Nutritional Aspects of Hydrogenated and Regular Soybean Oil Added to Diets of Broiler Chickens

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ABSTRACT The objective of the present study was to evaluate the effect of degree of saturation of fat incorporated into broiler diets on performance and body fatty acid (FA) profile. The various degrees of saturation were achieved by using regular soybean oil (SO) and hydrogenated soybean oil (HSO), mixed at different proportions. The work was carried out on commercial broilers (Experiment 1) and on lines of chickens divergently selected for high (HF) or low (LF) abdominal fat (Experiment 2). Daily BW gain and gain:feed ratio increased and the amount of feed intake decreased as the dietary fat saturation decreased. Digestibility of total fat and of each of the FA was lowest in the HSO group and reached maximal values when 23% or more of the added oil was SO. The AMEₙ values of the diets were almost parallel to fat digestibility. The performance of the HF and LF chickens was affected by the degree of saturation similarly to that observed for the commercial stock. The degree of dietary fat saturation had very little effect on saturated FA (C16:0 and C18:0) in body lipids, reduced the level of monoenoic FA (C16:1 and C18:1), and raised that of polyunsaturated FA (PUFA) (C18:2, C18:3, and C20:4). Monoenoic FA were higher, whereas PUFA were lower in the HF than in the LF line. The improved AMEₙ in diets containing unsaturated fat is probably due to higher fat digestibility, direct deposition of PUFA in body lipids, and lower lipogenesis, associated with lower heat production.

(Key words: dietary fat saturation, broiler, body fatty acids profile, metabolizable energy)

INTRODUCTION

Poultry meat constitutes a major part of worldwide meat consumption. The lipid composition of animal products is a primary consumer concern. Degree of adiposity may vary among different genetic sources (Leenstra, 1986) and is influenced by nutritional manipulations (Bartov et al., 1974; Farrel, 1974; Keren-Zvi et al., 1990). Fatty acid (FA) profile of body fats is also determined by dietary lipid composition (Sim et al., 1973; Keren-Zvi et al., 1992; Pinchasov and Nir, 1992).

The main factor affecting the ME value of fat is its digestibility. The digestibility of fats is dependent on factors such as length of the carbon chain and degree of saturation of the FA (Renner and Hill, 1961). The position of the FA on the glycerol molecule may also affect its absorption. Interactions between degree of saturation of endogenous FA in grains and that of added fats, relative to fat absorption, were suggested by several authors (Young and Garet, 1963; Leeson and Summers, 1976; Sell et al., 1976). Consequently, the ME of saturated fat such as tallow may be elevated if the basal diet contains ingredients high in polyunsaturated FA (PUFA) (Sibbald et al., 1961; Ketels et al., 1986; Wiseman et al., 1986). Artman (1964) showed that the utilization of relatively saturated fats or FA is increased by mixing them with relatively unsaturated fats or FA. Digestibility and AMEₙ of fats from different sources was improved with the increase of unsaturation of the dietary fat up to a maximal value achieved when the ratio of unsaturated to saturated FA was 2.5 (Ketels and DeGroote, 1989).

In the present study, the effect of degree of saturation of added fat on broiler performance was evaluated. In order to eliminate the effects of length of carbon chains of FA and their position on the glycerol molecule, various degrees of saturation were achieved by using regular soybean oil (SO) and hydrogenated SO (HSO), mixed at different proportions. Growth rate, feed intake and utilization, digestibility of total dietary fat and of each of the FA, and the AMEₙ values of the diets were...
TABLE 1. Fatty acid profile of soybean oil and hydrogenated soybean oil used in the present study

