

- White, K. K., Short, C. E., Hintz, H. F., Ross, M. W., Lesser, F. R., Leods, P. P., Lowe, J. E. and Schryver, H. F. (1978). The value of dietary fat for working horses. II. Physical evaluation. *J. Equine Med. Surg.* **2**, 525–530.
- Whitlock, R. H., Hintz, H. F., Schryver, H. F., Krook, L. and Craig, H. (1970). Effects of high calcium diets in horses. *2nd Equine Nutr. Research Symp.*
- Wierup, M. (1983). Food induced microbial diseases in the horse. *Proc. Horse Nutr. Soc. Symp.*, Uppsala, pp. 61–67.
- Wiechetek, M., Breves, G. and Höller, H. (1981). Effects of increased blood ammonia concentrations on the concentrations of some metabolites in rat tissues. *Quat. J. Exp. Physiol.* **66**, 423–429.
- Williams, C. (1985). Nutritional aspects of exercise induced fatigue. *Proc. Nutr. Soc.* **44**, 245–256.
- Winkel, Chr. (1977). Untersuchungen über Schweißmenge und -zusammensetzung der Pferde. *Veterinary Dissertation*, Hannover.
- Wisniewski, E. (1984). Effect of various doses of Escherichia coli endotoxin on some clinical values in horses. *Medycyna Weterynaryjna* **40**, 658–661.
- Witt, M. und Schröder, J. (1966). Sojaschrot als Energieträger in der Schweinemast. *Fleischwirtschaft* **H 3**, 270–277.
- Wolter, R. and Gouy, D. (1976). Etude expérimentale de la digestion chez les équides par analyse du contenu intestinal, après abattage. *Revue méd. vét.* **127**, 172–1736.

Effect of Dietary Fat on Blood Parameters in Exercised Thoroughbred Horses

S. E. DUREN, S. G. JACKSON, J. P. BAKER, and D. K. AARON
Animal Science Dept. University of Kentucky, Lexington,
KY 40546, USA.

Summary

Four Thoroughbred horses, 3 geldings and 1 mare were used in a 4 × 4 Latin square experiment to determine the suitability of dietary fat as an energy source for horses performing strenuous exercise. Diets were formulated to meet recommended energy requirements for exercise (NRC, 1978) such that 0, 5, 10 or 20% of the total dietary digestible energy was provided as corn oil. Four horses were assigned to dietary treatments and were exercised on a work day, rest day rotation. Blood samples were taken, during the work day exercise regime, at rest, after trotting, immediately after exercise, and at 15 and 30 minutes after exercise and subsequently analyzed for glucose, glycerol, triglyceride, lactic acid and free fatty acids. Blood pH, rectal temperature and body weight also were recorded. Plasma glucose concentrations were higher after trotting, immediately after exercise, and at 15 minutes after exercise in horses fed the 20% fat diet. Blood glycerol peaked 15 minutes after exercise for all horses with the highest glycerol concentrations observed in horses fed the 10% fat diet. Plasma triglyceride levels decreased with increasing level of dietary fat. Lactic acid increased with intensity of exercise and gradually decreased during recovery for all horses. Free fatty acid values are not reported due to sample loss resulting from storage freezer malfunction. No differences in blood pH or rectal temperature could be attributed to dietary treatments. There were no changes in body weights, indicating that dietary fat was utilized effectively as an energy source for horses performing strenuous exercise.

Index terms: Corn oil, nutrition; plasma glucose; plasma triglycerides; blood glycerol.

Introduction

The use of the horse for athletic competition has become increasingly popular. Equine athletic events such as endurance riding, three-day eventing, flat track racing and numerous other events require the horse to perform at high levels of physical activity. Because of this physical activity the equine athlete is faced with extremely high energy demands.

Traditionally, energy requirements for horses have been met with various combinations of forage and forage-grain mixtures. The use of more energy-dense feedstuffs to meet these energy requirements has attracted recent research attention. Although dietary

fat has not been added routinely to horse rations, its merit as an energy-dense feedstuff has been demonstrated in horses performing endurance exercise (Slade *et al.*, 1975; Hintz *et al.*, 1978; Hambleton *et al.*, 1980). The ability of the horse to utilize dietary fat during exercise at greater intensities has not been reported. The objective of this experiment was to determine the potential value of fat as an energy source in diets for horses performing strenuous exercise.

Materials and Methods

Four clinically healthy Thoroughbred horses (3 geldings, 1 mare) ranging in age from 4–10 years, with an average weight of 510 kg, served as experimental animals. Horses were fed diets which provided 155 kcal DE/kg⁷⁵/day plus an additional 23 kcal of DE/kg of mass/day (NRC, 1978). Timothy hay was provided at a rate of 4.54 kg/head/day. The remainder of the energy requirement was provided as a textured concentrate or a textured concentrate plus corn oil mixture (Table 1). Corn oil was top-dressed to prevent possible rancidity problems and to assure accurate intake. The diets were formulated such that 0, 5, 10, or 20% of the total dietary digestible energy (DE) was provided as corn oil. The DE values of the experimental diet were calculated using table values for dietary constituents (NRC, 1978). Horses were assigned to dietary treatments in a 4 × 4 Latin square crossover design (Gill, 1978).

