

DIGESTION AND PALATABILITY OF CORN OIL IN EQUINE

by

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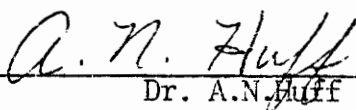
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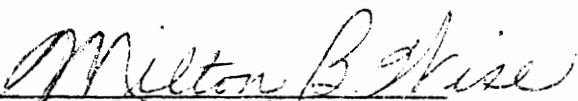
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INTRODUCTION

The addition of fat to certain poultry and livestock rations has become a widely used and successful economic practice. In cattle and poultry, fat has been mainly used for its caloric value. However, other possible benefits of adding fat include improving ration palatability, providing essential fatty acids, aiding in the absorption of fat soluble vitamins, controlling dust, stabilizing mixed feeds against stratification and lubricating and protecting feed handling equipment. It is recognized that small additions of fat or oil to horse rations improves hair coat, hoof appearance and promotes an overall attractive "bloom" to horses.

High performance horses are conventionally fed large amounts of grain to supply energy during prolonged exercise. However, the capacity of the digestive tract, problems with compaction and founder, and the excess weight, limit the level of grain that can be fed. The main source of energy in grain is carbohydrates. Oils supply 2.25 times as much energy as carbohydrates. Therefore, it has been suggested that one method to increase energy intake of the horse is to incorporate this concentrated source of energy into the ration.

The experiments to be reported here were conducted to study the tolerance of equine to high levels of fat and to measure digestibility of fat by ponies.

REVIEW OF LITERATURE

Utilization of Fat by Different Species

The primary site for fat absorption in most species is the small intestine (Pike and Brown, 1975). Previously it had been assumed that the horse could not utilize dietary fats very efficiently because equine do not possess a gall bladder. Swenson (1977) indicated the absence of a gall bladder in horses does not hinder fat digestion. Horses secrete a continuous flow of bile which is released directly into the intestine.

The excretion of fat on a fat-free or low-fat diet represents the metabolic fecal fat, the components of which were described by Langworthy and Holmes (1915) as residues from bacteria, digestive juices, internal secretions, and epithelial cells of the stomach and intestines along with some fat synthesis from carbohydrates and protein. Metabolic fecal fat excretion for adult men is 9.9% of the dry feces (Langworthy and Holmes, 1915). Wollieger et al. (1953) found an average of 1.5 g per day of metabolic fat for humans. Cats were found to excrete 1.76 g of metabolic fat per day (Hill and Bloor, 1922). Sperry and Bloor (1924) determined the metabolic fat excretion for dogs to be .51 g per day. Augur et al. (1947), Norcia and Lundberg (1954) and Carroll (1958) reported rats excreted .51, .005 and .11 g of metabolic fat per day, respectively. Russell et al. (1941) reported values of .09 to .12 g per day of metabolic fat for hens on a diet

with less than .08% crude fat. Bayley and Lewis (1965) determined the fecal excretion of lipids by pigs on a low fat diet containing 2.97 g of fat per day was 11.53 g per day. Bryant (1969) determined metabolic fecal fat of horses was 83.3 g per day. This more clearly shows that horses do indeed excrete more ether-soluble products in the feces per unit of body weight than do other species. Using the correction factor for the metabolic fecal fat Bryant calculated the digestibility of corn oil to be 90%.

Some of the beneficial results of fat cannot be attributed solely to the increased metabolizable calories from the fat, even though it contains 2.25 times the metabolizable calories of carbohydrates. An important part of the extra performance can be ascribed to the lower "associative dynamic effect" of the fat (Forbes and Swift, 1944). According to Forbes and Swift, this means there is an accumulated savings of calories associated with the use of high fat diets because smaller amounts of energy are lost, making more energy available for productive purposes. Potter (1967) fed diets containing 2 and 8% added fat to poultry. The high fat diet resulted in a 9.8% decrease in feed consumption, a 2.5% increase in weight, and 14% improvement in feed efficiency. Each 1% increase in fat improved feed efficiency 2.3%, whereas a 1.5% increase in efficiency would have been expected as calculated from the extra metabolizable energy added in the form of fat. Jensen (1967) reported that work with rats has demonstrated the heat increment is lower for fats than carbohydrates as an energy source; less heat was produced by the

chemical transformations of fats. Jensen also suggests that the energy value of fats available for growth in animals is higher than that predicted from its metabolizable energy value.

Ruminants. Armstrong and Blaxter (1960) found the efficiency of glucose used in fat synthesis to be 55% when ruminally infused. When glucose was infused into the abomasum or directly into the bloodstream the efficiency of utilization was 71%. Martin and Blaxter (1960) used this same approach to study the efficiency of protein for fat synthesis. The efficiency of ruminal and abomasal infusion was 50 and 65%, respectively. Blaxter (1967) reported glucose was more efficiently utilized than volatile fatty acids (VFA) as an energy source in ruminants.

Willey et al. (1952) indicated that feeding high fat rations to fattening steers had a beneficial effect upon feed utilization. Feeding higher levels of fat significantly improved absorption and utilization of dietary carotene and also caused a marked increase in the level of blood fat. Addition of as high as 10% fat can apparently replace cereal grain energy on a digestible energy basis for fattening steer rations (Grainger et al., 1961). Bohman et al. (1962) reported the effects of feeding three levels of alfalfa pellets and two levels of beef tallow to weanling steer calves. Fat appeared to have no effect on winter gains. Summer rate of gain was increased for animals fed fat during the winter. Bohman et al. (1963) fed isocaloric quantities of either barley or animal fat with three levels of alfalfa pellets to Hereford steers. An interaction between source of energy

and alfalfa level indicated that a high level of alfalfa pellets plus a source of starch were necessary for the utilization of animal fat by cattle. In that study, the digestion coefficient of ether extract was 83% for the fat supplemented rations and only 51% for the non-fat supplemented rations.

Addition of 4% tallow or hydrolyzed vegetable and animal fat to a basal fattening ration for cattle resulted in adequate utilization of the added fat as measured by digestible energy and TDN (Esplin et al., 1963). The response of growing finishing beef heifers to rations containing yellow grease, bleached tallow, or acidulated cottonseed oil at levels 2.5, 5.0, 7.5 and 10.0% of the ration was determined by Lofgreen (1965). The results showed there were no significant differences in the performance of animals fed the various fats or levels except for the decrease in feed required per unit of gain as the fat level increased. The addition of 3% dehydrated alfalfa plus 2% fat to an all concentrate fattening ration reduced the efficiency of the feed utilization, as compared to the same ration without fat (Albin and Durham, 1967). The feeding of 192 g of feed grade fat per head per day with corn silage did not improve rate of gain or feed efficiency in finishing beef steers (Perry et al., 1976). A depression of feed intake was also observed.

