AN ABSTRACT OF THE THESIS OF

John S. Powley for the degree of Master of Science

in Animal Science presented on March 6, 1980

Title: Utilization of Alfalfa Meal by Non-Ruminant Animals

Redacted for Privacy

Abstract approved ______________________

Dr. P. R. Cheeke

Factors influencing the growth or feed intake of swine and poultry fed alfalfa meal-containing diets were studied. These included use of dietary additives (antibiotics and feed flavors), the effect of alfalfa saponin level, and the effect of alfalfa level and type on feed preference responses.

In Experiment 1-1 dietary alfalfa meal levels of 0, 20, 40 and 60 percent reduced ($p < .05$) the average daily gain (ADG) of pigs and increased the feed/gain ratio as dietary alfalfa increased. Back-fat thickness, dressing percent and the weight of four lean cuts decreased while loin weight and the percent of four lean cuts increased as dietary alfalfa increased ($p < .05$). Loin length and loin eye area were not influenced by changes in dietary alfalfa levels. In Experiment 1-2 a chemotherapeutic agent (ASP-250), glutamic acid and wheat bran added to a 40 percent alfalfa-containing ration influenced ($p < .05$)

ADG of pigs. In Experiment 1-3 the efficacy of ASP-250 and virginiamycin were compared at 0 and 20 percent dietary alfalfa levels. Only the comparison between 0 drug and ASP-250 showed a difference in ADG ($p < .05$). In Experiment 1-4, ASP-250 increased ($p < .05$) ADG at 0 and 30 percent dietary alfalfa. The 30 percent alfalfa-containing diet increased the feed/gain ratio and there was no drug x alfalfa interaction.

In Experiment 2-1 swine were given a choice between an alfalfa-containing control diet and the same diet with a commercial flavor added. The swine preferred ($p < .05$) the flavored diet in only 1 of 24 choices. Experiment 2-2 showed no difference ($p < .05$) in ADG when 0 and 20 percent alfalfa-containing diets and 20 percent alfalfa-containing diets with a commercial feed flavor added were compared.

In Experiment 3-1 pigs preferred ($p < .05$) the control diet when given a choice between the control diet and the control diet containing 2.5, 5.0, or 10 percent ethanol extracted alfalfa meal. In Experiment 3-2, pigs did not discriminate between diets containing ethanol extracted alfalfa and a diet containing unextracted alfalfa meal ($p < .001$), suggesting that fiber *per se* may be responsible for the low palatability of alfalfa to swine.

In Experiment 4-1 rats preferred alfalfa-free diets containing 1, 2.5, 5.0, 10 and 20 percent alfalfa meal ($p < .05$). In Experiment 4-2 the rats did not discriminate ($p < .05$) at 1 and 2.5 percent levels when given a choice between the control diet and the ethanol extracted alfalfa-containing diets. At the 5, 10 and 20 percent levels of alfalfa the rats preferred the control diet ($p < .05$). Experiment 4-3 gave rats a choice between alfalfa-containing diets. At the 1 percent level the rats did not discriminate ($p < .05$) and at 2.5, 10 and 20 percent levels the rats preferred the diet containing ethanol extracted alfalfa. In Experiment 4-4 rats did not discriminate ($p < .05$) when 1 percent cholesterol was added to diets containing high saponin alfalfa or low saponin alfalfa. The rats preferred the basal corn diet with 1 percent cholesterol added over the same diet with no cholesterol ($p < .01$).

Experiment 5-1 gave turkeys, geese, roosters and quail a choice between a control diet and the control diet with .5, 1, 2.5, 10, 20 and 30 percent alfalfa meal substituted for corn. All species preferred the control diet above the 5 percent level ($p < .05$). Experiment 5-2 compared the dietary intake of the poultry given a choice between 1, 5, 10 and 20 percent low-saponin alfalfa meal-containing diets and like percentages of high-saponin alfalfa meal-containing diets. The geese did not discriminate at any level ($p < .05$) while the other species demonstrated a mixed preference. Experiment 5-3 presented a choice for the poultry between a control diet and the control diet with .01, .05 or 1.0 percent quinine sulfate added. At the .01 percent level of added quinine the geese and quail showed no preference and the turkeys and roosters preferred the control diet ($p < .05$). At the .05 percent level the geese and roosters preferred the control diet and the turkeys and quail did not discriminate ($p < .05$). At the .10 percent level the turkeys did not discriminate while the other birds preferred the control diet ($p < .05$). These studies indicate that low levels of dietary alfalfa are unpalatable to non-ruminants, and that saponins are involved in the taste response to alfalfa. Negative responses to quinine sulfate indicate that bitterness may be a factor in the rejection of alfalfa-containing diets.

Utilization of Alfalfa Meal by Non-Ruminant Animals

by

John S. Powley

A THESIS

submitted to

Oregon State University

in partial fulfillment of the requirements for the degree of

Master of Science

Completed March 6, 1980

Commencement June 1980

APPROVED: Redacted for Privacy

Professor of Animal Science
in charge of major

Redacted for Privacy

Department Head, Animal Science

Redacted for Privacy

Dean of Graduate School

Date thesis is presented March 6, 1980

Typed by Clara Homyer for John S. Powley

ACKNOWLEDGEMENTS

To my major professor, Dr. P. R. Cheeke, I would like to express my appreciation for his assistance and patience in guiding me through my graduate program.

Appreciation is extended to Dr. George Arscott, head of the Oregon State University Poultry Science Department, and Dr. David C. England, director of the Oregon State University Swine Center, for their cooperation and assistance in conducting my research project.

I would like to thank the members of my graduate committee, Dr. James E. Oldfield, Dr. George Arscott and Dr. Phil D. Whanger.

A note of appreciation is extended to Lamont Featherland Farms of Coburg, Oregon, and Pietrus Foods, Inc. of Sleepy Eye, Minnesota, for gratuitously supplying poultry for my research.

TABLE OF CONTENTS

LIST OF TABLES

Table		Page

UTILIZATION OF ALFALFA MEAL BY NON-RUMINANT ANIMALS

INTRODUCTION

Alfalfa, a mainstay of today's agriculture, had its beginning in the United States as a humble immigrant. From its origin in the Near East and Central Asia more than 3000 years ago, alfalfa developed and spread throughout Central Asia and eventually found its way to Europe. This forage plant probably came to the Americas by way of Spain and Portugal via Mexico where it was introduced by explorers in the sixteenth century. From Mexico, alfalfa came to the Southwestern United States as early as 1836. The Gold Rush in 1849 and the pioneer movement across the continent were of paramount importance in stabilizing alfalfa as a major crop for United States stockmen. Today alfalfa is widely cultivated throughout the world and is the subject of increasing interest because of its high protein production potential.

Alfalfa has many characteristics which warrant research efforts directed toward its increased use as a non-ruminant feed. Most importantly, alfalfa produces more protein per hectare than any other forage crop, oil seed crop or grain crop grown in the United States (Akeson and Stahmann, 1966). Alfalfa protein is of high quality and comparable to that of soybean meal and animal proteins.

Alfalfa is also a good source of many vitamins and minerals. Because alfalfa is not consumed directly by humans it is a noncompetitive source of essential amino acids. This fact looms even more important as the earth's energy derived from fossil fuels finds its way to the world markets at rapidly increasing prices and many protein deficient petroleum producing and exporting nations in Africa and the Near East with increasing populations find themselves in a viable position to compete for the world's protein.

Many cultivars of alfalfa exist and have been adapted to a much wider range of environmental conditions than bean or grain crops. These many varieties increase the potential for alfalfa products and therefore increase the potential for world protein production. Alfalfa may also be harvested frequently during one growing season. If moisture is kept constant alfalfa can grow and maintain its nutritional quality through hot and cool seasons. The root system of alfalfa is extensive and may act as a subsoiler breaking up hardpan and allowing nutrients and moisture to be utilized from a large volume of soil. The root system constantly allows for fertilizer and moisture to penetrate as older roots decay and areate the soil. The alfalfa plant may also reduce the cost of its production because it is a perennial and the time and cost of replanting are reduced. The plant is also a legume that fixes nitrogen with symbiotic nodule bacteria and is adaptable to crop rotation systems. Although alfalfa has many merits, it is not used extensively as a swine or poultry feed. Factors that hinder the full potential of alfalfa as a non-ruminant feed include: 1) a high fiber content resulting in a low digestible energy content; 2) the presence of saponins and phenolic compounds which reduce animal performance; 3) low protein digestibility due to protein complexes formed with other components of alfalfa; 4) low levels of palatability for non-ruminant species.

The object of this research was to investigate possible methods of making alfalfa meal more acceptable to non-ruminants and methods to increase the utilization of ingested alfalfa meal in the non-ruminant.

LITERATURE REVIEW

Digestion of Fiber

Sheunert (1906) established the fact that pigs have the ability to digest fiber and his work has been confirmed by many investigators. This work was reviewed by Woodman (1930), Mangold (1934), Cranwell (1968) and Pond and Kass (1977). Several workers concerned with the degree and manner of utilization of fiber by swine have pointed out that the apparent digestibility may vary widely (Axelsson 1947, Homb 1948, Mangold 1934, Woodman and Evans 1947). In a comparison of various feedstuffs to woodflock, Forbes and Hamilton (1952) showed the following decreasing order of cellulose digestibilities: alfalfa meal, woodflock, wheat straw and oat hulls. In addition, metabolizable energy values, expressed as a percent of the digestible energy, show that the organic acids produced in the digestion of cellulose are highly utilizable by the animal. The variability of the effects of fiber from different sources is supported by work showing that rations containing fiber from barley hulls were less digestible than similar rations containing equivalent amounts of fiber in the form of purified wood cellulose (Larsen and Oldfield 1961). Other workers have also found that fibrous portions of feedstuffs differed in their growth depressing effects and have attributed the differences to liquification of the materials or the variation in the chemical composition of the fiber or an interaction of these two components (Crampton and Maynard 1954, Dinusson et al., 1956. Hochstetler et al., 1959). In tests designed to determine the effects of various levels of crude fiber in diets of equal metabolizable energy on average daily gain, feed gain/ratio and carcass characteristics, Baird et al., (1970) using computer balanced rations determined that it was reduced energy and not specifically crude fiber level that was responsible for differences in performances and carcass traits. They fed pigs from weaning to market weight and found that fiber level, at constant energy level, generally had no effect on rate of gain, feed gain ratio, or carcass leanness. The varying degrees of digestibility of fiber from different sources and the concomitant varying growth performance and carcass traits of swine exemplifies the fact that the apparent digestibility of crude fiber varies widely. Cranwell (1968) gives the apparent digestibility of crude fiber for pigs values from 0 to 97 percent and states that it is clear that several factors influence the extent of the process. Factors which affect the digestibility have been reviewed by the Agricultural Research Council (1967). This report enumerates and reviews the following factors: 1) Encrusting Agents. There is a clear distinction between digestibilities of lignified and non-lignified fiber in the pig. Crude fiber in beets, for example, is digested similarly in sheep and swine (78 to 90 percent), whereas in lignified feedstuffs such as concentrates, crude fiber digestibilities of 11 to 23 percent for pigs and 32 to 58 percent for sheep have been recorded. 2) Body Weight. The digestibility of crude fiber increases as the pig increases in body weight and that is usually paralleled by an increased digestibility of other nutrients. 3) Level of Feeding. Pigs being fed on a maintenance ration are prone to digest crude fiber more efficiently than pigs being fed a grower or finisher ration with higher energy. 4) Level of Crude Fiber in the Diet. The amount of fiber in the diet has little effect on its coefficient of digestibility. Crude fiber has a significant effect on the digestibility of other nutrients. The apparent digestibility of organic matter, nitrogen free extract and crude protein decreases as fiber increases. 5) Individual Variation. A standard deviation of $\pm$ 5 percent is common for pigs of similar weight to digest purified forms of cellulose. Microbial fermentation in the digestive tract of swine has been reviewed by Cranwell (1968). This review points out that fermentation takes place in all sections of the pig's alimentary tract and begins in the first week of life. The substances fermented and the byproducts depend mostly on the age of the animal, what it is fed and the section of the digestion tract where the fermentation takes place. Cellulose digestion is reported to take place completely and depend wholly on bacterial breakdown in the large intestine. In addition efficient digestion depends on regular feeding of cellulosic substrate to establish and maintain suitable flora. Further, the products of carbohydrate fermentation are mostly volatile fatty acids and lactic acid which are absorbed in all parts of the alimentary tract. Friend et al. (1962) studied the effect of diet on the proportions of volatile fatty acids in pig feces. Cellulose or dried whey were added to the control ration. The digestibility of crude fiber in the ration increased when the level of intake of cellulose supplemented ration was reduced. This finding was supported by research done by Keys et al. (1970). Differences in the proportion of acetic, butyric and valeric acid occurred with different levels of dietary cellulose. The whey and the bran-supplemented rations also differed in the proportions of fecal valeric, propionic or acetic acid. The proportions of fecal VFA were relatively unaffected by the age and/or weight of pigs from weaning to market weight. Friend et al. (1963) also looked at the effect of diet on VFA and lactic acid in sections of the alimentary tract of pigs. These workers fed either a cellulose-bran, or dried whey supplemented diet before slaughter. The cellulose-supplemented diet generally gave a lower total organic acid content than the control diet for each section of alimentary tract examined. When the control diet was supplemented with either bran or dried whey, formic acid was found only in the stomach and small intestine of the pig. The digesta of the small intestine gave the lowest total concentration of organic acid. This work showed that the concentration of acid in the cecum of the control pigs was nearly twice that reported for the cecum of cattle. In addition, the proportion of lactic acid decreased progressively as the digesta passed along the digestive tract. The results showed that the type of ration and the location along the tract significantly affected the proportions of acids.