<table>
<thead>
<tr>
<th>Fatty acid</th>
<th>Soybean oil (% of fatty acids)</th>
<th>Hydrogenated soybean oil (% of fatty acids)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C\textsubscript{16:0}</td>
<td>11.1</td>
<td>13.4</td>
</tr>
<tr>
<td>C\textsubscript{18:0}</td>
<td>4.0</td>
<td>20.1</td>
</tr>
<tr>
<td>C\textsubscript{18:1}</td>
<td>25.0</td>
<td>53.0</td>
</tr>
<tr>
<td>C\textsubscript{18:2}</td>
<td>50.3</td>
<td>8.8</td>
</tr>
<tr>
<td>C\textsubscript{18:3}</td>
<td>8.0</td>
<td>1.9</td>
</tr>
<tr>
<td>U:S\textsuperscript{1}</td>
<td>5.53</td>
<td>1.90</td>
</tr>
<tr>
<td>PUFA:SM\textsuperscript{2}</td>
<td>1.45</td>
<td>1.12</td>
</tr>
</tbody>
</table>

\textsuperscript{1}(C\textsubscript{18:1} + C\textsubscript{18:2} + C\textsubscript{18:3})/(C\textsubscript{16:0} + C\textsubscript{18:0}).

\textsuperscript{2}(C\textsubscript{18:2} + C\textsubscript{18:3})/(C\textsubscript{16:0} + C\textsubscript{18:0} + C\textsubscript{18:1}).

studied. Net energy deposition in the body and FA profile of body fat, as affected by dietary FA composition, were also determined. The work was carried out on commercial broilers and on lines of chickens divergently selected for high (HF) or low (LF) abdominal fat (Cahaner and Nitsan, 1985).

MATERIALS AND METHODS

Experiment 1

One hundred day-old Anak male chicks were placed in a commercial poultry house with continuous lighting. A commercial starter diet (21% crude protein; 2,900 kcal ME/kg) and water were available at all times. At 23 d of age, the chicks were weighed, divided into 20 groups of similar weight, and randomly placed in battery cages. Four replicates were assigned to each of five treatments. Corn-soybean diets were formulated to contain 18% crude protein and 2,900 kcal ME/kg. The diets were in mash form. All diets except the control contained 3% added fat. The control diet was not supplemented with fat. Soybean oil was used as is or mixed with various amounts of HSO to form four degrees of saturation. The FA profile of SO and HSO and of the five experimental diets is shown in Tables 1 and 2, respectively.

A digestibility trial was conducted during 34 to 36 d of age, when feed intake was recorded, and total excreta were collected, weighed, and kept frozen at −20°C for further analyses. Metabolizable energy was calculated by determining gross energy in the feed consumed and in the excreta, and was corrected to zero nitrogen retention (Hill and Anderson, 1958).

All animal care and killing procedures were conducted according to the protocols approved by the Institute’s Animal Care and Use Committees.

FIGURE 1. Effect of dietary fat saturation on fat digestibility and AMEn of the diets. The unconnected points represent the respective values of the control diet (with no added fat).
TABLE 2. Fatty acid profile of the experimental diets

<table>
<thead>
<tr>
<th>Fatty acids</th>
<th>0.0</th>
<th>0.3</th>
<th>0.7:2:3</th>
<th>2:1</th>
<th>3:0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(% of fatty acids)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C16:0</td>
<td>14.9</td>
<td>13.1</td>
<td>13.6</td>
<td>13.8</td>
<td>14.2</td>
</tr>
<tr>
<td>C18:0</td>
<td>12.0</td>
<td>2.59</td>
<td>4.6</td>
<td>9.37</td>
<td>12.0</td>
</tr>
<tr>
<td>C18:1</td>
<td>39.5</td>
<td>23.7</td>
<td>27.7</td>
<td>35.2</td>
<td>39.5</td>
</tr>
<tr>
<td>C18:2</td>
<td>32.4</td>
<td>55.6</td>
<td>50.3</td>
<td>38.9</td>
<td>32.4</td>
</tr>
<tr>
<td>C18:3</td>
<td>1.8</td>
<td>4.9</td>
<td>4.01</td>
<td>2.61</td>
<td>1.8</td>
</tr>
<tr>
<td>U:S</td>
<td>4.78</td>
<td>5.36</td>
<td>4.50</td>
<td>3.31</td>
<td>2.81</td>
</tr>
<tr>
<td>PUFA:SM</td>
<td>1.43</td>
<td>1.53</td>
<td>1.18</td>
<td>0.72</td>
<td>0.52</td>
</tr>
</tbody>
</table>

