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Apparent metabolisable energy and digestibility of shea (*Vitellaria paradoxa*) fat, cocoa (*Theobroma cacao*) fat and soya bean oil in broiler chicks

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Abstract  1. The objective of this experiment was to determine and compare the apparent
l lipid digestibility coefficient and apparent metabolisable energy (AME) value of shea nut
(Vitellaria paradoxa, Gaertn.) fat in broiler chickens with that of soya bean oil and cocoa fat.
2. One hundred and sixty 13-d-old male broiler chicks were used in a randomised complete
block design. The fats were added at 30, 60 and 90 g kg\(^{-1}\) to a basal diet. A tenth dietary
treatment was the basal feed with no added fats or oils. The birds were fed on the diets for 8
d and all droppings were collected for the final 4 d.
3. The mean coefficient of apparent lipid digestibility for shea fat (0.58) was similar to that
of cocoa fat (0.54) but lower than that of soya bean oil (0.95). There was evidence of a lipid
x concentration interaction with the 90 g kg\(^{-1}\) shea fat diet having low lipid digestibility
(0.43).
4. There was an interaction between the effects of dietary lipid concentration and test lipid
on AME but, at dietary levels of 60 g kg\(^{-1}\) and below, the AME of shea fat (22.0 MJ kg\(^{-1}\)
DM) and cocoa fat (26.4 MJ kg\(^{-1}\) DM) was significantly lower than that of soya bean oil
(39.8 MJ kg\(^{-1}\) DM).

INTRODUCTION
Shea fat is obtained from the nuts of the shea tree (Vitellaria paradoxa, Gaertn.) It is the
most common tree found in the Sahelian parklands over a large area of Africa (Leakey,
1999). It is used extensively as cooking oil in some communities in West Africa (Hall \textit{et al.},
1996). The amount of nuts collected and processed has been increasing over the past decade
as a consequence of increasing exports of the fat. There are potential reductions in costs
associated in using shea fat as a cocoa fat substitute in chocolate (Lipp and Anklam, 1998) as
well as in cosmetics (Hall \textit{et al.}, 1996).

Shea fat has a relatively high economic value to the regions where it is grown and it
is, therefore, unlikely to be intentionally produced as an animal feed. However, some
downgraded or unwanted batches may become available occasionally to the animal feed industry. Shea fat is also an important component of shea nut meal, the residue obtained after fat extraction. Shea nut meal has the potential of becoming a useful non-conventional feedstuff for animals (Atuahene et al., 1998; Rhule, 1999). The meal has variable levels of fat (30-360 g kg\(^{-1}\) after oil extraction (Hall et al., 1996)) due to the many different fat extraction methods that may be used in the West African industry. The content of fat in the meal may contribute a large proportion of its overall dietary available energy value. The nutritional value of the varying amounts of residual fat in shea nut meal has not yet been investigated.

Shea fat is mostly comprised of saturated fats due to the presence of large amounts of stearic acid but, unlike cocoa fat, it does not contain any significant amount of palmitic acid. Even though there are detailed data on the fatty acid composition of shea fat (Lipp and Anklam, 1998), there is a dearth of information on its digestibility and metabolisable energy in farm animals. The specific objectives of this study were to compare the lipid digestibility and metabolisable energy of shea fat with soya bean oil and cocoa fat when fed to broiler chickens at three different inclusion levels (30, 60 and 90 g kg\(^{-1}\)).

**MATERIALS AND METHODS**

Shea fat was supplied by Aarhus Ltd, Denmark, cocoa (*Theobroma cacao*) fat by Cadbury Ltd, UK and soya bean oil by Target Feeds Ltd, UK. A basal diet was prepared that was based on maize, dehulled soybean meal, wheat feed and fish meal, but no supplemental fat or oil. Three dietary inclusion levels (30, 60, 90 g kg\(^{-1}\)) of shea fat, cocoa fat and soybean oil were added to the basal diet, which was calculated to contain adequate levels of required nutrients for young broiler chickens (Table 1).

