Effect of Supplementary Soya Oil on the Digestibility of Nutrients Contained in a 40:60 Roughage/Concentrate Diet Fed to Horses

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Summary

Four thoroughbred geldings were used in a 4 x 4 Latin Square digestiblity trial to investigate the effect of different levels of dietary oil on the digestibility of nutrients contained in a roughage/concentrate diet mixed in a 40:60 ratio.
Four coarse mix concentrates were used and the basal concentrate contained 52 g oil kg^{-1}; coarse mix was partially replaced with soya oil to produce 3 concentrates containing total oil levels of 122.1 g kg^{-1}, 192.1 g kg^{-1} and 250 g kg^{-1}. The roughage fed was a 50:50 mix of spring barley straw and alfalfa. The daily ration of each horse was adjusted so that energy intake was the same for all treatment diets.
A ten day adaptation period was followed by a seven day collection period. Horses were exercised for three hours daily at 6.6 km/h using a mechanical horse-walker in two 1 1/2 hour periods.
Each increment of soya oil resulted in a significant increase in the digestibility of ether extract, gross energy and absorption of phosphorus ($p < 0.001$); there were no consistent significant effects on the absorption of other minerals or on the digestiblity of other nutrients. Horses maintained body weight throughout the trial and there were no feed refusals.
Feeding concentrates containing up to 250 g oil kg^{-1} (170 g oil kg^{-1} total feed dry matter) improved nutrient availability, had no measurable adverse effect and allowed up to a 50 % reduction in the use of conventional starch-based concentrate, whilst maintaining the same energy intake.

Wirkung einer zusätzlichen Sojaölgabe auf die Verdaulichkeit verschiedener Nährstoffe bei Pferden, die Rationen mit 40 Prozent Rauhfutter/60 Prozent Kraftfutter erhielten

In einem Verdauungsversuch (Modell 4 x 4 Lateinisches Quadrat) mit 4 Wallachen (Vollblütern) wurde der Einfluß verschieden großer Ölmengen auf die Verdaulichkeit verschiedener Nährstoffe überprüft (Rationen: 40 Prozent Rauhfutter, 60 Prozent Kraftfutter).
Für die Untersuchungen standen 4 grobgemischte Kraftfutter zur Verfügung. Das Basalfutter enthielt 52 g Öl/kg. Teile der Mischung wurden durch Sojaöl ersetzt, so daß 3 Kraftfutter zur Verfügung standen mit 122, 192 und 250 g Öl/kg. Das Rauhfutter bestand zu 50 Prozent aus Sommergerstenstroh und zu 50 Prozent aus Luzerne. Die Futtermengen wurden so gewählt, daß in allen Behandlungsstufen die Energieaufnahme identisch war.
Einer 10tägigen Adaptationsperiode folgte eine 7tägige Kollektionsperiode. Die Pferde wurden täglich für 3 Std. an einem Bewegungsgerät bewegt (6,6 km/h; 2x je 1 1/2 Std.).
Mit steigender Sojaölgabe nahm die Verdaulichkeit des Ätherextraktes signifikant zu, ebenso wie die der Bruttoenergie und die Absorption von Phosphor (P < als 0,001). Die Verdaulichkeit anderer Nährstoffe oder die Absorption anderer Mineralien wurde nicht signifikant beeinflußt. Die Pferde hielten während des Versuches ihr Körpergewicht konstant. Futterrückstände traten nicht auf.
Mischfutter mit bis zu 250 g Öl/kg (170 g Öl/kg Gesamtfutter-TS) verbesserten die Verfügbarkeit der Nährstoffe, hatten keinen meßbaren negativen Einfluß und erlaubten die Menge an konventionell stärkereichen Kraftfuttermitteln bis zu 50 Prozent zu reduzieren bei gleichbleibender Energieaufnahme.

Introduction

Energy is the most important nutrient required by any species (*Hintz,* 1983; *Pagan,* 1992) and the consumption of sufficient energy by horses to meet the requirements for hard work poses a number of problems. Conventional concentrated energy sources, such as cereals, have been associated with metabolic problems such as azoturia, laminitis and colic (*Garner et al.,* 1978; *Carroll et al.,* 1987) and there is a need for safer energy sources. Fats can be used to reduce feed bulk as they are a more concentrated energy source than cereals. Experimental work has indicated that the horse is able to readily digest and utilize fat (*Goodman et al.,* 1973; *Hintz et al.,* 1978; *White et al.,* 1978; *Hambleton et al.,* 1980; *Glade,* 1983; *Frape,* 1988).
Most of the research concerning the utilisation of oil has been carried out with horses performing aerobic work rather than with those performing anaerobic work, and the oil has been used as a supplement to diets rather than as a cereal replacer. The current work was designed to investigate the effect of replacing starchy concentrate with vegetable oil on the utilisation of nutrients by thoroughbred horses performing aerobic exercise.

