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Some Nutritional Characteristics of a Naturally Occurring Alga (*Microcystis* sp.) in a Guatemalan Lake

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The nutritional characteristics of an alga (*Microcystis* sp.) that occurs naturally in a Guatemalan lake were determined. The sun-dried material proved to have a high protein content (55.6%) and to be a possible good source of calcium and phosphorus (1,169.1 and 633.4 mg/100 mg, respectively). Amino acid analysis showed that total sulfur amino acids were the most deficient ones, giving a protein score of 42 to the material. The in vitro protein digestibility of the material was 69.5%. Biological trials demonstrated that when the material was offered as the only protein source, very low consumption and a high mortality rate were obtained whether or not the diet was supplemented with 0.4% DL-methionine. However, when the material supplied 25% of the total protein of a corn-algae diet, the protein quality of the cereal was significantly improved ($P < 0.05$).

The possible utilization of algae as a nonconventional protein source in human or animal nutrition was first suggested some years ago (3, 16). Several types of algae have been tested for this purpose and, although toxicity problems have been reported for some species (18), promising results have been obtained with others (5, 16). Likewise, the technology for large-scale production of algae has already been developed (8, 14, 16).

In Guatemala, a blue-green alga (*Microcystis* sp.) grows wild on the surface of Lake Amatitlán almost throughout the year. Since several animal-breeding industries are located in its vicinity, we considered it of interest to investigate the possibility of harvesting such algae, sun drying them, and using them as a protein source in animal feeding. This possibility is supported by recent technological developments in algae harvesting (2) that probably could be applied for the purpose.

Prior to determining the practical feasibility of the harvesting and drying operations, some nutritional characteristics of the naturally occurring algae were investigated.

MATERIALS AND METHODS

The blue-green algae used in the study were obtained from the surface of Lake Amatitlán, a small (15.35 km^2) body of water located near Guatemala City at an altitude of 1,190 m above sea level. The sampling of the algae was done using plastic containers; the material was then transported to our central laboratories at the Institute of Nutrition of Central America and Panama (INCAP), where the algae were recovered through filtration. Initially the material was passed through 60- and 80-mesh screens to eliminate the contaminating substances; then the algae were recovered by filtration through either a 150-mesh screen or three superimposed layers of cheesecloth. During the last filtration stage the material was washed repeatedly with tap water and with a dilute solution of potassium permanganate (around 0.05%). Prior to further analyses, the algae were sun dried for approximately 24 h.

The main alga growing on the lake had previously been identified as a *Microcystis* sp. by a North Carolina State University research group at the Regional School of Sanitary Engineering of the University of San Carlos de Guatemala (20). Microscopic control as to the identity of each lot was performed at our laboratories by comparing it with the standard characteristics of the genus (17).

Moisture, nitrogen, ether extract, crude fiber, ash, calcium, and phosphorus were determined in duplicate following the *Official Methods of Analysis* of the Association of Official Agricultural Chemists (AOAC) (1). Protein was calculated using the customary conversion factor of 6.25.

The amino acid analyses were carried out using an amino acid autoanalyzer and following the general method of Spackman et al. (19). Available lysine was determined according to Conkerton and Frampton (4), and the caloric value of the material was estimated using the ballistic bomb calorimeter (model CB-370, A. Gallenkamp & Co., Ltd., London, England).

To evaluate protein quality, biological trials were carried out in Wistar strain rats from INCAP's animal colony.

The protein efficiency ratio was determined as described by Molina et al. (15). Protein in vitro digestibility was estimated following the AOAC method (1).

RESULTS AND DISCUSSION

All batches recovered through filtration were microscopically characterized as *Microcystis* sp. The composition (on an "as is" basis) of the sun-dried material is presented in Table 1. As the data reveal, the algae have a relatively high crude protein (N × 6.25) content (55.6%) and low fiber (1.6%) and ether extract (1.2%) contents. In general, the crude protein content of the *Microcystis* sp. considered in this study compared favorably with that reported for *Chlorella* sp. and other types of algae (5, 13). On the other hand, the fat (or ether extract) content reported herein is lower than the values reported by other authors for other algae species (13). The calcium and phosphorus content is nutritionally important in considering the dried algae as a good source of both minerals, not only because of the net amounts present but, more important perhaps, because both minerals appear very near a 2:1 calcium/phosphorus ratio, which is considered nutritionally optimum. The content of total nucleic acids (7.7%) is comparable to that cited for other biological materials considered as possible single-cell protein sources (12, 21). However, the considerably high amount of total nucleic acids found in the present case is indicative that not all of the nitrogen can be regarded as protein nitrogen and that, therefore, the true protein content of the material could be lower than the crude protein content (N × 6.25) reported. Furthermore, the total nucleic acids present in the material could give rise to the nutritional problems associated with those compounds (12). Its gross caloric value is similar to those for corn, sorghum, and other materials commonly used as animal feeds (11). However, since in the present case such caloric value is due mainly to the amount of protein contained in the algae product, the logical way of using this material would be as a protein rather than as a caloric source for the formulation of animal feed concentrates.