Swift et al. (1948) fed lard at varying levels to sheep to determine the effect on ration digestibility. A change of 1% fat in the ration did not significantly alter digestibility of energy and dry matter, but differences greater than 3% fat significantly decreased

digestibilities of these components. There was also a trend for a reduced digestibility of protein with increasing levels of the lard. Cameron and Hogue (1968) fed lambs 50 and 90% alfalfa meal rations with 15% corn oil and obtained gains equal to rations without oil. Addition of 15% oil did not create oily or soft carcasses. Feeding growing lambs 3% feed grade fat in a dry diet resulted in depressed crude fiber digestibility (Perry et al., 1976). Treatment of the fat with lecithin depressed protein digestibility significantly, as compared to the basal or diet with 3% added untreated fat.

Bradley et al. (1966) reported the rate of gain was consistently depressed by the simultaneous additions of fat and urea to rations for finishing steers. The digestibility of crude protein was also reduced ($P < .01$) by the addition of urea and fat. Addition of fat alone reduced ($P < .01$) digestibility of dry matter, energy and NFE. Ensiled fat plus urea when fed to dairy cows tended to decrease milk production, decreased dry matter intake, and decreased apparent digestibility of all proximate components except ether extract (Hall, 1970). Williams et al. (1939) reported an increase in total milk production when oil was fed to lactating cows, however, the level of fat in the milk was reduced.

Thomas et al. (1934) were unable to demonstrate any significant differences in degree of saturation, firmness or color in carcass fat from steers fed rations containing fat of varying degrees of saturation. Reiser (1951) and Reiser et al. (1959) have presented evidence to support the theory of "ruminal biohydrogenation." It

appears ruminants possess a process, not present in monogastrics, capable of transforming dietary unsaturated fats into saturated ones which are deposited in body tissues. Shorland et al. (1955) found sheep were able to completely saturate dietary linolenic, linoleic and oleic acids.

Poultry. The use of fats as an energy source in practical poultry rations has become a widely accepted practice. Apparent absorption coefficients of fats by chicks were highest for beef tallow and mutton fat (Duckworth et al., 1950 and Fedde et al., 1962). Natural fats were more efficiently utilized by chicks than were free fatty acids derived from the natural fats (Renner and Hill, 1960). Four-week-old chicks were fed four rations containing glucose, soybean meal and amino acids with varying levels of corn oil (Bos-sard and Combs, 1961). Results showed chicks on the low-fat diet (2% corn oil) had the highest gross energy content per gram of carcass gain, greatest retention of metabolizable energy and lowest heat increment as a percentage of metabolizable energy intake. Carew et al. (1964) found that the metabolic efficiency of the animal fats, beef tallow and bone fat, were as effective as corn, soybean and olive oil for growing chicks.

Feeding of relatively short chain (C_{12} and C_{14}) saturated fatty acids such as coconut fat did not increase metabolic efficiency. The net availability of the metabolizable energy for maintenance and growth was higher for corn oil than for glucose (Carew and Hill, 1967). Potter (1967) fed growing chicks diets containing 2 and 8% fat and

obtained a 2.5% increase in weight and a 14% improvement in feed efficiency with the 8% fat diet. Corn oil was superior to carbohydrate-rich feeds such as yellow corn, milo and wheat (DeGroot, 1968). DeGroot et al. (1971) concluded there were no differences among soybean oil, lard, fancy tallow, prime tallow or brown grease in the utilization of M.E. for maintenance and growth by chicks.

Renner and Hill (1960) established that as the age of the chick increased, utilization of tallows increased. However, the age of the bird had no effect on the absorption of other fats such as vegetable oils.

Abnormal lipid metabolism and lowered feed utilization were observed in mature chickens fed high levels of saturated animal fats (Weiss and Fisher, 1957; Price et al., 1957). Shutze et al. (1958) and Combs and Helbacka (1960) found a significant increase in egg size when layers were fed rations containing either hydrolyzed animal and vegetable fats, corn oil, safflower oil or acidulated soybean soap stock. Dagher et al. (1960) were unable to show any difference in egg quality resulting from the addition of fats to the basal ration. Marion et al. (1960) reported egg production was reduced from adding linoleic and oleic acids to the basal ration. The over consumption of energy by laying hens has been suggested to lower egg production, resulting in obesity and uneconomical feed to egg ratios (Waring et al., 1968). They also reported that feeding tallow improved feed efficiency in laying hens, but the efficiency of metabolic energy utilization decreased as the level of tallow increased. Chaney and Fuller (1975)

indicated that the level of carcass fat in laying hens did not adversely affect egg production.

The effect of dietary fat upon the composition of egg fat and body fat has been studied extensively. Titus et al. (1933) found that the diet of the hen did not affect the yolk fat to any great extent. However, Cruickshank (1934) and Cruickshank et al. (1939) found dietary fat had definite effects on the degree of unsaturation of fat in the yolk. Reiser (1950) and Wheeler et al. (1959) also reported that the fatty acid composition of yolks was significantly affected by the type and level of dietary fat. Evidence has been reported that body fat in poultry can be affected by the type and level of dietary fat (Cruickshank, 1934 and Kummerow et al., 1952).

Swine. Eusebio et al. (1965) and Frobish et al. (1970) reported that addition of fat to the diet of baby pigs resulted in reduced growth rates and increased energy per unit of weight gain. Allee et al. (1971) and Cline et al. (1977) found that the young pig is capable of utilizing fat calories just as effectively as carbohydrate calories when constant ratios of both nutrients are maintained in the diet. Leibbrandt et al. (1975) indicated that an increase from 5% to 10% of lard or hydrolyzed fat in the diet of baby pigs resulted in a decrease in total weight gain. The addition of 5% fat to growing-finishing swine rations, on the other hand, resulted in a 7.5% improvement in gains (.78 vs. .72 kg per day) and a 13% reduction in feed per unit gain (1.36 vs. 1.57) and back fat was 6.2% greater (3.90 vs. 3.68 cm) than on diets with no fat (Moser

et al., 1975).

Fat additions to high protein (14 and 16%) diets resulted in greater improvement in efficiency of feed utilization than when added to low protein (10 and 12%) diets. This emphasized the need for adequate protein to derive maximum benefits from the added fat (Hanke et al., 1975).

Adding corn oil to sow diets from the 109th day of gestation to parturition resulted in greater survival rate of the pigs up until 21 days and greater survival of light weight pigs (Seerley et al., 1975).

