The Nutritional Value of Sewage-Grown Samples of *Chlorella* and *Micractinium* in Broiler Diets[1]

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ABSTRACT Twenty-four samples of algae meal were collected during both winter and summer months from sewage ponds at different locations. The samples were assayed for protein, lipid, fiber, ash, phosphorus, calcium, aluminum, xanthophyll, and gross energy. The assayed composition was not significantly affected either by season or site of production.

Eight algae samples were selected on the basis of chemical analyses. Their metabolizable energy content and nitrogen absorption were evaluated by a short-term experiment with young chicks fed glucose-containing diets labeled with ^{144}Ce.

Large variations were found in metabolizable energy values (from 900 to 2782 kcal/kg) and percentages of nitrogen absorption (from 41.7 to 80.4%).

The nutritional value of two algae samples was further assessed in the broiler trial in which computer-formulated diets containing 5 and 10% algae meal were compared to a control diet containing no algae. These two algae meal samples, at both of the concentrations tested, were found to be suitable protein supplements in broiler diets and had no adverse effect on growth, feed efficiency, or carcass fat.

(*Key words:* nutritional value, algae, broilers)

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INTRODUCTION

Algae meal is rich in protein and the essential amino acids and is potentially important in poultry nutrition (Combs, 1952, Grau and Klein, 1957; Cook, 1960; Powell *et al.*, 1961; Cook *et al.*, 1963; Leveille *et al.*, 1962; Lubitz, 1963; Mokady *et al.*, 1977).

The results of previous studies (Lipstein and Hurwitz, 1980, 1981) point to wide variation in the nutritional quality of different sewage-grown algae meal samples. A great variety of factors can affect the nutritional value of algae meal; it would, therefore, be useful to have a method that could provide information on the nutritional value of a great number of algae-meal samples within a short time.

The aim of the present study was: 1) to screen a large number of batches of algae meal, and 2) to carry out a detailed evaluation of a few samples selected from the large number of algae samples in order to determine their suitability as sources of protein and metabolizable energy (ME) for broiler chicks.

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MATERIALS AND METHODS

Materials. The nutritional content of 24 different samples of sewage-grown algae was evaluated. The samples contained mostly *Chlorella* or *Micractinium* and were taken from two different sewage ponds (Neve Shaanan or Kiriat Ata) at different times of the year, thus enabling evaluation of the effect of the predominant species, season, and location. The samples were drum-dried following harvest by alum flocculation.

Chemical Analyses. Previous studies (Lipstein and Hurwitz, 1980, 1981) describe methods used for chemical analysis.

Experimental Procedures. In Experiments 1 and 2, 1-day-old White Rock male chicks obtained from a commercial hatchery were housed in electrically heated battery brooders. Feeding with the experimental diets began after a preparatory period of 7 days, during which time the chicks were fed commercial starter rations. Thereafter, about 70% of the original number of chicks (those closest to the average weight) were wing-banded and divided into groups of 12 each according to body weight, so that both mean weight and weight distribution were similar in all groups.

Experiment 1. This experiment was to evaluate the chemical composition of a large number of different algae samples and to determine the metabolizable energy (ME) values and nitrogen absorption coefficients in 8 representative samples.

During the 7 days of Experiment 1, two groups were fed glucose-containing control diets (Table 1), one high in energy and the other high in protein. Eight groups were fed a diet in which 25% of the glucose had been replaced by different samples of algae. The same diets, with the addition of 12 to 15 μCi/kg ^{144}Ce (Sklan *et al.*, 1975) as a nonabsorbable material, were then fed during the next 5 days.

At the end of the experiment, 8 chicks from each group, representing the middle weight range of the group, were killed and their lower ileum contents collected for measurement of radioactivity and nitrogen. Diets and excreta samples were analyzed for gross energy, using an adiabatic oxygen bomb calorimeter, nitrogen, and radioactivity.