Male 1-d-old broiler chicks (Ross 308, UK) were reared in a litter floored pen and fed on a proprietary broiler starter feed for 13 d. 160 birds were then randomly selected and two
birds placed into each of 80 metabolism cages (0.36 m x 0.36 m x 0.42 m) with wire floors, kept in an environmentally controlled room. Each cage of birds was fed one of the 10 experimental diets for the following 8 d. Weight gains and feed intakes were recorded for the whole period and feed intakes were recorded and all egesta and excreta (droppings) were collected for the final 4 d. The droppings were collected daily and stored at 4°C until the total sample could be dried in a forced-draught oven at 88°C to constant weight. After drying, the droppings samples were ground in a laboratory mill fitted with 1mm-mesh size screen and then stored in a sealed container at 4°C prior to chemical analysis.

The lipid in the basal diet was obtained by continuous extraction of the prepared basal diet with light petroleum (b.p. 40-60°C) using a Soxtec system (920.39; AOAC, 2000). The sample of lipid from the basal diet plus the three test lipid samples were analysed for their fatty acid profiles (963.22; AOAC, 2000) using the one-step extraction and esterification procedure of Sukhija and Palmquist (1988). Fatty acid analysis was completed using a gas-liquid chromatograph (Perkin Elmer 8500; Perkin Elmer Life and Analytical Sciences Ltd, USA) fitted with an automatic sampler (Perkin Elmer AS 8300), integrator, and flame ionization detector. Fatty acids were identified by their relative retention times by comparison with retention times of known pure fatty acid standards (Sigma-Aldrich, UK).

Free fatty acid, moisture content and peroxide value were determined using AOAC (2000) methods (940.28, 926.12, 965.33). The dry matter and lipid contents of the diets and droppings samples were determined using standard methods (934.01, 920.39; AOAC, 2000).

The experimental data were compared using a randomised block analysis of variance. Tier level of the cages was considered a blocking factor. Any experimental unit (a total of 6) that had measurements greater than three standard deviations from the treatment mean was omitted from the statistical analysis for all variables. Linear and non-linear regression techniques with grouping factors (fat or oil) were used to examine the effect of level of
dietary fat or oil addition on the lipid digestibility or determined AME respectively of the added lipids.

RESULTS

All three lipids (Table 2) had low free fatty acid and peroxide values. Thus, these fats met the suggested quality specifications for feed fats (Palmquist, 2002). The gross energy contents were typical of fats and oils. Shea fat contained predominantly stearic acid, while cocoa fat comprised mainly palmitic and stearic acids. The fatty acid profiles of the fats including soya bean oil in this study were typical of those reported in other studies (Banerji et al. 1984; Lipp and Anklam, 1998; Wiseman and Salvador, 1991). The lipid in the basal feed was comprised largely of unsaturated C:18, C:20 and C:22 fatty acids (Table 2). The presence of the long chain fatty acids was probably due to the fishmeal in the basal diet. Eicosapentaenoic acid (EPA, C:20:5n-3) and docosahexaenoic acid (DHA, C:22n-3) are found in fish oil (Hammershoj, 1995).

Feed intake of birds fed soya bean oil compared to those fed shea and cocoa fats was affected neither by the lipid nor level of inclusion in the diets \((P>0.05)\). The gain-to-feed ratio was increased \((P<0.001)\) in the birds fed on the soya bean oil and there was a non-linear effect of concentration, with the greatest gain:feed ratio being obtained in the birds receiving the 60 g kg\(^{-1}\) fat/oil additions. No lipid x level of inclusion interaction was observed \((P>0.05)\).

The digestibility coefficients for the dry matter, lipid and gross energy of the shea and cocoa fats were lower than those for soya bean oil (Table 4). The 90 g kg\(^{-1}\) level of lipid inclusion resulted in a decrease \((P<0.01)\) in lipid digestibility coefficients but there was also a lipid x level of inclusion interaction \((P<0.01)\) that was due to a very low digestibility coefficient of lipid (0.43) in the 90 g kg\(^{-1}\) shea fat diet. There were no differences \((P>0.05)\)
in lipid digestibility between the 30 g kg\(^{-1}\) and 60 g kg\(^{-1}\) inclusion levels for any of the three test lipids.

There was a significant effect of lipid source on AME of the diets \((P<0.001)\). The determined AME values of the soya bean oil diets were significantly \((P<0.001)\) greater than those of the shea and cocoa fat diets (Table 5). Increasing dietary lipid levels gave increasing \((P<0.05)\) determined AME values but there was a lipid x level interaction \((P<0.05)\). The increase in AME due to increasing lipid concentration occurred only up to 60 g kg\(^{-1}\) for the shea and cocoa fat diets.