It has been long known that the composition of depot fat in monogastrics can be altered significantly by the type of fat in the diet. Ellis and Hankins (1925) did considerable early work with soft pork resulting from feeding unsaturated fats to finishing swine.

Horses. It has not been established which energy source equine prefer or what amount is used at the tissue level. Carlson et al. (1964) reported a decrease in plasma glucose and an increase in free fatty acids in horses during exercise. This would suggest glucose is preferentially oxidized over volatile fatty acids (VFA).

Orally administering glucose to horses resulted in rapid hyperglycemia associated with high concentrations of glucose in the ileum and unchanged concentration in the cecum (Alexander, 1955). Crawford et al. (1970) also reported increasing blood glucose when carbohydrates were fed to equine. No changes in blood glucose levels were found in response to diets with various roughage to grain ratios

(Hintz et al., 1971). Argenzia and Hintz (1972) observed that glucose entry rates and glucose contribution to oxidative metabolism were more elevated in high grain than in hay diets. In this study plasma insulin and glucose oxidation rates increased directly with glucose entry rates, suggesting also that glucose is a preferred oxidative substrate in equine. They suggested that horses on a high grain diet adopt a metabolic pattern resembling monogastrics, while on a high fiber diet, they develop a ruminant-like pattern.

Lipemia in horses has been studied by Bartley (1970) in an attempt to use the plasma level of total lipids to measure metabolic response to disease. Results from this study on lipid content of plasma suggest that equine may differ from other species in the ability to accumulate lipoproteins in the plasma, resulting in "fatty plasma" rather than "fatty liver," observed in other species.

According to Evans (1971) the horse has a flexible metabolic pattern depending upon exercise and substrates present. Goodman et al. (1973) demonstrated that both fat and carbohydrates are utilized for energy during exercise in horses. In their study, after the horses had been trotted for 30 min, plasma free fatty acids rose and muscle glycogen levels were depressed.

In digestion trials with horses, digestion coefficients for ether extract have usually been low and sometimes negative when compared to ruminants on similar diets. The digestion coefficients for crude fat, determined by Langworthy (1903) for meadow grass, timothy, red clover, and alfalfa hays were 21, 47, 29 and 19% for horses and

54, 53, 57 and 49% for ruminants, respectively. Lindsey et al. (1926), using two horses, found digestion coefficients for crude fat of 7 and 16% for mixed hay and 14 and 2% for Kentucky bluegrass. However, 72 sheep receiving the same diets had crude fat digestion coefficients averaging 50%. Lindsey also compared horses and cattle on an oat diet and reported crude fat digestion coefficients of 57 and 89%, respectively.

Olsson and Ruudvere's (1955) review of the literature on equine nutrition cited values for crude fat digestibility for meadow grass, timothy, clover and alfalfa hay of 14, 10, 29, and -14%, respectively. More recently, Haenlein et al. (1966), using alfalfa pellets, wafers, and loose hay, found digestion coefficients for crude fat of -23, -14 and -26% for horses and 30, 20 and 34% for sheep, respectively. In this same study, cattle fed alfalfa pellets and loose hay digested 40 and 35% of the crude fat. Fannesbeck et al. (1967) found ether extract digestibilities for horses fed fescue, canary grass, bromegrass, timothy, alfalfa, or red clover hays to be 10, 22, 6, 19, 5 and 29%, respectively. Vander Noot and Gilbreath (1970) fed orchard grass, alfalfa, timothy, and bromegrass hays to steers and horses and found the crude fat digestibility of these forages to be 47, 31, 49 and 40% for horses, and 53, 48, 61 and 57% for steers, respectively.

According to Armsby (1922) the lower digestibility of ether extract by horses found throughout the literature is most likely due to the probability that horses excrete greater amounts of ether soluble

products in the feces and not to any real difference in digestibility. This theory was further supported by the work of Bryant (1969) who reported that the horse produced large amounts of metabolic fecal fat.

Slade et al. (1975) studied the effect of nutrition on performance in the endurance horse. Three horses were fed diets supplemented with either starch, protein or fat. Blood component changes indicated best performance by the horses supplemented with fat and poorest performance by those supplemented with protein. There appeared to be less dehydration in horses supplemented with fat than in those supplemented with starch or protein.

Kane and Baker (1977) reported that digestibility of ether extract, digestible energy, metabolizable energy and net energy increased as the level of corn oil in horse diets increased.

Monroe and Hintz (1970, unpublished data) found that a diet of 85% alfalfa pellets and 15% beef tallow was more digestible than alfalfa pellets alone.

Effect of Fats on Minerals

Ruminants. Brooks et al. (1954) found that the addition of varying amounts of corn oil to an artificial rumen resulted in a decreased cellulose digestion from 94% for the control to 40% for the tubes with added fat. Additions of corn oil and lard to sheep rations resulted in a decreased cellulose digestion. When 18 g of alfalfa ash were added to the rations containing corn oil and lard, cellulose digestion was similar to that of the basal ration. This effect may be due to the buffering capacity of alfalfa ash, its ability to emulsify

the fat and prevent its coating of the cellulose fibers, or its calcium content. Readily available carbohydrate (corn starch) and fat increased the mineral requirements of rumen microorganisms for cellulolytic activity (Summers et al., 1957). They found the substitution of 2% corn oil into a ration containing 65% corn cobs significantly reduced the digestibility of cellulose, organic matter and crude protein. Alfalfa added to the ration reversed all of these depressions. White et al. (1958) found that feeding 5% corn oil progressively decreased cellulose digestion during the first 40 days of the trial. The addition of 30 g of alfalfa ash to the 5% corn oil ration resulted in normal cellulose digestion. Addition of 4.4 g of calcium or 4.4 g of calcium plus .86 g of phosphorous had a similar effect. Phosphorous alone or a mixture of trace minerals containing copper, molybdenum, manganese, cobalt, iron, zinc and boron was ineffective.

Grainger et al. (1961) added 7% corn oil to a basal sheep ration and found it depressed apparent digestibility of calcium ($P < .05$) and cellulose ($P < .01$). The apparent digestibility of calcium decreased as the insoluble fecal soaps increased. The addition of 4.4 g of calcium per wether per day partially alleviated the depression of cellulose digestibility. Iron added at the level of 6.2 g per wether per day increased digestibility of cellulose but not to the level observed by the addition of calcium or that of the basal ration.

The influence of animal fat on the availability of magnesium for winter rations of milking cows was studied by Kemp et al. (1966).

