Algae-meal (Spirulina platensis) from lake Chad replacing soybean-meal in broiler diets

Algen-Mehl (Spirulina platensis) aus dem Tschad-See als Ersatz für Sojaextraktionsschrot in Broiler-Futter

G. P. Gongnet¹, E. Niess², M. Rodehutscord³, and E. Pfeffer²


Introduction
Interest in exploring algae as an ingredient for poultry feed is mainly based on algae as an alternative protein source (RICCARDI et al., 1988), as an option to produce docosahexaenoic acid-enriched eggs and poultry meat (ABRIL and BARCLAY, 1998; HERBER-MCNEILL and VAN ELSWYK, 1998), and as a source of a natural colorant (HERBER-MCNEILL and VAN ELSWYK, 1998; NAIDU et al., 1999). In Chad, algae are harvested from lake Chad in a small scale and used in poultry feed. This short presentation therefore deals with algae-meal from Lake Chad as an alternate protein source for broiler chicks and does not take into account the other mentioned purposes of algae supplementation to poultry feed.

Materials and methods
Preparation of samples
Algae (Spirulina platensis) used in this experiment were harvested from lake Chad in tubs, poured in flat dips made in the sand and sun-dried, powdered and stored in polyethylene bags until used in formulations.

Dietary treatments
Four experimental diets (Table 1) were formulated: a control diet containing no Spirulina-meal and 3 others in which Spirulina-meal was incorporated at 50, 100, and 150 g/kg replacing corresponding amounts of soybean-meal. Diets are named 0, 50, 100, and 150. An inorganic substance consisting of a silicagel preparation (Sipermat 50S, Degussa-Hüls-AG, Hanau, Germany) was added to the control diet and reduced in diets 2–4 in such a way that the concentration of organic matter in the four diets stayed at the same level. This procedure prevented a dilution of the diets with increasing proportion of Spirulina-meal due to its high ash content.

Supply of essential amino acids was calculated based on data from DEGUSSA-tables (DEGUSSA, 1996) for soybean-meal and maize and data from amino acid analysis for Spirulina-meal (Table 2). Valine and methionine were added to fulfill at least the NRC-recommendations (1994) for each essential amino acid. By mistake DL-methionine was added 10 times the calculated amount to each diet resulting in a total methionine plus cystine-concentration corresponding to 3 times the recommended value.

Experimental animals and management
Fifty male commercial one-day-old broiler chicks (Ross) were reared on two tiers of an electrically heated brooder. At an age of 6 days 32 chicks (8 per diet) were transferred to wire-cages and allotted to the four diets. All birds were individually housed. Mean and standard deviation of body weight in each group at start of the experiment were only marginally different. Feed and water were provided ad libitum for the following 4 weeks. Feed intake and body weight were determined on a weekly basis for each individual chick. Temperature of the experimental room was reduced from 30 to 22 °C at the end of the 2nd week. On the 32nd and 33rd day of life samples of excreta were collected from 5 randomly selected chicks per diet. Samples from the 2 days were pooled for each chick and analysed for dry matter; heat of combustion and HCl-unsoluble ash, which was used as a marker for determination of metabolisability of energy.

Chemical Analyses
In Spirulina-meal and diets dry matter (105 °C), ash (550 °C), HCl-insoluble ash, total nitrogen (Dumas method), lipids (petrol ether extract after HCl treatment), crude fiber (Weende analysis) were determined according to the official methods (NAUMANN and BASSLER, 1976). Analyses of elements were done in filtered ash solutions. Phosphorus was determined photometrically as orthophosphate using the vanado-molybdate method (NAUMANN and BASSLER, 1976). Calcium, magnesium, potassium and sodium were determined by atomic absorption spectrophotometry. Gross energy (adiabatic bomb calorimetry) was determined in diets and samples of excreta. Amino acid determinations were performed by the feed additives division of Degussa-Hüls AG in Hanau, Germany. Samples were oxidized with performic acid (except for tyrosine determination) and hydrolysed. Tryptophan was determined by 'reversed phase' HPLC after alkaline hydrolysis.