Each horse underwent a 60-day pretrial conditioning period consisting of walking, trotting, cantering and galloping 8.05 km/day, 6 days/week. During the experiment, horses were exercised 7 days/week on a work day, rest day rotation. The work day consisted of trotting 4.0 km at a rate of 4 meters/sec, galloping 1.6 km at a rate of 13.4 meters/sec and sprinting .2 km at an approximate rate of 16 meters/sec. On rest days, horses were trotted in pairs 4.8 km at a rate of 4.5 meters/sec alternating either being ridden or led in an effort to minimize skeletal stress. All exercise was performed on a 1.6-km, oval turf track. Throughout the duration of the trial horses were housed individually in 3.7 × 3.7 m box stalls, bedded on straw and provided trace mineralized salt and water free-choice. Horses were ridden by two riders of similar weight through-

TABLE 1. Composition of textured concentrate mixture

Ingredient (% of diet)	Treatment			
	0 ^a	5 ^a	10 ^a	20 ^a
Cracked corn	50	49	45	37
Rolled oats	30	30	30	31
Soybean meal	8	9	13	21
Molasses	9	9	9	8
Ground limestone	1	1	1	1
Dicalcium phosphate	1	1	1	1
Trace mineralized salt ^b	1	1	1	1
Vitamin premix	+	+	+	+

^aPercent D.E. supplied as fat.

^bTrace mineralized salt provided 70 mg Zn, 68mg Fe, 40 mg Mn, 6.6 mg Cu, 1.4 mg I and 1.0 mg Co per kg of concentrate

Corn oil was top dressed daily to provide the required amount of digestible energy.

out the trial except on data collection days when all horses were ridden by one rider. The use of one rider on test days was done to standardize work performance.

The experiment was conducted from April to July in four consecutive 20-day periods with each period consisting of two phases. These were a 10-day phase for adjustment to diets, followed by a 10-day data collection phase. The horses were fed 3 hours prior to exercise on those days when blood samples were taken and on other days shortly after exercise. Data collection occurred on the first and tenth day of the data collection phase of each period, with all data being collected during the work day exercise regime. Data from day one and ten of each period served as two replications. Blood samples were collected via jugular venapuncture and were taken: 1) at rest; 2) after trotting; 3) immediately after exercise; 4) 15 minutes after exercise; and 5) 30 minutes after exercise. Three 10-ml heparinized vacutainer blood tubes were filled at each of the five samplings, with an additional 10 ml of blood being collected in a heparinized syringe at rest and immediately after exercise for pH determination. All blood samples were placed in an ice bath immediately and, following collection of the last blood sample on each sampling day, transported to the laboratory. The blood was centrifuged, the plasma decanted and stored at -10°C for subsequent analysis. Rectal temperatures were recorded at rest and again 15 minutes after exercise for each horse.

Plasma samples were analyzed for glucose concentration using a modified procedure outlined by Raabo and Terkildsen (1960). Lactate concentration was determined using a modification of a procedure outlined by Henry (1968). Plasma glycerol and triglyceride concentrations were determined using the procedure of McGowan *et al.* (1983) modified to allow use of an automated system of analysis. Blood pH was determined within 3 hours of sampling using an Instrumentation Laboratory pH and blood gas analyzer. Data were analyzed using least-squares procedures (Harvey, 1975) assuming a mathematical model that included effects of replication, animal, diet period, bleeding and appropriate two-way interactions

Results

The corn oil added to the diets was readily accepted by all horses and no feed refusals of the concentrate or hay portions of the diet were observed for any of the experimental diets. Horses showed no indications of gastric disturbances and no changes in consistency of the feces was noted.

Due to the high energy density of the corn oil, horses consumed less feed (kg/day) when fed rations including corn oil than when consuming the conventional control ration. Horses consuming the corn oil supplemented diets maintained body weight and showed no evidence of negative effect on health or performance.

As the oil was added to the feed as a top-dressing, no problems with rancidity were encountered, however, if used in a commercially prepared feed, the use of a dietary antioxidant is probably warranted.

Glucose. The influence of dietary fat on plasma glucose concentration prior to and following exercise is shown in Fig. 1. Glucose concentrations at rest did not differ between dietary treatments. After trotting, horses fed the 0% fat diet had lower ($p < .05$) plasma glucose concentrations than those receiving either 5% or 20% fat diets, while horses fed the 10% fat diet were not different from those on the 0% fat diet. Blood glucose concentrations immediately after exercise were higher ($P < .05$) for