DISCUSSION

The experimental data indicated that, in both shea and cocoa fat diets, there was a reduced AME in the 90 g kg\(^{-1}\) diets. Although we considered it to be valid to examine this very high dietary level in the experiment, it is not of great practical significance. Practical poultry feeds typically contain a maximum of 50 g kg\(^{-1}\) of added fats and practical problems of mechanical handling difficulties and pellet quality prevent greater amounts being added. Further examination of the data from this experiment could therefore either eliminate, or otherwise deal with the 90 g kg\(^{-1}\) data, in order that conclusions can be made that are relevant to the commercial feed industry.

Linear regression analysis of the apparent lipid digestibilities of only the two lower inclusions (30 and 60 g kg\(^{-1}\)) of the three diet series indicated that there was neither an inclusion-level effect nor a lipid x level interaction. Thus the derived mean digestibility of test lipids in the total lipid supply in the diets indicated lipid digestibility coefficients of 0.95, 0.54 and 0.58 for soya bean oil, cocoa fat and shea fat respectively (Table 6). Wiseman \textit{et al} (1991) indicated that lipid digestibility decreased when the overall dietary unsaturated:saturated fatty acid ratio decreased. In the present experiment, there was also a strong linear relationship \((r^2=0.8792)\) between the total dietary unsaturated:saturated fatty
acid ratio and lipid digestibility. However, this relationship was not always consistent within each dietary test lipid treatment, particularly in the soya oil treatment. This agrees with the curvilinear model described by Ketels and de Groote (1989). The estimate for soya bean oil is similar to the value determined by Mossab et al. (2000) for soya bean oil in chickens. No digestibility coefficients for cocoa fat appear to have been determined in poultry but the present estimate is similar to the coefficient of fat digestibility reported by Chen et al. (1989) from work with rats.

The lower fat digestibility of the shea and cocoa fat was expected. Wiseman and Salvador (1991) demonstrated that saturated fats had a lower digestibility than unsaturated. Stearic acid that is esterified at the 1-or-3-position on the glycerol moiety is released as free fatty acid in rats and, in the presence of calcium and magnesium, is poorly absorbed due to soap formation (Mattson et al., 1979; Brink et al., 1995). Both shea and cocoa fats have either C16:0 or C18:0 as the major fatty acids in the sn-1/3 position of the glycerol backbone (Lipp and Anklam, 1998).

The contribution of the added dietary lipid can be estimated by deduction of the determined AME of that diet from the determined AME of the basal feed (Nitsan et al. 1997). The derived estimates for the three lipids used in the present experiment indicated AME concentrations of soya bean oil, cocoa fat and shea fat to be 39.8, 26.4 and 22.0 MJ kg\(^{-1}\) DM respectively (Table 6).

Prediction of the AME value of fats from the product of their apparent fat digestibility and gross energy concentration has been employed in a number of studies (Wiseman and Lessire, 1987). Wiseman (1990) observed that calculation of AME value of fat from its digestibility and gross energy tended to be lower than a directly determined AME. In the study, calculated AME values obtained by this method were 37.1, 21.5 and 23.1 MJ kg\(^{-1}\) DM for soya bean oil, cocoa fat and shea fat respectively with a standard error of
1.18 MJkg\(^{-1}\). The values for soya bean oil and cocoa fat were both lower than the determined values, but the calculated shea fat value was numerically larger. The data therefore indicate that the utilisation of the absorbed lipid hydrolysis products from shea fat may be poorer than expected or the dietary shea fat may have influenced the availability of other nutrients of the diet.

In conclusion, the present study has shown that shea fat contributes to the energy supply to a broiler chicken feed although it had a poor digestibility at high (90 g kg\(^{-1}\)) dietary concentration. The derived AME for shea fat of 22.0 MJ kg\(^{-1}\) DM gives a valid estimate of its energy concentration at dietary concentrations of 60 g kg\(^{-1}\) or less.