Friend et al. (1964) examined the VFA and lactic acid content of pig blood and stated that acetic, proprionic and butyric acids could provide from 15 to 28 percent of maintenance energy requirements. Thus there is evidence that the pig can utilize the fibrous portions of plants; fermentation of carbohydrates takes place producing organic acids which can be utilized.

Utilization of Alfalfa

Snyder (1907) reported that alfalfa pasture and fresh water supported .23 kg daily gain in pigs and suggested a more favorable performance of swine fed an alfalfa pasture as compared to pigs fed the same amount of alfalfa in confinement. Bohman et al. (1953) fed swine from 10 to 60 percent alfalfa and reported no significant difference in rate of gain from 10 to 30 percent alfalfa and fair gains for animals fed 50 percent alfalfa as compared to animals fed 10 percent alfalfa. Kidwell and Hunter (1956) studied alfalfa utilization by growing-fattening swine fed a 40 percent alfalfa-containing ration. The results indicate that at 50 percent alfalfa, 1 kg of alfalfa will replace .5 kg of concentrate. Research designed to study the nutritive value of dehydrated alfalfa meal fed at various levels to growing-finishing swine was conducted by Becker et al. (1956). Pigs fed a low protein (8.8 percent) diet, which did not support optimal gains, were supplemented with 10 or 20 percent alfalfa meal. Ten or twenty percent alfalfa meal did not provide enough supplemental protein and did not increase gains. Supplementation with 30 to 40 percent alfalfa meal significantly depressed the rate of gain and increased the feed gain ratio. When optimal levels of protein were fed, dietary levels of alfalfa meal of 20 percent or greater depressed the rate of gain and efficiency of gain. When alfalfa meal was used to replace 20 or 30 percent of the corn the increase in feed/gain ratio but not the decrease in average daily gain was completely eliminated when the ration was balanced for nutrient content by the addition of corn oil. Hanson et al (1956) studied the nature of the inhibitory effect of dehydrated alfalfa meal on the rate of gain and the efficiency of gain in swine. They fed 15 or 30 percent alfalfa to replace yellow corn in the diet, and refined corn oil to yield a calculated TDN value equal to the control diet either *ad libitum* or on an equal feeding basis. They concluded that the majority of growth-depressing effects of dehydrated alfalfa meal is due to the lowered TDN content of the diet and to a lowered feed intake by the animal. Heitman and Meyer (1959) looked further at alfalfa meal as a source of energy for swine and fed levels of 5, 20 and 40 percent alfalfa meal from three stages of maturity and three methods of preparation (suncured, dehydrated and pelleted dehydrated and reground). They observed that average daily gain, feed consumption and feed efficiency were reduced by increased levels of alfalfa. Average daily gain was less on rations containing sun cured meal and the stage of maturity had no effect. Using gains adjusted to equal feed consumption these workers determined that the average replacement value for 1 kg. of the alfalfa was 0.28 kg. of concentrate. This value is 56 percent of the value (.5 kg concentrate/kg alfalfa) reported by Kidwell and Hunter (1956).

Evidence has been presented by Snyder (1930), Rasmussen *et al*. (1942) and Hudman and Peo (1960) that suggests a better performance of pigs fed alfalfa on pasture rather than in confinement. Danielson *et al*. (1969) developed a method for estimating intake as well as nutrient utilization of alfalfa pasture by growing-finishing swine when fed diets differing in their content of dehydrated alfalfa meal. They fed pigs in confinement or pigs on alfalfa pasture pelleted diets in which dehydrated alfalfa meal was substituted for 0, 2, 4, 8, 16, and 32 percent of the corn. Levels of 0 to 16 percent dehydrated alfalfa meal did not significantly affect average daily gain but 32 percent dehydrated alfalfa meal reduced daily gain as did the experimental diets on alfalfa pasture. Feed/gain ratio increased as the level of alfalfa increased in the diet. The location (pasture vs. confinement) made no difference in feed/gain ratio. They determined that the lack of statistically significant interaction between location and the levels of added dehydrated alfalfa meal in the pelleted diets indicates that the same response from adding dehydrated alfalfa meal to swine diets would be expected on alfalfa pasture as in confinement.

The inhibitory effect of high levels of alfalfa on the rate of gain of growing-finishing swine has been demonstrated by several researchers as well as the beneficial aspect of feeding swine lower levels of alfalfa meal. The value of feeding low levels of alfalfa and the inhibitory effects on growth of feeding high levels can be combined in feeding gravid swine.

Alfalfa-Containing Rations for Gravid Swine

The value of using roughages to decrease the amount of grain concentrate and concommitantly the reduction in cost of gestation rations seems evident and has been recognized for several decades. Carroll (1936) and Peo (1975) suggest that by feeding alfalfa to dry or gestating swine a 50 percent reduction in grain cost could be achieved with no adverse effects on reproduction. Teague (1955) and Cunha et al. (1944) have noted that alfalfa is most beneficial during the reproductive stage by increasing ovulation rate and litter size at birth. Fairbanks et al. (1944) designed research to study the effect of alfalfa meal and dried corn distillers solubles when fed as natural carriers of B vitamins in gestation-lactation rations for swine. These researchers concluded that: 1) a basal ration composed of yellow corn, soybean meal, tankage, fish meal, fortified cod liver oil and minerals was nutritionally inadequate for gestation and lactation under drylot conditions; 2) The addition of alfalfa meal, dried corn distillers solubles, a combination of these two or six crystalline B-vitamins improved breeding efficiency, fertility and the strength of the pigs farrowed; 3) Nutrition is an important factor during gestation for satisfactory results during lactation, especially when considering the question of high mortality among neonatal pigs; 4) 13 and 7 percent of the pigs were weaned by the sows on a basal ration, while 83 and 82 percent of the pigs were weaned by sows fed alfalfa meal during gestation and basal during lactation. Sows fed the combination of 6 percent solubles and 4 percent alfalfa meal during gestation weaned 85 percent of their pigs although they were fed the basal ration during lactation. The six crystalline B vitamins were effective in supplementing the basal ration but did not manifest themselves to the same degree as the ration where alfalfa or the combination was used; 5) In the interpretation of the differences in lactation performance, the gestation and even the growth period ration should be considered.

Self et al. (1960) conducted research over a three year period with 90 weanling pigs grown at three different levels of feed. Group one was fed on one-third acre alfalfa-brome-ladino pasture plus an ad libitum balanced corn, soybean meal ration. Group two was fed on two-thirds acre and hand fed two-thirds of the daily intake of the same ration as group 1. Group three was fed on one acre of the pasture and hand fed one-third of daily intake of the same ration in group one. Reproductive traits (litter size, birth weight, weaning weight and number of pigs weaned) were analyzed in 36 litters. None of these traits was affected by the three feeding levels. Danielson and Noonan (1975) studied the value of alfalfa for gestation diets when added at levels higher than the levels previously reviewed. Three experiments were conducted utilizing

204 crossbred gilts to compare 25, 33, 66, and 96.75 percent alfalfa hay, 66 percent prairie hay and 23 percent dehydrated alfalfa meal. In all three studies the diet containing the highest level of alfalfa hay produced the greatest percentage of gilts farrowing. Consequently, the highest total pig weight weaned per diet occurred with the highest level of alfalfa.

These studies indicate that alfalfa hay could be economically efficacious when fed at high levels to lactating swine. Allee (1976) self-fed two trials of 47 second litter sows 96 percent dehydrated alfalfa meal during gestation. The control gestation diet (15 percent protein milo-soybean meal) was fed in individual feeding stalls at a rate of 2 kg per head per day. All sows were fed a 16 percent ration *ad libitum* during lactation. Reproductive performance of the combined trials show small and nonsignificant differences in the number of pigs born alive, birth weight, number weaned per litter and 14 to 28 day pig weights. The average weight gain of the self-fed sows was 27.35 kg and the control sows gained an average of 35.50 kg suggesting that sows can be self-fed during gestation without excessive weight gain.

Pollmann *et al.* (1979) conducted a study to determine the effect of feeding high levels of various roughages on the utilization of nitrogen, energy and fiber by pregnant sows. The diets were a 97 percent sun-cured alfalfa, a

66 percent tall wheatgrass and a conventional corn-soybean meal diets. Water consumption, backfat depletion, pregnancy weight gain and reproductive performance were used as response criteria. The corn-soybean meal group gained more weight and had a greater amount of backfat than those fed high fiber diets during gestation. Sows in the corn-soybean meal group retained more nitrogen than those in the alfalfa and tall wheatgrass groups.

A period X treatment interaction was observed for dry matter digestibility. The sows on the high fiber diets showed decreased dry matter digestibility from day 0 to day 30 and then increased 3.0 percent (alfalfa) and 2.8 percent (tall wheatgrass) to day 80 of gestation. The corn-soybean meal group showed an increase in dry matter digestibility slightly above the base at 30 days and then a decrease of 2.7 percent at 80 days. Thus it appears that as the digestive system became more accustomed to the fibrous diets, more nutrients from the diets were utilized. As the fiber content of the diets increased, digestibility of the fiber components, utilization of energy and retention of nitrogen decreased.

Several methods to enhance the utilization of alfalfa by swine have been studied, including the use of antibiotics, feed flavors or masking agents, alteration of particle size, feeding lactose with alfalfa and other treatments.

Antibiotics

A possible effect of dietary antibiotics on the utilization of fibrous feeds by non-ruminants can be rationalized. Alterations in gut microflora could result in more effective fiber digestion, for instance, if the population of cellulolytic organisms were increased. Relatively few studies have been made in this area.

Bohman *et al*. (1953) reported that feeding terramycin in a diet with 20 percent alfalfa failed to give growth response. In further studies, Bohman *et al*. (1955) found that dietary aureomycin improved rate gain and feed conversion when fed with alfalfa-containing diets (10, 30, and 50 percent alfalfa).

Castell (1977) fed pigs from 10 to 95 kg liveweight to examine the effects of including virginiamycin at 0 and 1.102 g/100 kg of diet, in starter and grower diets containing a low-glucosinolate rapeseed meal or soybean meal. He showed that the inclusion of virginiamycin did not significantly influence average daily feed intake although there was a trend toward higher consumption when the diet contained the antibiotic. It was further shown that growth rates were significantly increased by virginiamycin supplementation in the starter and grower diets and that although the protein source X virginiamycin interactions were not significant, the growth-promoting effect of virginiamycin appeared to be greater with the soybean meal diets in the starter period than when the rapeseed meal diets were fed in the starter period. Carcass measurements showed no apparent adverse effects which could be attributed to virginiamycin supplementation.

March _et al_. (1978) fed broilers virginiamycin at a dietary concentration of 22 ppm which stimulated growth rate and improved feed efficiency. The diets involved the use of wheat vs corn as principal dietary cereal, different levels of fat and different levels of protein. All the diets supported similar performance and there were no significant interactions in response between diet and antibiotic.

It is possible that additional factors may influence the growth response of non-ruminants fed antimicrobials with high fiber diets. Leibrandt and Becker (1977) fed pigs a basal corn-soybean meal diet and the basal diet supplemented with several antimicrobials. Rates of gain and feed efficiency were similar for all treatments. This study was conducted with a herd derived from specific pathogen free stock and maintained as a closed herd in a new facility not previously used for swine production so the disease load was low.

Many research projects have been conducted to evaluate the efficacy of antibiotics as growth promotants for non-ruminants and relatively few designed to evaluate antibiotic X fiber interaction. However, it is evident that many factors enter into the final response that is achieved. In swine alone the magnitude of response has varied from 0 to over 100 percent (Burnside et al., 1949).

Feed Flavors

Several components of alfalfa, singly or in combination, may contribute to its low palatability for non-ruminants. These components include saponins, phenolics, products of heat damage, sugars, minerals, coumesterol, amino acids, non-protein nitrogen compounds, organic acids and plant pigments (LeaMaster 1978). A relationship exists between the chemical composition of plants and their palatability. Protein (Hardison et al., 1954), carbohydrates and sugars (Hanson et al., 1954) and fat content (Blaser et al., 1960) have been shown to positively affect preference by animals. However, chemical properties (taste, smell, and flavor) of a plant are not alone in inducing acceptance or rejection by an animal. Temperature, texture, feel, appearance and density of a feed, climate, soil and topography of the surroundings where the plant is grown or eaten, previous exposure to or experience with the plant, species, breed, age physiological or nutritional state and the senses of the animal ingesting the feed may also contribute to palatability.

