The effect of replacing nonstructural carbohydrates with soybean oil on the digestibility of fibre in trotting horses

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Summary

The hypothesis tested was that the intake of extra fat at the expense of an iso-
energetic amount of nonstructural carbohydrates reduces fibre utilization in horses.
In a cross-over trial with feeding periods of 42 days each, 6 mature trotting horses
(age 4-12 years, bodyweight 340 - 476 kg) were given either a control or test diet.
The test concentrate was formulated to contain 37% of net energy in the form of
soybean oil. The control concentrate contained an iso-energetic amount of
cornstarch plus glucose. The concentrates were fed in combination with the same
amount of hay so that the control and test diet contained 25.1 and 86.5 g crude fat/
kg dry matter, respectively. Apart from the amounts of fat and nonstructural
carbohydrates the 2 diets were identical. The test diet reduced the apparent total
tract digestibilities of crude fibre, neutral and acid detergent fibre by 6.6 (P=0.02),
5.3 (P=0.009) and 7.2 (P=0.002) percentage units, respectively. It is suggested
that a high-fat intake by horses may increase the amount of fat entering the large
intestine to levels that depress fermentation by cellulolytic bacteria. The observed
interaction between fat content of the diet and fibre utilization may have
consequences for practical horse feeding in that calculating the energy content of
test diets on the basis of feedstuff tables leads to overestimating the amount of
energy provided by the high-fibre ingredients of the diets.

Introduction

Performance horses are frequently given high-fat diets with fat contents up to 130
g/kg dry matter. The addition of extra fat raises the energy density of feeds. Diets
with a high-energy density facilitate a high-energy intake, which is advantageous
for horses with high-energy requirements (Kane and Baker 1977; Snyder et al.
1981; Kronfeld 1996). High-energy diets also allow a reduction in total feed intake
(Hintz et al. 1978), which lowers the weight of gastrointestinal contents, this effect
being considered beneficial to performance horses (Meyers et al. 1987). There is
indeed suggestive evidence that exercising horses perform better when fed a high-
fat diet (Potter et al. 1992).
Microorganisms in the caecum and colon of horses ferment dietary cellulose and hemicellulose into well-resorbable volatile fatty acids, which provide energy (Hintz et al. 1971). In ruminants, an increase in the fat content of diets above 50 g/kg dry matter inhibits cellulose fermentation by the ruminal microflora (Brooks et al. 1954). On the basis of the similarity of crude fibre fermentation in the rumen of ruminants and that in the caecum and colon of horses (Argenzio et al. 1974), it can be suggested that feeding high-fat diets to horses might reduce fibre utilization. Fat digestion in the small intestine of horses is rather efficient, apparent fat digestibilities being in the order of 55 - 70 % of the intake (Swinney et al. 1995), but in absolute terms more undigested fat will enter the caecum when more fat is consumed.

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 fibre (Davison et al. 1987; Kane and Baker 1977; Kane et al. 1979; McCann et al. 1987; Meyers et al. 1987; Rich et al. 1981) or acid detergent fibre (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 also been reported that administration of a high-fat diet lowered the apparent digestibility of neutral-detergent fibre (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 fibre. A change in fibre intake by itself may affect the percentage of apparent fibre digestibility, digesta passage rate may be altered and the microflora will be more or less saturated with 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 iso-energetically substituted for hay. (Hughes et al. 1995; Julen et al. 1995; Scott et al.
The effect of replacing nonstructural carbohydrates with soybean oil on the digestibility of fibre in trotting horses

1987; Swinney et al. 1995) or one (Davison et al. 1987) or more (McCann et al. 1987; Meyers et al. 1987; Webb et al. 1987) other feed ingredients with complex composition, such as grains.

The above-mentioned studies indicate that there are interactive effects of fat intake and fibre utilization by horses. This prompted us to study further the interaction and here we present the apparent digestibility of crude fibre, neutral and acid detergent fibre, as influenced by the consumption of extra fat at the expense of an iso-energetic amount of nonstructural carbohydrates.

Materials and methods

Six mature trotters, age 4 -12 years (2 mares and 4 geldings), 340 to 476 kg bwt were used. Horses were housed in individual tie-up stalls and exercised for 60 minutes each day in a mechanical walker. The feeding trial had a 42 x 42 days cross-over design.