The ME content of the experimental diets was calculated from the energy/^{144}Ce ratios in diets and in excreta after correcting for nitrogen retained by the chicks (Sibbald *et al.*, 1960). Proportional absorption of protein was determined from the N/^{144}Ce ratios in diets and in the contents of the lower ileum (Hurwitz and Bar, 1965).

Experiment 2. The purpose of Experiment 2 was to validate the calculated nutritional quality of two samples of algae meal as sources of protein and ME for broiler chicks.

Chicks were individually weighed every week and feed consumption was determined on a group basis. Three replicate groups of 12 chicks each were assigned to each of the five dietary treatments (2 algae samples each at 2 levels—5% and 10%—and control diet).

The chemical composition, ME content, and absorption coefficients of algae meal were included in an LP-1 program of a Cyber computer (Control Data). The program was constrained to include algae meal at increasing concentrations in the diets. To avoid phosphate deficiency, the algae-containing diets were supplemented with dicalcium phosphate in amounts equivalent to the aluminum content (Lipstein and Hurwitz, 1982). Table 2 presents the composition of the five diets, which were based on National Research Council (1977) requirements for the experimental period.

At 28 days of age, 8 birds per treatment were killed and the degree of fatness was evaluated on the basis of dry matter in a sample of back skin and the quantity of abdominal fat expressed as percentage of body weight.

RESULTS

Experiment 1. The results of chemical assays of the 24 different samples of algae meal are summarized in Table 3. In general, the main nutrient contents varied by less than 10% except in the case of fiber and xanthophyll. The protein content varied only slightly, ranging from 38.1 to 41.4%. The fat content

TABLE 1. *Composition of diets for the assessment of metabolizable energy content and nitrogen absorption*[1] *(Experiment 1)*

Ingredients	Reference diets: Metabolizable energy	Reference diets: Nitrogen absorption	Experimental diets
(%)			
Algae	...	...	25.0
Glucose	51.30	31.45	26.30
Soybean meal	41.00	55.00	40.00
Fish meal	...	5.00	...
DL-Methionine	.15	...	.15
Constant ingredients[2]	8.55	8.55	8.55
Assayed protein, %	19.1	28.6	28.4
Metabolizable energy, kcal/kg	3000	2800	

[1]The diets contained 12 to 15 μCi/kg of labeled ^{144}Ce.

[2]Percentage of diet constituents: soybean oil refined, 4.9; limestone, 1.0; dicalcium phosphate, 2.5; vitamin mixture, .4; trace mineral mix, .1; sodium chloride, .25; choline chloride (50%), .2; coccidiostat, .1.

TABLE 2. *Composition of diets fed during the 1- to 4-week period (Experiment 2)*

	Control	Chlorella		Micractinium	
Treatment no.	1	2	3	4	5
	(%)				
Ingredients					
Algae	...	5.00	10.00	5.00	10.00
Soybean meal	36.8	33.7	30.8	32.9	25.4
Sorghum grain	55.8	52.8	46.8	53.0	48.9
Corn	...	...	2.70	...	5.2
Soybean oil soapstock	3.8	4.4	5.0	4.8	5.0
Dicalcium phosphate	1.81	2.98	3.50	3.45	3.58
Sodium phosphate	...	...	.50	...	1.25
Limestone	1.07	.35	...	.09	...
Sodium chloride	.29	.29	.16	.29	.16
DL-Methionine	.16	.17	.19	.16	.10
L-Lysine	...	...	...	...	.23
Vitamin mix	.25	.25	.25	.25	.25
Mineral mix	.10	.10	.10	.10	.10
Composition calculated:					
Crude protein, %	21.56	21.56	21.56	21.56	21.38
ME,[1] kcal/kg	3000	3000	3000	3000	3000
SAA,[2] %	.780	.780	.780	.780	.780
Lysine	1.227	1.198	1.173	1.201	1.110
Arginine	1.532	1.479	1.430	1.482	1.359

[1] Metabolizable energy.