Many research projects have been undertaken to determine what factor(s) cause non-ruminants to accept or reject plants or diets. While many factors enter into the final choice of the animal, numerous single factors of certain plants or classes of plants appear major determinants of response. Little is known about the responses of animals to factors known to humans and animal response should not be evaluated solely by human response to the components of plants. Kare (1961) points out that the presence of taste buds and the ability to discriminate between chemical solutions are certainly not evidence that an animal shares man's taste sensations and we cannot consider lower animals as a living replica of man's sensory world. This author also points out that laboratory and domestic animals have for generations been bred without selection for their ability to taste, although it might be argued that selection for improved animal performance might involve those individuals which most readily consume current feedstuffs.

Kare et al., (1965) observed the reactions to compounds, usually described as sweet by man, by pigs. Using 38 pigs it was determined that substantial individual variation exists in their behavioral reaction to saccharin solutions. This taste reaction to saccharin was neither related to the taste response of the pig to other compounds nor substantially influenced by prior taste experience. The pig exhibits a preference behavior for sugars described as sweet by man and the responses to specific compounds show differences in degree between individuals and absolute differences among species.

Kare (1961) showed that the fowl on an adequate diet is indifferent to sucrose in a choice situation while the calf prefers sugar. Also, the fowl is aversive to saccharin and the calf is indifferent while the rat prefers a wide range of concentrations. Kare *et al.*, (1957) and Duncan (1960) have shown that some animals will fail to respond to a concentration of chemical which is readily detected by other animals of the same species. Kare and Ficken (1963) found that in some instances this phenomenon, referred to as "taste blindness," is chemically specific rather than related to a general inability to taste. It further has been observed that baby pigs preferred diets containing saccharin to diets containing no saccharin (Aldinger *et al.*, 1959) and in contrast that synthetic sweetness reduced the acceptance of a ration (Grimsted *et al.*, 1960).

Kare *et al.*, (1957) evaluated flavors in drinking water by testing 4,000 chicks. Thirty-two flavors were screened against tap water. From these tests it was determined that chicks have a sense of taste and that this sense is more than rudimentary. Further, the chicks' response to a variety of sweet and bitter flavors suggests that the broad classifications of taste recognized by man are not applicable to the domestic fowl.

Previous exposure or experience in some cases has been shown to influence response in animals. A flavoring agent (Firanor No. 3) designed to be transferred into the sow's milk when fed during lactation produced significant response by pigs during the first three weeks after weaning (Campbell, 1976). Gains and feed intakes of the weaned pigs were significantly greater when both sow and weaner pig diets contained the flavor than when the flavor was omitted from one or both of the diets. This suggests that the transfer of the flavor component to the suckling pigs may "imprint" a preference for the flavor when it is later offered in a diet.

Kennedy (1978) conducted three separate experiments to examine the effects of familiarization processes on dietary preferences in pigs and poultry. The first experiment looked at the responses to a novel raw material, guar meal (Cyamopsis tetragonobola), within a herd of sows. The second experiment looked at preference development in poultry to determine the effects of immediate post-hatching experience on diet color response. The third experiment was conducted with 22 sows and 238 piglets to study the hypothesis that flavor components of the dam's diet pass into her milk and are perceived by the suckling young, who then develop a preference for those flavors and select in favor of them after weaning. The responses of the sows in experiment 1 to a novel raw material indicated that refusals of the new diet tended to be confined to its first introduction. The diet color preferences of poultry were also shown to be subject to the effects of early feeding experience. The third experiment did not show it was possible to achieve early dietary conditioning in suckling pigs by the transfer of flavor to the milk of the lactating sow. Relatively little quantitative information is available on the sense of taste in the pig. The taste preferences of groups of young pigs have been examined by Kare _et al._, (1965) and the effects of adding sweetners to the diets of pigs has been studied by Diaz _et al._, (1956), Aldinger _et al._, (1959) and Kennedy and Baldwin (1972).

Cheeke (1976) reviewed the nutritional and physiological properties of alfalfa saponins in non-ruminant animals. It is his opinion that one of the major factors limiting the use of alfalfa by most non-ruminant animals is that they reject diets containing alfalfa, presumably because of the bitter taste of saponin. Cheeke _et al._, (1977) evaluated alfalfa samples with low (.4 percent) and high (1.7 percent) saponin contents in diets for rats, rabbits, and swine. Growth studies and pair-feeding and feed preference trials were conducted. The results indicate that low saponin alfalfa supports a higher growth rate in swine and rats than high saponin alfalfa. The pair-feeding and preference trials suggest that increased palatability of low saponin alfalfa is the major factor involved. LeaMaster and Cheeke (1979) conducted two-choice feed preference tests showing that growing swine preferred alfalfa-free diets over diets containing alfalfa at alfalfa levels of 1 percent and higher. They also selected diets containing low saponin alfalfa over the same dietary level of high saponin alfalfa but rejected both in favor of an alfalfa free diet. Further, growing swine discriminated against quinine sulfate at all dietary levels above .05 percent. These researchers conclude that swine are sensitive to bitterness and it is possible that the rejection of alfalfa is due to its bitter taste.

A minimal amount of work has been done pertaining to feeding flavoring agents to swine to improve acceptance of unpalatable feeds. Robel (1979) fed weanling pigs under controlled environmental conditions isocaloric diets containing 26 and 34 percent protein (soybean meal) with or without the addition of a flavoring mixture. (Pig Nector #2-7123, Flavor Corporation of America Division, Northbrook, Ill. 60062). Addition of the flavoring mixture to the 26 and 34 percent protein diets did not increase dietary intake. Zivkovic _et al._, (1978) conducted a series of experiments on two large-scale pig farms to determine the effect of flavor addition to the ration of piglets and growers. These workers found that: 1) supplementation of the prestarter diets with flavors increased solid feed intake and improved the daily gain rate in piglets on the sow; 2) supplementation of starter diets with flavor gave no satisfactory results; 3) flavors had a positive effect on the performance of growers during the first 14 days of feeding. The experiment duration was 58 days.

Jacobs et al. (1978) determined that there are many factors and combinations of these factors which are involved in the preferences for and aversions to feeds by animals. Animals exhibit inherent preferences, conditioned aversions, neophilia and neophobia and that the genetic background and growth environment of an animal must be considered when doing flavor research.

Dietary Lactose and Fiber Interactions

Stangel (1972) hypothesized that the inclusion of lactose might increase fiber digestion through stimulation of bacterial growth in the large intestine leading to improved animal performance. Since lactose is only slightly digested in the small intestine, because of inadequate lactase secretion, it is digested in the large intestine by bacterial action. Diets with 10 percent whey with and without 20 percent alfalfa were compared. The addition of whey did not improve the utilization of alfalfa.

Cheeke and Stangel (1973) showed that when 10 percent dried whey and 20 percent alfalfa were fed to pigs the growth rate and feed efficiency were less than either treatment alone suggesting a possible antagonism between alfalfa and whey. They also showed that feeding lactose, a major component of whey, to rats reduced the digestibility of alfalfa fiber. In addition, feeding 10 or 20 percent lactose did not influence the growth performance of rats but with 30 percent lactose the growth rates of rats were significantly reduced.

Alteration of Particle Size

Bohman *et al.*, (1955) fed a 50 percent alfalfa-grain mixture as pellets and meal. When a pelleted ration containing 50 percent alfalfa was fed to growing-finishing swine there was a significant increase in rate of gain as compared with the gain of swine fed the same mixture ground. Less feed was required per kg of gain while there was no difference in feed wastage between the two groups. The pellet fed group actually consumed less feed than the group fed the ground-feed mixture.

Part One: Various Additives and Antibiotics in Alfalfa-Containing Diets

Objectives

The objectives of this experiment were:

1) To determine growth response and carcass characteristics of pigs fed diets containing various amounts of alfalfa.
2) To determine growth response of pigs fed bentonite, glutamic acid and wheat bran in alfalfa containing diets.
3) To compare the efficacy of virginiamycin* and ASP-250** in alfalfa containing diets.
4) To determine if antibiotic response is influenced by dietary fiber level.

Experimental Procedure

Four experiments with pigs were conducted. In the

*Virginiamycin--growth promotant and antibiotic produced by Smith Kline Corporation from the mold Streptomyces virginiae.

**ASP-250--growth promotant and antibiotic containing aureomycin, sulfamethadine and penicillin produced by American Cyanamid, Inc., Princeton, N.J.

first experiment growth rate, feed efficiency, and carcass characteristics of pigs fed varying percentages of alfalfa in barley based rations were studied. Experiment two was conducted with pigs fed a 40 percent alfalfa-containing ration with various additives. Experiment three was done with pigs fed 20 percent alfalfa-containing wheat based diets with ASP-250 or Virginiamycin. Experiment four was done with pigs fed a control ration and the control ration containing 30 percent suncured alfalfa, with or without ASP-250.

Experiment 1-1

This experiment was designed to evaluate the performance of growing-finishing swine fed varying percentages of alfalfa meal, and to determine any operational or health problems which may occur with high levels of dietary alfalfa.

Eighty Yorkshire pigs were divided into two replicates of forty pigs each. Each replicate was divided into four pens of 10 pigs each and assigned diets containing 0, 20, 40, or 60 percent alfalfa as described in Table 1. The solid concrete floor pens measured 1.52m x 4.85m and contained a self feeder, automatic waterer and a self-flushing gutter. Pigs in this experiment were put on test at a weight from 50 to 57 kg and terminated at approximately 100 kg.

Table 1

Percentage Composition Of Swine Rations
Experiment 1-1

Ingredient	Percent			
sun-cured alfalfa meal	-	20.0	40.0	60.0
barley	79.0	60.0	40.5	20.5
soybean meal	13.0	13.0	13.0	13.0
tracemineralized salt	.5	.5	.5	.5
bentonite	2.0	2.0	2.0	2.0
molasses	3.0	3.0	3.0	3.0
dicalcium phosphate	1.0	1.0	-	-
lime stone	1.5	.5	-	-
monosodium phosphate	-	-	1.0	1.0
vitamin A	1,500,000IU	-	-	-
vitamin D	200,000IU	200,000IU	200,000IU	200,000IU
vitamin B12	12µg	12µg	12µg	12µg
zinc sulfate	341g	341g	341g	341g

Results

The average daily gains, feed efficiency, average daily feed intake and estimated daily digestible energy intake of the market hogs are shown in Table 2. An analysis of variance was done for average daily gain and feed efficiency and showed significant differences in both instances ($p < .05$). The Student Newman-Keuls Multiple Range Test indicated that all comparisons were statistically significant ($p < .05$) for the average daily gain and for the feed efficiency measurements. An analysis of variance was done for average daily feed intake means which showed no statistical difference between means.

Table 2

Performance of Growing Swine Fed Various Dietary Levels of Alfalfa, Experiment 1-1

Percent Alfalfa	ADG (kg)	SD	F.E.	Average Daily Feed Intake (kg)	Estimated Daily DE Intake (kcal)
0.0	.86[a]	.13	3.66[a]	3.05[a]	8913
20.0	.73[b]	.27	4.05[b]	2.97[a]	7800
40.0	.63[c]	.17	5.11[c]	3.17[a]	7399
60.0	.41[d]	.24	6.41[d]	2.73[a]	5495

Unlike superscripts differ in columns ($p < .05$)

Rate of gain decreased and feed required per kg of gain increased as the level of alfalfa in the diet increased. These results are expected because of the low digestible energy content of the rations. The energy content per kg of diet decreased from 2922 kcal to 2012 kcal as the percentage of alfalfa in the diet increased from 0 to 60 percent. Average daily feed intake did not increase, as the energy level of the diet decreased, indicating an aversion for the high fiber diets. Pigs on the 40 and 60 percent alfalfa levels had loose watery feces. The fecal material was bright green in color. Because of the watery feces, the pens of the pigs fed high alfalfa were wet, and the pigs were green from contamination with feces. Compared to the control group, the pigs fed alfalfa were hyperactive, especially when being driven to the scales for weighing. The significance of these observations is unknown, but the difference in behavior of the market hogs is shown in Table 3.

An analysis of variance was done for the following six measurements: loin length, average backfat thickness, loin eye area, loin weight, percent of four lean cuts, and dressing percent. Significant statistical differences were indicated for all measurements except for loin length and loin eye area (p .05). Backfat thickness and dressing percent decreased as dietary alfalfa increased and loin weight and the percent of the four lean cuts decreased as dietary alfalfa increased.