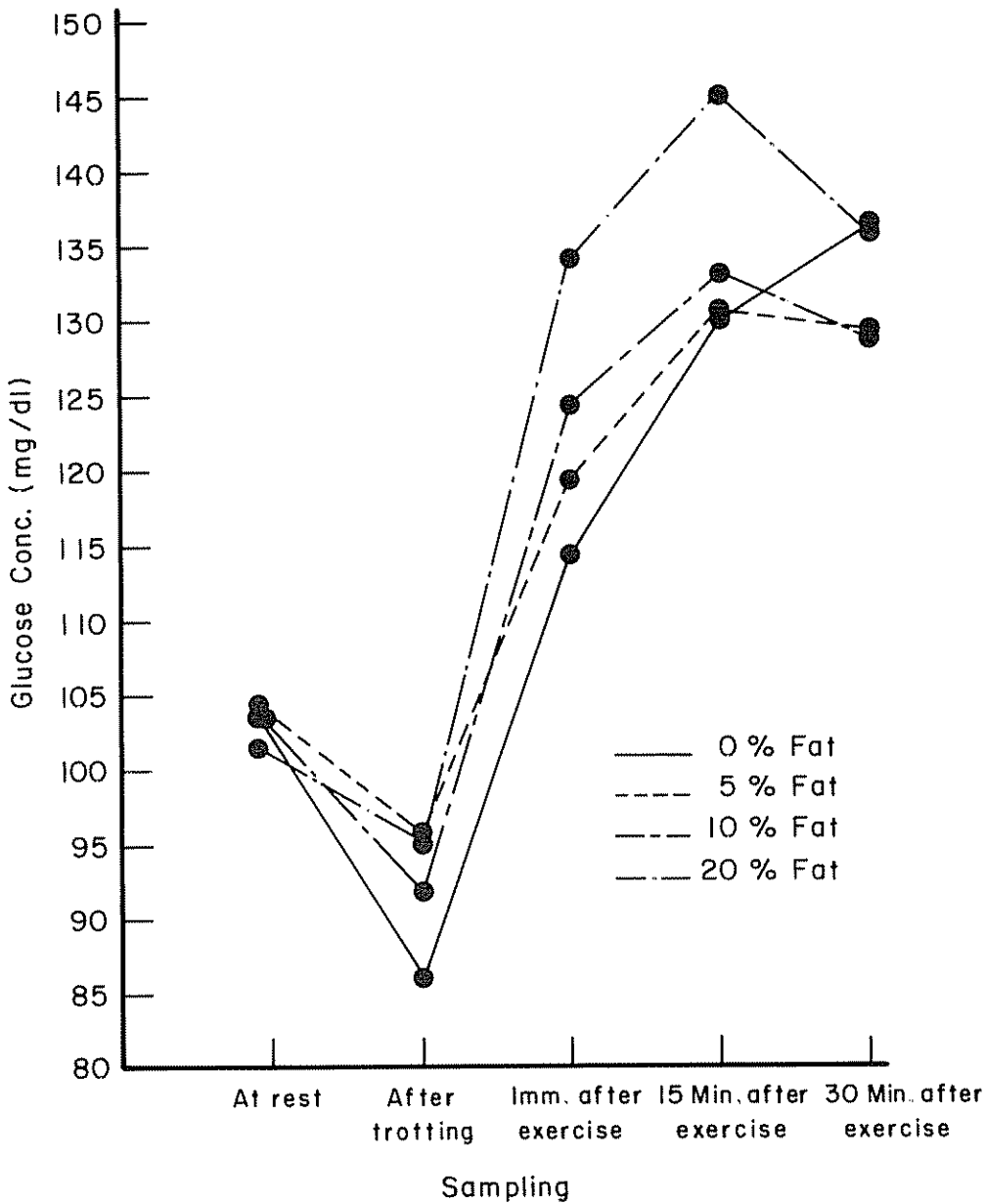


FIGURE 1. The effect of diet on plasma glucose concentrations prior to and following exercise in Thoroughbred horses. Standard error of least-square mean for glucose is 2.73 mg/dl.

horses fed the 20% fat diet than for those fed the 0, 5 and 10% fat diets. Horses receiving the 10% fat diet had higher ($P < .05$) glucose concentrations than those fed the 0% fat diet, but were no different from those fed the 5% fat diet. At the 15-minute after exercise sampling, horses fed the 20% fat diet again were observed to have higher

($P < .05$) glucose concentrations than horses fed the lower fat diets. At 30 minutes after exercise, blood glucose did not differ between the 0% and 20% fat diets. Plasma glucose was lower ($P < .07$) in horses fed the 5% and 10% fat diets than those fed the 0% and 20% fat diets.

Glycerol. The influence of dietary fat on plasma glycerol concentrations, prior to and following exercise, is shown in Fig. 2. Glycerol concentrations at rest, after trotting,