The results indicated that dietary animal fat caused an increase in magnesium excretion, decreasing the apparent availability. This confirmed the earlier observations that milking cows receiving additional fat excreted more alkali earth soaps in the feces (Esplin et al., 1963). Fresh spring grass contains substantial amounts of lipid and unsaturated fatty acids which parallel the protein content of the grass (Molloy et al., 1973). This may explain in part the decrease in serum magnesium of cows grazing on high protein spring grass (Wind et al., 1966).

Hall (1970) fed complete corn silage rations with 2% fat and .7% urea, 2% fat plus 5% soybean meal and a basal with no fat or urea to dairy cows. The fat decreased dry matter intake and consumption of a vitamin-mineral mix. Hypomagnesemia resulted from borderline mineral intake and reduced digestibility of the magnesium in both of the lipid rations. The addition of excess calcium above NRC recommendations did not improve feedlot performance of steers on rations containing fat (Hatch et al., 1972).

Horses. Hintz et al. (1973) and Monroe and Hintz (1970, unpublished data) in two separate studies did not find decreased absorption of calcium when up to 15% fat was fed.

Plasma Cholesterol

Ruminants. Beef tallow and corn oil, when fed at 2.5 and 4% of the basal diet, did not significantly increase plasma cholesterol in lambs after 2 months, but feed efficiency was increased. The addition of saturated oils (medium chain triglycerides) decreased the feed efficiency and also decreased plasma cholesterol levels (Devier

and Pfander, 1974).

Poultry. Reiser (1950), Fisher and Leveille (1957) and Dagher et al. (1960) reported that type or amount of fatty acids in the ration of the hen did not affect the cholesterol content of the egg. Combs and Helbacka (1960), however, observed a significant increase in the egg cholesterol in hens supplemented with 10% corn oil. Sgoutas and Kummerow (1968) also found various sources of dietary fat had a significant effect on serum and liver cholesterol in chickens. Serum cholesterol was lowest in animals fed 10% corn oil, intermediate in animals fed 10% milk fat and highest in chickens fed 10% hydrogenated coconut oil. It appears that in this species, as blood cholesterol decreases, liver cholesterol accumulates.

Lofland and Clarkson (1968) studied lipid metabolism and atherosclerosis in a breed of pigeons susceptible to atherosclerosis, and concluded that both the level of protein and type of fat influenced coronary atherosclerosis. Hydrogenated coconut oil and corn oil were added to diets containing three levels of protein (5, 15 and 30%). Highest incidence of atherosclerosis was observed in birds on coconut oil and 30% protein diet. The authors suggested serum cholesterol levels may not be valid indicators of atherosclerosis, as the pigeons with increased plaque formation did not necessarily have the highest serum cholesterol levels. Teekell et al. (1975) showed dietary cholesterol played a small role in atherosclerosis in chickens. Cholesterol was fed to young male and female birds at levels of 2 and 6% of the diet. On both treatments, males had higher cholesterol

levels than females. Cholesterol deposited in the livers and aortas of these birds was primarily of endogenous origin and not from the labelled dietary source.

Swine. Lundberg (1965) reported that high fat diets fed to miniature pigs were temporarily hypercholesteremic and tended to increase the incidence of atherosclerosis. He found no difference between beef tallow and corn oil concerning the effects on plasma cholesterol and vascular pathology when fed for 7 years. Blood clotting times of pigs fed high safflower oil levels were significantly longer and hemoglobin levels were lower than those of animals on the same level of beef tallow. Serum cholesterol levels were elevated by feeding 5 or 10% animal or plant fat to growing gilts (Raby and Robinson, 1975).

Toxicity and Oxidative Problems

Ruminants. Some investigators have found the incidence of oxidized flavor in milk to be directly related to type and amount of dietary fat (Stebnitz and Sommer, 1937; Brown et al., 1941). However, Corbett and Tracy (1940) and Prewitt and Parfitt (1935) reported that the same fats as used above did not increase the oxidative flavor in milk.

Poultry. Few toxicity problems have been observed as a result of feeding high fat rations to poultry. However, storage and carcass quality of poultry meat decreased appreciably when high levels of unsaturated fats were fed prior to slaughter (Kummerow et al., 1948;

Klose et al., 1953). Another problem related to feeding fat was reported by Singsen et al. (1958). They found energy needs of broilers on a high energy ration do not regulate energy intake. Under these conditions Plymouth Rock hens became obese and suffered high mortality related to the excess caloric intake.

Swine. Addition of 4 and 8% rancid fat to a corn-soy diet did not depress performance nor affect palatability of pork steaks (Lewis et al., 1975).

Rats. Toxicity problems in rats resulting from the ingestion of autoxidation products from various oils have been reported (Holman and Greenberg, 1958; Johnson et al., 1956). The formation of peroxides and polymers during thermal oxidation of the oils resulted in growth depression, intestinal irritation, a laxative effect and possible enzyme-inhibiting or vitamin-destroying effects in the rats.

Horses. Monroe and Hintz (1970, unpublished data) reported that ponies could tolerate up to 18% fat in the ration without any digestive disturbance. Tyznik (1976, personal communications) reported that ponies would tolerate up to 40% corn oil in a ration using dried beet pulp to absorb the fat and enhance palatability. However, Tyznik found the digestibilities of ration components decreased as the level of fat reached 40%.

OBJECTIVES

Experiments were conducted to evaluate the feeding of corn oil to equine.

The specific objectives of this research project were to determine:

1. The palatability of rations containing different levels of corn oil
2. The ability of the equine to tolerate high levels of oil without developing digestive disturbances
3. The digestibility of the corn oil

EXPERIMENTAL PROCEDURE

Palatability Experiment

A pilot palatability study was conducted with four Hackney-Welsh-Shetland ponies fed three times per day in 3.7 X 3.7 m box stalls and allowed 1 hr per feeding. Ponies were fed rations with various amounts and ratios of components in an attempt to determine the most acceptable ration. The final rations which were found to be consumed in moderate amounts are shown in table 1.

A palatability trial was conducted with four ponies to establish the upper level of corn oil accepted by the animals. Rations containing 0, 10, 20 and 30% corn oil were offered to the animals. The basal ration consisted of 55% alfalfa hay, 25% cracked corn and 20% crimped oats. Corn oil was substituted into the basal ration at 10, 20 and 30% by weight. The ingredient composition of the rations is given in table 1. The basal (0% oil) ration was formulated to meet minimum digestible energy requirements for a 225 kg mature horse at rest with excess phosphorous, calcium, and crude protein, according to NRC (1973) requirements, so that when 30% oil was substituted in the ration minimum requirements of calcium, phosphorous, and crude protein were met.