The average slaughter weight of the market hogs decreased even though the average number of days on feed increased as dietary alfalfa increased. This can be explained by the lower energy content of the higher fiber diets and the apparent aversion of the pigs to the higher fiber diets which resulted in the failure of the animals to increase their average daily feed intake as fiber content increased and energy decreased. Carcass weight expressed as a percent of live weight decreased as dietary fiber increased and can be accounted for by the increased size and weight of the gut of the hogs as they became accustomed to the higher fiber diets. Because of adequate levels of protein in all diets, the loin length and the loin eye area did not change with increasing fiber and

Table 3

Carcass Information of Pigs Fed Varying
Percentages of Alfalfa, Experiment 1-1

		Percentages of Alfalfa in Rations			
		0	20	40	60
Number of Pigs		18	17	18	19
Days on Feed	mean	54.83	60.42	66.15	72.80
	SD	7.3	4.79	6.61	10.51
Live Weight (kg)	mean	99.22	99.40	92.73	89.34
	SD	3.74	4.75	4.90	5.06
Carcass Weight as Percent of Live		77.88	76.54	75.24	73.70
Loin Length (cm)	mean	79.02[a]	79.00[a]	78.81[a]	78.84[a]
	SD	.88	.93	.53	.93
Average Backfat (cm)	mean	3.93[a]	3.53[bc]	3.19[cd]	2.94[d]
	SD	.61	.50	.47	.58
Loin Eye Area (cm^2)	mean	29.31[a]	30.66[a]	30.24[a]	28.62[a]
	SD	3.39	4.72	3.69	3.68
Loin Weight (kg)	mean	11.85[ab]	12.05[a]	11.21[bc]	11.01[c]
	SD	1.00	1.03	.89	.97
Percent 4 Lean Cuts	mean	52.39[a]	54.06[ab]	55.22[bc]	57.48[d]
	SD	3.41	2.49	3.82	4.12
Dressing Percent	mean	77.89[a]	76.16[bc]	75.42[cd]	75.16[d]
	SD	1.59	3.07	2.40	1.93

Unlike superscripts differ in rows ($p < .05$)

decreasing energy. Average backfat thickness decreased as fiber content of the diets increased due primarily to decreasing energy levels as the fiber increased. Loin weight changed very little as fiber increased but the trend toward lighter loin weight is probably due to lighter live weights at slaughter and less fat deposition. The percent of the four lean cuts increased as dietary fiber decreased indicating a leaner carcass as the dietary alfalfa increased from 0 to 60 percent. Dressing percent decreased as dietary fiber increased and appears to be a function of the increased gut size of the market hogs as dietary fiber increased.

Experiment 1-2

The primary purpose of this experiment was to investigate use of dietary additives to improve performance of pigs fed diets containing high levels of alfalfa. One reason for reduced consumption may be that pigs find alfalfa unpalatable. Glutamic acid was included as a means of masking a possible bitter taste. Since some pigs scoured at 40 and 60 percent alfalfa, bentonite and bran were included as possible absorbers of fluid in the digestive tract. The antibiotic treatment (ASP-250) was included to determine if modification of intestinal flora might increase the ability of the pig to utilize high alfalfa levels.

Ninety-six Yorkshire pigs were divided into two replications of forty-eight pigs each. Each replicate was divided into six pens of eight pigs (four barrows and four gilts). Treatments were as follows: 1) control, 2) 40 percent alfalfa, 3) 40 percent alfalfa plus ASP-250, 4) 40 percent alfalfa plus 5 percent bentonite, 5) 40 percent alfalfa plus 1.3 percent glutamic acid, 6) 40 percent alfalfa plus 10 percent wheat bran. Diet composition is shown in Table 4. The pigs were housed in solid concrete floor pens which measured 1.52m x 4.85m and were equipped with an automatic waterer, an *ad libitum* feeder and a self flushing gutter. The animals were put on test at weights between 50 and 57 kg and terminated at approximately 91 kg.

Table 4

Percentage Composition of Swine Diets
Experiment 1-2

Ingredient	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6
Sun cured alfalfa	-	40.0	40.0	40.0	40.0	40.0
Barley	77.0	38.5	38.3	35.5	38.2	28.5
Soybean meal	15.0	15.0	15.0	15.0	15.0	15.0
Tracemineralized salt	.5	.5	.5	.5	.5	.5
Bentonite	2.0	2.0	2.0	5.0	2.0	2.0
Molasses	3.0	3.0	3.0	3.0	3.0	3.0
Dicalcium	1.0	1.0	1.0	1.0	1.0	1.0
Phosphate limestone	1.5	1.5	1.5	1.5	1.5	1.5
Monosodium	-	1.0	1.0	1.0	1.0	1.0
Phosphate wheat bran	-	-	-	-	-	10.0
Glutamic acid	-	-	-	-	.3	-
ASP-250	-	-	.5	-	-	-
Vitamin A	1,500,000IU	-	-	-	-	-
Vitamin D	200,000IU	200,000IU	200,000IU	200,000IU	200,000IU	200,000IU
Vitamin B12	12µg	12µg	12µg	12µg	12µg	12µg
Zinc sulfate	341gm	341gm	341gm	341gm	341gm	341gm

Results

An analysis of variance was done for average daily gain. Means for average daily gain and feed efficiency are tabulated in Table 5. The group feeding design did not allow sufficient data for an analysis of variance for feed efficiency.

Table 5

Average Daily Gain and Feed Efficiency of Pigs Fed 40 Percent Alfalfa With Various Additives, Experiment 1-2

Ration	ADG (kg)	F.E.
0.0% alfalfa	$.87^{a}$	3.34
40.0% alfalfa		
a. no additives	$.64^{b}$	4.52
b. ASP-250 (341 gm/ton)	$.69^{c}$	4.19
c. bentonite (5%)	$.65^{b}$	5.53
d. glutamic acid (.3%)	$.61^{d}$	4.18
e. wheat bran (10%)	$.58^{e}$	5.17

Different superscripts differ significantly ($p < .05$)

Means for average daily gain differ significantly ($p < .05$). These means were subjected to the Student Neuman-Keuls Multiple Range Test which showed fourteen significant differences out of a total of fifteen possible comparisons. Treatment 2 (40 percent alfalfa with no additives) and treatment 4 (5.0 percent bentonite) did not differ statistically ($p < .05$). Glutamic acid does not show promise as a means of masking the bitterness of alfalfa. However, the improved performance with ASP-250 supplementation is of interest.

Experiment 1-3

This work was designed to further examine antibiotic response in growing-finishing swine as well as to compare the efficacy of virginiamycin when compared to ASP-250 in rations containing a fixed percentage of sun-cured alfalfa meal. In addition, low levels of antibiotics fed growing-finishing swine may enhance the utilization of fiber by swine by advantageously altering the gut micro flora of swine.

One hundred ninety-two pigs were divided into four replicates of forty-eight pigs each. Each replicate was divided into six pens of eight pigs each (four barrows and four gilts). Each replicate was further divided into drug assignments of no drugs, virginiamycin or ASP-250 with or without 20 percent alfalfa. Virginiamycin was fed at 10 g/ton in the grower phase and 25 g/ton during the finisher phase. ASP-250 was fed at 250 g/ton the entire feeding period.

Rations as described in Table 6 and 7 were changed from grower to finisher when the average pen weight reached approximately 50 kg. The pigs were put on test after a week of pen acclimation at pen weights which varied from 10 to 17 kg. The animals were housed in solid concrete

Table 6

Composition of Swine Diet (Grower)
Experiment 1-3

	Percentage Composition	
	Low Fiber	20% Alfalfa
Wheat	77.0	57.3
Soybean meal	18.0	18.0
Sun-cured alfalfa meal	-	20.0
Bentonite	2.0	2.0
Trace mineralized salt[a]	0.5	0.5
Dicalcium phosphate	1.0	1.5
Limestone	1.5	0.5
Vitamin mix (2.27kg/ton)[b]		
Zinc supplement (150 g/ton)[c]		

Table 7

Composition of Swine Diet (Finisher)
Experiment 1-3

	Percentage Composition	
	Low Fiber	20% Alfalfa
Wheat	82.0	62.5
Soybean meal	13.0	13.0
Sun-cured alfalfa meal	-	20.0
Bentonite	2.0	2.0
Trace mineralized salt[a]	0.5	0.5
Dicalcium phosphate	1.0	1.5
Limestone	1.5	0.5
Vitamin mix (2.27kg/ton)[b]		
Zinc supplement (150 g/ton[c]		

[a]In addition to NaCl, provides the following element levels (mg/kg diet): Zn, 17.5; Mn, 14.0; Fe, 8.75; Cu, 1.75; I, 0.35; Co, 0.35.

[b]Ingredients per kg mix: Vitamin A, 1,320,000 USP Units; Vitamin D-3, 440,000 IC Units; Vitamin E, 440 I Units; Vitamin K (MSBC), 2,000 mg/ Vitamin B-12, 4.40 mg; Riboflavin, 1.760 mg; Pantothenic acid, 3.238 mg; Niacin, 8.800 mg; Choline Chloride, 110,000 mg; Ethoxyquin, 24.97 gm; Manganese, 24 gm; Zinc, 40 gm; Iron, 8 gm; Copper, 0.8 gm; Iodine, 0.48 gm; Cobalt, 0.08 gm; Selenium, 39.60 mg.

[c]$ZnSo_4$

floor pens which measured 1.52m x 4.85m. The pens were equipped with a self-feeder and an automatic waterer.

Results

An analysis of variance was done with two independant variables--two levels of alfalfa and the feed additives. In addition a covariate analysis was done with the covariates sex and initial weight. Corrected means were compared by the Neuman-Keuls method. Corrected means are presented in Table 8 and 9. The average daily gain analysis showed no significant statistical difference between means for the finisher phase. The grower phase showed no statistical difference between the means for zero drug and virginiamycin nor between virginiamycin and ASP-250. However, the difference between zero drug and ASP-250 was significant ($p < .05$). Twenty percent alfalfa did not affect growth rate. There were no statistical differences between the drug treatments for feed/gain ratio but 20 percent alfalfa did significantly increase the feed/gain ratio. There was no alfalfa x drug interaction. The covariate analysis of sex and initial weight showed significant differences with the younger pigs showing slightly more response to the antibiotic and the barrows showing overall a higher average daily gain.

Table 8

Average Daily Gain of Pigs Fed Antibiotics
Experiment 1-3

	Grower		Finisher	
Drug	Low Fiber	20% Alfalfa	Low Fiber	20% Alfalfa
0	.72[a]	.67[a]	.80[a]	.86[a]
Virginia-mycin	.71[ab]	.73[ab]	.80[a]	.79[a]
ASP-250	.75[b]	.75[b]	.85[a]	.83[a]

Unlike superscripts differ in columns ($p < .05$)

Table 9

Feed Efficiency of Pigs Fed Antibiotics
Experiment 1-3

	Grower		Finisher	
Drug	Low Fiber	20% Alfalfa	Low Fiber	20% Alfalfa
0	2.61	2.81	3.47	3.95
Virginia-mycin	2.54	2.74	3.37	3.85
ASP-250	2.58	2.78	3.36	3.84

Experiment 1-4

Because of the slight response of animals in Experiment 1-3 to antibiotics and the lack of antibiotic and fiber interaction, Experiment 1-4 was designed using 30 percent alfalfa in the diets of 64 growing Yorkshire barrows. There were four treatments with four pigs per treatment. This was replicated four times, giving a total of 16 pigs per treatment. The treatment diets were wheat based as described in Table 10. Treatment 1 was the basal diet. Treatment 2 was the basal diet with 2.27 kg/ton of ASP-250 added. Treatment 3 was the basal diet with 30 percent alfalfa and treatment 4 was the 30 percent alfalfa diet with 2.27 kg/ton of ASP-250 added. The animals were housed four pigs to a pen which measured 1.52m x 4.85m. These pens had solid concrete floors and were equipped with a self-flushing gutter, an *ad libitum* feeder and an automatic waterer. The animals went on test at weights from 9 to 13.6 kg and were terminated when average replicate weight reached approximately 68 kg.

Table 10

Swine Grower Diets (Percentage)
Experiment 1-4

Ingredient	Treatment 1	2	3	4
Wheat	77.0	77.0	47.0	47.0
Soybean meal	18.0	18.0	18.0	18.0
Sun-cured alfalfa meal	-	-	30.0	30.0
Bentonite	2.0	2.0	2.0	2.0
Traceminer-alized salt	0.5	0.5	0.5	0.5
Dicalcium phosphate	1.0	1.0	1.0	1.0
Limestone	1.5	1.5	1.5	1.5
ASP-250	-	2.27kg/ton	-	2.27kg/ton
Vitamin mix 2.27kg/ton[a]				

[a]Ingredients per kg of mix: Vitamin A, 1,320,000 USP Units; Vitamin D-3, 440,000 IC Units; Vitamin E, 440 I units; Vitamin K (MSBC), 2,000 mg; Vitamin B-12, 4.40 mg; Riboflavin, 1,760 mg; Pantothentic acid, 3,238 mg; Niacin, 8,800 mg; Choline Chloride, 110,000 mg; Ethoxyquin, 24.97 gm; Manganese, 24 gm; Zinc, 40 gm; Iron, 8 gm; Copper, 0.8 gm; Iodine, 0.48 gm; Cobalt, 0.08 gm; Selenium, 39.60 mg.

Results

A 2 x 2 factorial analysis of variance was done for average daily gain and feed efficiency. Means for these measurements are shown in Tables 11 and 12. The ASP-250 had a significant affect on average daily gain ($p < .01$) at both levels of fiber. The fiber level did not significantly affect average daily gain. There was no interaction between drug and fiber level. The analysis showed a significant affect ($p < .01$) on feed/gain ratio for the level of fiber but the drug did not affect feed/gain ratio at either level of alfalfa. There was no interaction between alfalfa and drug.