Material and Methods

Experimental Design

Four horses were used in a 4 x 4 Latin Square digestibility trial. There were four treatment diets and each diet was fed for a 17 day period; ten days adaptation followed by a seven day collection. The experimental layout is shown in table 1.

Animals

Four thoroughbred geldings (weight range 406 – 617 kg), were kept individually in 3.5 x 4 m loose boxes, bedded on wood shavings and exercised for 1 1/2 hours twice daily using a horse walker, set at 6.6 km/h at 10.00 and 14.00 h. Animals were fed at 08.00, 12.00, 16.00 and 20.00 h. The coarse mix was top-dressed with oil just prior to feeding according to the treatment; forage was fed after all the concentrates had been consumed and each meal was of equal size.

Table 1: Experimental Design and Feed Allocation (kg DM day^{-1})

	Period	1	2	3	4
Treatment A (42 g oil kg^{-1} DM)	Horse	G	S	T	R
	Coarse Mix	6.22	5.16	4.47	5.15
	Roughage	4.21	2.60	3.03	2.57
	TOTAL	10.43	7.76	7.50	7.72
Treatment B (90 g oil kg^{-1} DM)	Horse	S	T	R	G
	Coarse Mix	3.24	3.04	3.27	5.25
	Oil	0.29	0.27	0.29	0.46
	Roughage	2.31	2.17	2.35	3.76
	TOTAL	5.84	5.48	5.91	9.47
Treatment C (130 g oil kg^{-1} DM)	Horse	R	G	S	T
	Coarse Mix	2.87	4.45	2.81	2.56
	Oil	0.53	0.85	0.53	0.49
	Roughage	2.17	3.51	2.21	1.98
	TOTAL	5.48	8.81	5.55	5.03
Treatment D (170 g oil kg^{-1} DM)	Horse	T	R	G	S
	Coarse Mix	2.25	2.42	3.92	2.41
	Oil	0.64	0.70	1.12	0.70
	Roughage	1.87	2.04	3.3	2.0
	TOTAL	4.76	5.16	8.34	5.11

Mean Horse Weights
G: 617 kg; S: 490 kg; T: 406 kg; R: 490 kg

Treatment Diets
Feed requirements were calculated on the basis of NRC recommendations for medium work (*NRC*, 1989). Four treatment diets were fed and the quantity adjusted so that the energy intake of each horse was the same, irrespective of treatment.
Horses were fed roughage and coarse mix in a 40:60 ratio. The analysis of the dietary ingredients is shown in table 2. The roughage was composed of a 50:50 mix of molassed, precision-chopped alfalfa and chopped spring barley straw. The coarse mix was a mixture of micronised cereals and contained 52 g oil kg^{-1}. Soya oil was substituted for coarse mix to give calculated levels of 122, 192 and 250 g oil kg^{-1} coarse mix.
The different coarse mixes were combined with the roughage to produce four treatment diets; details of the treatment diets A, B, C and D are shown in table 1. The treatments provided 42 g, 90 g, 130 g and 170 g oil kg^{-1} of ration dry matter.

Sampling
Freshly voided faeces were sampled twice daily after each exercise period when the animals were resting in stalls, floored with rubber mats. Acid-insoluble ash has been shown to be a reliable internal marker in equine digestibility studies (*Schurg et al.*, 1977, where total collections are impractical and this methodology was adopted to obtain estimates of apparent digestibility.
Food was sampled daily during the collection period, dried and stored at room temperature until analyzed.

Analytical Procedures
Subsamples of feed and faeces were dried in a forced-draught oven at 60 °C to constant weight and analyzed for gross energy (GE), crude protein (CP), ether extract (EE), acid-insoluble ash (AIA), calcium (Ca), magnesium (Mg) and phosphorus (P) according to methods described by M. A. F. F. (M. A. F. F., 1981). Acid detergent fibre (ADF) and neutral detergent fibre (NDF) were estimated according to the method of *Van Soest* (1983) and a modification of the method of *Robertson* and *Van Soest* (1977).
The data was subject to an analysis of variance using the Genstat Five Release 1:2 (1987) Statistical package (Lawes Agricultural Trust, Rothamstead Experimental Station) followed by Students "t" test to determine the significance of the difference between individual treatment means.