The alfalfa (mid-bloom) was chopped in a high speed hammermill through a 2.5 cm screen. The oats and corn were processed in a "Grain Buster" roller.¹

The feeds for the palatability trial were offered cafeteria style to each pony for 15 days. Each stall had a feed trough partitioned

¹Allen Eng. Co., Detroit, Michigan.

TABLE 1. INGREDIENT COMPOSITION OF RATIONS USED IN
PALATABILITY AND DIGESTION TRIALS

Experiment	Ingredient	Corn oil, % of ration ^a				
		0	5	10	20	30
		-----kg/day-----				
Palatability	Alfalfa	1.99		1.79	1.59	1.39
	Corn	.96		.87	.78	.69
	Oats	.69		.62	.56	.49
	Oil	--		.33	.66	.99
	Total	3.64		3.61	3.59	3.56
Digestion	Alfalfa	1.99	1.89	1.79	1.59	
	Corn	.96	.92	.87	.78	
	Oats	.69	.66	.62	.56	
	Oil	--	.16	.33	.66	
	Total	3.64	3.63	3.61	3.59	

^aCorn oil levels calculated as percent of dry matter.

into four 35 X 40 cm sections. The dividers between each section were 30 cm high to prevent dropping and mixing of the feeds as the animals moved from one section to another. The animals were fed three times per day and allowed 20 min per feeding. At the end of 20 min, refusals were collected and weighed to determine preference. The rations were randomly rotated daily to prevent animals from establishing a feeding pattern. Animals were housed in individual 3.7 X 3.7 m stalls.

Digestion Experiment

Three digestion trials were conducted with eight mature Hackney-Welsh-Shetland ponies averaging 225 kg. The ponies were assigned to two groups (blocks) of four on the basis of weight. The animals within each group were randomly allotted to four rations in two randomly selected 4 X 4 Latin square (appendix table 1). Each digestion trial consisted of a transition period, a 7-day preliminary period, followed by a 7-day period during which total fecal excreta was collected. Each animal was fed 1.82 kg of the experimental ration twice daily at 12 hr intervals. Rations were sampled at each feeding starting 2 days prior to the initiation and 2 days prior to the end of the collection period.

Chemical Composition of Rations. The chemical composition of the experimental rations is shown in table 2. The dry matter content of the four rations increased with increasing levels of oil. The values were 90.30, 91.49, 92.51 and 93.50% for 0, 5, 10 and 20% oil, respectively. The percent crude protein ranged from 14.1% in the 0% corn oil ration to 9.7% in the 20% level.

The fatty acid content of the rations increased linearly as expected according to the addition of the oil. The percent of naturally

TABLE 2. CHEMICAL COMPOSITION OF RATIONS USED IN DIGESTION TRIALS

Item	Corn oil, % of ration			
	0	5	10	20
Dry matter, %	90.30	91.49	92.51	93.50
Composition of dry matter, %				
Crude protein	14.05	12.96	10.91	9.74
Fatty acids	3.69	7.58	12.81	23.32
Acid detergent fiber	23.30	21.89	20.72	23.19
Ash	5.58	5.21	4.87	4.31
Calcium	.68	.61	.59	.53
Phosphorous	.275	.260	.246	.224
Magnesium	.158	.145	.134	.126

occurring fatty acids in the basal ration containing alfalfa hay, corn and oats was 3.69%, dry basis. The addition of 5, 10 and 20% corn oil increased the fatty acid content to 7.58, 12.81 and 23.32%, respectively. In all cases the actual fatty acid values are slightly below the theoretical content of 8.69, 13.69 and 23.69%, respectively. Small amounts of the oil were observed adhering to the surfaces of mixing equipment, feed containers, and sample jars. This may partially explain the differences between actual and theoretical fatty acid content.

Acid detergent fiber (ADF) decreased as the level of oil in the ration increased up to the 10% level, then increased at the 20% level. This discrepancy could be due to the large amount of oil in the 20% ration, which may have interfered with the chemical processes or due to the differences in the particle size of the sample. The samples of 0 and 5% oil rations were ground through a 1 mm screen in the Wiley mill. However, the samples containing 10 and 20% oil clogged the mill. For these rations, it was necessary to use a Waring blender to grind the feed samples, resulting in larger particle size. With this increased particle size, it is suggested that the degradation of components was incomplete, resulting in an overestimation of the fiber content of these two rations.

The ash content decreased as the oil was substituted into the rations. Calcium, phosphorous, and magnesium values also decreased as the level of oil increased.

Rations were mixed at 7-day intervals to prevent oil rancidity during hot weather. Rations were mixed in a horizontal mixer and stored in 135 liter containers with double plastic linings.

Ponies were individually housed in 1.9 X 3.7 m stalls. Water

and trace mineralized salt were available ad libitum. Animals remained free in stalls except for being exercised by walking for 10 min daily. Stalls were bedded with hardwood sawdust. Internal parasites were controlled by paste worming all animals prior to trial 1 and again prior to trial 3.

Total fecal collection was made with fecal collection bags described by Carle (1975). The bag was attached to each animal by means of a modified version of the harness described by Carle (1975). The collection bags were constructed of heavy canvass and the harnesses were made of nylon webbing. The various parts of the harness were sewn together with heavy gauge nylon thread. The design of the bag and harness is shown in figure 1. The unit fit securely on the animal and did not appear to cause discomfort. The front view in figure 1 shows the webbing which encircled the chest, preventing the weight of the feces in the bag from pulling the harness and bag backwards. This chest strap was adjusted by means of a friction-grip buckle attached to the sursingle-like strap around the heartgirth. This heartgirth strap was adjusted by means of a Latigo knot. An adjustable "holddown" strap passing forward between the front legs from the girth strap kept the chest strap from riding up on the throat of the animal. Three straps came off each end of the chest strap and were attached to metal rings on the bag. These straps were also adjusted by means of small friction-grip buckles. The straps were adjusted tightly enough so the bags fit securely in order to collect all feces, without causing irritation or chaffing of the animal.