Table 11

Average Daily Gain of Pigs Fed 0 or 30 Percent Alfalfa With or Without ASP-250 Experiment 1-4

Low Fiber		30% Alfalfa	
0 Drug	ASP-250	0 Drug	ASP-250
.67[a]	.76[b]	.64[a]	.73[b]

Unlike superscripts differ ($p < .01$)

Table 12

Feed Efficiency of Pigs Fed 0 or 30 Percent Alfalfa With or Without ASP-250 Experiment 1-4

Low Fiber		30% Alfalfa	
0 Drug	ASP-250	0 Drug	ASP-250
2.84[a]	2.88[a]	3.60[b]	3.53[b]

Unlike superscripts differ ($p < .01$)

Summary: Part One

The results in Experiment 1-1 support work done by Bohman *et al.* (1953) in showing that as the percentage of dietary alfalfa of swine rations increased average daily gain decreased and feed/gain ratio increased. Statistically, average daily feed intake was not significantly changed as the amount of alfalfa in the ration increased. Dietary energy was thus limited by increasing levels of alfalfa and the test animals did not consume more of the ration to compensate, presumably because of the low palatability of alfalfa. Average live weight and average carcass weight decreased in this study as the percentage of dietary alfalfa increased. This trend towards leaner lighter pigs is supported by decreasing back fat thickness, loin weight and the weight of the four lean cuts. Dressing percent also decreased as dietary alfalfa increased and is probably a result of an increase in gut size and weight as dietary fiber increased. Loin length and loin eye area did not change as dietary alfalfa increased indicating that the increasing dietary alfalfa influences deposition of fat more than muscle. The percent of the four lean cuts decreased as dietary alfalfa increased which can be attributed to the leaner carcass.

Three of four additives showed statistically significant differences for average daily gain when compared to the same diet without additives. Addition of an antibiotic increased average daily gain, glutamic acid and wheat bran decreased average daily gain and the addition of bentonite had no effect.

Experiment 1-3 showed a slight response to antibiotics when swine were fed an alfalfa-free diet and a 20 percent alfalfa-containing diet. The difference between the compared antibiotics (ASP-250 and virginiamycin) was also slight. When the growth response of swine to ASP-250 in an alfalfa free diet and a diet containing 30 percent alfalfa were compared to similar diets with no drugs there was a significant positive response to ASP-250. There was no drug x fiber interaction. Feed/gain ratio was increased with the addition of 30 percent alfalfa but the addition of ASP-250 did not affect feed/gain ratio.

Part Two: Feed Flavoring Agents Added to Alfalfa-Containing Swine Diets

Objectives

The objectives of this experimental work were:

1) To determine if two types of feed flavors would influence the intake of alfalfa-containing diets by growing swine.
2) To determine if a commercial feed flavor would influence the average daily and feed/gain ratio of growing-finishing hogs fed a pelleted 20 percent alfalfa-containing diet.

Experimental Procedure

Two experiments with pigs were conducted. In the first experiment, Yorkshire pigs were used in a two choice preference test. The second experiment was a growth study using Yorkshire pigs fed *ad libitum*.

Experiment 2-1

Yorkshire pigs, with an initial weight of approximately 27 kg, were given a choice between diets containing 2.5, 10, and 30 percent alfalfa and no flavor or diets containing 2.5, 10, and 30 percent alfalfa with either flavor 1 or flavor 2. The diets were presented in a meal form and the alfalfa used was a commercial dehydrated meal

(20 percent crude protein). Composition of the diets is shown in Table 13.

Twelve pigs (six barrows and six gilts) were fed in each of three replicates. For each replicate each alfalfa level was tested, beginning with the 2.5 percent alfalfa level. The barrows had a choice of two diets: alfalfa diet with no flavor and alfalfa diet with flavor 1. The gilts had the same choice but flavor 2 was used. Flavor 1 was formulated and described by the manufacturer* as "Aromatic" while flavor 2 was described as "Proteinaceous" in taste. Both flavors were added at a level of 1.1 g/kg diet.

Pigs were housed individually in 1.22m. x 3.64m. pens. A self feeder was attached at each end of the pen with an automatic waterer provided equidistant from each feeder. The area adjacent to each feeder was solid concrete while the middle portion of the pen was concrete slats. The feeders were switched each day to avoid a position effect. The experimental period at each level of alfalfa was 5 days. At the beginning of each 5 day period the diets provided in the feeders were weighed and fed *ad libitum*. At the termination of the 5 day period the

---

*Agrimerica, Northbrook, Ill.

Table 13

Percent Composition of Swine Diet Used in Feed Flavor Preference Study Experiment 2-1

Ingredient	Percent
Soybean meal	23.0
Ground corn[a]	70.0
Trace mineralized salt	0.5
Dicalcium phosphate	2.0
Ground limestone	0.5
Molasses	3.0
Vitamin mix	0.25
ASP-250	0.25

[a]Alfalfa was substituted directly for corn.

[b]Contains per kg mix: Vitamin A, 1,320,000 USP Units; Vitamin D-3, 440,000 IC Units; Vitamin E, 440 I Units; Vitamin K(MSBC) 880 mg.; Vitamin B-12, 4.4 mg.; Riboflavin, 1,760 mg.; Pantothentic acid, 3,230 mg.; Niacin, 8,800 mg.; Choline Chloride, 110,000 mg.; Ethoxyquin, 24.97 mg.; Manganese, 24 gm.; Zinc, 40 gm.; Iron, 8 gm.; Copper, 0.8 gm.; Iodine, 0.48 gm.; Cobalt, 0.08 gm.; Selenium, 39.60 mg.

remaining feed was weighed and intake from each feeder calculated. Metal commercial feeders were used and carefully adjusted to minimize spillage.

Results

Results of this experiment were analyzed using two methods. A 2 x 3 factorial analysis of variance was done which showed no significant differences between flavors or alfalfa levels. Flavored feed as a percent of total diet consumed is shown in Table 14. In addition "t" value was

Table 14

Dietary Preference of Flavored Rations by Swine Experiment 2-1

Percent Dietary Alfalfa	Flavor Treatment	Intake of Each Diet as a Percent of Total Feed Intake		
		Rep 1	Rep 2	Rep 3
2.5	No flavor	44[a]	49[a]	67[a]
	Flavor 1	56[a]	51[a]	33[b]
2.5	No flavor	49[a]	64[a]	55[a]
	Flavor 2	51[a]	36[b]	45[a]
10.0	No flavor	33[a]	62[a]	51[a]
	Flavor 1	67[b]	38[b]	49[a]
10.0	No flavor	41[a]	85[a]	49[a]
	Flavor 2	59[a]	15[b]	51[a]
30.0	No flavor	45[a]	49[a]	53[a]
	Flavor 1	55[a]	51[a]	47[a]
30.0	No flavor	57[a]	46[a]	60[a]
	Flavor 2	43[a]	54[a]	40[b]

a different from b ($p < .05$)

calculated using the formula:

$$t = \frac{\bar{x} - m}{s/\sqrt{n}}$$

where $\bar{x}$ = mean percent intake of flavor diet
m = .50
s = standard deviation
n = number of animals

The intake of flavor diet as a percent of total feed intake was compared with a value of 50 percent because with no preference, total intake would be expected to be 50 percent from each feeder.

There were 6 instances of statistical difference in means. In one of these, the flavored diet was preferred over the non-flavored diet. In 5 cases the control diet was preferred. The remaining 12 cases showed no preference for either diet.

To determine if switching the feeders daily did avoid position preference for a feeder, a trial was conducted using the same diet (OSU Grower) in both feeders. The procedure of switching feeders daily was compared to not switching them. There was no difference ($p < .05$) in intake. Twelve pigs were used in this test for two seven day periods. Feed consumed from one feeder was calculated as a percent of total feed consumed and a "t" value of 1.2560 was calculated when the feeds were changed every day and .9117 when the feeders were not changed. The means were 43.00 percent ± 19.31 and 55.17 percent ± 19.63 respectively.

Experiment 2-2

Sixty Yorkshire pigs with an initial weight of 18 kg were used in feeding trials conducted in two replicates of three pens of ten pigs each. The three pens were assigned either a control diet, a 20 percent alfalfa-containing diet or a 20 percent alfalfa-containing diet containing a commercial feed flavor at 1g/kg diet. The pens were 1.52m x 4.85m and five barrows and five gilts were assigned to each of the six pens. The pens were solid concrete with a self-flushing gutter, an *ad libitum* feeder and an automatic waterer. The diets were pelleted and are described in Table 15. The animals remained on test until the average pen weight was approximately 100 kg.

Table 15

Composition of Swine Diets Using Feed Flavor
Experiment 2-2

Ingredient	Percent Diet 1	Diet 2	Diet 3
Wheat	77.0	51.0	51.0
Soybean meal	18.0	18.0	18.0
Bentonite	2.0	2.0	2.0
Alfalfa	-	20.0[a]	20.0[a]
Trace mineralized salt	0.5	0.5	0.5
Dicalcium phosphate	1.0	1.5	1.5
Limestone flour	1.5	0.5	0.5
Shamrock Vitamin mix[b]	0.2	0.2	0.2
Zinc sulfate	0.02	0.02	0.02
Feed flavor	-	-	0.10
ASP-250	0.03	0.03	0.03

[a]Alfalfa was substituted directly for wheat.

[b]Contains per kg of mix: Vitamin A, 1,320,000 USP units; Vitamin D-3, 440,000 IC units; Vitamin E, 440 I units; Vitamin K, 880mg.; Vitamin B-12, 4.4mg.; Riboflavin, 1,760mg.; Pantothentic acid, 3,230mg.; Niacin, 8,800mg.; Choline chloride 110,000mg.; Ethoxyquin, 24.97mg.; Manganese, 24gm.; Zinc, 40gm.; Iron, 8gm.; Copper, 0.8gm.; Iodine, 0.48gm.; Cobalt, 0.08gm.; Selenium, 39.6mg.

[c]Hog Krave, produced by Feed Flavors, Inc., Wheeling, Illinois.

Results

An analysis of variance for average daily gain and feed/gain ratio was performed. Means for average daily gain and feed/gain ratio are shown in Table 16. The addition of the flavor did not improve performance. However, the level of alfalfa meal used did not reduce growth rate, so an effect of the flavor probably would not be expected. A higher alfalfa level should have been used.

Table 16

Average Daily Gain and Feed Efficiency for Swine Fed Diets Containing 0 and 20 Percent Alfalfa and 20 Percent Alfalfa with Feed Flavor, Experiment 2-2

Average Daily Gain (kg)

	Control	20% Alfalfa	20% Alfalfa + Flavor
Rep 1	.80	.71	.75
Rep 2	.67	.79	.77

Feed/Gain Ratio

	Control	20% Alfalfa	20% Alfalfa + Flavor
Rep 1	3.09	3.74	3.62
Rep 2	2.93	3.02	3.27

There were no statistically significant differences for either measurement ($p < .05$).

Summary: Part Two

This work was designed primarily to determine if the palatability of alfalfa meal could be enhanced for swine by adding commercially prepared feed flavors to alfalfa meal-containing diets. The results support a conclusion that pigs do not prefer alfalfa-containing rations that are flavored over rations that are not flavored. In addition when swine are fed a diet containing 20 percent alfalfa meal, the alfalfa meal did not reduce growth response or increase feed/gain ratio when compared to the alfalfa free diet. Supplementation of a 20 percent alfalfa diet with a feed flavor did not improve performance.

Part Three: Swine Fed Diets Containing Ethanol Extracted Alfalfa Meal

Objective

The objective of these experiments was to determine if the unpalatability of alfalfa meal to swine as demonstrated by LeaMaster (1979) was associated with factor(s) that can be removed by ethanol extraction. LeaMaster (1979) found that when pigs were given a choice between a control diet and one containing alfalfa, they preferred the control diet at all alfalfa levels above 1 percent of the diet. The intent of this study was to determine if this unpalatability is due to fiber *per se* or to other components (e.g., saponins) which can be removed by ethanol extraction.

Experimental Procedure

Two separate experiments with pigs were conducted. In both experiments, Yorkshire pigs were used in a two choice preference test. Alfalfa was extracted with ethanol and the extracted alfalfa was used to make up various percentages of a diet which was compared to a control diet or to a diet containing the same percentages of unextracted alfalfa.

Experiment 3-1

Twelve Yorkshire pigs weighing from 18 to 19 kg were given a choice between a control diet (OSU Grower) and the control diet with 2.5, 5 or 10 percent ethanol extracted, commercially prepared, sun-cured alfalfa meal. The alfalfa meal was extracted with 95 percent ethanol using a Soxhlet Extractor. Three hundred g of alfalfa meal was extracted with 2.5 to 3.1 of 95 percent ethanol until the ethanol passed through the alfalfa and remained clear. The alfalfa meal was then air dried and mixed with enough corn to return the sample to the original 300g. This process was repeated several times to prepare enough extracted alfalfa to carry out a twenty-one day experiment. The experiment was carried out in three periods of seven days each, corresponding to a comparison of the control diet to 2.5, 5 or 10 percent extracted alfalfa meal. The pigs were individually confined in pens which measured 1.22m x 3.64m. A self-feeder was provided at each end of the pen with an automatic waterer provided equidistant from each feeder. The area adjacent to each feeder was solid concrete and the middle portion of the pen was concrete slats. The feeders were switched each day to avoid a position effect. The feeders used were metal commercial feeders which were carefully adjusted to avoid spillage. The feed was weighed at the onset and termination of each seven day period. The diet containing the extracted alfalfa meal was then calculated as a percentage of the total diet consumed.

