A Review of Research on Digestion and Utilization of Fat by the Equine

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Summary

It appears that equines can digest and utilize supplemental amounts of fat or oil effectively, and there appears to be extracaloric effects of feeding some fats and oils. Some of the variation in experimental results of feeding various fats and oils is likely due to differences in the source and quality of the fat or oil, amounts fed and composition of diets. Additional comparative research is needed to determine safe and effective upper limits to use of various fats or oils in equine diets. Other research and field studies are needed to more clearly define the efficacy of feeding fat-supplemented diets on the health, productivity and athletic performance of equines.

Verdauung und Ausnutzung von Fetten beim Pferd – ein Überblick

Pferde scheinen supplementierte Fette oder Öle gut zu verdauen, bei einigen Fetten und Ölen besteht offenbar ein zusätzlicher energetischer Effekt.
Als Ursachen für die Variation der Versuchsergebnisse bei verschiedenen Fetten und Ölen kommen ihre Art und Qualität, aber auch eingesetzte Mengen und die Zusammensetzung der Gesamtration in Frage.
Um Fette und Öle in Pferdefutterrationen besser und sicherer einsetzen zu können und um die obere Verträglichkeitsgrenze zu ermitteln, sind weitere Untersuchungen notwendig. Dies gilt auch für weitere Erkenntnisse im Hinblick auf die Wirkung fettangereicherter Rationen auf Gesundheit, Produktivität sowie Leistungsfähigkeit des Pferdes.

There has been a lot of interest recently in the use of fat to increase energy intake in horses with high energy requirements. Research on the use of fat in equine diets has lagged behind that in other areas, but several studies have revealed that horses and ponies digest fat effectively. There seem to be both caloric and extracaloric effects of feeding fat to equines. This paper summarizes those reported effects.

Digestion of Fat

Bowman et *al.* (1977) fed corn oil at 0, 5, 10, and 20 % of a basal ration and found that the apparent digestibility of fatty acids was increased with the level of corn oil in the diet. Apparent digestibilities of fatty acids were 43, 62, 70, and 85 % for rations containing 0, 5, 10, and 20 %, respectively. Some of the apparent increase in fat digestion at higher fat intake was likely due to the diluting effects on metabolic fecal fat. When fed 20 % of the ration, the energy in corn oil was apparently 94 % digestible. There was no affect on apparent digestibility of crude protein.
Bowman et *al.* (1979) compared the acceptability and digestibility of various fats. In three palatability trials the horses preferred a diet containing corn oil. The second preference was a blended fat followed by inedible tallow and peanut oil, respectively. The digestibilities of the fats were reported later by *Rich* et *al.* (1981). When each fat was substituted into a basal ration at 10 %, apparent digestibilities of the energy in fat, calculated by difference, was 94, 74, and 70 %, respectively, for corn oil, inedible tallow and blend No. 3 (a blended animal and vegetable fat). The apparent digestibilities of cell contents, crude protein and acid detergent fiber were similar for all diets. Neutral detergent fiber digestibility was higher ($P < .05$) when diets contained no fat and corn oil, compared to a diet containing blend No. 3.
Apparent digestibilities of diet constituents were also determined in a second experiment by *Rich* et *al.* (1981). Diets contained 0, 7.5 and 15 % corn oil, peanut oil, blend No. 3 and inedible tallow. Dry matter digestibility was higher ($P < 0.1$) when the peanut oil diet was fed vs. the diet containing inedible tallow, with diets containing corn oil and blend No. 3 intermediate. There was no significant effect of the source or amount of fat on apparent digestibility of crude protein. Apparent digestibility of ether extract was higher ($P < .05$) when diets containing 15 % fat were fed compared to the diets containing 7.5 % fat, and feeding both amounts of added fat resulted in higher ($P < .05$) digestibility of ether extract than feeding the basal diet. These effects are likely the result of the effects of metabolic fecal fat on apparent digestibility of fat. Apparent digestibility of cell contents and neutral detergent fiber were highest ($P < .05$) for the diet containing peanut oil and similar among other diets. This appeared to be due to the very high digestibility of the 15 % peanut oil diet (84 %). However, the level of fat did not affect the digestibility of either neutral detergent fiber or cell contents. The digestibility of acid detergent fiber was increased ($P < .05$) with increasing amounts of fat and was lower ($P < .05$) in the basal diet than in the fat-supplemented diets. Apparent digestibility of energy was higher ($P < .05$) in the corn oil diet than those containing inedible tallow and blend No. 3 with the lowest being the basal diet. At 15 % added fat, the apparent digestibility of energy in the fat was 90, 84, 77, and 76 % for corn oil, peanut oil, blend No. 3 and inedible tallow, respectively. Apparent absorption of calcium and phosphorus were not affected by the type or level of fat, however the absorption of magnesium was higher in the basal diet and that containing blend No. 3.
Kane et *al.* (1979) found that the addition of 10 % corn oil to a basal diet had no significant effect on digestibilities of dry matter, energy or neutral detergent fiber, however, it did result in a significant increase ($P < .01$) in apparent digestibility of ether extract. Again, this observation was probably due to the diluting effects on metabolic fecal fat at