[2] Sulphur amino acids.

hardly varied at all and was almost constant for algae from the two sewage ponds and at different months of the year (4.1 to 4.6%). The only significant variation was found in the case of ash concentration; the ash content during the winter months was significantly higher than that in the summer months, and the ash concentration in the Neve Shaanan Pond was lower than that of the Kiriat Ata Pond.

All of the samples contained a high concen-

TABLE 3. *Chemical composition of 24 algae meal samples obtained from two different ponds and in two different seasons of the year*

	Neve Shaanan Pond		Kiriat Ata Pond	
	Apr – Sep	Oct – Mar	Apr – Sep	Oct – Mar
	(Average ± SD)			
Protein, %	40.6 ± 1.90	41.1 ± 3.46	39.0 ± 3.43	38.1 ± 4.41
Fat, %	4.58 ± .79	4.66 ± .86	4.10 ± .62	4.60 ± 1.10
Crude fiber, %	.96 ± .61	1.06 ± 1.51	.68 ± .25	.48 ± .52
Ash, %	18.8 ± 2.08	22.8 ± 3.92	21.8 ± 1.41	24.4 ± 2.17
Phosphorus, %	2.54 ± .35	2.81 ± 1.04	2.56 ± .48	2.62 ± .52
Calcium, %	.72 ± .18	.81 ± .14	.91 ± .35	1.05 ± .47
Aluminum, %	4.61 ± .53	5.73 ± 1.12	5.55 ± .78	6.20 ± 1.80
Xanthophyll, μg/g	246 ± 123	342 ± 258	257 ± 145	206 ± 184
Gross energy, kcal/kg	3704 ± 298	3766 ± 637	3395 ± 420	3533 ± 394

TABLE 4. *Amino acid composition of 24 algae meal samples compared with soybean meal*

Amino acid	Average ± SD[1]	Soybean meal[2]
	(Percentage of N X 6.25)	
Arginine	5.24 ± .36	7.48
Lysine	4.82 ± .45	6.30
Methionine	1.91 ± .45	1.44
Cystine	.68 ± .23	1.49
Histidine	1.61 ± .10	2.37
Leucine	6.98 ± .19	7.48
Isoleucine	4.07 ± .26	5.28
Phenylalanine	4.67 ± .38	4.95
Tyrosine	3.39 ± .23	3.08
Threonine	4.56 ± .16	3.97
Valine	5.31 ± .13	4.98
Glycine	4.57 ± .14	5.28

[1] The analysis was performed on an amino acid analyzer (Technion TSM 1) by the Division of Animal Nutrition, Institute of Animal Science.

[2] Maryland Feed Composition Data for Poultry, Maryland Nutrition Conference, 1971.

tration of alum, which had been used for flocculation. The phosphorus concentrations were several times higher than those of calcium.

The fiber concentration was particularly low in comparison with that of conventional plant feedstuffs. The variation in xanthophyll content of the samples was not dependent on location or season. The differences in their amino acid composition, except for methionine, were rather small (Table 4).

On the basis of the chemical analyses, eight samples were selected, and ME content and nitrogen absorption were established by biological tests. In contrast to the small differences in chemical composition, wide variations were found in ME and nitrogen absorption (Table 5).

The coefficient of variation of ME content was about 30% (Table 5); gross energy, however (Table 3), varied only by about 12%.

Experiment 2. The two samples used in Experiment 2 were selected from a large number of algae samples. The first contained primarily *Chlorella*, and the second primarily *Micractinium*. Both were drum-dried after harvest from sewage ponds by alum flocculation.

Results of the chemical analyses are presented in Table 6. There were only small differences in chemical composition between algae samples. Both *Chlorella* and the *Micractinium* samples contained high concentrations of alum due to its use as a flocculant.