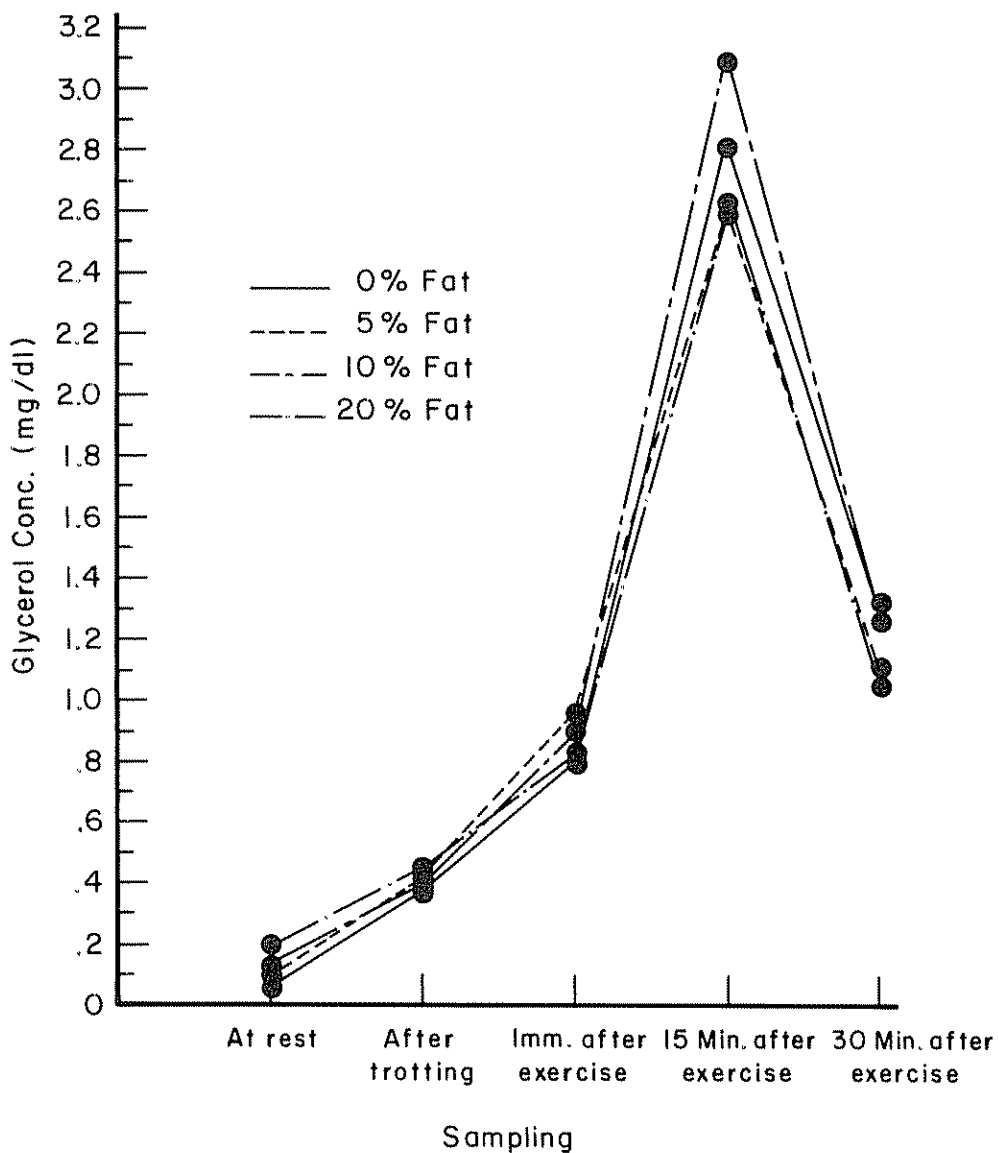


FIGURE 2. The effect of diet on plasma glycerol concentrations prior to and following exercise in Thoroughbred horses. Standard error of least-square mean for glycerol is .13 mg/dl.

immediately after exercise and at 30 minutes after exercise did not differ between dietary treatments. At the 15-minute after exercise sampling, plasma glycerol concentrations were higher ($P < .05$) for horses fed the 10% fat diet than for those fed the 0, 5 and 20% fat diets. Plasma glycerol concentrations among horses fed the 0, 5 and 20% fat diets were not different at the 15-minute after exercise sampling.

Triglyceride. The influence of dietary fat on plasma triglyceride (TG) concentrations, prior to and following exercise, is shown in Fig. 3. Resting plasma TG concentrations were higher ($P < .05$) in horses fed the 0% fat diet than in those fed the 5, 10 or 20%