Results

A "t" value was calculated using the formula $t = \frac{x-m}{s\sqrt{n}}$

where x = mean percent intake of extracted alfalfa meal diet
m = .50
s = standard deviation
n = number of pigs

The intake of the extracted alfalfa diet was compared with a value of 50 percent because with no preference, the total intake would be expected to be 50 percent from each feeder. At all three levels of extracted alfalfa the animals preferred the control diet ($p < .001$). Means are shown in Table 17.

Table 17

Percentage Intake of Extracted Alfalfa Diet
vs. Control Diet
Experiment 3-1

Percent Extracted Alfalfa in Diet	Extracted Diet	Control	SD
2.5	26.23[a]	73.77[b]	6.53
5.0	30.16[a]	69.84[b]	11.76
10.0	7.00[a]	93.00[b]	4.87

[a]differs from [b] in rows ($p < .001$)

Experiment 3-2

The procedure used in preparing the extracted alfalfa meal, the confinement system and the experimental periods described in experiment 3-1 were used in this experiment. In this experiment six Yorkshire pigs weighing from 18.2 to 19 kg were used and diets containing 1, 5 and 10 percent ethanol extracted alfalfa were compared with diets containing like percentages of unextracted alfalfa meal. The amount of each diet consumed was determined at the end of each seven day period and the extracted alfalfa meal diet was calculated as a percent of the total diet consumed.

Results

A "t" value was calculated as described in experiment 3-1 which showed no statistically significant preference at any of the three levels. ($p < .001$) means are shown in Table 18.

Table 18

Percentage Consumption of Extracted Alfalfa Diet vs. Nonextracted Alfalfa Diet, Experiment 3-2

Percent Alfalfa in Diet	Extracted	Nonextracted	SD
1.0	63.48	36.52	15.30
5.0	51.10	48.90	17.53
10.0	63.17	36.83	17.71

Summary: Part Three

These experiments were designed to separate the flavor factor from the fiber factor when assessing the reduced palatability of alfalfa meal for pigs. Several compounds found in the ethanol soluble portion of alfalfa meal impart a bitter flavor to the plant. The extracted alfalfa, however, was significantly rejected ($p < .001$) when the pigs were given a choice between the control and the extracted alfalfa-containing diets. This may indicate that the lower density or the fiber fraction is involved in reducing the palatability of alfalfa meal for swine. When the extracted and unextracted alfalfa-containing diets were compared the animals did not show a significant preference for either one. This suggests that in swine, the low palatability of alfalfa may be due primarily to its fiber content, and not to extractable substances such as saponins.

Part Four: Rats Fed Diets Containing Alfalfa, Ethanol-Extracted Alfalfa, or Alfalfa With 1 Percent Cholesterol Added

Objective

The objectives of these experiments were:

1) To compare the dietary intake of rats fed a control diet with rats fed a control diet containing varying percentages of alfalfa.
2) To compare the dietary intake of rats fed a control diet with rats fed the control diet containing varying percentages of ethanol-extracted alfalfa.
3) To compare the dietary intake of rats fed a diet containing varying percentages of alfalfa meal with rats fed a diet containing the same percentages of ethanol-extracted alfalfa meal.
4) To determine if the reduction of growth inhibition by cholesterol in saponin-containing diets as reviewed by Cheeke (1971) and Cheeke *et al.*, (1977) can be attributed to an action of cholesterol involving palatability. This was determined by comparing dietary intake of rats fed a diet containing low saponin or high saponin alfalfa in various percentages with rats fed a diet containing like percentages of the same alfalfa with 1 percent cholesterol added to the diet.

Experimental Procedure

Four experiments using mature Long Evans (Simonson Origin) rats weighing approximately 200g initially were conducted. In each of the four experiments the animals were used in a two choice preference test. Each choice was presented over a period of five days.

Experiment 4-1

In this experiment eight Long Evans rats were housed individually in 40 x 25 x 17.5cm wire mesh cages equipped with two feeders placed equidistant from the water source. The feeders were switched each day to avoid a position effect. The control diet as described in Table 19 was presented in one feeder and a diet containing 1, 2.5, 5, 10, or 20 percent sun-cured alfalfa was presented in the second feeder. The alfalfa was substituted directly for corn in the control ration to prepare the alfalfa based diet. The experimental period at each level of alfalfa was five days. At the end of each five day period the amount of diet consumed from each feeder was calculated, and the intake of the alfalfa containing diet calculated as a percent of total feed consumed.

Table 19

Percentage Composition of Rat Diets
Experiment 4-1

Ingredient	Percent
Corn	84.0[a]
Soybean meal	10.0
Trace mineralized salt	.5
Vitamin mix[b]	.5
Vegetable oil	5.0

[a]Alfalfa substituted directly for corn.

[b]Amounts per kg of mix: Vitamin A, 200,000 IU; tocopherol, 6,000mg; Vitamin D-3, 20,000 IU; Menadione, 10 mg; Thiamine, 250 mg; Riboflavin, 250 mg; Pyridoxing-HCl, 120 mg; Niacin, 1,500 mg; Calcium pantothenate, 800 mg; Vitamin B-12, 1 mg; Choline chloride, 75 g.

Results

A "t" value was calculated using the formula:

$$t = \frac{\bar{x}-m}{s/\sqrt{n}}$$

where $\bar{x}$ = mean percent intake of tested diet
m = .50
s = standard deviation
n = number of animals

The intake of tested diet as a percent of total feed intake was compared with a value of 50 percent because with no preference, total intake would be expected to be 50 percent from each feeder. The rats preferred the control diet over all five levels of the alfalfa-containing diet, ($p < .05$) as described in Table 20.

Table 20

Dietary Preference of Rats Given a Choice Between a Control Diet and a Control Diet Containing Varying Percentages of Alfalfa
Experiment 4-1

Compared Diets	Percentage Level of Alfalfa				
	1.0	2.5	5.0	10	20
Control	65.0[a]	70.9[a]	80.3[a]	91.0[a]	95.9[a]
Alfalfa	35.0[b]	29.1[b]	19.7[b]	9.0[b]	4.1[b]

[a]different from [b]. ($p < .05$) in columns.

Experiment 4-2

In this experiment, the procedure, confinement and experimental periods followed Experiment 4-1 except the alfalfa meal in the alfalfa-containing diet was extracted with 95 percent ethanol as described in Experiment 3-1 and the rate initially weighed approximately 225 g. The basal diet is described in Table 19.

Results

A "t" value was calculated as described in Experiment 4-1. The rats showed no statistical preference at the 1 or 2.5 percent level of washed alfalfa when compared to the control ($p < .05$). However, the rats preferred the control diet at the 5, 10 and 20 percent levels ($p < .05$), as shown in Table 21. This suggests that with rats the unpalatability of alfalfa at very low dietary levels is associated with extractable substances (e.g., saponins) while at higher levels (above 2.5 percent) the fiber *per se* is involved.

Table 21

Dietary Preference of Rats Given a Choice Between a Control Diet and a Control Diet Containing Various Percentages of Ethanol Extracted Alfalfa Meal
Experiment 4-2

Compared Diets	Percentage Level of Alfalfa				
	1.0	2.5	5.0	10.0	10.0
Control	47.3[a]	57.4[a]	76.7[a]	82.1[a]	94.9[a]
Ethanol extracted alfalfa	52.7[a]	42.6[a]	23.3[b]	17.9[b]	5.1[b]

[a]differs from [b]($p < .05$) in columns.

Experiment 4-3

In this experiment the procedure, confinement and experimental periods followed Experiment 4-1. However, the eight rats were fed the basal diet containing 1.0, 2.5, 5.0, 10.0 or 20.0 percent alfalfa meal compared with the diets containing the same percentage of the ethanol extracted alfalfa meal. The basal diet is described in Table 19.

Results

A "t" value was calculated as described in Experiment 4-1. The rats showed no statistical preference at the 1 percent level ($p < .05$). At the remaining levels of the two added alfalfa meals the animals preferred the diets containing the ethanol extracted alfalfa meal as shown in Table 22.

Table 22

Dietary Preference of Rats Given a Choice Between a Diet Containing Various Percentages of Alfalfa Meal and a Diet Containing the Same Percentages of Ethanol Extracted Alfalfa Meal
Experiment 4-3

Compared Diets	Percentage Level of Alfalfa				
	1.0	2.5	5.0	10.0	20.0
Alfalfa	46.6[a]	44.0[a]	34.4[a]	32.9[a]	26.7[a]
Ethanol extracted alfalfa	53.4[a]	66.0[b]	65.6[b]	67.1[b]	73.3[b]

[a]differs from [b] ($p < .05$) in columns.

Experiment 4-4

In this experiment 2.5, 5.0, 10.0, and 20.0 percent low saponin alfalfa meal containing diets with 1 percent cholesterol added were compared with diets containing like percentages of low saponin alfalfa meal no cholesterol added. Also, 2.5, 5, 10 and 20 percent high saponin alfalfa meal containing diets containing 1 percent cholesterol were compared to high saponin alfalfa meal containing diets with no cholesterol added. In addition a comparison of the basal corn diet and the basal corn diet with 1 percent cholesterol added was done. The procedure, confinement and experimental periods followed Experiment 4-1. Twenty-four rats were used in this work, eight for each type of alfalfa and eight for the basal diet cholesterol test. The saponin contents of the low and high alfalfa meals were 1.01 and 2.80 percent respectively.

Results

A "t" value was calculated as described in Experiment 4-1. When the basal corn diet was compared to the same diet with 1 percent cholesterol added, the diet with the cholesterol diet was preferred ($p < .01$). However, at all percentages of high or low saponin there was no statistical difference between the diets with 1 percent cholesterol and diets with no cholesterol (Table 23).

Summary, Part Four

The control diet when compared to the alfalfa-containing diet was significantly preferred by the rats at all levels of alfalfa. Thus both rats and swine find diets with even low levels of alfalfa less palatable than diets without alfalfa. However, the rats showed no statistically significant preference for the ethanol extracted alfalfa meal at the 1 and 2.5 percent level of alfalfa and preferred the control at the three higher levels. This would indicate that the ethanol removed

Table 23

Dietary Preference of Rats Given a Choice Between Diets Containing Various Percentages of High or Low Saponin Alfalfa Meal or Control Diet and the Same Diets With 1 Percent Cholesterol Added
Experiment 4-4

Compared Diets	Percentage Level of Additive				
	1.0	2.5	5.0	10.0	20.0
Control	25[a]				
+ 1% cholesterol	75[b]				
Low saponin		57.9[a]	58.2[a]	50.4[a]	51.0[a]
+ 1% cholesterol		42.1[a]	41.8[a]	49.6[a]	49.0[a]
High saponin		39.1[a]	48.1[a]	47.2[a]	53.1[a]
+ 1% cholesterol		60.9[a]	51.9[a]	52.8[a]	46.9[a]

[a]differs from [b] ($p < .05$) for each comparison.

a component that allows for discrimination at least at the low fiber levels. These studies suggest that fiber is the major factor involved in the low palatability of alfalfa to swine and rats, but at low alfalfa levels, ethanol-soluble substances contribute to the unpalatability. It is also possible that ethanol-insoluble substances other than fiber could be involved.

Cheeke (1971) points out numerous instances in which feeding of saponins resulted in reduced serum and tissue cholesterol levels in poultry. The feeding of cholesterol also reduces the growth inhibition attributed to saponins

(Cheeke 1971). Cheeke, Kinzell and Pederson (1977) reported that rats fed a low saponin diet grew more rapidly than those fed a high saponin diet and that feed intake of the high saponin groups was less than that of the other groups. If saponins reduce growth primarily by effects on feed intake, and cholesterol reduces the growth depression caused by saponins, then it is possible that the mode of action of cholesterol could involve palatability.

In Experiment 4-4, the high and low saponin diets with one percent cholesterol were fed to determine if the gustatory response to high and low saponin alfalfa meal would be altered. When one percent cholesterol was added to the control diet the rats discriminated ($p < .05$) by consuming more of the cholesterol containing diet. However, the rats showed no preference at any of the three levels when offered a choice between the alfalfa-containing diets with or without one percent cholesterol.

Part Five: Poultry Fed Diets Containing Alfalfa Meal, High or Low Saponin Alfalfa Meal or Quinine

Objectives

The objectives of this experiment were:

1) To compare the dietary intake of geese, turkeys, quail and roosters fed an alfalfa free control diet and diets containing varying percentages of sun-cured alfalfa meal.
2) To compare the dietary intake of the four species of poultry fed diets containing varying percentages of high or low saponin alfalfa meal.
3) To compare the dietary intake of the four species of poultry fed a quinine free control diet or a control diet containing varying percentages of quinine. Quinine was used as a model of a bitter compound.
4) To determine if dietary preference of geese, turkeys, quail and roosters are similar to other non-ruminants which appear to prefer alfalfa-free diets over alfalfa-containing diets and reject quinine-containing diets.

