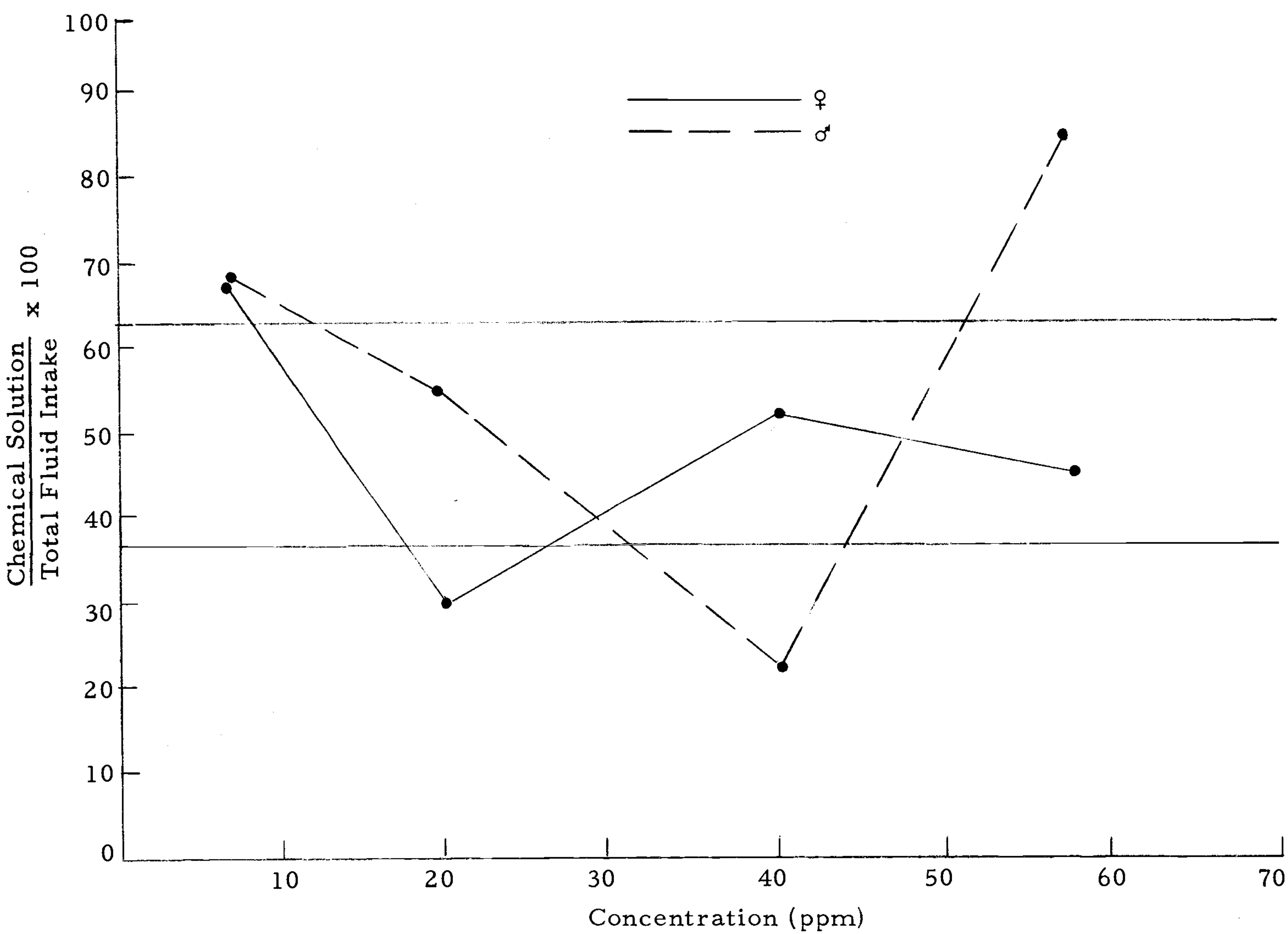
Appendix Figure 13. Average taste responses of male and female calves to increasing concentrations of NaCl vs. Na_2SO_4.