The experimental diets consisted of hay and concentrates with different compositions. The ingredient composition of the concentrates is given in Table 1. The test concentrate contained 37% of net energy in the form of soybean oil. The control concentrate contained an identical portion of energy as cornstarch plus glucose. Table 2 shows the analyzed composition of the concentrates. The horses were fed an amount of energy that was 10% below their maintenance requirements, i.e. 351 kJ net energy/ kg\(^{0.75}\) (Vermorel et al. 1984), so as to insure that all feed provided was consumed. Meals of equal size were given each day at 0800 and 2000 h. On average, the horses were supplied daily with 1.78 kg hay (25 % of net energy) and 2.57 kg test concentrate or 3.06 kg control concentrate (75 % of net energy). Tap water was always available except for the period of exercise.

Horses were assigned randomly to the order of the 2 treatments. After 33 days on the diets, faeces were collected quantitatively during a subsequent period of 9 days. Faeces produced during exercise were also collected. Each day, faecal samples, representing 5% (w/w) of the total faeces of each horse, were stored at -20° C until pooling per dietary period per animal for chemical analysis. Faeces
were dried at 60°C for 72 hours and then dry matter, nitrogen, fat, fibre and energy were determined.

Table 1. Composition of the experimental concentrates

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Control concentrate</th>
<th>Test concentrate</th>
<th>Control concentrate</th>
<th>Test concentrate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>g as fed</td>
<td>% Net energy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cornstarch</td>
<td>193</td>
<td>17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glucose</td>
<td>140</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soybean oil</td>
<td></td>
<td></td>
<td>150</td>
<td>37</td>
</tr>
<tr>
<td>Constant</td>
<td>850</td>
<td>63</td>
<td>850</td>
<td>63</td>
</tr>
<tr>
<td>components*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1183</td>
<td>100</td>
<td>1000</td>
<td>100</td>
</tr>
</tbody>
</table>

*The constant components consisted of the following (g): alfaffameal, dehydrated, 342.4; cornstarch, 150; glucose, 150; soybeans, extracted, 100; molasses, beet, 50; linseed expeller, 20; Ca₃(PO₄)₂, 15; NaCl, 15; MgO, 3.4; CaCO₃, 1.7; premix **, 2.5.

** The premix consisted of the following (g/kg): CoSO₄.7H₂O, 0.66; Na₂SeO₃.5H₂O, 0.76; KIO₃, 0.32; MnSO₄.4H₂O, 172.4; CuSO₄.5H₂O, 27.2; ZnSO₄.7H₂O, 192.4; vitamin A, 12.0 (500.000 IU/gr); vitamin D₃, 5.2 (100.000 IU/gr); vitamin E, 240.0 (500 IU/gr); vitamin B₁, 1.8 (purity 100%); vitamin B₂ (purity 100%), 1.8; vitamin B₁₂ (purity 0.1%), 1.8; biotin (purity 100%), 0.4; cornstarch (carrier), 343.26.

Dry matter (DM) was determined gravimetrically. Nitrogen was determined using the Kjeldahl technique and crude protein calculated as nitrogen (g) times 6.25. Fat content of feed and faeces were analyzed in accordance with Berntrop's method. Crude fibre was determined by the NEN 5415 protocol and neutral and acid detergent fibre according to the procedures of Goering and Van Soest (1970). Cellulose was calculated as acid detergent fibre minus lignine. Gross energy contents of feed and faeces were determined by oxygen bomb calorimetry.

Apparent digestibilities of nutrients were calculated as (intake - faecal excretion) / (intake) X 100%. All data within dietary treatments were checked for normal distribution (Kolmogorov-Smirnov test). Apparent digestibilities were not
The effect of replacing nonstructural carbohydrates with soybean oil on the digestibility of fibre in trotting horses

significantly affected by the period of treatment (F-test). So that diet effects were evaluated with Student's paired t-test (Wilkinson 1990). A P value < 0.05 was preset as the level of statistical significance.

Table 2. Analyzed composition and calculated energy density of the experimental concentrates and hay.