REFERENCES


Table 1. Calculated composition (g kg\(^{-1}\)) of the basal diet

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Amount (g kg(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>400</td>
</tr>
<tr>
<td>Dehulled soya bean meal</td>
<td>300</td>
</tr>
<tr>
<td>Fishmeal</td>
<td>30</td>
</tr>
<tr>
<td>Wheatfeed</td>
<td>220</td>
</tr>
<tr>
<td>Lysine (HCl)</td>
<td>3</td>
</tr>
<tr>
<td>Methionine</td>
<td>4</td>
</tr>
<tr>
<td>Limestone</td>
<td>4</td>
</tr>
<tr>
<td>Dicalcium phosphate</td>
<td>13</td>
</tr>
<tr>
<td>Vitamin and trace element premix(^*)</td>
<td>22</td>
</tr>
<tr>
<td>Salt</td>
<td>4</td>
</tr>
</tbody>
</table>

**Calculated composition (g kg\(^{-1}\))**

| Crude protein                      | 239.4                   |
| Crude fibre                        | 36.9                    |
| Calcium                            | 11.4                    |
| Phosphorus                         | 7.6                     |
| Sodium                             | 2.0                     |
| Lysine                             | 15.2                    |
| Methionine                         | 7.6                     |
| Methionine + Cystine               | 11.6                    |
| ME (MJ kg\(^{-1}\))\(^**\)       | 11.5                    |

\(^*\)Vitamin-trace mineral premix for broilers (Ian Hollows Feed Supplement, UK) added per kg:
- 800 mg retinol,
- 150 mg cholecalciferol,
- 1.25 g tocopherol,
- 150 mg thiamin,
- 500 mg riboflavin,
- 150 mg pyrodoxine,
- 750 mg cyanocobalamin,
- 3 g nicotinamide,
- 0.5 g pantothenic acid,
- 75 mg folic acid,
- 6.25 g biotin,
- 12.5 g choline chloride,
- 1 g iron,
- 50 mg cobalt,
- 5 g manganese,
- 0.5 g copper,
- 4 g zinc,
- 50 mg iodine,
- 10 mg selenium,
- 25 mg molybdenum.

\(^**\)ME calculated using soya bean oil ME (36.5 MJ kg\(^{-1}\)).

Determined crude fat (g kg\(^{-1}\) DM) contents of diets with added lipid at 30, 60 and 90 g kg\(^{-1}\) including basal diet were: basal diet (26.9); soya bean oil diets (50.1, 78.8, 102.5); cocoa fat diets (51.1, 77.1, 108.6); and shea fat diets (50.0, 76.9, 97.2).
Table 2. Composition of test lipids and oil extracted from the basal diet

<table>
<thead>
<tr>
<th></th>
<th>*Oil in basal diet</th>
<th>Soya bean oil</th>
<th>Cocoa fat</th>
<th>Shea fat</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Relative proportions of fatty acids (g kg(^{-1}))</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Myristic acid (<strong>C(_{14:0})</strong>)</td>
<td>5.5</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Pentadecanoic acid (C(_{15:0}))</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>1.5</td>
</tr>
<tr>
<td>Palmitic acid (C(_{16:0}))</td>
<td>151.7</td>
<td>110.6</td>
<td>259.3</td>
<td>35.6</td>
</tr>
<tr>
<td>Palmitoleic acid (C(_{16:1}))</td>
<td>8.7</td>
<td>0.0</td>
<td>2.9</td>
<td>0.0</td>
</tr>
<tr>
<td>Heptadecanoic acid (C(_{17:0}))</td>
<td>1.2</td>
<td>1.0</td>
<td>1.8</td>
<td>0.0</td>
</tr>
<tr>
<td>Stearic acid (C(_{18:0}))</td>
<td>24.4</td>
<td>36.2</td>
<td>377.4</td>
<td>430.6</td>
</tr>
<tr>
<td>Oleic acid (C(_{18:1}))</td>
<td>253.8</td>
<td>227.1</td>
<td>341.9</td>
<td>449.8</td>
</tr>
<tr>
<td>Linoleic acid (C(_{18:2}))</td>
<td>466.2</td>
<td>546.2</td>
<td>3.1</td>
<td>63.8</td>
</tr>
<tr>
<td>Linolenic acid (C(_{18:3}))</td>
<td>39.3</td>
<td>69.4</td>
<td>1.9</td>
<td>0.0</td>
</tr>
<tr>
<td>Arachidic acid (C(_{20:0}))</td>
<td>4.2</td>
<td>3.3</td>
<td>11.7</td>
<td>15.1</td>
</tr>
<tr>
<td>Erucic acid (C(_{20:1}))</td>
<td>13.0</td>
<td>2.7</td>
<td>0.0</td>
<td>3.6</td>
</tr>
<tr>
<td>Eicosapentaenoic acid (C(_{20:5}))</td>
<td>10.1</td>
<td>4.4</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Cetoleic acid (C(_{22:1}))</td>
<td>10.4</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Docosahexaenoic acid (C(_{22:6}))</td>
<td>12.9</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td><strong>Total unsaturated fatty acids</strong></td>
<td>814.4</td>
<td>849.8</td>
<td>349.8</td>
<td>517.2</td>
</tr>
<tr>
<td><strong>Total saturated fatty acids</strong></td>
<td>187</td>
<td>151.1</td>
<td>650.2</td>
<td>482.8</td>
</tr>
<tr>
<td><strong>Unsaturated/saturated fatty acid ratio</strong></td>
<td>4.36</td>
<td>5.62</td>
<td>0.54</td>
<td>1.07</td>
</tr>
<tr>
<td><strong>Moisture (g kg(^{-1}))</strong></td>
<td>nd</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td><strong>Free fatty acids (g kg(^{-1}))</strong></td>
<td>nd</td>
<td>13.0</td>
<td>14.0</td>
<td>2.0</td>
</tr>
<tr>
<td><strong>Peroxide value (meq kg(^{-1}))</strong></td>
<td>nd</td>
<td>0.26</td>
<td>0.08</td>
<td>0.13</td>
</tr>
<tr>
<td><strong>Gross energy (MJ kg(^{-1}))</strong></td>
<td>37.54</td>
<td>39.20</td>
<td>39.82</td>
<td>39.93</td>
</tr>
</tbody>
</table>