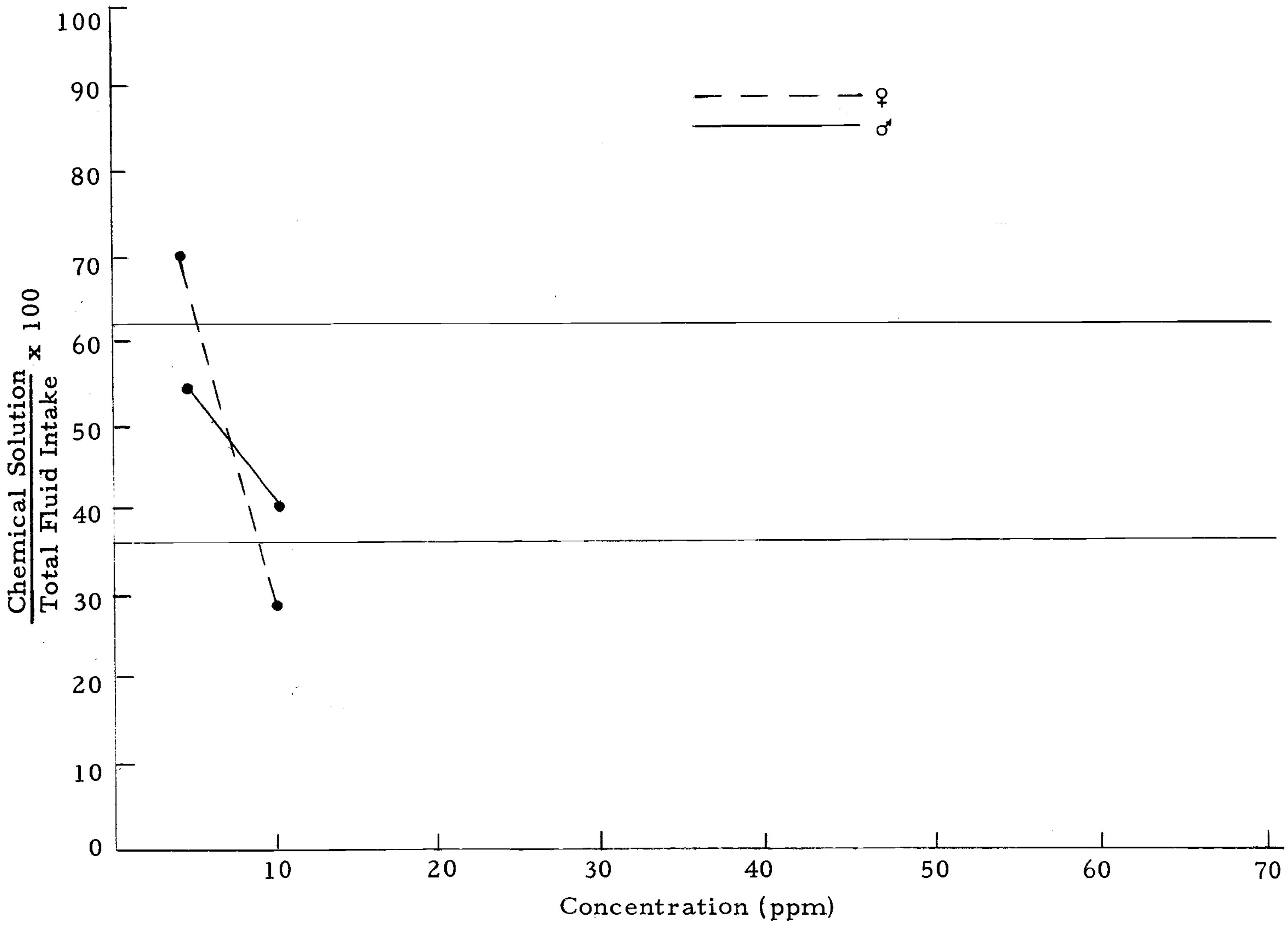
Appendix Figure 14. Average taste responses of male and female calves to increasing concentrations of NaCl vs. Na_2HPO_4.



