HIGH-FAT DIETS FOR HORSES

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Summary
A review is given on the use of high-fat diets for horses. Fat levels higher than 8% of the total dietary dry matter can be achieved only by the addition of pure oils. High-fat diets have an inhibitory effect on the apparent digestibilities of crude fibres, protein and non-structural carbohydrates. Increasing the amount of fat in the diet raises the activity of lipoprotein lipase and lowers plasma concentrations of triacylglycerols. The reported effects of high-fat diets on muscle glycogen and on exercise-induced plasma lactate accumulation are not consistent. It cannot be concluded unequivocally that high-fat diets would enhance athletic performance.

Fats and fatty acids in feedstuffs
Table 1 shows the contents of crude fat and of selected fatty acids in common feedstuffs used in equine rations. Grass contains little fat, but has a high relative percentage of alpha-linolenic acid. Barley, oats, corn and rye have a high relative percentage of linoleic acid and linseed particularly has a high content of alpha-linolenic acid. Coconut oil is an exception in having the saturated lauric acid (C12:0) as its major fatty acid. Palm oil contains a relatively large proportion of long chain saturated fatty acids, especially palmitic acid, but also is rich in oleic acid.
Table 1
Contents of crude fat and that of selected fatty acids in common equine feedstuffs.

<table>
<thead>
<tr>
<th>Feedstuff</th>
<th>Dry Matter (DM)</th>
<th>Crude fat</th>
<th>C12:0</th>
<th>C16:0</th>
<th>C18:1 n-9</th>
<th>C18:2 n-6</th>
<th>C18:3 n-3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley</td>
<td>870</td>
<td>17</td>
<td>-</td>
<td>3.1</td>
<td>1.8</td>
<td>7.7</td>
<td>0.8</td>
</tr>
<tr>
<td>Oats</td>
<td>885</td>
<td>49</td>
<td>-</td>
<td>9.5</td>
<td>17.4</td>
<td>19.4</td>
<td>1.0</td>
</tr>
<tr>
<td>Corn</td>
<td>864</td>
<td>38</td>
<td>0.08</td>
<td>4.8</td>
<td>11.1</td>
<td>21.8</td>
<td>0.4</td>
</tr>
<tr>
<td>Rey</td>
<td>863</td>
<td>16</td>
<td>-</td>
<td>2.3</td>
<td>1.9</td>
<td>7.1</td>
<td>0.9</td>
</tr>
<tr>
<td>Wheat</td>
<td>863</td>
<td>14</td>
<td>-</td>
<td>2.2</td>
<td>1.7</td>
<td>6.5</td>
<td>0.6</td>
</tr>
<tr>
<td>Linseed</td>
<td>910</td>
<td>351</td>
<td>-</td>
<td>25.7</td>
<td>66.0</td>
<td>58.6</td>
<td>197.9</td>
</tr>
<tr>
<td>Soybean meal</td>
<td>876</td>
<td>19</td>
<td>-</td>
<td>1.6</td>
<td>3.1</td>
<td>7.6</td>
<td>1.1</td>
</tr>
<tr>
<td>Fat extracted</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheat bran</td>
<td>869</td>
<td>35</td>
<td>-</td>
<td>5.4</td>
<td>4.2</td>
<td>16.1</td>
<td>1.4</td>
</tr>
<tr>
<td>Coconut expeller</td>
<td>914</td>
<td>82</td>
<td>32.3</td>
<td>6.1</td>
<td>4.7</td>
<td>1.3</td>
<td>-</td>
</tr>
<tr>
<td>Grass</td>
<td>150</td>
<td>5</td>
<td>-</td>
<td>0.4</td>
<td>0.1</td>
<td>0.3</td>
<td>1.5</td>
</tr>
<tr>
<td>Palm oil</td>
<td>1000</td>
<td>1000</td>
<td>1.0</td>
<td>435</td>
<td>366</td>
<td>91</td>
<td>2.0</td>
</tr>
<tr>
<td>Coconut oil</td>
<td>1000</td>
<td>1000</td>
<td>446</td>
<td>82</td>
<td>58</td>
<td>18</td>
<td>-</td>
</tr>
<tr>
<td>Soybean oil</td>
<td>1000</td>
<td>1000</td>
<td>-</td>
<td>103</td>
<td>228</td>
<td>510</td>
<td>68</td>
</tr>
</tbody>
</table>