TABLE 1. *Composition of the algae Microcystis sp.*

Component	% of Algal material
Moisture	10.4
Protein (N × 6.25)	55.6
Ether extract	1.2
Crude fiber	1.6
Ash	5.2
Nitrogen-free extract	26.0
Ribonucleic acid	7.4
Deoxyribonucleic acid	0.3
Caloric value (kcal)	540.3
Calcium (mg)	1,169.1
Phosphorus (mg)	633.4

The amino acid composition of the algal product is presented in Table 2, which includes the Food and Agriculture Organization (FAO) protein reference pattern (6). As the data clearly show, the total sulfur amino acids appear to be the most limiting in this protein, similar in this respect to other algae, yeasts, and molds reported as possible single-cell protein sources (12). In fact, when the protein score was calculated for the product against the FAO protein reference pattern (6), it was found to be 42, the total sulfur amino acids being the most limiting. The second most limiting amino acid was found to be lysine, with a protein score of 81. When determination of available lysine was carried out, it was found that 70% of the total lysine content was chemically available, thus indicating that not all the lysine content found may be available for growth support.

The biological results on protein evaluation of the material are given in Table 3. Its protein efficiency ratio could not be calculated due to the fact that the rats lost weight during the 4-week period of the test; furthermore, some of the animals died during the experimental period. The data presented, as well as personal

TABLE 2. *Amino acid composition of the algae Microcystis sp.*

Amino acid	g/16 g of N	
	Algal material	FAO protein reference pattern
Aspartic acid	14.93	
Serine	2.64	
Glutamic acid	13.74	
Glycine	5.25	
Alanine	9.13	
Arginine	10.06	
Histidine	1.49	
Ammonia	1.71	
Threonine	4.31	4.00
Valine	7.40	4.96
Methionine	0.90	3.52[a]
Cystine	0.92	
Isoleucine	7.55	4.00
Leucine	8.88	7.04
Tyrosine	3.22	6.08[a]
Phenylalanine	4.19	
Lysine	5.41	5.44
Tryptophan	1.51	0.96

[a] Represents the sum of methionine and cystine and of tyrosine and phenylalanine, respectively, according to the FAO protein reference pattern used.

observations during the test, indicated that the loss in weight, and possibly the mortality occurring in the group of animals receiving the algal diet, was due to a low food consumption rate. This low intake was not due to hygroscopicity of the material, but it may have been caused by unpalatability of the diet, as suggested by Fisher and Burlew (5) in the case of *Chlorella* sp. Although a toxic factor has been reported to exist in *Microcystis aeruginosa* (7, 10, 18), in our study the mortality of the animals could not be attributed to a similar toxic factor, since the rats did not present symptoms of toxicity other than loss of weight. Similar results were obtained when the diet was supplemented with 0.4% DL-methionine, a finding that indicates that an improvement in the amino acid pattern did not affect the general biological results. Similar biological findings have been generally reported for yeast strains with a similar nucleic acid content, but such yeasts could be used successfully as a protein supplement when included at levels varying from 5 to 8% of the total diet (Bressani, unpublished data). For this reason, it was thought of interest to evaluate the algal protein as a supplement to corn protein. For this purpose, three diets were prepared: (i) a corn diet (8.3% protein); (ii) a corn-algae diet (8.2% protein) in which 25% of the protein (2.05%) was supplied by the algal protein; and (iii) a casein control diet (8.3% protein). The biological results obtained with these rations are presented in Table 4. As may be appreciated, the algal protein exerted a significant ($P < 0.05$) beneficial effect on the corn protein quality, which proves the complementary effect of the algal protein on the corn protein. These results are encouraging, since they show a possible use of the algal material as protein supplement in the preparation of corn (or cereal)-based diets for monogastric animals. Furthermore, our findings support the contention that the mortality found in the group receiving the algal product (Table 3) was due to a low food intake caused by unpalatability of the diet.

In summary, it can be concluded that the algae (*Microcystis* sp.) product evaluated in this study cannot be used as the only protein source in the formulation of diets (or concentrates) for monogastric animals, but it could be used successfully as a protein supplement of such diets.

At present we are interested in determining the optimum amount of algae protein to be used as a protein supplement for corn-based diets, as well as the efficiency of such a supplement in other animal species. Similarly, we are investigating the role of the nucleic acid content in the biological behavior of the algal protein. Since several processes now offer possibilities for use in lowering the total content of these cell constituents (21), we believe that this should not be a major problem.

The in vitro protein digestibility as determined for the algal material used in the present study was 69.5%. Therefore, efforts are being made to devise practical techniques for improving these parameters in order to provide the animal industry of Guatemala with another possible protein source. It is probable that, concomitantly with an increase in digestibility, improvement of the algal protein quality to be used as a supplement could also be obtained.

TABLE 3. *Performance of rats fed the algae Microcystis sp.*

Diet	Protein in diet (%)	Wt (g)		Avg feed intake (g/week)	Mortality
		Initial	Final		
Algal diet	10.4	43 ± 1[a]	35 ± 2	21 ± 4	5/8[b]
Casein	9.8	43 ± 1	121 ± 3	72 ± 2	0/8

[a] Standard deviation of the mean.
[b] All deaths occurred during week 4 of the test.

TABLE 4. *Performance of rats fed a corn-algae protein diet*

Diet	Protein in diet (%)	Wt (g)		Avg feed intake (g/week)	Protein efficiency ratio
		Initial	Final		
Corn-algae[a]	8.2	50 ± 2	76 ± 4	73 ± 2	1.08
Corn	8.3	50 ± 2	65 ± 3	59 ± 3	0.71
Casein	8.3	50 ± 2	123 ± 4	98 ± 2	2.30

[a] 25% of the total protein in the diet was supplied by algae protein.

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