Results

Digestibility Data
The effect of increasing the oil content of the diet on nutrient digestibility is summarised in table 3.
Digestibility of gross energy was significantly improved ($p < 0.01$) by oil addition and this improvement occurred with every increment of oil.
Organic matter digestibility was significantly increased ($p < 0.05$) when oil was added; the incremental improvements were not significantly different although those between animals on treatment A and those on treatment C

Table 2: Mean Composition of Dietary Ingredients
(g kg^{-1} DM unless otherwise stated)

Nutrients	Coarse Mix	Alfalfa	Straw	Soya Oil
Ash	64	93	33	
AIA	7.0	4.9	23.0	
OM	936	907	967	
CP	153	156	42	
EE	52	14	7	
ADF	106	279	660	
NDF	274	375	951	
Ca	10.4	9.8	2.2	
P	5.7	2.6	0.8	
Mg	1.9	2.1	0.2	
GE (MJ kg^{-1} DM)	20.4	20.0	20.7	
Assumed DE (MJ kg^{-1} DM)	14.9	9.5	7.8	37.6
DM (g kg^{-1})	836	860	866	

and D ($p < 0.01$) were. Differences between treatments B and D ($p < 0.05$) were also significant ($p < 0.01$).
Addition of oil improved the digestibility of ether extract although this difference was only significant ($p < 0.001$) between treatment A and the other treatments.
The digestibility of protein and fibrous components appeared to be unaffected by treatment. Apparent phosphorus absorption was significantly improved with each increment of oil ($p < 0.001$) and whilst the apparent absorption of both calcium and magnesium increased with the incremental addition of oil, the changes were non-significant.

Discussion

The traditional diet for performance horses is a mixture of forage and concentrates. In ruminants the feeding of concentrates can modify forage digestibility and the importance of forage/concentrate interactions is well recognised. However, forage/concentrate interactions are considered to be of negligible importance in horses (*Martin-Rossett and Dulphy*, 1987). Thus dietary organic matter digestibility will reflect that of individual components of the diet. The increase in digestibility of ration organic matter following oil addition, was therefore probably due in part to the replacement of cereal by oil; vegetable oil has a higher digestibility compared to cereals (*Rich et al.*, 1981). The effect may have also been partly due to the reduction in fibre intake. The increase in organic matter digestibility was only significant at the upper 2 levels of oil inclusion (130 g kg^{-1} DM and 170 g kg^{-1} DM) which corresponds to the findings of *Rich et al.* (1981). He showed that a 100 g kg^{-1} DM inclusion of fat had no effect on organic matter digestibility, compared to the unsupplemented diet, however, 150 g fat kg^{-1} DM significantly increased organic matter digestibility. In the current study 90 g fat kg^{-1} DM had no effect on organic matter digestibility compared to the basal treatment (42 g fat kg^{-1} DM).
The digestibility of **ether extract** increased as soya oil was added to the diet. Some of the effect may have been attributable to a proportional reduction in the contribution of metabolic faecal fat (*McCann et al.*, 1987). Reliable

Table 3: Effect of Increasing the Oil Content of the Diet on the Apparent Digestibility and Absorption of Nutrients (n = 4)

Nutrients	Treatment Means				SED	F Ratio	t
	A	B	C	D			
GE	0.59	0.62	0.65	0.67	0.0087	**	
							**
							**
							**
OM	0.61	0.62	0.64	0.65	0.0091	*	
							NS
							NS
							NS
							**
							**
							*
EE	0.50	0.61	0.64	0.70	0.498	***	
							***
							NS
							NS
							NS
NDF	0.33	0.37	0.34	0.36	0.0638	NS	
ADF	0.19	0.18	0.20	0.24	0.1006	NS	
CP	0.72	0.74	0.75	0.72	0.0221	NS	
Ca	0.35	0.41	0.48	0.52	0.0427	NS	
P	-0.04	0.05	0.10	0.24	0.0385	*	
							***
							***
							***
Mg	0.30	0.36	0.38	0.39	0.0560	NS	

A - 42 g oil kg^{-1} ration dry matter
B - 90 g oil kg^{-1} ration dry matter
C - 130 g oil kg^{-1} ration dry matter
D - 170 g oil kg^{-1} ration dry matter

└──┘ = Treatment Comparisons

*** $P < 0.001$
** $P < 0.01$
* $P < 0.05$

estimates of endogenous fat output in defined dietary situations are sparse and the origin and definition of endogenous fat output are still unclear.