1Ratio of hydrogenated soybean oil (HSO):soybean oil (SO) included in diets.
20:0 = no added fat.
3(C18:1 +C18:2 +C18:3):(C16:0 +C18:0).
4(C18:2 +C18:3):(C16:0 +C18:0 +C18:1).

The SO group exhibited a daily BW gain that was 12% higher and the time required to achieve the target weight of 2 kg was 10% less (P < 0.05) than the HSO group (P < 0.05). Feed consumption and utilization (gain:feed) were 15 and 10% lower in the HSO than in the SO group, respectively (P < 0.05).

**Digestibility Coefficients or Retention of Dietary Components.** Retention of dry matter, ash, and protein was not affected by the degree of saturation of the SO. Digestibility of total fat (Figure 1) and of each of the FA (Figure 2) was lowest for the HSO group fed a diet having a PUFA:SM (SM = saturated + monoenoic FA) ratio of 0.52. It increased by approximately 10 percentage units (for the different FA) (P < 0.05) when 23% of the added oil was SO and the PUFA:SM ratio was 0.72. Further increase in the relative level of SO and in the unsaturation of the dietary fat was not accompanied by a further increase in digestibility coefficients of the FA.

The digestibility values of total fat and each of the FA of the control diet were lower than those expected according to the degree of saturation of dietary fat of this group (Figure 2). Previously, it was shown that adding fat to a control diet (with no added fat) increased fat digestibility (Nitsan *et al*., 1997).

**ME of the Experimental Diets.** Although the experimental diets were programmed to contain 2,900 kcal ME/kg, the actual values of ME (and AMEn) of all the diets were higher. An increase in PUFA:SM ratio from 0.54 to 0.72 was followed by a marked increase in AMEn of the diet, as was observed for fat digestibility (Figure 1). However, in contrast to fat digestibility, the AMEn values gradually increased when the relative level rose beyond 23%, and the PUFA:SM ratios were elevated up to 1.53.

**Weight of Organs and Body Composition.** There were no differences among treatments in weight of liver and pancreas. The weight of the abdominal fat was approximately 2 g higher when the added fat was 100% SO or when the ratio SO:HSO was 2:1 than when the added fat was more saturated; but this was not significant. There were no statistical differences among treatments in the level of dry matter, ash, and protein in the whole body. The only difference among the groups was in the level of total body fat (P < 0.05), which was reduced when dietary fat saturation was increased (Table 4).

**Profile of FA in the Body Lipids.** An increase in the PUFA:SM ratio of the added fats was accompanied by elevated levels of linoleic (C18:2) and linolenic (C18:3) acids in body lipids, whereas the levels of arachidonic acid (C20:4) and of monoenoic FA (C16:1 and C18:1) were reduced.

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**Weight of Organs and Body Composition.** There were no differences among treatments in weight of liver and pancreas. The weight of the abdominal fat was approximately 2 g higher when the added fat was 100% SO or when the ratio SO:HSO was 2:1 than when the added fat was more saturated; but this was not significant. There were no statistical differences among treatments in the level of dry matter, ash, and protein in the whole body. The only difference among the groups was in the level of total body fat (P < 0.05), which was reduced when dietary fat saturation was increased (Table 4).