*Oil extracted from the basal diet  **Carbon chain length followed by number of double bonds

nd = not determined
Table 3. Growth performance of broiler chickens (13-21d) fed 3 lipids at 3 levels

<table>
<thead>
<tr>
<th>Variable</th>
<th>Lipid level (g kg⁻¹)</th>
<th>Test lipids</th>
<th>Analysis of variance</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Soya bean oil</td>
<td>Cocoa fat</td>
<td>Shea fat</td>
<td>mean</td>
</tr>
<tr>
<td>Mean feed intake</td>
<td>0</td>
<td>68.6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>67.0</td>
<td>69.5</td>
<td>67.9</td>
<td>68.2</td>
</tr>
<tr>
<td></td>
<td>60</td>
<td>69.8</td>
<td>70.3</td>
<td>71.7</td>
<td>70.6</td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>64.1</td>
<td>71.9</td>
<td>72.2</td>
<td>69.4</td>
</tr>
<tr>
<td>mean</td>
<td></td>
<td>67.0</td>
<td>70.6</td>
<td>70.6</td>
<td>69.4</td>
</tr>
<tr>
<td>Mean live weight gain (g/bird.day)</td>
<td>0</td>
<td>41.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>42.2</td>
<td>41.1</td>
<td>41.1</td>
<td>41.5</td>
</tr>
<tr>
<td></td>
<td>60</td>
<td>46.9</td>
<td>42.0</td>
<td>43.8</td>
<td>44.2</td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>41.2</td>
<td>42.4</td>
<td>41.3</td>
<td>41.6</td>
</tr>
<tr>
<td>mean</td>
<td></td>
<td>43.4</td>
<td>41.8</td>
<td>42.1</td>
<td>42.4</td>
</tr>
<tr>
<td>Gain : Feed ratio</td>
<td>0</td>
<td>0.61</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>0.63</td>
<td>0.59</td>
<td>0.60</td>
<td>0.61</td>
</tr>
<tr>
<td></td>
<td>60</td>
<td>0.67</td>
<td>0.60</td>
<td>0.61</td>
<td>0.63</td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>0.64</td>
<td>0.59</td>
<td>0.57</td>
<td>0.60</td>
</tr>
<tr>
<td>mean</td>
<td></td>
<td>0.65</td>
<td>0.59</td>
<td>0.60</td>
<td>0.61</td>
</tr>
</tbody>
</table>

Polynomial contrasts: L-linear effects, Q-quadratic effects, SED-standard error of difference, P-probability, r.d.f.-residual degrees of freedom.
Table 4. Apparent metabolisability of dietary dry matter, lipid and gross energy in broiler chickens (13-21d) fed 3 lipids at 3 levels