The differences in amino acid composition (Table 7) between these samples, expressed on the basis of protein (N X 6.25), were small. Both samples contained smaller amounts of arginine, lysine, and isoleucine than soybean meal. The composition of diets (Table 2) shows that 5% of the two examined algae samples

TABLE 5. *Metabolizable energy and protein absorbability in eight examined algae samples (Experiment 1)*

	Weight gain	Metabolizable energy	Protein absorption
	(g)	(kcal/kg)	(%)
Control diet[1]	438	...	...
Algae samples			
1	331	2296	68.2
2	306	1240	66.1
3	350	1792	80.4
4	306	900	56.9
5	307	1041	...
6	343	1873	58.5
7	331	1864	41.7
8	355	2782	64.3
$\overline{X}$		1765	62.3
SD		612	11.9

[1] Reference diets, see Table 1.

TABLE 6. *Chemical composition, metabolizable energy, and protein absorbability of the two algae samples used (Experiment 2)*

Parameter	Algae samples	
	Chlorella	Micractinium
(%)		
Total protein	39.5	39.1
Total lipid	4.6	3.8
Crude fiber	.5	.7
Ash	21.8	20.7
Phosphorus	3.0	2.1
Calcium	.67	.77
Aluminum	3.9	4.9
Gross energy, kcal/kg	3372	3359
Protein absorption, %[1]	68.2	80.4
Metabolizable energy, kcal/kg[1]	2296	1792

[1] Determined by biological assay.

replaced 8 and 11%, respectively, of the soybean meal, and 10% of the algae replaced 16 and 31%, respectively, of the soybean meal.

The performance of the chicks is summarized in Table 8. There were no significant differences in weight gain, feed consumption, or feed/gain ratio between chicks consuming algae-containing diets and control chicks. At the two levels (5% and 10%) of *Micractinium*-containing diets the feed intake was increased by 7 and 9%,

TABLE 7. *amino acid composition of the two algae samples compared with that of soybean meal Experiment 2*

Amino acid	Algae samples[1]		Soybean meal[2]
	Chlorella	*Micractinium*	
	(Percentage of N × 6.25)		
Arginine	5.19	5.08	7.48
Lysine	5.26	4.88	6.30
Methionine	1.89	1.79	1.44
Cystine	.60	1.23	1.49
Histidine	1.77	1.60	2.37
Leucine	6.91	6.85	7.48
Isoleucine	4.00	3.99	5.28
Phenylalanine	4.38	4.68	4.95
Tyrosine	3.39	3.53	3.08
Threonine	4.58	4.83	3.97
Valine	5.42	5.44	4.98
Glycine	4.78	4.65	5.28

[1] The analysis was performed on an amino acid analyzer (Technion TSM 1) by the Division of Animal Nutrition, Institute of Animal Science.

[2] Maryland Feed Composition Data for Poultry, Maryland Nutrition Conference, 1971.

respectively, resulting in a corresponding change in the feed/gain ratios. The increased feed consumption suggests the ME value determined for these samples (Table 6) had been somewhat overestimated.

In addition to broiler performance, the effects of the algae on the carcass fat and liver size of broilers were evaluated at the end of the experimental period. The results of degree of fatness (Table 9) do not show any differences between the various diets. However, there were differences in the liver sizes, expressed as percent of body weight.

DISCUSSION

Neither the season nor the locality of algae production affected the chemical composition of the algae meals. The fiber concentration was particularly small, and it is likely that the method of the Association of Official Agricultural Chemists (1960) used for analyzing conventional feedstuffs is not suitable for the assessment of fiber in algae meal. The amino acid composition of these samples indicates lower concentrations of arginine, lysine, and isoleucine but higher levels of theonine and valine than in soybean meal, which agrees with the findings of Cook *et al.* (1963), Lubitz (1963), and Lipstein and Hurwitz (1980, 1981).