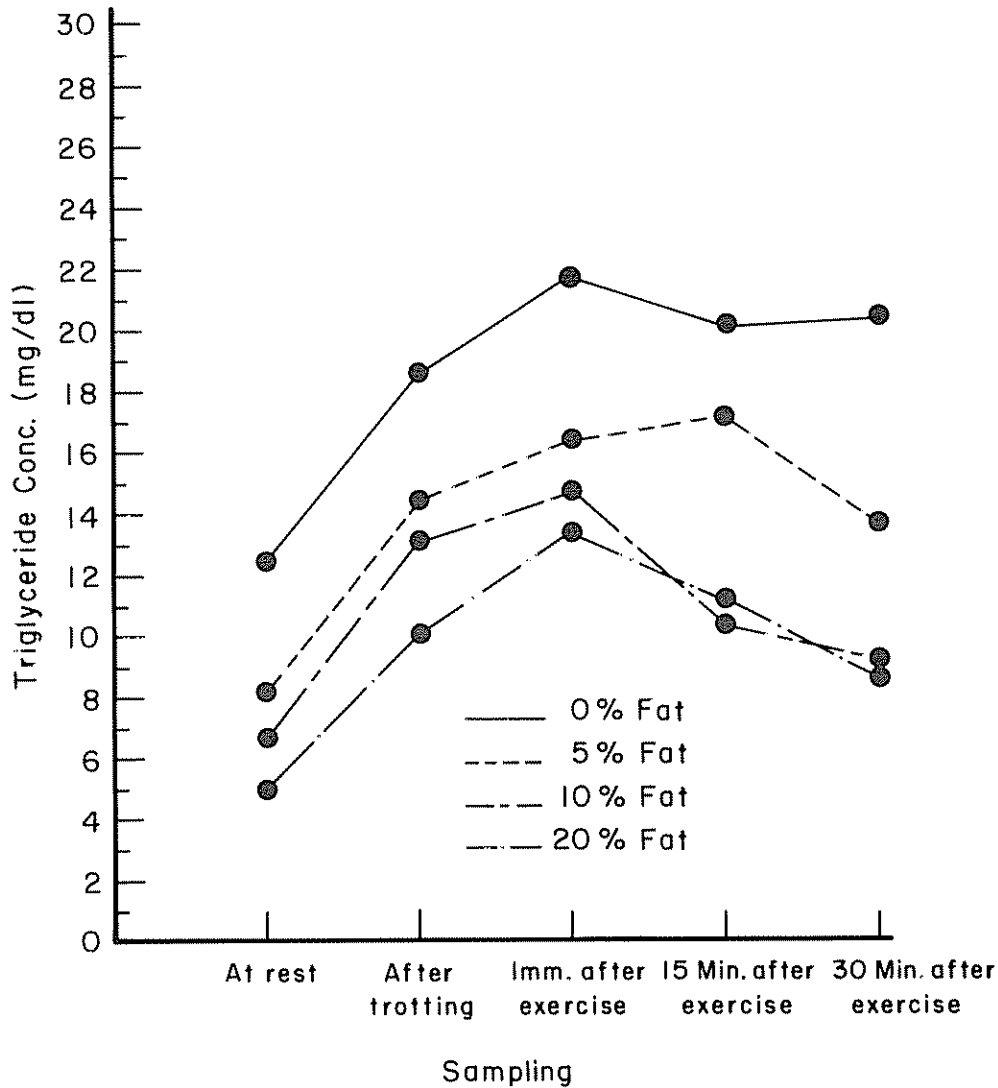


FIGURE 3. The effect of diet on plasma triglyceride concentrations prior to and following exercise in Thoroughbred horses. Standard error of least-square mean for triglyceride is 1.05 mg/dl

fat diets. Horses receiving the 5% fat diet had TG concentrations no different from horses fed the 10% fat diet, but higher ($P < .05$) than those fed the 20% fat diet. Resting plasma TG concentrations for horses fed the 10 or 20% fat diets did not differ. Blood TG concentrations after trotting were higher ($P < .05$) in horses on the 0% fat

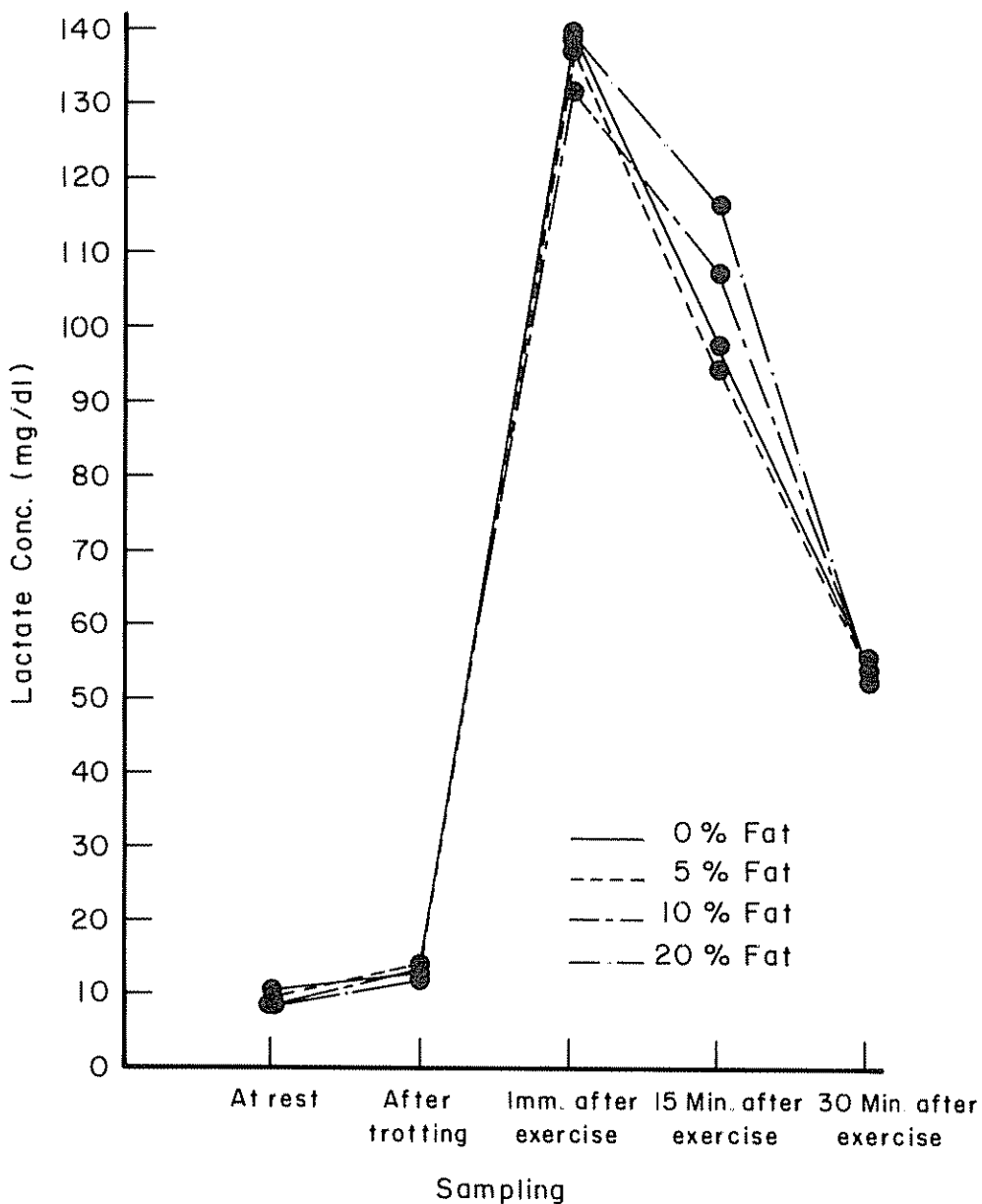


FIGURE 4 The effect of diet on plasma lactate concentrations prior to and following exercise in Thoroughbred horses. Standard error of least-square mean for lactate is 4.17 mg/dl