Experimental Procedure

Three experiments were done with the four species of poultry. The birds were subjected to a two choice preference study in each experiment.

Experiment 5-1

In this experiment eight mature Wrolstad Medium White tom turkeys, nine mature Embden geese, eight mature Shaver Star Cross 288 Single Comb White Leghorn male chickens and eight mature Japanese quail were given a choice between a control diet (Table 24) and the control diet with .5, 1, 2.5, 5, 10, 20, and 30 percent sun-cured alfalfa meal substituted directly for corn. At each level of alfalfa the birds were given the choice for seven days. The turkeys and geese were individually confined in wire mesh cages which measured 2.12m x 36.4m and were .91m high. The cages were elevated and had wire mesh floors. Each cage was equipped with two commercial tube type feeders carefully adjusted and suspended at a height to minimize spillage. The roosters were individually confined in wire mesh cages which measured .3m x .45m and .4m high. These cages were elevated and had wire mesh floors. The roosters had access to two trough feeders at the front of the cage and an automatic waterer at rear of the cage. The quail were individually housed in elevated wire mesh cages which measured .4m x .2m and were .2m high. The floors of these cages were wire mesh and each cage was equipped with two feeders and two waterers. These feeders were dish type feeders equipped with top screens to prevent wastage of feed. Feeders for all birds were switched daily to avoid a position effect.

Table 24

Percentage Composition of Basal Poultry
Ration (OSU 1687)
Experiment 5-1 - 5-3

Ingredient	Percent
Corn[a]	81.15
Animal fat	2.00
Soybean meal	12.70
Defluorinated phosphate	2.50
Limestone flour	1.00
Salt	.50
Trace mineral mix[b]	.03
Vitamin mix[c]	.12

[a]alfalfa substituted directly for corn.

[b]OSU trace mineral mix-65 - amount per kg: calcium, 195g; iron, 40g; manganese, 120g; copper, 4g; iodine, 2.4g; zinc, 55g; cobalt, .4g.

[c]OSU vitamin premix 1-75 - amount per kg of mix: Vitamin A, 1,650,000 IU; Vitamin D, 550,000 ICU; riboflavin, 1,650 mg; D-Pantothentic acid, 2,750mg; Niacin (total), 11,000mg; choline, 95,469mg; Vitamin B-12, 2,750mcg; Vitamin E, 550 IU; Vitamin-K, 275mg; Folacin, 110mg; Niacin (avail), 11,000mg; Ethoxyquin, 31,212mg.

Results

A "t" value was calculated using the formula:

$$t = \frac{\bar{x}-m}{a/\sqrt{n}}$$

where $\bar{x}$ = mean percent intake of treated diet
m = .50
s = standard deviation
n = number of animals

The intake of tested diet as a percent of total feed intake was compared with a value of 50 percent because with no preference, total intake would be expected to be 50 percent from each feeder.

All species showed no significant statistical difference between the control diet and the diets containing .5, or 1 percent sun-cured alfalfa meal. At the 2.5 percent level the turkeys, quail and roosters showed no significant preference while the geese preferred the control diet. At the 5 percent level all species preferred the control diet except the roosters. All species significantly preferred the control at the 10, 20 and 30 percent levels with increasing rejection of the alfalfa-containing diet as the percentage of alfalfa increased. At the 30 percent level the quail, roosters, turkeys, and geese consumed 9.02, 7.58, 7.32 and 0 percent respectively of the alfalfa containing diet (Table 25).

Table 25

Preference for Alfalfa-Containing Diets for Birds Given a Choice Between a Control Diet and the Control Diet Containing Varying Percentages of Alfalfa Meal Expressed as a Percent of Total Feed Consumed
Experiment 5-1

Percent Alfalfa	SPECIES							
	Geese	sem[e]	Turkey	sem[e]	Quail	sem[e]	Rooster	sem[e]
0.5	39.75[a]	5.60	48.86[a]	2.07	47.76[a]	1.26	48.77[a]	1.90
1.0	35.66[a]	6.27	46.59[a]	2.08	47.03[a]	6.69	48.41[a]	1.23
2.5	38.00[b]	4.53	43.45[a]	4.25	41.92[a]	4.71	50.68[a]	1.98
5.0	35.06[c]	3.50	40.30[b]	3.79	28.74[c]	4.49	45.94[a]	2.03
10.0	24.88[b]	8.27	36.30[c]	3.16	22.12[d]	3.09	34.51[c]	3.33
20.0	9.15[d]	4.77	14.17[d]	5.34	17.31[d]	4.01	25.94[c]	4.99
30.0	0.00	0.00	7.32[d]	2.36	9.02[d]	0.78	7.58[d]	3.03

[a]nonsignificant ($p < .05$)

[b]significant-preferred control diet ($p < .05$)

[c]significant-preferred control diet ($p < .01$)

[d]significant-preferred control diet ($p < .001$)

[e]standard error of the mean

Experiment 5-2

In this experiment the same birds were given a choice between the basal diet (Table 26) containing 1, 5, 10, or 20 percent low saponin alfalfa meal and the basal diet containing like percentages of high saponin alfalfa meal. The saponin contents of the low and high saponin alfalfa meals were .03 and .62 percent respectively. The confinement system and the test period were the same as described in Experiment 5-1. There were eight birds of each species in this experiment.

Results

A "t" value was calculated as described in Experiment 5-1. Statistically, the geese in this experiment showed no preference for the high or the low saponin alfalfa meal containing diet at any level tested. The quail preferred the low saponin diet at 10 percent but showed no preference at the 20 percent level. The roosters showed no statistical preference except at the 1 percent level where they ate more of the high saponin alfalfa meal diet. The turkeys preferred the high saponin diet at the 1 and 5 percent level but showed no significant statistical preference at the 10 and 20 percent levels (Table 26).

Table 26

Preference for High Saponin Alfalfa-Containing Diets
for Birds Given a Choice Between High and Low Saponin
Alfalfa-Containing Diets
Experiment 5-2

Percent Alfalfa	SPECIES			
	Geese SEM	Turkey SEM	Quail SEM	Rooster SEM
1.0	52.91[a] ± 5.00	71.15[c] ± 3.28	52.29[a] ± 3.86	57.95[b] ± 1.02
5.0	48.47[a] ± 4.06	64.22[d] ± 3.32	46.03[a] ± 5.69	46.95[a] ± 5.24
10.0	47.37[a] ± 9.27	60.23[a] ± 4.82	38.01[a] ± 3.93	42.20[a] ± 2.89
20.0	34.29[a] ± 11.67	51.34[a] ± 3.16	43.31[e] ± 6.66	46.46[a] ± 1.52

[a]nonsignificant ($p < .05$)

[b]significant (preferred high saponin diet) ($p < .05$)

[c]significant (preferred high saponin diet ($p < .001$)

[d]significant (preferred high saponin diet)($p < .01$)

[e]significant (preferred low saponin diet)($p < .05$)

Experiment 5-3

In this experiment the same eight birds of each species were given a choice between the control diet (Table 18) and the control diets containing .01, .05, .1 percent quinine sulfate. The confinement system and test periods were the same as described in 5-1.

Results

A "t" value was calculated as described in Experiment 5-1. The roosters significantly preferred the control diet at all levels of added quinine. The geese significantly preferred the control diet at the .05 and .1 percent levels and showed no significant statistical preference at the .01 percent level of added quinine. The quail showed no significant statistical preference at the .01 and .05 levels but preferred the control at the .1 percent level of added quinine. The turkeys preferred the control at the .01 percent level and showed no significant statistical preference at the .05 percent and .10 percent levels of added quinine.

Table 27

Dietary Preference of Quinine-Containing Rations by Poultry
Expressed as a Percent of Total Feed Consumed
Experiment 5-3

Percent Quinine	SPECIES			
	Geese SEM	Turkey SEM	Quail SEM	Rooster SEM
.01	42.51[a] ± 3.29	37.49[b] ± 3.91	41.95[a] ± 5.36	40.66[c] ± 2.03
.05	28.60[b] ± 6.46	40.12[a] ± 5.83	46.42[a] ± 5.23	46.82[b] ± 1.09
.10	19.33[c] ± 7.40	37.67[a] ± 5.78	38.54[b] ± 4.44	38.71[b] ± 3.31

[a]nonsignificant ($p < .05$)

[b]significant (preferred control)($p < .05$)

[c]significant (preferred control)($p < .01$)

Summary, Part Five

When the birds were offered a choice between an alfalfa-containing diet and an alfalfa-free control diet there was no discrimination at the .5 and 1 percent levels. Rejection of the alfalfa meal was evident beginning at the 5 percent level with geese, turkeys and quail, and at the 10 percent level for the roosters. Variation among the birds within a species was evident (Table 25) with more birds conforming to a pattern of rejection at the higher levels of alfalfa meal.

In an effort to separate fiber factors from saponin taste factors, the high and low saponin cultivars of alfalfa were compared in a two choice test. The geese did not discriminate suggesting that fiber content may be a preference factor. The standard error of the mean was large at the higher levels of alfalfa showing a marked difference among the geese. The turkeys preferred the high saponin diet at the lower two levels of alfalfa meal and did not show a preference at the two higher levels. Because the turkeys showed a highly significant preference for the high saponin diet at the 1 percent ($p < .001$) and the 5 percent ($p < .01$) alfalfa meal levels and did not discriminate at the two higher levels, the preference factor, high saponin in this case, appears to have been overpowered by a rejection factor, possibly high amounts of fiber, resulting in nondiscrimination between the alfalfa types.

When the quail were offered high or low saponin-containing diets they did not differentiate at the lower two levels of alfalfa meal, but at the 10 and 20 percent alfalfa level did prefer the low saponin type.

Roosters followed a pattern similar to the turkeys when offered a choice between the high and low saponin alfalfa-containing diets.

When a choice was given between control and control with quinine added only the response to the quinine sulfate flavor was tested. The geese did not discriminate at .01 percent added quinine sulfate but significantly rejected the quinine sulfate at .05 and 1 percent. This would indicate (the geese did not discriminate between the high and low saponin alfalfa-containing diets) that saponins do not produce the same taste sensation for geese that quinine sulfate does.

The turkeys in this test rejected the lowest level of quinine sulfate and did not discriminate at the two higher levels. Here again it appears that the taste sensation produced by saponins (the turkeys preferred the high saponin at the two low levels of alfalfa) is not the same as that produced by quinine for turkeys.

The quail expressed similar nondiscrimination for the high saponin alfalfa meal-containing diet and the quinine sulfate containing diet at low levels and similar rejection at higher levels of both the high saponin alfalfa meal-containing diets. This indicates that at the higher levels (1 percent quinine and 10 and 20 percent high saponin alfalfa meal) the quail experience similar rejection responses or that each is individually unpalatable at these levels.

The roosters rejected all three levels of quinine sulfate while preferring the high saponin alfalfa at the 1 percent level and expressing no preference for high or low saponin alfalfa meal containing diets at 5, 10, and 20 percent. This indicates different gustatory responses to quinine and saponin.

Mixed responses are evident between avian species. Birds within a species also vary widely as indicated by the relatively large standard errors of means in Tables 25, 26 and 27.

General Summary and Conclusions

Several factors are apparent from this study of the utilization of alfalfa by non-ruminants. It was shown that pigs have an aversion to alfalfa-containing diets. This was demonstrated by decreased average daily gain as dietary alfalfa increased and by the carcass characteristics of market hogs fed alfalfa-containing diets. As dietary alfalfa increased and digestible energy decreased, swine failed to increase their average daily feed intake because of the low palatability of alfalfa in swine.

Second, it was shown that the low palatability of alfalfa-containing diets is due primarily to its high fiber content. When components of alfalfa known to impart a bitter taste to alfalfa were extracted with ethanol, pigs did not show a preference for ethanol extracted alfalfa-containing diets over unextracted alfalfa-containing diets. This indicates that the ethanol soluble portion of alfalfa is not a major factor in its low palatability in swine. In addition, commercially prepared feed flavors or flavor masking agents are not effective in enhancing the palatability of alfalfa in swine. This indicates that the fiber content of alfalfa-containing diets is a major factor in the low palatability in swine.

Third, additives (bentonite, wheat bran, glutamic acid) do not improve the utilization of alfalfa-containing diets for swine. The addition of an antibiotic, however, increased the average daily gain but there was no fiber X antibiotic interaction demonstrated. There is little difference in efficacy between the two drugs (ASP 250 and virginiamycin) tested.

Fourth, rats like swine find alfalfa-containing diets less palatable than alfalfa-free diets. However, at low alfalfa levels ethanol soluble substances appear to contribute to the low palatability in rats. One percent cholesterol added to alfalfa containing diets does not enhance the palatability of these diets in rats.