On the basis of the chemical analyses of 24 samples, 8 were selected and used to establish ME and nitrogen absorption by biological tests. Large variations in ME and nitrogen absorption was encountered (Table 5). Nitrogen absorption in all 8 samples was considerably lower than that found in one previous study on algae meal (Lipstein and Hurwitz, 1980), but similar to that in another work (Lipstein and Hurwitz, 1981). This nitrogen absorption coefficient is in agreement with the findings of Cook (1960) on protein digestibility for sewage-grown algae and with the value given by Hayami and Shino (1958) who used rats and different species of algae.

We are not aware of any published data on the ME value of algae for chicks; our results of ME (Table 5) showed a wide variation, ranging from 900 to 2782 kcal/kg relative to conventional feedstuffs. The causes of these variations are not known to us. The two samples used in our broiler experiments contained *Chlorella*, 2296 kcal/kg, and *Micractinium*, 1792 kcal/kg. The ME value of the *Chlorella* samples was

TABLE 8. *Performance of broilers fed algae-containing diets from 1 to 4 weeks (Experiment 2)*

	Control	Chlorella		Micractinium	
	T1, 0[1]	T2, 5%	T3, 10%	T4, 5%	T5, 10%
Weight gain, g[2]	676	671	675	676	670
Weight gain, %[4]	100	99.3	99.9	100	99.1
Feed consumption, g[3]	1183	1194	1215	1296	1262
Feed consumption, %	100	100.9	102.7	109.5	106.7
Feed/gain ratio	1.75	1.78	1.80	1.92	1.88
Feed/gain ratio, %	100	101.7	102.9	109.7	107.4

[1] Treatment number and percent of algae.

[2] Averages of three replicates of 10 chicks each; initial body weight was 88.0 g.

[3] Standard error was 9.6 and 38.1 for weight gain and feed intake, respectively.

[4] Relative to the performance of the control birds (Treatment 1).

similar to that of soybean meal; the value of the *Micractinium* sample was lower. These marked variations indicate that the nutritional value of algae samples as feedstuffs cannot be established solely by their chemical composition (Lipstein *et al.*, 1980). This is an important point that must be taken into consideration with regard to most by-products and nonconventional feedstuffs.

Comparisons of the results with those of our previous studies (Lipstein and Hurwitz, 1980, 1981) point to wide variations in the nutritional quality of different algae samples. In our first study (Lipstein and Hurwitz, 1980), *Chlorella*-algae meal was substituted for soybean meal. In the second study (Lipstein and Hurwitz, 1981), alum-flocculated *Micractinium* replaced only sorghum grain according to computerized linear programming.

In the present study, two samples were of high nutritional value and replaced soybean meal. One of the samples contained the same predominant species, *Chlorella,* as in our previous study (Lipstein and Hurwitz, 1980) but was flocculated by alum. The second sample contained as its predominant species *Micractinium* (Lipstein and Hurwitz, 1981). In both cases the *Micractinium* was flocculated by alum; however, in our previous study it replaced sorghum grain, and in the present one it replaced soybean meal due to the difference in nutritional quality.

A perfomance experiment confirmed the validity of the determined chemical composition of the *Chlorella.* The poorer feed efficiencies obtained with the *Micractinium* sample as compared with the control indicate that some factor not evaluated by chemical composition was either deficient or in excess, or, alternatively, that the determined ME was an overestimate.

TABLE 9. *Influence of algae-containing diets on the abdominal fat and liver weight*[1] *(Experiment 2)*

Algae supplement in diet		Abdominal fat	Liver	Dry matter and skin
	(%)	(% of body weight)		(%)
Control	. . .	1.54	3.10	68.7
Chlorella	5	1.29	3.10	70.7
	10	1.26	3.00	69.1
Micractinium	5	1.18	3.00	68.9
	10	1.51	2.86	72.2

[1] Average of 8 broilers per treatment.

This experiment and our previous work demonstrate the potential value of algae in poultry feeds (Lipstein and Hurwitz, 1980, 1981). However, until the sources of variation in chemical composition are clearly identified, quality control must rely heavily on biological experiments.

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