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Table 1. Composition, chemical analysis, gross energy, calculated amino acid concentration of diets and recommended concentrations of amino acids (GfE, 1999)

<table>
<thead>
<tr>
<th>Ingredients [g/kg]</th>
<th>0</th>
<th>50</th>
<th>100</th>
<th>150</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spirulina-meal</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Soybean-meal</td>
<td>380</td>
<td>330</td>
<td>280</td>
<td>230</td>
</tr>
<tr>
<td>Silicagel preparation</td>
<td>35</td>
<td>23</td>
<td>12</td>
<td>0</td>
</tr>
<tr>
<td>L-Valine</td>
<td>5</td>
<td>5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>DL-Methionine</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Wheat-starch</td>
<td>163</td>
<td>175</td>
<td>190</td>
<td>202</td>
</tr>
<tr>
<td>Maize</td>
<td>333</td>
<td>333</td>
<td>334</td>
<td>334</td>
</tr>
<tr>
<td>Oil</td>
<td>29</td>
<td>29</td>
<td>29</td>
<td>29</td>
</tr>
<tr>
<td>Premix</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Calciumcarbonate, feed grade</td>
<td>17</td>
<td>17</td>
<td>17</td>
<td>17</td>
</tr>
<tr>
<td>Monocalciumporphosphate</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Chemical analysis (g/kg DM)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crude ash</td>
<td>87</td>
<td>98</td>
<td>99</td>
<td>105</td>
</tr>
<tr>
<td>ClH-unsoluble ash</td>
<td>31.3</td>
<td>34.7</td>
<td>34.1</td>
<td>33.9</td>
</tr>
<tr>
<td>Crude protein</td>
<td>233</td>
<td>226</td>
<td>224</td>
<td>230</td>
</tr>
<tr>
<td>Crude fiber</td>
<td>43</td>
<td>39</td>
<td>37</td>
<td>35</td>
</tr>
<tr>
<td>Ether extract</td>
<td>66</td>
<td>59</td>
<td>63</td>
<td>65</td>
</tr>
<tr>
<td>Calcium</td>
<td>9.6</td>
<td>10.6</td>
<td>10.6</td>
<td>10.8</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>5.8</td>
<td>5.9</td>
<td>5.9</td>
<td>6.3</td>
</tr>
<tr>
<td>Magnesium</td>
<td>0.9</td>
<td>1.0</td>
<td>1.2</td>
<td>1.4</td>
</tr>
<tr>
<td>Gross energy (MJ/kg DM)</td>
<td>18.51</td>
<td>18.47</td>
<td>18.46</td>
<td>18.46</td>
</tr>
<tr>
<td>Amino acids, calculated, (recommended), g/kg DM</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Methionine incl. supplement</td>
<td>24.4 (4.1)</td>
<td>24.6 (4.2)</td>
<td>24.7 (4.2)</td>
<td>24.8 (4.1)</td>
</tr>
<tr>
<td>Cystine</td>
<td>2.7</td>
<td>2.6</td>
<td>2.4</td>
<td>2.2</td>
</tr>
<tr>
<td>Lysine</td>
<td>11.3 (11.2)</td>
<td>10.8 (11.3)</td>
<td>10.2 (11.3)</td>
<td>9.5 (11.0)</td>
</tr>
<tr>
<td>Threonine</td>
<td>7.3</td>
<td>7.3</td>
<td>7.3</td>
<td>7.3 (7.8)</td>
</tr>
<tr>
<td>Valine incl. supplement</td>
<td>14.1 (11.3)</td>
<td>14.3 (11.5)</td>
<td>14.6 (11.5)</td>
<td>14.7 (11.2)</td>
</tr>
</tbody>
</table>

Statistical analysis

The data obtained were analysed statistically using SAS software (SAS, 1987) for regression analysis and analysis of variance. Linear regressions of concentration of Spirulina-meal on feed intake, weight-gain, and feed efficiency showed that only 28, 40 and 36% of the variance could be explained by the proportion of Spirulina-meal in the diet, respectively. Therefore, analysis of variance was calculated.