diet than in those on the 5, 10 or 20% fat diets. Horses receiving the 5% fat diet had higher ($P < .05$) TG concentrations than horses fed the 20% fat diet, but did not differ from those fed the 10% fat diet. Horses fed the 20% fat diet had lower ($P < .05$) blood TG concentrations than those fed the 0, 5, and 10% fat diets. Immediately after exercise, plasma TG concentrations again were higher ($P < .05$) in horses fed the 0% fat diet than in those receiving the other dietary treatments. Horses fed the 5% fat diet had TG concentrations no different from those fed the 10% fat diet, but higher ($P < .05$) than those fed the 20% fat diet. Plasma TG concentrations immediately after exercise did not differ between horses fed the 10 or 20% fat diets. During recovery from exercise, plasma TG concentrations, at both the 15 and 30-minute after exercise sampling, were higher ($P < .05$) in horses fed the 0% fat diet than in those fed the 5, 10 or 20% fat diets. Horses fed the 5% fat diet had higher ($P < .05$) plasma TG concentrations during all sampling times than horses fed the 10% and 20% fat diets. Plasma TG concentrations were not different between horses fed the 10 and 20% fat diets at either the 15- or 30-minute after exercise sampling times.

Lactate. The influence of dietary fat on plasma lactate concentrations, prior to and following exercise, is shown in Fig. 4. Lactate concentrations at rest, after trotting, immediately after exercise, and at 30 minutes after exercise did not differ between dietary treatments. At the 15-minute after exercise sampling, plasma lactate concentrations were higher ($P < .05$) for horses fed the 20% fat diet than for those fed the 0 or 5% fat diet. Horses receiving the 0% fat diet had plasma lactate concentrations which were not different from those for horses fed the 5 or 10% fat diets. Plasma lactate concentrations among horses fed the 10 and 20% fat diets were not different at the 15-minute after exercise sampling.

Rectal temperature and pH. Venous pH and rectal temperatures did not differ between dietary treatments.

Discussion

Glucose. The increased plasma glucose concentrations following exercise in horses receiving dietary fat compared with those receiving none, are in agreement with results reported by Slade *et al.* (1975), Hintz *et al.* (1978), and Hambleton *et al.* (1980), despite marked differences in exercise regimes. The consistent observation that plasma glucose concentrations are higher in horses receiving dietary fat, following exercise at different intensities of work, seems to indicate a glucose sparing effect associated with the feeding of fat. The mechanisms for this protection from decline in blood glucose concentrations, glucose sparing, are not understood completely; however, a number of possible explanations exist. Fatty acids liberated from the enzymatic hydrolysis of triglyceride may be utilized for energy production. Borensztajn and Robinson (1980) reported that exercise increases lipoprotein lipase activity. Lipoprotein lipase breaks triglycerides down into free fatty acids and glycerol, subsequently making them available for oxidative metabolism. Gollnick (1985) reported that in humans a notable consequence of endurance training is the shift of metabolism toward a greater use of fat, resulting in glycogen sparing. A possible explanation for the increased utilization of fat during exercise may be increased oxidative metabolism in muscle. The increased potential for oxidative metabolism is illustrated by increases in mitochondrial protein, and concomitant activity of the enzymes associated with the citric acid cycle and for oxi-

ductive phosphorylation (Ingjer, 1979). An increased ability of the horse to utilize fat as an energy source (Goodman *et al.*, 1973) may be due to similar changes in muscle metabolism associated with training. In the studies of Slade *et al.* (1975), Hintz *et al.* (1978), and Hambleton *et al.* (1980), as well as in this study, pretrial conditioning periods were included prior to data collection to allow adaptations due to training to occur. A glucose sparing effect may result solely from consumption of high-fat diets. In work cited by Gollnick (1985), ingestion of a high fat diet resulted in a decreased respiratory exchange ratio (R) during exercise compared with increases in (R) when exercise of the same intensity was performed after consumption of a carbohydrate-rich diet. Therefore, the body may adapt partially to the dietary energy source provided, by modifying enzyme systems to utilize different ratios of energy substrates. Finally, conversion of glycerol, derived from either dietary or endogenous triglyceride hydrolysis, to glucose in the liver may increase blood glucose levels. Glucose formed in the liver may be stored as glycogen, or be released into circulation, depending on energy demand and hormone balance.

Glycerol. Changes in blood glycerol concentrations as a result of dietary treatments were not markedly evident. The increased plasma glycerol concentrations observed 15 minutes after exercise in horses fed the 10% fat diet may have reflected an increased rate of lipolysis, although a complete explanation of dietary treatment and resulting blood glycerol concentration is unclear. Plasma glycerol concentrations, for all horses across all diets, were observed to increase from resting concentrations throughout exercise, with peak values measured during recovery from exercise. This finding is in agreement with results reported by Snow and MacKenzie (1977), Lucke and Hall (1980a), Lucke and Hall (1980b), and Snow *et al.* (1983). Since glycerol is not utilized to a large extent during exercise, plasma glycerol concentrations may reflect the extent of lipolysis occurring during exercise (Havel *et al.*, 1964), and if true, the elevated plasma glycerol concentrations observed throughout exercise and at 15 minutes after exercise may indicate a large degree of lipolysis.