*Fat levels in equine rations*

The amount and type of fat in horse rations is determined by the roughage:concentrate ratio and by the type of roughage and concentrate. In general, the fat content of horse diets is about 5% in the dry matter (Meyer, 1992, Van ‘t Klooster, 1999). Commercial concentrates typically contain 3 - 6 % crude fat in the dry matter. Muesli’s may contain 9 - 10 % crude fat. For satisfactory pelleting performance, the amount of fat in concentrates is 2 - 3 %. However a level of up to 7 % may be achieved by spraying fat (Atkinson, 1980).
The fat content of the whole ration is related to the amount of hay or roughage. Table 2 gives examples of how the fat intake can be modulated. The daily rations shown provide an amount of energy required by a 600 kg horse with 1 hour of exercise each day. With a low-fat concentrate (3% fat) the proportion of the total net energy provided by fat (NE) is 10% when feeding hay and concentrate in a 1:1 ratio on NE basis. Using a high-fat concentrate (8% fat) this proportion will be 25%. Dietary fat levels higher than 8% in the dry matter can be achieved only when pure oils are added to the diet. It should be stressed that extra fat in the ration raises its energy density and that less dietary dry matter is required to satisfy the energy need of the horses. High-fat rations by definition are rations that are low in carbohydrates and/or protein when expressed as percentage of dietary energy.

Table 2. Examples of fat-rich rations

<table>
<thead>
<tr>
<th>Concentrate : hay ratio on energy basis</th>
<th>1:1</th>
<th>1:1</th>
<th>3:1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fat content of total ration (g/kg DM)</td>
<td>30</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>Ingredient</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hay, kg/d</td>
<td>7.3</td>
<td>7.3</td>
<td>4.0</td>
</tr>
<tr>
<td>Concentrate (3% crude fat/kg), kg/d</td>
<td>4.3</td>
<td>2.7</td>
<td>-</td>
</tr>
<tr>
<td>Muesli (8% crude fat/kg), kg/d</td>
<td>-</td>
<td>-</td>
<td>5.0</td>
</tr>
<tr>
<td>Vegetable oil, ml/d</td>
<td>-</td>
<td>500</td>
<td>180</td>
</tr>
<tr>
<td>Dry matter intake, kg/d</td>
<td>10.0</td>
<td>9.1</td>
<td>8.0</td>
</tr>
<tr>
<td>Vitamin E, mg/d¹</td>
<td>± 700</td>
<td>± 700</td>
<td>± 700</td>
</tr>
<tr>
<td>Total NE, MJ</td>
<td>69</td>
<td>69</td>
<td>69</td>
</tr>
<tr>
<td>NE % of fat</td>
<td>10</td>
<td>25</td>
<td>25</td>
</tr>
</tbody>
</table>

¹ Amount of extra vitamin E depends on the contribution of the feedstuffs
NE = Net Energy
Palatability and preferences
Because of a decrease in palatability, more than 10-15% fat in the diet is not advisable under practical conditions. Under experimental conditions high-fat concentrates containing either soybean oil, palm oil or medium chain triglycerides were accepted for periods up to at least 3 months (Hallebeek and Beynen, 2001a; 2002a; 2002b; 2002c). The concentrates had fat levels of 12-18%, and fed in a 3:1 ratio with hay so that whole-ration fat levels were 11-16 %. We have frequently observed that the time of feed intake was increased when horses were fed high-fat diets (12 %) when compared to low-fat diets (3 %). Likewise, Landes and Meyer (1998) saw an increase in time of feed intake by 58% when horses were fed high-fat diets containing 10% sunflower oil. Oxidation of unsaturated fatty acids and consequent rancidity makes the feed unpalatable. We have observed that when concentrates have an rancid odour, they may be rejected by horses.