the higher levels of fat intake. A by-difference calculation revealed that digestibility of the corn oil was 93 %.
Snyder et *al.* (1981) determined the digestibility of diets containing three fats fed at a level of 15 % of the basal ration. The fats used were corn oil, inedible tallow and blended fat (animal and vegetable fat mixture). Apparent dry matter and protein digestibilities were not affected by the addition of 15 % fat to the basal ration. The apparent digestibility of energy in the diets tended to be higher with the addition of corn oil.
McCann et *al.* (1987) fed different sources of fat to mature ponies in diets containing 15 % corn oil, 15 % blended fat or 15 % inedible tallow. The addition of fat did not affect apparent digestibility of dry matter, protein, cell contents, neutral detergent fiber or acid detergent fiber. There was an increase ($P < .01$) in apparent digestibilities of ether extract and fatty acids in all fat supplemented diets when compared to the basal diet. Estimated true digestibility of fatty acids was not different between sources of fat, but in all fat-supplemented diets, the estimated true digestibility of fatty acids was higher (84 %) than the basal diet (59 %). This resulted in a trend for higher energy digestibilities in the fat-supplemented diets. Absorption of calcium and phosphorus were not affected by adding fat to the diets.
Worth et *al.* (1987) reported that feeding a diet containing 14 % added fat resulted in lowered digestibilities of dry matter, crude protein and neutral detergent fiber. Conversely, *Webb* et *al.* (1987) reported in two experiments that feeding a concentrate diet containing 10 % fat actually resulted in increased digestibility of neutral detergent fiber over the control, high-concentrate diet. This effect was thought to be due to removing some of the suppressing effects of starch fermentation on fiber digestion in the large intestine by the substitution of fat for carbohydrates.
Meyers et *al.* (1989) found no differences in nutrient digestibilities when feeding 5 % and 10 % feed grade rendered animal fat to mature exercising horses, but *Davison* et *al.* (1991) reported increased apparent protein and energy digestibilities ($P < .05$) in mature mares fed fat-supplemented diets.
Scott et *al.* (1989) reported that energy digestibility was higher ($P < .05$) in yearling horses fed a concentrate containing 10 % added fat (65.6 %) compared to those fed a control diet (61.4 %). Further, apparent digestion of protein and ether extract were higher in the horses fed fat-supplemented diets, but again these effects were due to diluting effects on metabolic fecal protein and fat. Digestibility of neutral detergent fiber was increased in the horses fed the fat-supplemented diet similar to the report of *Webb* et *al.* (1987).
In a study with weanlings, *Davison* et *al.* (1991) found that the digestibility of all nutrients tended to be higher in those weanlings fed a fat-supplemented diet with the increase in digestion of neutral detergent fiber discussed previously.
In summary, it appears that horses digest fat rather efficiently when fat is fed at approximately 5 – 15 % of the diet. At these levels of fat in the diet, there is no apparent detrimental effect on fermentative digestion in the large intestine. However, further research is needed to determine the upper limit to fat digestion in the equine small intestine.