Fifth, poultry prefer alfalfa-free diets over alfalfa-containing diets, vary widely between and among species in gustatory response but seem to conform to a rejection pattern when high percentages of alfalfa are offered. Poultry do not discriminate between high saponin and low saponin cultivars of alfalfa at low dietary levels and tend to reject both choices at the higher levels of dietary alfalfa. This suggests that for poultry high fiber content is the primary rejection factor. Japanese quail demonstrate a similar rejection pattern for high saponin alfalfa-containing diets and quinine-containing diets while the remaining three species do not. This indicates different gustatory responses to saponins and quinine and exemplifies mixed responses between avian species. Generally, non-ruminants do not like alfalfa and the primary reason appears to be the high fiber content of alfalfa. The numerous desirable characteristics of alfalfa, especially for non-ruminants, warrants continuing research in feeding alfalfa to non-ruminants. Future research could study the impact of "imprinting" the flavor of alfalfa on prenatal and neonatal pigs by feeding alfalfa to sows during gestation and lactation. Research in the alteration of gut microflora of non-ruminants could also be studied to enhance the utilization of alfalfa by non-ruminants.

BIBLIOGRAPHY

Agricultural Research Council. 1967. The nutrient requirement of farm livestock. No. 3, Pigs, p.p. 60-63. HMSO, London.

Akeson, W. R. and M. A. Stahmann. 1966. Leaf protein concentrates: a comparison of protein production per acre of forage with that from seed and animal crops. Econ. Bot. 20:244.

Aldinger, S. M., J. C. Speer, V. W. Hays and D. V. Cantron. 1959. Effect of saccharin on consumption of starter rations by baby pigs. J. Anim. Sci. 18:1350.

Allee, G. L. 1976. Evaluation of a self-fed sow gestation diet. (abstract) J. Anim. Sci. 42:1348.

Axelsson, J. 1947. The ability of cattle, sheep, horses and swine to digest the nutrients of the feeding stuffs. Ann. Roy. Agr. College of Sweden. 16:84.

Baird, D. M., H. C. Campbell and J. R. Allison. 1970. Levels of crude fiber with constant energy levels for growing-finishing swine using computer 4 rations. J. Anim. Sci. 31:518.

Becker, D. E., L. S. Hanson, A. H. Jenson, S. W. Terrill, and H. W. Norton. 1956. Dehydrated alfalfa meal as a dietary ingredient for swine. J. Anim. Sci. 15:820.

Blaser, R. E., R. C. Hames, Jr., H. T. Bryant, W. A. Hardison, J. P. Fontenot and R. W. Engel. 1960. The effect of selective grazing on animal output. Proc. 8th Inter. Grassl. Cong. 8:601-606.

Bohman, J. R., J. F. Kidwell and J. A. McCormick. 1953. High levels of alfalfa in rations of growing-fattening swine. J. Anim. Sci. 12:876.

Bohman, J. R., J. E. Hunter, J. McCormick. 1955. The effect of graded levels of alfalfa and aureomycin upon growing-fattening swine. J. Anim. Sci. 14:499.

Burnside, J. E., T. J. Cunha, A. M. Pearson, R. S. Glasscock, A. L. Shealy. 1949. Effect of APF supplement on pigs fed different protein supplements. Arch. Biochem. 23:328.

Campbell, R. G. 1976. A note on the use of a feed flavour to stimulate the feed intake of weaner pigs. Anim. Prod. 23:417.

Carroll, W. E. 1936. Possibilities of increasing the use of forage and roughage in swine production. Proc. Amer. Soc. Anim. Prod. p. 26.

Castell, A. G. 1977. Effects of Virginiamycin on the performance of pigs fed barley diets supplemented with soybean meal or low-glucosinolate rapeseed meal. Can. J. Anim. Sci. 57:313.

Cheeke, P. R. 1976. Nutritional and physiological properties of saponins. Nutrition Reports International. 13:315.

Cheeke, P. R. 1971. Nutritional and physiological implications of saponins: a review. Can. J. Anim. Sci. 51:621.

Cheeke, P. R. and D. E. Stangel. 1973. Lactose and whey utilization by rats and swine. J. Anim. Sci. 37:1142.

Cheeke, P. R., J. H. Kinzell and M. W. Pedersen. 1977. Influence of saponins on alfalfa utilization by rats, rabbits and swine. J. Anim. Sci. 46:476.

Cranwell, P. D. 1968. Microbial fermentation in the alimentary tract of the pig. Nutr. Abs. Rev. 38:721.

Crampton, E. W. and L. A. Maynard. 1954. The relation of cellulose and lignin content to the nutrition value of animal feeds. J. Nutr. 15.383.

Cunha, T. J., O. B. Ross, P. H. Phillips and G. Bohstedt. 1944. Further observation on the dietary insufficiency of a corn-soybean ration for reproduction in swine. J. Anim. Sci. 3:415.

Danielson, D. M., J. E. Butcher and J. C. Street. 1969. Estimation of alfalfa pasture intake and nutrient utilization by growing-finishing swine. J. Anim. Sci. 28:6.

Danielson, D. M. and J. J. Noonan. 1975. Roughages in swine gestation diets. J. Anim. Sci. 41:94.

Diaz, F., J. C. Speer, G. C. Ashton, C. H. Liu and D. V. Contron. 1956. Comparison of refined cane sugar, invert cane molasses and unrefined cane sugar in starter rations for early weaned pigs. J. Anim. Sci. 15:315.

Dinusson, W. E., D. W. Bolen and M. L. Buchanan. 1956. Alfalfa and other roughage for growing fattening swine. N.D. Agr. Exp. Sta. Bimonthly Bul. 19:28

Duncan, C. J. 1960. Preference tests and the sense of taste in the feral pigeon. Anim. Behav. 8:54.

Fairbanks, B. W., J. L. Krider and W. E. Carroll. 1944. Effect of diet on gestation lactation performance of sows. J. Anim. Sci. 4:410.

Forbes, R. M. and T. S. Hamilton. 1952. The utilization of certain cellulosic materials by swine. J. Anim. Sci. 11:480.

Friend, D. W., H. M. Cunningham and J. W. G. Nicholson. 1962. The production of organic acids in the pig. I. The effect of diet on the proportions of volatile fatty acids in pig feces. Can.J. Anim. Sci. 42:55.

Friend, D. W., H. M. Cunningham and J. W. G. Nicholson. 1963. The production of organic acids in the pig. II. The effect of diet on the levels of volatile fatty acids and lactic acid in sections of the alimentary tract. Can. J. Anim. Sci. 43:156.

Friend, D. W., J. W. G. Nicholson and H. M. Cunningham. 1964. Volatile fatty acid and lactic acid content of pig blood. Can.J. Anim. Sci. 44:303.

Grimstead,L. E., V. C. Speer, D. V. Cantron and V. W. Hays. 1960. Comparison of sugar and artificial sweetners in baby pig diets (Abstract) J. Anim. Sci. 19:1264.

Hanson, L. E., E. A. Rutledge, J. M. Russo and E. F. Ferrin. 1954. Dry rations for pigs weaned at three weeks. 32 Annual Swine Feeder day report 11-124. Univ. of Minn.

Hanson, L. J., D. E. Becker, S. W. Terrill, A. H. Jensen and H. W. Norton. 1956. The inhibitory effect of dehydrated alfalfa meal in the diet of swine. J. Anim. Sci. 15:830.

Hardison, W. A., J. T. Reid, C. M. Martin and P. G. Woolfolk. 1954. The inhibitory effect of dehydrated alfalfa meal in the diet of swine. J. Anim. Sci. 15:830.

Heitman, H., Jr., and J. H. Meyer. 1959. Alfalfa meal as a source of energy by swine. J. Anim. Sci. 18:196

Hockstetler, L. W., J. A. Hoefer, A. M. Pearson and R. W. Luecke. 1959. Effect of varying levels of fiber of different sources upon the growth and carcass characteristics of swine. J. Anim. Sci. 18:1397.

Homb, T. 1948. Feeding experiments with Beckmann-treated straw. Inst. of Animal Writ., the Goy. Agr. College of Norway, 64th Report, pp. 89.

Hudman, D. B. and E. R. Peo, Jr. 1960. Carcass characteristics of swine as influenced by levels of protein on pasture and in drylot. J. Anim. Sci. 19:943.

Jacobs, W. W., G. K. Beauchamp and M. R. Kare. 1978. Progress in Animal Flavor Research. In Flavor Chemistry of Animal Foods. R. W. Ballard, ed. American Chem. Sci., Washington, D.C. pp. 1-17.

Kare, M. R. 1961. Comparative aspects of the sense of taste. In Physiological and behavioral aspects of taste. ed. by M. R. Kare and B. P. Halpern. Chicago: University of Chicago Press.

Kare, M. R., W. C. Pond and J. Campbell. 1965. Observations of taste reactions in pigs. Anim. Behavior. 13:265.

Kare, M. R. and M. S. Ficken. 1963. Comparative studies on the sense of taste. In Olfaction and Taste, Ed., Y. Zotterman. London. Permagon Press.

Kare, M. R., R. Black and G. E. Allison. 1957. The sense of taste in fowl. Poultry Sci. 36:129.

Kennedy, J. M. 1978. The development of dietary preferences in pigs and poultry. Working papers. First International Symposium on Palatability and Flavor Use in Animal Feeds. Institute of Animal Production. Nutrition Group. Swiss Federal Institute of Technology (ETH) Zurich pp. 151.

Kennedy, J. M. and B. A. Baldwin. 1972. Taste preferences in pigs for nutritive and non-nutritive sweet solutions. Anim. Behavior. 20:706.

Keys, J. E., P. J. Van Soest and E. P. Young. 1970. Effect of increasing dietary cell wall content on the digestability of hemicellulose and cellulose in swine and rats. J. Anim. Sci. 31:1172.

Kidwell, J. F. and J. E. Hunter. 1956. The utilization of high level of alfalfa by growing-fattening swine. J. Anim. Sci. 15:1067.

Larson, L. M. and J. E. Oldfield. 1961. Improvement of barley rations for swine. II. Effect of fiber from barley hulls and purified cellulose in barley and corn rations. J. Anim. Sci. 20:440.

LeaMaster, B. R. 1978. Factors influencing the utilization of alfalfa meal by rats and swine. Master's thesis, Oregon State University, Corvallis.

LeaMaster, B. R. and P. R. Cheeke. 1979. Feed preferences of swine: alfalfa meal, high and low saponin alfalfa, and quinine sulfate. Can. J. Anim. Sci. 59:467.

Leibbrandt, V. D. and H. N. Becker. 1977. Feed anti-microbials for growing-finishing swine. Research reports, 22nd. Annual Swine Field Day, University of Florida, Gainsville, Fla.

Mangold, E. 1934. The digestion and utilization of crude fiber. Nutr. Abst. Rev. 3:647.

March, B. E., R. Soong and C. MacMillan. 1978. Growth rate, feed conversion and dietary metabolizable energy in response to virginiamycin supplementation of different diets. Poult. Sci. 57:1346.

Peo, E. R., Jr. 1975. Hay reduces sow feed cost. Swine Information Service, National Hog Farmer Bull. Eq.

Pollmann, D. S., D. M. Danielson and E. R. Peo, Jr. 1979. Value of high fiber diets for gravid swine. J. Anim. Sci. 48:1385.

Pond, W. G. and M. L. Kass. 1977. Higher fiber diets for swine. Cornell Conference for feed manufacturers. pp. 33-38. Cornell University, Ithaca, N.Y.

Rasmussen, R. A., H. H. Smith, R. W. Phillips and T. J. Cunha. 1942. Nutritional inadequacy of beet molasses rations for swine. Utah Agr. Exp. Sta. Tech. Bul. 302.

Robel, E. J. 1979. Effect of dietary protein intakes and flavoring mixture on the performance of early weaned pigs. Nutrition Reports International. 19(3):428.

Self, H. L., R. H. Grummer, O. E. Hays and H. G. Spies. 1960. Influence of three different feeding levels during growth and gestation on reproduction, weight gains and carcass quality in swine. J. Anim. Sci. 19:274-282.

Sheunert, A. 1906. Hoppe Seyler's ZTCH. 48:9. Cited by P. D. Cranwell. 1968. Microbiol fermentation in the alimentary tract of the pig. Nutr. Abs. Rev. 38:72.

Snyder, W. P. 1907. Growing hogs in western Nebraska. Netu. Agr. Sta. Bul. No. 99.

Snyder, W. P. 1930. Pork production at the North Platte substation. Nebr. Agr. Exp. Sta. Bul. No. 243.

Stangel, D. E. 1972. Lysine-arginine interrelationships and dried whey utilization in monogastric rations. Master's thesis, Oregon State University, Corvallis.

Teague, H. S. 1955. The influence of alfalfa on ovulation rate and other reproductive phenomena in gilts. J. Anim. Sci. 14:261.

Woodman, H. E. 1930. The role of cellulose in nutrition. Biol. Rev. 5:273.

Woodman, H. E. and R. E. Evans. 1947. The nutritive value of fodder cellulose by growing and fattening pigs. Jour. Agr. Sci. 37:211.

Zivkovic, S., M. Vapa, B. Tarasenro, S. Kovcin and Dj. Segetlija. 1978. Experiments with flavor feeds on rations for piglets and growers. Working papers First International Symposium on palatability and flavor use in animal feeds. Institute of Animal Production, Nutrition Group. Swiss Federal Institute of Technology (ETH) Zurich. pp. 117-123.