The following have been shown to effect monogastric digestion of fats, saturation state of fatty acids; percentage of glycerides; fatty acid chain length; level of fat inclusion and age of animal (*Freeman,* 1983). He also showed that young animals such as chicks and piglets absorb fats less well than mature animals. In contrast *Scott et al.* (1989) found that feeding fat to young horses (yearlings) stimulated growth and efficiency of feed utilisation. This implies that fat was well-absorbed in these animals.

Kane et al. (1979) showed that ether extract digestibility increased slightly from 0.89 to 0.91 following the addition of 150 g oil kg^{-1} DM to the diet. *Rich et al.* (1981) showed that diets containing 75 g oil kg^{-1} DM had an ether extract digestibility of 0.79, whereas diets containing 150 g oil kg^{-1} DM had an ether extract digestibility of 0.88. In the current study ether extract digestibilities ranged from 0.5 to 0.7, being considerably less than previously published values.
Calculation of ADF in total ration dry matter, where sufficient dietary information is published, shows that the difference in reported digestibility values for oil are probably a consequence of the fibre content of the rations fed. The 15 % oil diet used by *Kane et al.* (1979) contained 146 g ADF kg^{-1} DM and the 30 % oil diet contained 138 g ADF kg^{-1} DM; in contrast treatment A contained 253 g ADF kg^{-1} DM and treatment D contained 235 g ADF kg^{-1} DM in the present study. The high oil diet contained less indigestible fibre than the basal diet which is consistent with the differences in dietary organic matter digestibility. However, both diets contained appreciably more fibre than was present in experimental diets where higher fat digestibilities have been reported (*Kane et al.,* 1979; *Rich et al.,* 1981).
Fat in the basal diet appeared to be less well-digested and this may partly be because fat is intracellular and is not so freely available as the supplementary soya oil. Some fibre may have to be digested to free cereal fat before it can be fully utilised, and since fat is primarily digested in the small intestine of the horse it is likely that cell wall material, which is digested in the hind gut, may have an inhibitory influence.

In ruminants, free vegetable oils disturb ruminal fermentation by coating the **fibre** whereas if it is fed in the form of an oilseed it does not cause the same problems because the oil is released slowly, (*Coppock and Wilks,* 1991). The results of the current experiment confirm that there were no apparent adverse effects of free vegetable oil on fibre digestion in the horse. *Rich et al.* (1981) has shown that the addition of fat significantly ($p < 0.5$) increased the digestibility of neutral and acid detergent fibre, although *McCann et al.* (1987) findings are similar to those of the current study in that slight but nonsignificant increases in fibre digestibility were measured. Thus, the horse is better able to digest free oil than the ruminant and caecal fermentation is the superior adaptation with respect to the utilisation of dietary oil.

The absence of an effect of oil addition on the digestion of **crude protein** supports earlier work (*Bowman et al.,* 1977; *Rich et al.,* 1981; *McCann et al.,* 1987) and the digestibility coefficients obtained in the current study were similar to those reported previously; mean values were never lower than 0.72.
Apparent mineral absorption increased with incremental oil additions but only phosphorus absorption increased significantly ($p < 0.001$). Although most phosphorus is reportedly absorbed from the hind gut, (*Schryver et al.,* 1972) it is possible that oil enhances phosphorus uptake in the small intestine. *McCann et al.* (1987) reported this effect but could offer no explanation for the differences they observed. In sheep, added fat did not significantly affect the utilisation of dietary phosphorus (*Tillman and Brethour,* 1958). However, fat-supplemented diets have been shown to depress calcium absorption in poultry (*Feede et al.,* 1960) and sheep (*White et al.,* 1958; *Tillman et. al.,* 1958) and it is suggested that this is because oil stimulates the formation of a calcium/lipid complex (*White et al.,* 1958; *Palmquist et al.,* 1986) and thereby reduces calcium availability. The calcium may also combine with fats to form soaps in the lower small intestine (*Wheeler + Noller,* 1976); *Bowman et al.* (1977) showed no such effect in horses. *McCann et al.* (1987) found that corn oil increased calcium absorption and the results obtained in this experiment support this finding. *Palmquist* and *Jenkins (1980)* suggest that pH has an effect on fatty acid absorption in ruminants; low pH decreases the amount of soluble fatty acids but may solubilise calcium soaps allowing an increased absorption of fatty acids and calcium than would be possible at alkaline or neutral pH. Although there is little work investigating the interrelationship between feeding and the pH of digesta within the horses small intestine, *Frape* (1986) states that the pH of the digesta leaving the stomach rapidly rises to slightly over 7.0. It is thus, unlikely that the hypothesis proposed by *Palmquist and Jenkins* (1980) is valid for the horse.

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