Metabolic Effects of Feeding Fat

Energy Balance
Kane et *al.* (1979) investigated energy partitioning in ponies fed supplemental fat. Corn oil was fed to provide 15 % and 30 % additional digestible calories to a maintenance diet of oats. An open circuit respiration calorimetry system was used to determine heat production and to calculate energy balance. The digestible and metabolizable energy densities of diets were increased due to the addition of the corn oil. However, heat production was not significantly affected. Therefore, since the increase in metabolizable energy was not lost as additional heat, the energy available for production or work was increased due to feeding corn oil. The conversion of metabolizable energy to net energy for fattening averaged approximately 85 %.
Snyder et *al.* (1981) determined heat production values for corn oil, inedible tallow and blended fat. Even though, the total heat production increased with the addition of fat to the diet, the increase in metabolizable energy was greater than the increase in heat production. The energy balance was approximately 20 % greater for the 15 % fat diets than for the basal diet, therefore, more energy was available for body gain or production. Heat production was highest for the inedible tallow followed by corn oil and blended fat (754, 671, and 591 kcal/kg fat, respectively).
McCann et *al.* (1987) also measured heat production by ponies fed three sources of fat. They found that energy balance was increased approximately 88 % over the basal diet due to feeding fat, but there were no differences in heat production nor in the utilization of energy between corn oil, inedible tallow and a blended fat.
Potter et *al.* (1990) conducted a study to determine if the substitution of fat in diets for exercising horses under varying degrees of thermal stress would alter digestible energy requirements. Mature horses fed to fleshy or moderate condition were fed a control and a fat-supplemented diet in a repeated switchback design. All horses were given a constant workload at the same intensity. When the horses were fed the fat-supplemented diet, they required significantly less digestible energy than when they were fed the control diet. This reduction in the demand for digestible energy was thought to be due to the reduction in the heat of fermentation and subsequent reduction in energy requirements for thermal regulation when the horses were fed the fat supplemented diet.

Blood Chemistry
Bowman et *al.* (1977) reported that serum cholesterol increased ($P < .05$) from basal concentrations when ponies were fed rations containing 0, 5, 10 and 20 % corn oil (122, 144, 148, and 155 mg/100 ml, respectively). However, feeding corn oil had no effect on blood hemoglobin, hematocrit, serum triglycerides, serum calcium or magnesium. Subsequently, *Rich* et *al.* (1981) reported that total fatty

acids and blood glucose were not significantly influenced by the amount or type of fat fed. However, serum cholesterol was higher ($P < .05$) in blood from ponies receiving a diet with 15 % fat than those receiving a diet with 7.5 % fat.

Hintz et *al.* (1978) studied the effects of adding 8 % feed grade animal fat to the diet of horses that were subjected to exercise of long duration. They found that the fat partially protected against the decline in blood glucose during aerobic exercise. However, there were no differences in plasma free fatty acids, lactate, sodium, calcium, phosphorous, pH, CO_2, total plasma protein, hematocrit or hemoglobin due to feeding fat.

Hambleton et *al.* (1980) fed four isocaloric diets containing 4, 8, 12, and 16 % soybean oil to exercising horses. Elevation of plasma glucose following exercise was found to be highly correlated with increasing intake of dietary fat. The increase in glucose after exercise was 58 % greater for horses fed the 16 % fat diet than for those on the 4 % fat diet. No dietary effect was observed on serum enzymes or serum electrolytes before or after exercise. Increased dietary fat resulted in increased resting concentrations of stearate and linoleate but decreases in palmitate and oleate. The linoleate increased directly in relation to the amount of soybean oil in the diet, and the probable source of stearate was microbial hydrogenation of the oleate and linoleate in the cecum. Finally, there was no dietary effect on packed cell volume or hemoglobin.

Duren et *al.* (1987) studied the effects of dietary fat on blood parameters in exercised Thoroughbreds. Diets were formulated containing 0, 5, 10 and 20 % of the total digestible energy in the form of corn oil. After trotting there was no difference in blood glucose concentrations in horses on the 0 and 10 % fat diets, but they were lower than in the horses fed the 5 and 20 % fat diets. Horses fed the 20 % fat diet tended to have higher glucose concentrations after trotting, immediately after exercise, and 15 minutes after exercise. No differences in blood glycerol were recorded except during the 15-minute recovery period. During this time, plasma glycerol was elevated in all diets with a larger increase in the horses fed the 10 % fat diet. There was a trend for a decrease in plasma triglycerides as levels of dietary fat increased. Lactate concentrations were similar except during the 15-minute recovery period when highest concentrations were found in the horses fed the 20 % fat diet.

McCann et *al.* (1987) noted no effect on serum calcium and magnesium or plasma cholesterol in ponies fed diets with added fat. Serum palmitic acid was highest in the ponies fed the basal diet, and oleic acid was highest in the ponies fed the diet containing inedible tallow. No significant differences were seen in serum stearic and linoleic acids between the diets.