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TABLE 5. Effect of degree of saturation of added soybean oil on fatty acid profile of carcass fat

<table>
<thead>
<tr>
<th>Fatty acids</th>
<th>0.52</th>
<th>0.72</th>
<th>1.18</th>
<th>1.53</th>
<th>1.43</th>
</tr>
</thead>
<tbody>
<tr>
<td>C16:0</td>
<td>21.8b</td>
<td>21.1b</td>
<td>21.9b</td>
<td>23.0b</td>
<td>24.2a</td>
</tr>
<tr>
<td>C16:1</td>
<td>6.8c</td>
<td>6.4b</td>
<td>6.4b</td>
<td>6.0b</td>
<td>9.1a</td>
</tr>
<tr>
<td>C18:0</td>
<td>7.8a</td>
<td>7.6ab</td>
<td>7.0a</td>
<td>7.1c</td>
<td>6.8c</td>
</tr>
<tr>
<td>C18:1</td>
<td>38.4a</td>
<td>36.7ab</td>
<td>34.8b</td>
<td>32.4c</td>
<td>37.0a</td>
</tr>
<tr>
<td>C18:2</td>
<td>20.5c</td>
<td>23.4b</td>
<td>25.3a</td>
<td>27.1a</td>
<td>18.3d</td>
</tr>
<tr>
<td>C18:3</td>
<td>0.7a</td>
<td>1.1b</td>
<td>1.5a</td>
<td>1.6b</td>
<td>0.6c</td>
</tr>
<tr>
<td>C20:4</td>
<td>2.4ab</td>
<td>2.4a</td>
<td>2.0ab</td>
<td>2.0b</td>
<td>2.4ab</td>
</tr>
<tr>
<td>PUFA:SM</td>
<td>0.32</td>
<td>0.38</td>
<td>0.41</td>
<td>0.45</td>
<td>0.28</td>
</tr>
<tr>
<td>n6:n3</td>
<td>30.2</td>
<td>21.5</td>
<td>18.2</td>
<td>18.2</td>
<td>34.5</td>
</tr>
</tbody>
</table>

\*Means within columns with no common superscript differ significantly (P < 0.05).
\^PUFA:SM = ratio of polyunsaturated fatty acids to saturated and monoenoic fatty acids.
\^Control diet with no added fat.
C18:3, which are not synthesized by the chicken, are AMEn as unsaturation of the dietary fat increased. Fuller elevated PUFA:SM ratio and may explain the better heat production observed in chicks fed diets with the lipogenesis are probably related to the lower metabolic tion of body fats. Direct PUFA deposition and low lower lipogenesis, which contributed to the low saturated fat. Therefore, control chicks, consuming diets devoid of added fat, probably had the highest lipogenesis and their body fats were most saturated (Table 5). In contrast, chicks fed diets with high PUFA levels had a lower lipogenesis, which contributed to the low saturation of body fats. Direct PUFA deposition and low lipogenesis are probably related to the lower metabolic heat production observed in chicks fed diets with the elevated PUFA:SM ratio and may explain the better AMEₙ as unsaturation of the dietary fat increased. Fuller and Rendon (1977), using various fats, found no relationship between the degree of saturation of the added fats and heat production. It seems therefore, that in addition to the degree of fat saturation, there are other factors, associated with the characteristics of the specific fat, which affect heat production.

Genetic selection for HF or LF broiler lines was associated with increased PUFA and decreased monoenoic FA in the body lipids of LF chicks as a result of reduced lipogenesis in this line compared with the HF line (Keren-Zvi et al., 1992). Increasing the PUFA level in the diet had a similar effect on FA profile in chicken body lipids of both selected lines and commercial broilers. It seems that nutritional manipulation had a more pronounced effect on FA profile of chicken body lipids than did the genetic selection.

Human nutritionists recommend that the ratio of unsaturated fat in the diet be increased with special emphasis on reducing the n6:n3 ratio. In the present work, the increase in the PUFA:SM ratio in the diet not only increased unsaturation of body fats but also reduced the n6:n3 ratio.

In conclusion, the best performance of the broilers was achieved by feeding regular SO. Saturating the oil was accompanied by reduced growth rate and ME of the diet and increased heat production. Moreover, the nutritional value for human consumption was reduced.

REFERENCES