<table>
<thead>
<tr>
<th></th>
<th>Control concentrate</th>
<th>Test concentrate</th>
<th>Hay</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>g/ kg DM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crude protein</td>
<td>109</td>
<td>124</td>
<td>137</td>
</tr>
<tr>
<td>Crude fat</td>
<td>24</td>
<td>129</td>
<td>27</td>
</tr>
<tr>
<td>Crude fibre</td>
<td>79</td>
<td>85</td>
<td>365</td>
</tr>
<tr>
<td>NDF</td>
<td>220</td>
<td>244</td>
<td>670</td>
</tr>
<tr>
<td>ADF</td>
<td>87</td>
<td>93</td>
<td>366</td>
</tr>
<tr>
<td>Cellulose</td>
<td>71</td>
<td>78</td>
<td>327</td>
</tr>
<tr>
<td>Crude ash</td>
<td>74</td>
<td>83</td>
<td>65</td>
</tr>
<tr>
<td>Nitrogen-free extract *</td>
<td>714</td>
<td>579</td>
<td>406</td>
</tr>
<tr>
<td>Gross energy (kJ/kg DM)</td>
<td>16858</td>
<td>19915</td>
<td>18373</td>
</tr>
<tr>
<td>Net energy (kJ/kg DM) **</td>
<td>8783</td>
<td>10393</td>
<td>4876</td>
</tr>
</tbody>
</table>

* Calculated as 1000 minus sum of contents of protein, fat, crude fibre and ash. ** Calculated using CVB tables (Anon 1996); NDF = neutral-detergent fibre; ADF = acid detergent fibre

Results

Bodyweights of the horses were not significantly influenced by dietary treatment. Due to the restricted feeding regimen, the horses on average lost 8.3% bwt during the entire experiment. Apparent total tract digestibilities of nutrients and energy are shown in Table 3.
Table 3. Apparent total tract digestibilities of nutrients and energy

<table>
<thead>
<tr>
<th>Digestibility</th>
<th>Control diet</th>
<th>Test diet</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of intake</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry matter</td>
<td>74.4 ± 1.83</td>
<td>66.3 ± 4.17</td>
<td>0.012</td>
</tr>
<tr>
<td>Crude protein</td>
<td>74.0 ± 3.01</td>
<td>71.3 ± 2.86</td>
<td>0.266</td>
</tr>
<tr>
<td>Crude fat</td>
<td>51.3 ± 7.88</td>
<td>65.3 ± 10.19</td>
<td>0.036</td>
</tr>
<tr>
<td>Crude fibre</td>
<td>51.5 ± 5.91</td>
<td>44.9 ± 2.58</td>
<td>0.016</td>
</tr>
<tr>
<td>NFE</td>
<td>84.4 ± 1.38</td>
<td>77.7 ± 1.46</td>
<td>0.002</td>
</tr>
<tr>
<td>NDF</td>
<td>58.4 ± 3.43</td>
<td>53.1 ± 4.51</td>
<td>0.009</td>
</tr>
<tr>
<td>ADF</td>
<td>47.8 ± 4.68</td>
<td>40.6 ± 4.38</td>
<td>0.002</td>
</tr>
<tr>
<td>Cellulose</td>
<td>54.8 ± 4.04</td>
<td>48.8 ± 4.04</td>
<td>0.002</td>
</tr>
<tr>
<td>Gross energy</td>
<td>66.7 ± 2.93</td>
<td>59.5 ± 2.36</td>
<td>0.010</td>
</tr>
</tbody>
</table>

Results are expressed as means ± SD for 6 horses.

Iso-energetic replacement of cornstarch plus glucose by soybean oil significantly (P=0.014) reduced the digestibility of dry matter by 8.1 percentage units. Consumption of extra fat did not significantly affect protein digestibility. When the horses were fed the test diet instead of the control diet, the digestibility of fat was significantly higher. Feeding the test diet significantly (P=0.016) reduced the digestibility of crude fibre by 6.6 percentage units. The digestibilities of NDF, ADF and cellulose were decreased by 5.3, 7.2 and 6.0 percentage units, respectively. The digestibilities of the nitrogen-free extract were 84.4 ± 1.4 (mean ± SD) and 77.7 ± 1.5 % of intake for the control and test ration, respectively (P=0.002). The digestibility of energy was significantly (P=0.010) lower when the test diet was given. When the horses were fed the control diet the faecal pH was 6.41 ± 1.14 and when the test diet was given it was 5.53 ± 0.82. The diet-induced difference in faecal pH was statistically significant (P=0.01).
Discussion

The primary objective of this study was to test the hypothesis that a high-fat intake by horses reduces the apparent digestibility of crude fibre. To meet the objective, the diets used contained iso-energetic amounts of either soybean oil (test diet) or glucose plus cornstarch (control diet). When the test diet was fed instead of the control diet, the apparent total tract digestibility of crude fibre was significantly lower. Similar reductions were seen for the digestibility of neutral and acid detergent fibre. The difference in dry matter intake of 0.41 kg/day between the control and the test diet will not have affected the observed digestibilities of DM, CP and GE (Todd et al. 1995). Our results seem to disagree with those obtained by various other researchers (Davison et al. 1987; Hughes et al. 1995; Julen et al. 1995; Kane and Baker 1977; Kane et al. 1979; McCann et al. 1987; Meyers et al. 1987; Rich et al. 1981; Scott et al. 1987; Webb et al. 1987). Moreover, in those other studies there were multiple dietary variables associated with increased fat intake. This could point to complex interactive effects of fat intake and fibre utilization. In addition, the amount of extra fat used by the other authors varied from 57.5 to 300 g/kg of diet, whereas in our test diet it was 61.4 g/kg of dry matter. The differences in fat intakes between studies complicate a direct comparison of the outcomes.