Results and discussion

Chemical analysis of Spirulina-meal

From proximate analysis the following data (g/kg) were obtained: crude protein 423, ether extract 42, crude fiber 4.5, total ash 344, HCl-insoluble ash 240, calcium 7.93, phosphorus 8.42, magnesium 4.35, potassium 17.1, sodium 25.4. More than one third of the air dry material of Spirulina-meal used in this experiment consisted of total ash. Since the portion of HCl-insoluble ash in the total ash was about 70%, it can be concluded that the high content of total ash is mainly caused by sand or soil, which contaminated the material during the drying process. Improvement of harvesting and drying conditions could reduce total ash content to a lower level. Reduction for instance to 100 g/kg DM would increase the concentration of crude protein from 423 to 560 g/kg DM. In this experiment concentration of total ash in all diets was counterbalanced by adding an inorganic substance in corresponding amounts. This kind of diet-formulation led to almost equal concentrations of crude nutrients, which is reflected by the data in the second part of Table 1.

Amino acid composition (g/16 g N) is given in Table 2. Venkataraman et al. (1994) published data on the amino acid composition of protein of Spirulina platensis, which was grown under standardised cultivation conditions in Mysore, India. From the data in Table 2 it can be seen that the concentration of essential amino acids in protein of this material is up to 25% higher than in protein of Spirulina-meal from lake Chad in the present investigation, only tryptophan is much lower, which may possibly have resulted from analytical difficulties. Overall the amino acid patterns are quite similar. In column 3 of Table 2 the amino acid composition of Spirulina-meal from a commercial supplier in California, USA (Grinsted et al., 2000) is shown. Most of the concentrations fall between those of Spirulina from Chad and India. Again amino acid patterns are quite similar. Amino acid concentration of Spirulina-meal from Hawaii (Ross and Dominy, 1990) is presented in column 4. It was cultivated in a synthetic medium in outdoor culture tanks. Concentrations are about 50% lower than in the 3 other Spirulina-meals. Any reasons for this are unknown. A comparison of tabulated concentrations of amino acids in soybean-meal (Degussa, 1996) with Spirulina-meal from Chad shows that in the protein of the Spirulina-meal methionine, threonine, tryptophan, isoleucine, leucine, and valine were higher and cystine, lysine, histidine, and phenylalanine lower concentrated than in the protein of soybean-meal. From this it was hypothesised that this Spirulina-meal from lake Chad is a potentially valuable source for essential amino acids. This hypothesis was checked in the feeding experiment.
Table 2. Amino acid composition of Spirulina-meal from Chad, India, USA, Hawaii, and of soybean-meal

<table>
<thead>
<tr>
<th>Amino acid</th>
<th>Concentration (g/kg DM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methionine</td>
<td>2.0</td>
</tr>
<tr>
<td>Cystine</td>
<td>0.9</td>
</tr>
<tr>
<td>Lysine</td>
<td>4.1</td>
</tr>
<tr>
<td>Threonine</td>
<td>4.6</td>
</tr>
<tr>
<td>Tryptophan</td>
<td>1.4</td>
</tr>
<tr>
<td>Arginine</td>
<td>7.0</td>
</tr>
<tr>
<td>Isoleucine</td>
<td>5.4</td>
</tr>
<tr>
<td>Leucine</td>
<td>8.4</td>
</tr>
<tr>
<td>Valine</td>
<td>6.2</td>
</tr>
<tr>
<td>Histidine</td>
<td>1.5</td>
</tr>
<tr>
<td>Phenylalanine</td>
<td>4.3</td>
</tr>
<tr>
<td>Glycine</td>
<td>4.8</td>
</tr>
<tr>
<td>Serine</td>
<td>4.2</td>
</tr>
<tr>
<td>Proline</td>
<td>4.2</td>
</tr>
<tr>
<td>Alanine</td>
<td>7.2</td>
</tr>
<tr>
<td>Aspartic acid</td>
<td>10.1</td>
</tr>
<tr>
<td>Glutamic acid</td>
<td>16.3</td>
</tr>
</tbody>
</table>