Pagan et *al.* (1987) fed three Standardbreds a „high-fat" diet, a „high-protein" diet, or a carbohydrate diet, and performed fast and slow exercise tests on a treadmill. During the high-speed exercise test, there were no significant differences between treatments in blood glucose or plasma free fatty acid concentrations before, during, or after exercise. During the long, slow test, blood glucose concentrations were significantly decreased from resting values at 15 minutes of exercise in each treatment group, and these concentrations remained depressed throughout exercise. At 60 minutes of exercise, the high fat group had significantly higher ($P < .05$) free fatty acid concentrations in the blood than the control group.

Webb et *al.* (1987) studied the physiologic and metabolic responses of racing and cutting horses to a fat-supplemented diet. In experiment 1, plasma glucose levels dropped during the exercise tests when race horses were fed the control diet, but remained steady with the fat-supplemented diet. In experiment 2, lactate concentrations were higher during recovery when cutting horses were fed a fat-supplemented diet, and the elevated lactate concentrations declined more slowly when the horses were fed the fat-supplemented diet. This was determined to be due to greater effort extended when the horses were fed the fat-supplemented diet.

Worth et *al.* (1987) also reported that blood lactate trended toward being higher in horses fed a fat-supplemented diet toward the end of exercise and during recovery, but the differences were not significant.

Greiwe et *al.* (1989) studied the effects of fat as an energy source for 2-year-old horses beginning training. There were no significant differences in concentrations of blood constituents between the control and fat-supplemented diets.

Lawrence et *al.* (1989) reported the effects of a fat-supplemented diet on circulating hormone profiles associated with growth in horses. During the early growth phase there were no differences in glucose, insulin or cortisol concentrations, but feeding the fat-supplemented diet tended to lower triiodothyronine concentrations. During a later growth phase, the glucose, insulin, thyroxine and cortisol concentrations were higher in the control-fed horses compared to the fat-fed horses.

Meyers et *al.* (1989) observed a decrease ($P < .05$) in lipid concentrations in exercising horses fed a fat-supplemented diet.

Webb et *al.* (1987) and *Oldham* et *al.* (1990) found that cutting horses and race horses adapted to fat-supplemented diets had higher blood lactate concentrations following intense exercise than horses fed control diets.

Davison et *al.* (1991) reported that feeding a fat-supplemented diet to weanling horses resulted in lowered plasma insulin concentrations, but concentrations of thyroid hormones were not affected.

Harkins et *al.* (1992) studied the effects of added dietary fat on racing Thoroughbreds. Feeding fat reduced resting plasma nonesterified fatty acids (71.8 %) and beta-hydroxybutyric acid (41.9 %), while resting plasma glucose concentrations were increased (25.9 %) when horses were switched from a control diet to a fat-supplemented diet.

Effects on Performance or Productivity

Performance

Hintz et *al.* (1978) found that exercising horses needed 15 % less feed to maintain constant body weight when fed a diet containing 8 % feed-grade animal fat and that the fat partially protected against the decline of blood glucose during exercise. However, they observed no differences in muscle glycogen concentrations due to feeding fat.

Hambleton et *al.* (1980) reported higher muscle glycogen concentrations in horses prior to exercise when feeding up to 12 % fat added to the diet. However, there was a decline in muscle glycogen from the 12 % fat-added diet to the 16 % fat-added diet.

Pagan et *al.* (1987) suggested that feeding a high-fat diet allows the body to shift from carbohydrate oxidation to fat oxidation resulting in muscle glycogen sparing. They fed horses a „high-fat" diet, a „high-protein" diet, or a carbohydrate diet and performed fast and slow exercise tests on a treadmill. Horses fed the carbohydrate diet used anaerobic glycolysis more heavily than when fed the fat and protein supplemented diets. There was a glycogen sparing effect in horses fed the fat and protein diets during exercise at around 75 % VO_2max. During the high-speed exercise test, muscle glycogen utilization averaged 12.2 mmol/kg dry wt/min for the control diet, 5.6 when fed the protein supplemented diet, and 7.3 when fed the fat-supplemented diet. During the long, slow test, there was a trend for the heat produced by carbohydrate oxidation to decrease as exercise increased indicating a shift towards fat oxidation.