Since there is no fat absorption in the caecum and colon of horses (Swinney et al. 1995), the amount of fat that enters the large intestine can be calculated on the basis of the apparent total tract digestibility of fat. This approach neglects endogenous fat. When the horses were given the control diet, 54 g of fat entered the large intestine each day. For the test diet this amount was 121 g. The fatty acids that are present, as such, or are released by hydrolysis of acylglycerols, may inhibit the cellulolytic activity of the microflora (Palmquist, 1984), which leads to a reduced apparent digestibility of crude fibre. The high-fat intake in this study implied a simultaneous low carbohydrate intake. It could be suggested that the low carbohydrate intake had caused an underestimation of the effect of fat on fibre utilization. High intakes of poorly digestible, highly fermentable carbohydrates may depress fibre utilization due to caecum acidosis (Garner et al. 1977). However, when the horses were fed the control diet total starch intake was only about 100 g/
100 kg bwt, so that less than 15% of the ingested starch can be expected to have flown into the large intestine (Potter et al. 1992). This amount is too low to affect fibre digestion in the large intestine (Potter et al. 1992). Indeed, the faecal pH was not lowered by the starch-rich, control diet. Contrary to what would be expected, the faecal pH was significantly lower when the fat-rich, test diet was fed instead of the control diet. It cannot be excluded that at least part of the low fibre digestibility, seen when the test diet was given, relates to a decrease in caecal pH. Possibly, the high-fat intake had reduced pre-caecal starch digestion so that there was an increase in caecal fermentation of starch, which in turn lowered caecal pH. Such a process could affect fibre utilization, which needs to be explored.

The increase in fat digestibility, seen when the test diet was fed, can be explained by various mechanisms. An increase in fat intake raises the amount of faecal fat of dietary origin and therefore lowers the proportion of endogenous fat in the faeces. This effect can cause a high-fat intake to elevate apparent fat digestibility. Furthermore, feeding a high-fat diet may trigger bile and lipase production, which improve fat digestion. It is also possible that soybean oil in the test diet was more easily digested than the fats present in the ingredients of the control diet. There are several studies with horses that also report an increase in apparent digestibility of fat after the addition of fat to the diet (Hughes et al. 1995; Julen et al. 1995; Kane and Baker 1977; Kane et al. 1979; McCann et al. 1987; Rich et al. 1981; Scott et al. 1987).

Feeding the test diet depressed protein digestibility, but the effect was not statistically significant. As described above, when the test diet was fed, there may have been less growth of large intestinal bacteria, which would lead to a lower faecal output of microbial protein. This would raise apparent protein digestibility. On the other hand, a high-fat intake may depress apparent protein digestion in the small intestine due to increase of the endogenous N flow (Meyer et al. 1997). In this study, the 2 opposing effects on apparent protein digestibility may have been of the same order of magnitude. The intake of extra fat also reduced the apparent digestibility of the nitrogen-free extract, but an explanation for this effect cannot yet be given.

The decline in crude fibre utilization, when the horses were given the test diet explains the lower apparent total tract digestibility of energy observed in this
The effect of replacing nonstructural carbohydrates with soybean oil on the digestibility of fibre in trotting horses

experiment. If this observation can be generalized it may have consequences for practical horse feeding. The energy content of horse feeds is generally assessed by taking the sum of the contributions of the various digestible nutrients. This method assumes that there are no interactions between ingredients. The results of this study show that the addition of fat, at the expense of nonstructural carbohydrates, lowers the amount of digestible crude fibre, indicating that the digestible energy content of dietary crude fibre can be dependent on fat intake. For a high-fat diet, the digestible energy from components rich in crude fibre may be overestimated when calculating the energy content of the diet on the basis of feedstuffs. It should be stressed that the issue is more complex as a high-fat intake may also affect the digestibility of energy providing nutrients other than fibre.

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