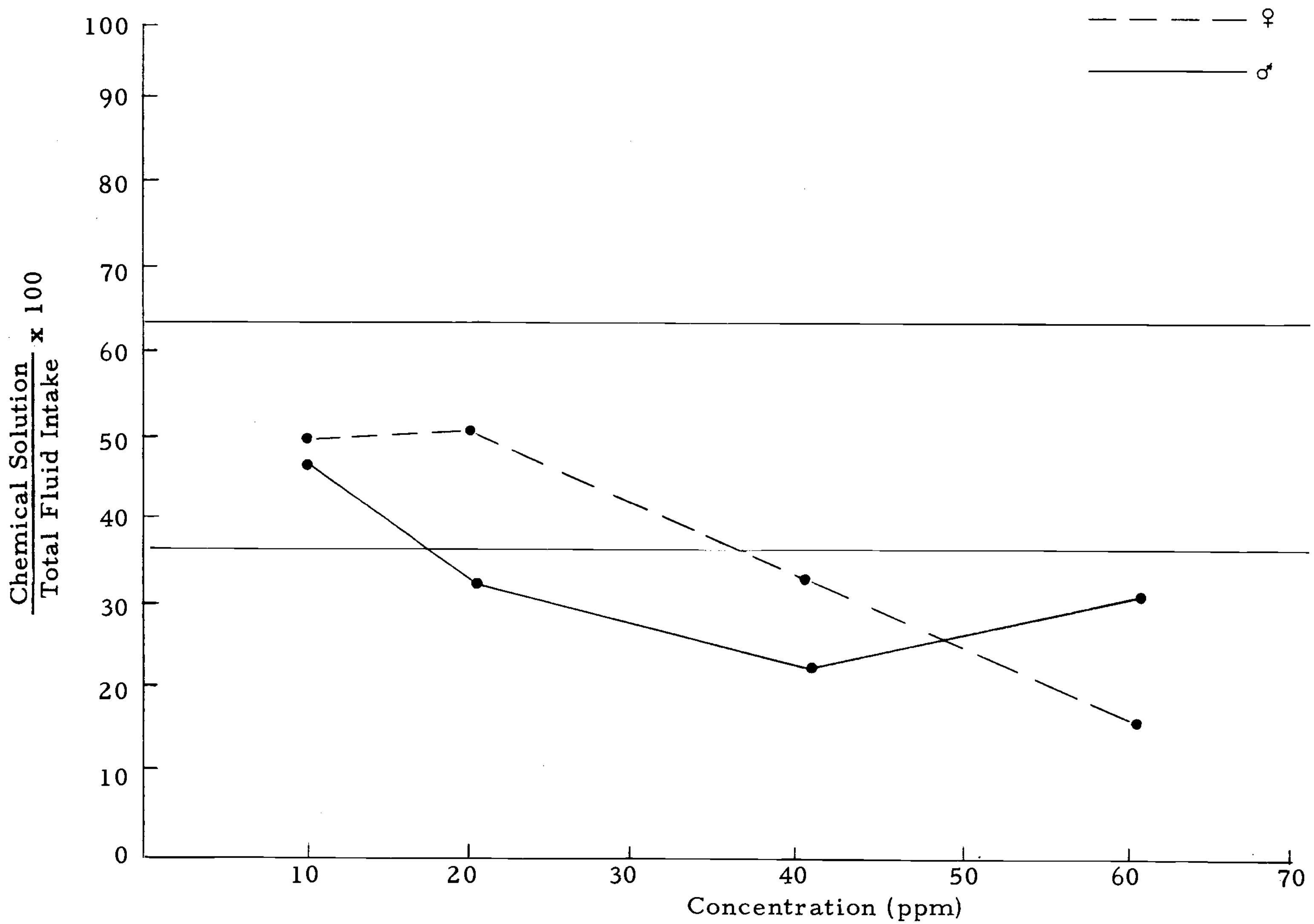
Appendix Figure 15. Average taste responses of male and female calves to increasing concentrations of $ZnCl_2$.



Appendix Figure 16. Average taste responses of male and female calves to increasing concentrations of $CoCl_2$.



Appendix Figure 17. Average taste responses of male and female calves to increasing concentrations of MoO_3.



Appendix Figure 18. Average taste responses of male and female calves to increasing concentrations of $CuCl_2$.