Triglyceride. Resting blood samples, taken 3 hours after feeding, were higher in blood TG concentrations for horses fed the 0% fat diet than for those fed the 5, 10, or 20% fat diets. Horses fed diets containing fat (corn oil) absorb a portion of the dietary energy in the form of TG contained in chylomicrons. The half-life of chylomicrons in circulation is only a few minutes (Kaplan and Pesce, 1984). Horses fed high carbohydrate diets absorb dietary energy as glucose. Circulating glucose then enters the liver and, depending on energy need, is converted to glycogen or very low density lipoproteins (VLDL) for storage in adipose tissue. The higher plasma TG concentrations for horses fed low fat diets may have resulted from conversion of glucose to TG in the liver, with the subsequent release of VLDL into circulation.

Lactic acid. Differences in plasma lactate concentrations associated with dietary treatment were observed only during recovery from exercise at the 15-minute after exercise sampling time. The higher ($P < .05$) lactate levels 15 minutes after exercise in horses fed the 20% fat diet, than in those fed the 0, 5 and 10% fat diets, seem to indicate a slower removal of lactate from circulation in horses receiving the 20% fat diet. During recovery from exercise, lactate primarily is oxidized to carbon dioxide and water, or converted to glucose or glycogen (Astrand and Rodahl, 1977; Fox and Mathews, 1981). The horses fed the 20% fat diet may not have converted lactate to glucose or glycogen as rapidly as horses fed the other diets, due to the increased ($P < .05$) blood glucose

concentrations already present in these horses immediately following exercise and at 15 minutes after exercise. Since plasma lactate concentrations did not differ for the horses across all diets at the 30-minute after exercise sampling, and since blood pH was not significantly influenced by diet, the physiological significance of the differences observed 15 minutes after exercise remains in question. Hintz *et al.* (1978) reported no differences in plasma lactate concentrations following endurance exercise between horses fed 8% fat diet and those fed a control diet.

pH. Venous pH values, for all horses across all diets, were lower immediately after exercise than at rest, which are in agreement with results reported by Krzywanek (1974), Milne (1974), Krzywanek *et al.* (1976), Snow and MacKenzie (1977), Bayly *et al.* (1983), Snow *et al.* (1983), and Thornton *et al.* (1983). Milne (1974) reported that work intensity determines the extent to which blood pH is altered. The pH values, which were lower immediately after exercise than at rest, indicate that the buffering capacity of the blood was overwhelmed due to the large measured increases in lactic acid concentrations and, presumably the increases in carbonic acid concentration.

Rectal temperature. Rectal temperatures were elevated for all horses across all diets following exercise. The increased rectal temperatures reflected an elevated heat production in response to the energy demands of exercise. The dietary treatments imposed did not significantly affect rectal temperature.

Conclusion

In conclusion, corn oil may be added at a rate up to 20% of the total ration digestible energy and used efficiently in satisfying energy requirements of horses performing strenuous exercise. Furthermore, the addition of fat to equine diets showed no negative effects on the parameters monitored, and did protect against a decline in blood glucose often associated with exercise.

Acknowledgments

This study was supported by State and Hatch funds allocated to the Kentucky Agriculture Experiment Station.

References

- Astrand, P. O. and Rodahl, K. (1977). *Textbook of Work Physiology*, 2nd Ed. McGraw Hill Book Co., New York.
- Bayly, W. M., Grant, B. D., Breeze, R. G., and Kramer, J. W., (1983). The effects of maximal exercise on acid-base balance and arterial blood gas tension in Thoroughbred horses. *In: Equine Exercise Physiology*. Snow, D. H., Persson, S. G. B., and Rose, R. J., (eds.) Granta Editions, Cambridge. pp 400-407.
- Borensztajn, J. and Robinson, D. S., (1970). The effect of fasting on the utilization of chylomicron triglyceride fatty acids in relation to clearing factor lipase (lipoprotein lipase) releasable by heparin in the perfused rat heart. *J. Lipid Res.* 11:111-117.
- Fox, E. L. and Mathews, D. K., (1981). *The Physiological Basis of Physical Education and Athletics*. 3rd Ed. CBS College Publishing, Philadelphia, PA
- Gill, J. L. (1978). *Design and Analysis of Experiments in the Animal and Medical*