The front of the chest strap and the top of the heartgirth strap where it fit over the withers were padded with a layer of

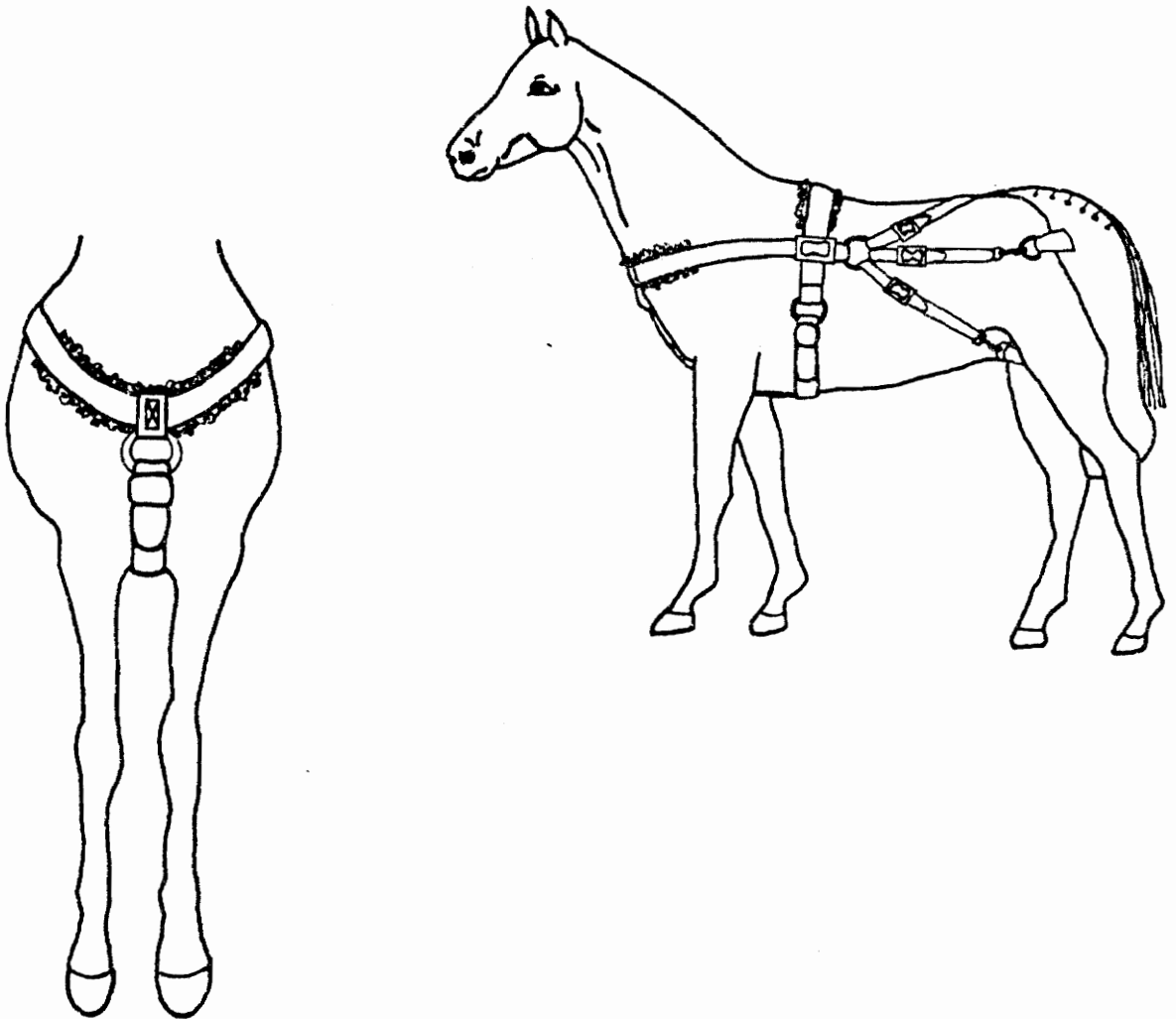


Figure 1. Adjustable harness designed for use with fecal collection bag for medium-sized male pony.

synthetic fleece material to avoid pressure sores. The harnesses, although designed to fit medium sized ponies could be adjusted to fit smaller horses.

During the collection periods the fecal bags were changed and emptied 2 hr after each feeding. At the end of each day, the two fecal collections for each animal were composited in metal cans, weighed, thoroughly mixed, a 5% sample was taken, treated with a small amount of thymol and stored under refrigeration. At the end of the collection period, the seven daily fecal samples for each animal were mixed and one half was dried in a forced air oven at 55 C and the remainder was frozen. The dried fecal samples were allowed to equilibrate to atmospheric moisture. Feed and feces were finely ground in a Wiley mill through a 1 mm screen.

Nitrogen was determined on the feed and wet fecal samples by A.O.A.C. (1975) procedures. Due to the formation of ether insoluble soaps in the gastrointestinal tract, the conventional wet ashing, crude fiber, and ether extract methods were not used. Dry ashing of all samples was accomplished by a modification of the method of Kemp et al. (1961). Feed and fecal samples were analyzed for acid detergent fiber by the method of Van Soest (1963). Total fatty acids in feeds and feces were determined by a modification of the method of van de Kamer (1965). Calcium, phosphorous and magnesium in feed and feces were determined on the dry ashed samples by Perkin-Elmer 403 atomic absorption spectrophotometric methods.

Blood samples were drawn by jugular vein puncture at the end of each trial. Inorganic phosphorous in blood serum was determined using the method of Fiske and Subbarow (1925). Serum calcium and

magnesium were determined using the Perkin-Elmer 403 atomic absorption spectrophotometric methods. Serum cholesterol and triglycerides were simultaneously determined using the Technicon Auto Analyzer.

Acid insoluble lignin in feeds and feces were determined according to TAPPI (1974).

Analyses of variance were conducted to determine the significance of differences among treatment means. When differences among treatments were significant, curvilinear regressions were computed (Snedecor and Cochran, 1967).

True digestibility of the fatty acids was calculated according to an equation presented by Bryant (1969). This equation defined metabolic fecal fat (y) of equine as a function of fecal dry matter (x), where $y = .07 + .0321x$. True digested fat can then be determined as the difference between total fat intake and total fat outgo minus the metabolic fecal fat.

RESULTS AND DISCUSSION

Palatability Experiment

Preliminary Trial. Initially 50% grass hay, 30% corn, 15% oats, and 5% soybean meal were used. Molasses was added at levels of 5 and 10% to enhance the palatability of rations containing high levels of oil. Alfalfa hay was then substituted for the mixed grass hay. The addition of the alfalfa increased acceptance, so the molasses was deleted. Alfalfa also increased the protein level making the soybean meal unnecessary.

Palatability Trial. Results of the palatability trial are shown in table 3. Over the 15-day period, 52.6% of the total feed consumed was the basal ration. Only 9.6% of the total amount consumed was the 30% corn oil ration. The 10 and 20% oil rations represented 22.9 and 14.9% of the total feed consumed, respectively. Due to the low voluntary consumption of the 30% ration, it was decided to use 20% as the maximum level of corn oil for the subsequent digestion trials.

Digestion Experiment

Feed Consumption. All ponies consumed the rations in all three trials with the exception of one animal in trial 2. This animal was receiving the 20% corn oil ration and refused a total of 462 g.