Chemical analyses of the 4 diets (Table 1) show that the concentrations of total ash, HCl-insoluble ash, crude protein, crude fiber, ether extract, calcium, and phosphorus were similar. Magnesium-concentration was increased with increasing portion of Spirulina-meal. In all diets recommendations for the supply with magnesium were fulfilled. Concentration of gross energy was almost equal in the 4 diets. For 5 essential amino acids, which were either supplemented or whose concentrations were lower than recommended, the calculated concentrations are shown and compared with the recommendations of GfE (1999), which are given in brackets. As mentioned above the concentration of methionine + cystine was about 3 times the recommended values. Lysine-concentration met the recommendations of GfE (1999) in diet 0 and decreased with increasing portion of Spirulina-meal to 96, 90 and 86% of the GfE-recommendations in diet 50, diet 100, and diet 150, respectively. The provision with threonine made up 91% of recommendations for all diets. Lysine and threonine were not supplemented because in the first calculations for the composition of the diets they met the recommendations. The experimental determination of the concentration of metabolisable energy led to higher values than calculated with the consequence of the above mentioned deficiency in lysine and threonine. Valine was supplemented and well above the recommendations.

**Feeding experiment**

The results of the feeding experiment are summarised in Table 3. Feed intake was reduced with increasing concentration of Spirulina-meal, slightly in birds fed diet 50, significantly in birds fed diets 100 and 150. Weight gains in birds fed diet 0 and 50 were not different and reached almost the weight gains of about 45 g/d, which were taken as basic values for requirement-calculations by the GfE (1999) for broilers up to the middle of the 5th week of life and which correspond to gains in commercial production. It therefore can be concluded that overdosing the methionine concentration in the diets had no detrimental effect. Han and Baker (1993) fed broiler-chickens an excess of 5 or 10 g DL-methionine per kg diet, which is comparable to the excess in our experiment, and did not obtain reduced weight gain or feed conversion.

Weight gains of birds fed diets 100 and 150 were significantly reduced to 80% and 76% of the control-diet. Feed conversion (feed intake/weight gain) for diets 0, 50 and 100 was within the range of good commercial production, whereas in diet 150 significantly more feed was necessary per unit body weight gain. Part of the depression in weight gain is certainly caused by the above mentioned deficiency in provision with lysine. There is, however, no explanation for the depressive effect which exceeds that of lysine deficiency. This result is controversial to the conclusion drawn by Riccardi et al. (1988) in their review stating that in the existing reports in all cases Spirulina has turned out to be nontoxic and as good as comparable feeds for chicken, pigs and fish. Venkataraman et al. (1994) fed diets with 14 and 17% Spirulina replacing fishmeal to broiler from 4th to 8th and 12th week of life. None of the diets effected weight gain, feed efficiency or meat quality. Because of the very low daily weight gains the applicability of these results on more intensive production is limited. Ross and Dominy (1990) observed depressed weight gains in chicks fed diets with 10 and 20% Spirulina platensis, which substituted soybean meal, in the first 3 weeks of life. With 12% of Spirulina in the diet fed for 41 days birds grew slower than those receiving the control diet or diets with lower concentrations of Spirulina. In similar diets fed to Japanese quail no significant differences in growth, egg production, fertility, hatchability, and the growth of the F1 generation of dams fed Spirulina were observed. Naidu et al. (1999) fed high concentrations of phycocyanin, the blue colourant from Spirulina platensis, to rats and did not obtain any adverse effects. These publications and the data of the presented experiment show that the picture of feeding value of Spirulina platensis is not uniform and that the value seems to depend on effects like cultivation media and methods of processing. Speculations on reasons for the depressive effect of Spirulina-meal harvested from the lake Chad used in this experiment could concern, besides lysine
and threonine deficiency, contamination by soil of these algae during the process of drying.