Fat intake and digestibility of macronutrients other than fat
When going through the literature, there is controversy about the influence of high fat intakes on apparent crude fiber digestibility in horses. Studies on the influence of high-fat intakes on total tract digestibility of crude fibre in horses have yielded conflicting results. Several researchers reported that the addition of fat to the diet did not affect the apparent digestibility of cell wall contents (McCann et al., 1987; Rich et al., 1981), neutral detergent fiber (Davidson et al., 1987; Kane and Baker, 1977; Kane et al., 1979; McCann, 1987; Meyers et al., 1987; Rich et al., 1981) or acid detergent fiber (McCann et al., 1987). Others reported an increase in apparent digestibility of either neutral-detergent fibre (Hughes et al., 1995; Julen et al., 1995; Scott et al., 1987; Webb et al., 1987) or acid detergent fibre (Rich et al., 1981) after the feeding of fat-supplemented diets. In contrast, it has been reported that administration of a high-fat diet lowered the digestibility of neutral-detergent fiber (Rich et al., 1981; Worth et al., 1987). The conflicting results probably relate to the fact that the low-fat and high-fat diets used in the various studies differed with respect to multiple components, including the amount of crude fiber. A change in fibre intake by itself may affect the percentage of apparent fibre digestibility as digesta passage rate may be altered and the microflora will be exposed to a change in the amount of fermentable substrates. In order to maintain energy balance, the intake of extra fat must be associated with less energy intake in the form of other nutrients. In some studies fat was provided as a supplement (Kane and Baker, 1977; Rich et al., 1981; Snyder et al., 1981) so that the intake of extra fat coincided with lower intakes of carbohydrates, crude fibre and crude
protein. In other studies, up to 162.5 g fat/kg of diet was isoenergetically substituted for hay (Hughes et al., 1995; Julen et al., 1995; Scott et al., 1987; Swinney et al., 1995) or one (Davidson et al., 1987) or more (McCann et al., 1987; Meyers et al., 1987; Webb et al., 1987) other feed ingredients with complex compositions, such as grains.

Jansen et al. (2001) substituted soybean oil isoenergetically with non-structural carbohydrates. Increasing fat intakes are associated with increased apparent digestibilities of fat. The intake of extra fat also changed the apparent total tract digestibility of macronutrients other than fat in a statistically significant, dose-dependent fashion. An increase in dietary fat concentration by 10 g/kg dry matter was associated with a decrease in crude fibre digestion by 0.9 percentage units, a decrease in protein digestibility of 0.7 percentage units and an increase in fat digestibility by 0.9 percentage units. The effects have been repeated in further experiments in which non-structural carbohydrates were isoenergetically replaced by soybean oil (Jansen et al., 2001). The observed interaction between fat content of the diet and macronutrient utilization could have consequences for practical horse feeding in that calculating the energy content of high-fat diets on the basis of feedstufs tables will lead to over- or underestimating the amount of energy provided by the ingredients of the diets. However, the impact is negligible. It can be calculated that, as a result of changes in macronutrient digestibilities, with an increase in fat intake by 25 g/kg dry matter the net energy value of the ration will be about 4% lower than that expected.