No visible digestive disturbances were observed on any level of corn oil. One animal had abnormally wet feces, but this condition persisted regardless of level of corn oil consumed.

Hair coat of all animals improved in sheen and an overall "bloom" was evident in all animals.

TABLE 3. PALATABILITY OF RATIONS WITH DIFFERENT LEVELS
OF CORN OIL

Level of corn oil	Consumed, 15 days	Percent of total consumption
%	g	
0	10,077	52.6
5	4,388	22.9
10	2,860	14.9
20	1,826	9.6

Apparent Digestibility of Crude Protein. The apparent digestibility of crude protein is shown in table 4. There was no significant change in the crude protein digestibility due to the addition of fat to the ration. Average values were 70.7, 70.9, 67.1 and 69.3% for the rations with 0, 5, 10 and 20% corn oil, respectively. Swift et al. (1948) reported that the addition of greater than 3% fat tended to cause a decrease in the crude protein digestibility by sheep. Summers et al. (1957) reported reduced crude protein digestibility in sheep fed 2% fat in the ration.

Energy Digestibility. The apparent digestibility of energy increased linearly ($P < .05$) as the level of oil increased (table 4). The values ranged from 46.5% at the 0% level to 69.7% at the 20% oil level. The values for the 5 and 10% oil rations were similar (55.9 and 56.5). The increase in energy digestibility with the addition of corn oil has been observed by Bryant (1969) and Kane and Baker (1976). A trial difference was also apparent in this study. The digestibility of energy in trial 1 was higher ($P < .05$) than in trials 2 and 3.

The apparent digestibility of energy of the corn oil, calculated by difference, showed a trend for a linear increase with the level of oil in the ration. Due to large variations in the values when calculated by difference, the differences were not significant. The apparent digestibility of energy in the oil over all treatments, calculated by difference, averaged approximately 90%. This agrees closely with the value of 91% reported by Bryant (1969).

Fatty Acid Digestibility. Values for apparent digestibility of fatty acids are given in table 5. The apparent digestibility of the

TABLE 4. APPARENT DIGESTIBILITY OF CRUDE PROTEIN AND ENERGY
BY PONIES FED DIFFERENT LEVELS OF CORN OIL

Level of corn oil	Apparent digestibility, %		
	Ration		Fat
	Crude protein	Energy	Energy ^b
0	70.7	46.5	
5	70.9	55.9	65.4
10	67.1	56.5	93.7
20	69.3	69.7	108.3

^aLinear effect was significant ($P < .05$).

^bCalculated by difference using the formula $S = \frac{100(T - B)}{s} + B$

where S is the digestibility of fat, T is the digestibility of the basal plus fat, B is the digestibility of the basal, and s is the calories from the % fat (Crampton and Harris, 1969).

TABLE 5. FATTY ACID DIGESTIBILITY BY PONIES FED DIFFERENT LEVELS OF CORN OIL^a

Level of corn oil	Apparent digestibility		True digestibility ^d
	Ration ^b	Corn oil ^{bc}	
%	%	%	%
0	42.8		87.0
5	61.8	74.4	77.2
10	70.2	84.8	76.4
20	84.7	94.4	84.7

^aEach value represents the mean of six animals.

^bLinear effect was significant ($P < .05$).

^cCalculated by difference.

^dCalculated by Bryant's equation (1969). True digested fat = $\frac{\text{total fat intake} - (\text{total fat in feces} - \text{metabolic fat})}{\text{total fat intake}} \times 100$
 where metabolic fat = $.07 + .0321 (\text{fecal dry matter})$.

of the fatty acids in the rations increased in a linear fashion ($P < .05$) as the corn oil increased from 0 to 20%. The greatest increase, 19 percentage units was between 0 and 5% corn oil levels, with an 8.4 unit increase between 5 and 10% levels and 14.5 units between the 10 and 20% levels. When calculated by difference, the fatty acids showed the same increase in digestibility of 10 percentage units between 5 and 10% and between 10 and 20% corn oil levels. The best true digestibility of fat occurred in animals fed the basal ration. Since there was only 3.69% fatty acids present in this ration, perhaps this component would be most efficiently used by the animal. When 5% corn oil was used the true digestibility decreased from 87.0 to 77.2%. The digestibility remained at approximately the same level when corn oil was increased to 10%. At the 20% level of corn oil the value rose to 84.7%

Blood Constituents. Blood serum levels of calcium, inorganic phosphorous, and magnesium are shown in table 6. Serum calcium levels exhibited a cubic effect ($P < .05$). Serum calcium levels of ponies on 0, 10 and 20% corn oil rations were similar, but the level of ponies on 5% oil tended to be higher. Serum levels of calcium in trials 1 and 2 were higher ($P < .05$) than in trial 3. However, all serum calcium levels remained within the normal range reported by Swenson (1977). It would appear this trial difference in calcium level was not due to differences in calcium levels of the experimental rations (appendix table 2).

Serum inorganic phosphorous and magnesium values were not affected by the level of corn oil in the diet. Inorganic phosphorous

TABLE 6. EFFECT OF DIFFERENT LEVELS OF CORN OIL ON SERUM LEVELS OF CALCIUM, INORGANIC PHOSPHOROUS AND MAGNESIUM^a

Level of corn oil	Calcium ^b	Inorganic phosphorous	Magnesium
%	-----mg/100 ml-----		
0	12.56	4.36	1.97
5	13.12	4.12	1.99
10	12.36	4.06	1.87
20	12.45	4.19	1.94

^aEach value represents the mean of six animals.

^bCubic effect was significant ($P < .05$)

varied only slightly and averaged 4.18 mg per 100 ml of serum for all diets. Serum magnesium ranged from 1.87 to 1.99 and averaged 1.94 mg per 100 ml of serum. All levels of inorganic phosphorous and magnesium were within the normal range for horses (Swenson, 1977).

Serum cholesterol (table 7) values demonstrated a quadratic effect ($P < .05$) as the level of oil in the ration increased. The greatest increase ($P < .05$) occurred between the 0 and 5% oil levels (122 to 144 mg per 100 ml). The values for the 10 and 20% oil rations continued to show increases to 148 and 155 mg per 100 ml, respectively, but the increases were not as dramatic. All of the cholesterol values were within the normal range of 75 to 150 mg per 100 ml of serum (Swenson, 1977). Triglyceride values were not significantly affected by the addition of corn oil to the ration. Lundberg (1965) reported increases in both cholesterol and triglyceride levels in animals fed diets containing oil. The trials, however, were conducted over prolonged periods of time.