- Sciences*, Vol. 2. The Iowa State University Press, Ames, Iowa.
- Gollnick, P. D. (1985). Metabolism of substrates: energy substrate metabolism during exercise and as modified by training. *Fed. Proc.* 44:353.
- Goodman, H. M., Vander Noot, G. W., Trout, J. R., and Squibb, R. L. (1973). Determination of energy source utilized by the light horse. *J. Anim. Sci.* 37:56–62.
- Hambleton, P. L., Slade, L. M., Hamar, D. W., Klienholtz, E. W., and Lewis, L. D. (1980). Dietary fat and exercise conditioning effect on metabolic parameters in the horse. *J. Anim. Sci.* 51:1330–1339.
- Harvey, W. R. (1975). Least-squares analysis of data with unequal sub class members. U.S.D.A., ARS H-4.
- Havel, R. J., Carlson, L. A., Ekeland, L. G., and Holmgren, A. (1964). Turnover rate and oxidation of different free fatty acids in man during exercise. *J. Appl. Physiol.* 19:613–618.
- Henry, R. J. (1968). *Clinical Chemistry-Principles and Technics*. Harper and Row, New York.
- Hintz, H. F., Rose, M. W., Lesser, F. R., Leids, P. F., White, K. K., Lowe, J. E., Short, C. E., and Schryver, H. F. (1978). The value of dietary fat for working horses I. Biochemical and hematological evaluations. *J. Equine Med. Surg.* 2, 483–488.
- Ingjier, F. (1979). Effects of endurance training on muscle fibre ATP-ase activity, capillary supply and mitochondrial content in man. *J. Physiol.* 294:419–432.
- Kaplan, L. A. and Pesce, A. J. 1984. *Clinical Chemistry*. The C.V. Mosby Company, St. Louis, MO.
- Krzywanek, H. (1974). Lactic acid concentrations and pH values in trotters after racing. *J. S. Afr. Vet. Assoc.* 45:355–360.
- Krzywanek, H., Milne, D. W., Gabel, A. A., and Smith, L. G. (1976). Acid-base values of Standardbred horses recovering from strenuous exercise. *Am. J. Vet. Res.* 37:291–294.
- Lucke, J. N. and Hall, G. N. (1980a). Long distance exercise in the horse: Golden Horseshoe Ride 1978. *Vet. Rec.* 106:405–407.
- Lucke, J. N. and Hall, G. N. (1980b). Further studies on the metabolic effects of long distance riding: Golden Horseshoe Ride 1979. *Equine Vet. J.* 12:189–192.
- McGowan M., Artiss, J., Standbergh, D., and Zack, D. (1983). A peroxidase-coupled method for the colorimetric determination of serum triglycerides. *Clinical chemistry.* 29:538–542.
- Milne, D. W. (1974). Blood gases, acid-base balance and electrolyte and enzyme changes in exercising horses. *J. S. Afr. Vet. Assoc.* 45:345–354.
- NRC (1978). Nutrient requirements of domestic animals, No. 6. Nutrient requirements of horses. 2nd ed. National Academy of Sciences. National Research Council, Washington D.C.
- Raabo, E. and Terkildsen, T. C. (1960). On the enzymatic determination of blood glucose. *Scand. J. Clin. Lab. Invest.* 12:402–407.
- SAS. (1982). *SAS User's Guide*. Statistical Analysis System Institute, Inc., Cary, N.C.
- Slade, L. M., Lewis, L. D., Quinn, C. R., and Chandler, M. L. (1975). Nutritional adaptation of horses for endurance type performance. *Proc. 4th Equine Nutr. Physiol. Soc. Symp.* pp. 114–128.
- Snow, D. H. and MacKenzie, G. (1977). Effect of training on some metabolic changes

- associated with submaximal endurance exercise in the horse. *Equine Vet. J.* 9:226–230
- Snow, D. H., Mason, D. K., Ricketts, S. W., and Douglas, T. A. (1983). Post-race blood biochemistry in Thoroughbreds. In: Snow, D. H., Persson, S. G. B., and Rose, R. J. (eds.) *Equine Exercise Physiology*. Granta Editions, Cambridge. pp 389–399.
- Thornton, J., Essén-Gustavsson, B., Lindholm, A., McMiken D., and Persson, S. (1983). Effects of training and detraining on oxygen uptake, cardiac output, blood gas tension, pH and lactate concentrations during and after exercise in the horse. In: Snow, D. H., Persson, S. G. B., and Rose, R. J. (eds.) *Equine Exercise Physiology*. Granta Editions, Cambridge. pp 470–486.

The Effect of Dietary Energy Source on Exercise Performance in Standardbred Horses

J. D. PAGAN, B. ESSÉN-GUSTAVSSON, A. LINDHOLM,
and J. THORNTON

Department of Medicine I, Swedish University of Agricultural Sciences,
S 750 07 Uppsala, Sweden

Summary

Three Standardbred horses were used in a 3 × 3 Latin square design trial to determine the effect of feeding diets containing different levels of carbohydrate, fat, and protein to exercised horses. During each one month period the horses were fed either a 12% crude protein (CP) (as fed basis) commercial horse feed (control), a 20% CP feed (high protein diet) or an 11% CP feed containing 15% added soybean oil (high fat diet). During week 3 of each period the horses performed a stepwise exercise test and a high speed exercise test on a flat motor-driven treadmill. During week 4 of each period the horses performed a long slow exercise test (105 min at 5 m/sec). Muscle and liver glycogen concentrations were significantly lower after the long slow exercise test when the horses were fed the high protein and high fat diets than when fed the control diet. Respiratory quotients were also significantly lower than control values during sub-maximal exercise when the horses were fed the high protein and high fat diets. Type of diet affected the glycogen storage and metabolic response to exercise. Horses fed the high protein and high fat diets appeared to respond similarly.

Index terms: Equine nutrition; muscle and liver glycogen; standardized exercise test; oxygen consumption.

Introduction

Energy is the factor that should be considered first when evaluating the nutrition of the performance horse, since it is the factor most likely influenced by exercise (Hintz, 1983). A number of studies have been conducted to evaluate different sources of energy for performance horses. Different levels of fat (Slade *et al.*, 1975; Hintz *et al.*, 1978; Hambleton *et al.*, 1980; and Hintz, 1983) and protein (Slade *et al.*, 1975; Hintz *et al.*, 1980; and Patterson *et al.*, 1985) have been fed to exercised horses in an attempt to alter performance. Also, combinations of high protein, high fat and high carbohydrate diets have been used to alter muscle glycogen storage in horses (Kline and Albert, 1981; Topliff *et al.*, 1983; and Topliff *et al.*, 1985). The results of these dietary manipulations on equine exercise performance have not been conclusive. Therefore, the following