Webb et *al.* (1987) observed an increase in rump fat and body condition score in racing and cutting horses fed-fat-supplemented diets, and the cutting horses fed the fat-supplemented diet exerted more effort in a standardized exercise test than those that were fed a control diet.

Greiwe et *al.* (1989) studied the effects of fat as an energy source for 2-year-old horses beginning training. Muscle glycogen concentrations during the final exercise test decreased only 19 % in the fat-fed horses as compared to 65 % in the control group.

Meyers et *al.* (1989) reported an increase ($P < .05$) in resting muscle glycogen concentration due to feeding supplemental fat at isocaloric energy intakes compared to a control diet.

Oldham et *al.* (1990) observed that adapting racehorses to a fat-supplemented diet increased muscle glycogen stores which enhanced their anaerobic performance potential. Mobilization of the glycogen during intense exercise was greater ($P < .05$) during the exercise test when the horses were fed the fat-supplemented diet. Most importantly, when the horses were fed the fat-supplemented diet they ran faster at a constant heart rate than when they were fed the control diet.

Harkins et *al.* (1992) studied the effects of feeding fat on the racing performance of Thoroughbred horses. When the horses were fed the fat-supplemented diet they had increased muscle glycogen stores (15.8 %) and resting plasma glucose concentrations (25.9 %). Fourteen of the 15 horses had faster race times when fed the fat-supplemented diets. Glycogen utilization tended to be similar between diets.

Scott et *al.* (1992) studied the efficacy of feeding a fat-supplemented diet on muscle glycogen concentrations in exercising Thoroughbred horses in varying body conditions. The horses were maintained at either moderately low (ML), moderate (M), or moderately high (MH) body fat concentrations. When horses were fed the fat-supplemented diet they had greater resting muscle-glycogen concentrations than when fed the control diet ($P < .05$). Post-exercise muscle glycogen concentrations were similar ($P < .05$) in all horses regardless of the body condition or diet, thus glycogen utilization was higher when horses were fed the fat-supplemented diet. When the horses consumed the fat-supplemented diet and were in M and MH body condition, they utilized significantly greater ($P < .05$) amounts of muscle glycogen than when in ML condition.

Growth

Lawrence et *al.* (1989) reported no differences in feed intake, feed efficiency or average daily gain in growing horses fed a control or fat-supplemented diet. During a later growth phase, the control group tended to eat more feed than the fat-fed group.

Scott et *al.* (1989) found that feeding fats at the expense of carbohydrates stimulated early growth in yearling horses, but as the horses matured the effects were not maintained. Yearlings fed the fat-supplemented diet required less total feed per kg weight gain than the control. There were no significant differences in the wither height, heart girth, or rump fat thickness due to feeding fat. This study indicates that fat can be fed safely for yearlings to support growth and development.

Davison et *al.* (1991) conducted an experiment to determine if added dietary fat would facilitate rapid growth in weanling horses and if skeletal abnormalities often attributed to high carbohydrate diets could be reduced by feeding fat. Concentrate intake was lower ($P < .05$) in weanlings fed a fat-supplemented diet compared to the control. The weanlings fed fat had higher average daily weight gain than those fed the control ration, and the feed-to-gain ratio decreased ($P < .05$) due to feeding fat. Gain in heart girth circumference was also higher ($P < .05$) in those weanlings fed the fat-supplemented diet. No structural unsoundnesses were observed in either group, and there was no difference between treatments in radiographic bone density.

Reproduction

Davison et *al.* (1991) conducted a study to determine if the addition of fat to mares' diets during late gestation and early lactation would influence reproductive performance or lactation. Mares fed the fat-supplemented diet consumed less feed ($P < .09$) during the gestation period compared to the mares fed the control while maintaining body fat content. However, the caloric intake during early lactation was greater for those mares fed fat, but no weight or body fat gain occurred. Milk fat concentration was increased due to feeding fat to the mares. There was no dietary effect on birth weight of foals or weight gains to day 60. However, foals from dams fed the fat-supplemented diet tended to gain more weight during the first week (1.85 vs. 1.56 kg/d) and hat thicker rump fat measurements at day 60 (.53 vs. .44 cm). Mares fed the fat-supplemented diet tended to require fewer cycles per conception (1 vs. 2) and have a higher pregnancy rate (100 vs. 89 %).

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