The relation of metabolisable energy to gross energy was determined by calorimetry of diets and samples of excreta and referring these data to HCl-insoluble ash, which was contained in relatively high concentration in all diets and originated from included sipernat and/or Spirulina-meal. Since the concentration of metabolisable energy (Table 3) was not statistically different between the 4 diets, it can be concluded that the content of metabolizable energy in the Spirulina-meal was not much different from that in the other main components of the diets namely maize, soybean-meal, and wheat starch. Since the available amount of Spirulina-meal for the presented experiment was restricted, number of birds per treatment and duration of experiment had to be limited, as well. Further experiments under regional conditions are therefore necessary.

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Summary

Algae-meal from Spirulina platensis harvested from lake Chad was evaluated as a poultry feed ingredient in an experiment with broiler-chicks. The algae-meal contained 344 g total ash and 423 g crude protein per kg dry matter. Amino acid composition was analysed and showed a lower concentration of lysine, histidine and phenylalanine in protein of the Spirulina-meal than in protein of soybean-meal, whereas the other essential amino acids were present in higher concentrations. Four diets (0, 50, 100 and 150) containing 0, 50, 100 and 150 g algae-meal per kg diet were fed to male broiler chicks from 6th to 34th day of life. Eight birds per treatment were individually housed in cages and fed ad libitum with free access to water. Feed intake was reduced in birds fed diets 100 and 150. Weight gains were decreased in birds fed diets 100 and 150 to less than 80% of the control group. Feed intake per weight gain for diets 0, 50 and 100 was within the range of good commercial production, birds fed diet 150 consumed significantly more feed per unit weight gain than birds fed the other diets. Metabolisability of gross energy of diets was determined by calorimetry and HCl-insoluble ash as marker. There was no difference between the 4 diets, which shows that the ME-concentration in the Spirulina-meal was not much different from the mixture of maize, soybean-meal, and wheat-starch.

Keywords

Broiler, nutrition, algae, Spirulina platensis, amino acid composition, growth performance, metabolisable energy

Zusammenfassung

Algen-Mehl (Spirulina platensis) aus dem Tschad-See als Er satz für Sojaextraktionsschrot in Broiler-Futter

In einem Fütterungsversuch mit Masthähnchen wurde die Eignung der Alge Spirulina platensis aus dem Tschad-See als Futterkomponente geprüft. Das Algenmehl enthielt pro kg Trockenmasse 344 g Rohasche und 423 g Rohprotein. Die Aminosäurenanalyse ergab, bezogen auf das Protein, für Lysin, Histidin und Phenylalanin niedrigere, für die übrigen essentiellen Aminosäuren höhere Werte als in Sojaextraktionsschrot. Männliche Broiler erhielten vom 6. bis 34. Lebenstag 4 Futtermischungen (0, 50, 100 und 150) mit 0, 50, 100 und 150 g Algenmehl pro kg. Pro Behandlung wurden 8 Hühnchen in Einzelkäfigen gehalten und ad libitum gefüttert. Im Vergleich zur Kontrollgruppe ohne Algenmehl waren die Lebendmassezunahmen der Hühnchen, die die Mischungen 100 und 150 erhielten, um ca. 20% reduziert. Die Relation von Futteraufwand zu Lebendmassezunahme lag für die Mischungen 0, 50 und 100 im Bereich kommerzieller Produktion, die mit Mischung 150 gefütterten Hühnchen benötigten pro Einheit Zunahme deutlich mehr Futter. Unter Anwendung des Kalorimierer und der HCl-unlöslichen Asche als Marker wurde die Umsetzbarkeit der Bruttoenergie der Mischung bestimmt. Sie differierte zwischen den Mischungen nur unwesentlich, was vermuten lässt, dass der ME-Gehalt in Spirulina-Mehl von dem der Mischung aus Mais, Soja­ schrot und Weizenstärke nicht sehr verschieden war.

Stichworte

Broiler, Fütterung, Alge, Spirulina platensis, Aminosäuren, Lebendmassezunahme, Umsetzbare Energie

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