Influence of amount of dietary fat
The feeding of extra fat generally is associated with a decrease in the intake of nonstructural carbohydrates. The effects on lipoprotein metabolism seen after giving a high-fat diet to horses and ponies are caused by the combination of consuming more fat and less carbohydrates. The feeding of high-fat diets causes pronounced changes in equine lipid metabolism. Fat feeding in the form of soybean oil lowered the concentration of plasma triacylglycerols and raised heparin-released LPL activity, pointing at an increased flux of triacylglycerol-fatty acids (Orme et al., 1997; Geelen et al., 1999). The fat-induced metabolic adaptations are comparable to those described as induced by training (McMiken, 1983; Hodgson et al., 1986). The relationship between fat intake and LPL activity is linear. An increase in fat intake by 1 g/kg dry matter was associated with an increase in LPL activity by 0.98 µmol free fatty acids released per ml plasma per hour (Geelen et al., 2001b).
The fat-induced lowering of plasma triacylglycerols may be secondary to the increase in LPL activity and thus to an increased removal of lipoprotein particles. However, a diminished production rate of triacylglycerols could also be involved, as well. Geelen et al. (2001c) have shown that the fat-induced reduction of plasma triacylglycerols in ponies was associated by a decrease in de novo fatty acid synthesis as evidenced by decreased activities of acetyl-CoA carboxylase and fatty acid synthase in liver. The rates of hepatic de novo fatty acid synthesis is directly related with the rate of VLDL secretion (Beynen et al., 1981). Furthermore, fat feeding in ponies rendered hepatic carnitine palmitoyltransferase-I less sensitive to inhibition by malonyl-CoA, which could result in an increased fatty acid oxidation rate (Geelen et al., 2001c). In addition, dietary fat supplementation caused enhancement of carnitine palmitoyltransferase-I and citrate synthase activity in the masseter muscle which is highly oxidative (Geelen et al., 2001c).

In the steady state, the rate of input of triacylglycerols into plasma must equal the output. When assuming that the output is determined by LPL activity, then fat-feeding raises triacylglycerol output and thus should also lead to more input of plasma triacylglycerols. Triacylglycerol production can be measured indirectly by using a non-ionic detergent such as Triton WR 1339 (oxyethylated t-octyl-phenol polymethylene polymer). The Triton-induced block of lipoprotein lipase causes triacylglycerol accumulation in plasma which has been used as an index of triacylglycerol secretion rates in rodents (Borensztajn et al., 1976; Nicolosi et al., 1976). When horses were fed a high-fat diet, they had significantly less triacylglycerol production rates than when they were fed a low-fat diet (Geelen et al., 2002). The unexpected result was explained by Triton administration being less effective when the horses were given a high-fat diet because their post-heparin LPL activity was increased. The amount of Triton used was too low to completely block LPL activity, but higher dosages were avoided as they can be toxic (Scanu et al., 1961; Sato et al., 1997). Post-heparin LPL activity measured 5 hours after Triton administration was still 50-60% of the baseline activity (Geelen et al., 2002).

Fat feeding is associated with lower post-prandial plasma insulin concentrations in the horse (Pagan et al.,1995, Stull et al., 1987). Possibly, on a high-fat diet the insulin-mediated down-regulation of muscle LPL activity (Kiens and Lithell, 1989) is diminished. The fat-induced increase in heparin-released LPL in the fasting state could reflect LPL from muscle (Mackie et al., 1980; Terjung et al., 1982). The feeding of extra fat to horses did not increase fasting plasma FFA concentrations (Orme et al., 1997; Geelen et al., 2001c). Thus, horses fed a high-fat diet may not have enhanced mobilisation of fatty acids.
from adipose tissue. However, the noradrenaline-induced stimulation of lipolysis in adipose tissue biopsies tended to be higher when the donor horses had been fed a fat-rich diet. When fat feeding inhibits de-novo fatty acid synthesis, but stimulates the turnover of triacylglycerol-fatty acids, fatty acid turnover and thus fatty acid mobilization should be increased which might be associated with an unaltered concentration of free fatty acids.