<table>
<thead>
<tr>
<th>Variable</th>
<th>Lipid level (g kg(^{-1}))</th>
<th>Test lipids</th>
<th>Analysis of variance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Soya bean oil</td>
<td>Cocoa fat</td>
<td>Shea fat</td>
</tr>
<tr>
<td>Dry matter</td>
<td>0</td>
<td>0.64</td>
<td></td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>0.66</td>
<td>0.64</td>
</tr>
<tr>
<td></td>
<td>60</td>
<td>0.67</td>
<td>0.63</td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>0.65</td>
<td>0.63</td>
</tr>
<tr>
<td>mean</td>
<td></td>
<td>0.66</td>
<td>0.63</td>
</tr>
<tr>
<td>Lipid</td>
<td>0</td>
<td>0.72</td>
<td></td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>0.85</td>
<td>0.63</td>
</tr>
<tr>
<td></td>
<td>60</td>
<td>0.87</td>
<td>0.59</td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>0.80</td>
<td>0.56</td>
</tr>
<tr>
<td>mean</td>
<td></td>
<td>0.84</td>
<td>0.59</td>
</tr>
<tr>
<td>Gross energy</td>
<td>0</td>
<td>0.68</td>
<td></td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>0.71</td>
<td>0.68</td>
</tr>
<tr>
<td></td>
<td>60</td>
<td>0.72</td>
<td>0.67</td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>0.70</td>
<td>0.64</td>
</tr>
<tr>
<td>mean</td>
<td></td>
<td>0.71</td>
<td>0.66</td>
</tr>
</tbody>
</table>

SED-standard error of difference, P-probability, r.d.f.- residual degrees of freedom.

Polynomial contrasts for lipid x level interaction: L-linear effects.
### Table 5. Determined AME of experimental diets

<table>
<thead>
<tr>
<th>Variable</th>
<th>Lipid level (g kg(^{-1}))</th>
<th>Test lipids</th>
<th>Analysis of variance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Soya bean oil</td>
<td>Cocoa fat</td>
<td>Shea fat mean</td>
</tr>
<tr>
<td>AME (MJ kg(^{-1}) DM)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>12.43</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>13.28</td>
<td>12.87</td>
<td>12.57</td>
</tr>
<tr>
<td>60</td>
<td>13.96</td>
<td>13.10</td>
<td>13.08</td>
</tr>
<tr>
<td>90</td>
<td>13.94</td>
<td>12.64</td>
<td>12.55</td>
</tr>
<tr>
<td>mean</td>
<td>13.73</td>
<td>12.87</td>
<td>12.73</td>
</tr>
</tbody>
</table>

**Analysis of variance**

<table>
<thead>
<tr>
<th>Factor</th>
<th>SED</th>
<th>(P)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lipids</td>
<td>0.1635</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Level</td>
<td>0.1635</td>
<td>0.001</td>
</tr>
<tr>
<td>Lipids x Level</td>
<td>0.2003</td>
<td>0.015</td>
</tr>
</tbody>
</table>

SED-standard error of difference, \(P\)-probability, r.d.f.- residual degrees of freedom.

Polynomial contrasts for lipid x level interaction: L-linear effects.
Table 6. Apparent lipid digestibility and AME estimates of soya bean oil, shea fat and cocoa fat at 2 lipid levels (30, 60 g kg\(^{-1}\))

<table>
<thead>
<tr>
<th>Test lipids</th>
<th>30 g kg(^{-1})</th>
<th>60 g kg(^{-1})</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digestibility coefficient</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soya bean oil</td>
<td>0.96</td>
<td>0.93</td>
<td>0.95</td>
</tr>
<tr>
<td>Cocoa fat</td>
<td>0.55</td>
<td>0.53</td>
<td>0.54</td>
</tr>
<tr>
<td>Shea fat</td>
<td>0.58</td>
<td>0.58</td>
<td>0.58</td>
</tr>
<tr>
<td>AME (MJ kg(^{-1}) DM)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soya bean oil</td>
<td>42.0</td>
<td>37.6</td>
<td>39.8</td>
</tr>
<tr>
<td>Cocoa fat</td>
<td>29.5</td>
<td>23.3</td>
<td>26.4</td>
</tr>
<tr>
<td>Shea fat</td>
<td>21.2</td>
<td>22.7</td>
<td>22.0</td>
</tr>
</tbody>
</table>