Hemoglobin and hematocrit levels (table 8) were within the normal range and were not affected by the level of oil in the ration. However, the hemoglobin levels of the ponies were higher ($P < .05$) in trials 1 and 2 than in trial 3. According to Swenson (1977) these hemoglobin levels are still within the normal range of 13 to 18 g per 100 ml. The hematocrit values recorded in the present study are within the normal range of 35 to 55% (Swenson, 1977). Lundberg (1965) found low hemoglobin values and a decreased blood clotting time in pigs fed high fat diets for extended periods.

TABLE 7. SERUM CHOLESTEROL AND TRIGLYCERIDE LEVELS OF PONIES
FED DIFFERENT LEVELS OF CORN OIL^a

Level of corn oil	Cholesterol ^b	Triglyceride
%	mg/100 ml	mg/100 ml
0	122	24.4
5	144	24.1
10	148	16.8
20	155	19.7

^aEach value indicates the mean of six animals.

^bQuadratic effect was significant ($P < .05$).

TABLE 8. HEMOGLOBIN AND HEMATOCRIT OF PONIES FED DIFFERENT LEVELS OF CORN OIL^a

Level of corn oil	Hemoglobin	Hematocrit
%	g/100 ml	%
0	15.7	41.2
5	17.1	43.8
10	16.2	45.6
20	15.8	44.1

^aEach value indicates the mean of six animals.

Large negative values were recorded for apparent digestibility of acid detergent fiber, resulting from the consumption of the sawdust bedding by the ponies. According to TAPPI (1974) the lignin predominant in hardwood sawdust is largely undigestible by non-ruminants. Lignin determinations were conducted to estimate the percent of acid-insoluble lignin in the feed and feces. The large amounts of oil present in the feeds interfered with the lignin determinations (W.F. Glasser, personal communications). Furthermore, since all ponies consumed sawdust in varying amounts, a reliable standard for comparison was not possible.

Sawdust is low in crude protein and fatty acids but high in acid detergent fiber. The gross energy of the sawdust is very similar to that of feces. Therefore, probably ADF was the only component which was substantially affected.

SUMMARY

Experiments were conducted to determine the palatability and digestibility of corn oil by ponies. A 15-day palatability trial established 20% as the maximum level of corn oil readily consumed by the ponies. Three digestion trials were conducted with eight mature gelding ponies weighing about 225 kg (incomplete Latin squares). A 7-day preliminary period preceded each 7-day collection period. Canvas collection bags and harnesses were used to collect total fecal excreta. In each trial, two ponies were fed each of four rations. The basal ration was composed of chopped alfalfa hay, cracked corn and crimped oats. In the experimental rations, corn oil was substituted for 5, 10 and 20% of the basal ration. At the end of each trial blood samples were taken.

Addition of oil to the ration did not affect the apparent digestibility of crude protein. Apparent digestibility of fatty acids increased linearly with the level of corn oil. Values were 43, 62, 70 and 85% for rations containing 0, 5, 10 and 20% corn oil, respectively. Apparent digestibility of fatty acids in the corn oil, calculated by difference increased with level of corn oil. The value was 94% for the oil when substituted for 20% of the basal ration. Blood hemoglobin and hematocrit were normal and were not affected by feeding corn oil. Serum cholesterol increased from the addition of corn oil (122, 144, 148, 155 mg/100 ml for rations containing 0, 5, 10, and 20% oil, respectively). Serum triglyceride levels were not affected by ration fed. Serum calcium and magnesium levels remained in the normal range, and were not consistently affected by the corn oil level in the ration.

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APPENDIX TABLE 1. ARRANGEMENT OF LATIN SQUARES

Latin square no. 1 (Heavy)

<i>Animal no.</i> <i>Trial no.</i>		8	1	5	3
1	C	D	B	A	
2	A	B	C	D	
3	B	A	D	C	
4	D	C	A	B	

Latin square no. 2 (Light)

<i>Animal no.</i> <i>Trial no.</i>		4	6	2	7
1	C	D	A	B	
2	D	C	B	A	
3	A	B	C	D	
4	B	A	D	C	

Letters refer to rations as follows:

- A - Basal ration with 0% oil
- B - 5% oil
- C - 10% oil
- D - 20% oil

APPENDIX TABLE 2. HEMOGLOBIN OF PONIES FED DIFFERENT LEVELS OF CORN OIL

Level of corn oil	Trial			Mean
	1	2	3	
%	-----g/100 ml-----			
0	18.21	17.63	11.23	15.69
5	18.37	19.85	12.89	17.05
10	17.58	17.54	13.53	16.21
20	16.33	16.23	14.84	15.80
Mean	17.62 ^a	17.81 ^a	13.13 ^b	

^{ab}Means in the same row having different superscript letters differ significantly (P<.05)

APPENDIX TABLE 3. CALCIUM CONTENT OF FEEDS CONTAINING DIFFERENT
LEVELS OF CORN OIL

Level of corn oil	Trial			Mean
	1	2	3	
	-----%			
0	.67	.67	.71	.68
5	.58	.62	.62	.61
10	.57	.60	.60	.59
20	.51	.54	.53	.53
Mean	.58	.61	.62	

VITA

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DIGESTION AND PALATABILITY OF CORN OIL IN EQUINE

by

Virginia Ann Bowman

(Abstract)

Experiments were conducted to determine the palatability and digestibility of corn oil by ponies. A 15-day palatability trial established 20% as the maximum level of corn oil readily consumed by the ponies. Three digestion trials were conducted with eight mature gelding ponies weighing about 225 kg (incomplete Latin squares). A 7-day preliminary period preceded each 7-day collection period. Canvas collection bags and harnesses were used to collect total fecal excreta. In each trial, two ponies were fed each of four rations. The basal ration was composed of chopped alfalfa hay, cracked corn and crimped oats. In the experimental rations, corn oil was substituted for 5, 10 and 20% of the basal ration. At the end of each trial blood samples were taken. Addition of oil to the ration did not affect the apparent digestibility of crude protein. Apparent digestibility of fatty acids increased linearly with the level of corn oil. Values were 43, 62, 70 and 85% for rations containing 0, 5, 10 and 20% corn oil, respectively. Apparent digestibility of fatty acids in the corn oil, calculated by difference increased with level of corn oil. The value was 94% for the oil when substituted for 20% of the basal ration. Blood hemoglobin and hematocrit were normal and were not affected by feeding corn oil. Serum cholesterol increased from the addition of corn oil (122, 144, 148, 155 mg/100 ml for rations

containing 0, 5, 10 and 20% oil, respectively). Serum triglyceride levels were not affected by ration fed. Serum calcium and magnesium levels remained in the normal range, and were not consistently affected by the corn oil level in the ration.