Performance
The increased activity of post-heparin lipoprotein lipase activity and decreased plasma level of triacylglycerol concentrations in horses fed a high-fat diet points at a rise in the flux of fatty acids in the form of triacylglycerols. It could be suggested that preferential and more use of fatty acids for generation of energy utilization has advantageous effects on other aspects of intermediary metabolism. Enhanced oxidation of fatty acids during aerobic exercise might lead to a sparing of glucose and thus to less lactate accumulation which in turn could extend the onset of fatigue (Frage, 1994). In addition, enhanced fatty acid oxidation could spare glycogen, which could increase the potential of sprinting (Oldham et al., 1990; Scott et al., 1992; Hughes et al., 1995).

In non-trained ponies there was a decrease in muscle glycogen in various muscle types when a high-fat diet was fed (Geelen et al., 2001c). This outcome is in line with results of Pagan et al. (1987), but most reports describe an increase in resting muscle glycogen following supplementation of the diet with fat (Meyers et al., 1989; Oldham et al., 1990; Harkins et al., 1992; Jones et al., 1992; Scott et al., 1992, Julen et al., 1995; Hughes et al., 1995). In the studies showing a fat-induced increase in glycogen, the horses were intensively trained during the period of fat feeding. The decrease in muscle glycogen found by Pagan et al. (1987) was in horses doing a long, slow work test. It would appear that a glycogen-sparing effect of high-fat diets is seen only with simultaneous exercise. The mobilization of glycogen during anaerobic exercise was increased in fat-supplemented horses (Pagan et al., 1987; Meyers et al., 1989; Oldham et al., 1990; Essen-Gustavson et al., 1991; Harkins et al., 1992; Jones et al., 1992; Scott et al., 1992; Julen et al., 1995; Hughes et al., 1995 and Geelen et al., 2001c) but, in horses performing a 1600-m race, the rate of glycogen utilization was not increased (Harkins et al., 1992).

In sprint-trained horses fed a diet with 10% corn oil instead of a diet without added fat, there was increased lactate accumulation during repeated sprints (Ferrante et al., 1993; Taylor et al., 1995, Kronfeld et al., 1994). No effect of fat feeding on blood lactate concentrations was seen when horses...
completed either a simulated cutting test (Julen et al., 1995), a 1600-m race (Harkins et al., 1992) or repeated sprints (Scott et al., 1992). When performing a standardised sub-maximal exercise test, horses fed a high-fat (11.8% in the dietary dry matter) instead of a low-fat (1.5% fat) diet showed lower blood lactate accumulation (Sloet van Oldruitenborgh-Oosterbaan, 2002). Clearly, the anticipated decrease in lactate accumulation in exercising horses fed a high-fat diet was not observed in most experiments.

The discrepancies in the outcome of the above-mentioned studies could not relate to the type of dietary fat used. Pagan et al. (1993) fed to horses hay and a concentrate without added fat or a concentrate containing either 10% soybean oil, coconut oil or a 50:50 mixture of the two oils. The velocity achieved at a heart rate of 200 bpm (V200) was higher when the diet with soybean oil diet was fed instead of the diets with coconut oil or the mixed oil. Plasma free fatty acids concentrations were highest in horses fed the diet containing coconut oil. The velocity at which blood lactate reached 4 mmol/l was lowest in the horses fed the low-fat control diet. Plasma lactate after an 8 minute gallop was lowest in horses supplemented with coconut oil. The authors concluded that the medium chain fatty acids in coconut oil are oxidized quickly and thus spare glucose (Pagan et al, 1993). Ingested MCT may not deliver fatty acids to the exercising muscle for oxidation (Berning, 1996), but are preferentially oxidized in the liver so that the ketone bodies formed may be used for oxidation in muscle. However, most published studies do not support the use of MCTs to spare muscle glycogen and thus improve exercise performance (Berning, 1996).

References


Hallebeek, J.M. and Beynen, A.C.(2002b) Production and clearance of plasma triacylglycerols in ponies fed diets containing either medium-chain triacylglycerols or soybean oil. submitted


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