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Potential Value of the Mormon Cricket (Orthoptera: Tettigoniidae) Harvested as a High-Protein Feed for Poultry[1]

G. R. DEFOLIART,[2] M.D. FINKE,[2] AND M. L. SUNDE[3]

University of Wisconsin, Madison, Wisconsin 53706

ABSTRACT

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Adults of *Anabrus simplex* Haldeman collected near Greystone, Colo., were found to have a mean dry weight (males and females combined) of 1.08 g and a crude protein content of 58%. At cricket densities of 10 to 20/m², a 1-km² band of crickets represents ca. 11 to 22 metric tons of potentially harvestable high-protein powder. Corn-cricket-based diets produced significantly better growth of broiler chicks than was produced by a conventional corn-soybean based diet. Based on current prices for corn and soybean meal, the wholesale value of crickets of the aforementioned densities in a km² band would range from $3,300 to $6,600 if harvested for use as a high-protein feed.

Bodenheimer (1951) compiled and discussed the scattered literature up to 1951 pertaining to the use of insects as a source of food for humans. Preindustrial cultures have made wide use of insects, and as observed by Ruddle (1973) in Colombia, they are utilized not only during emergency periods but as a complementary food source throughout the year. In addition, insects form a major source of food for many kinds of birds and other animals.

Insects have been almost totally bypassed as a source of food in western industrialized nations. Nevertheless, in describing taster reaction to honeybee pupae in Canada, Hocking and Matsumura (1960) stated that, "Most reactions were favourable and some were eulogistic; initial prejudice proved easier to overcome than we had expected." Other similar statements by persons of educated taste could be quoted. Recipes that incorporate insects have been published in two recent books (Taylor 1975, Taylor and Carter 1976).

There have been only a few studies of the nutritional value of insects in recent decades. Calvert et al. (1969) and Teotia and Miller (1973, 1974) investigated the nutritional value of house fly, *Musca domestica* L., pupae produced by larvae reared in poultry manure. The fly pupae were found to contain slightly more than 60% crude protein. The metabolizable energy value of pupae was higher than that of soybean meal and only slightly lower than that of fish meal. Analyses of amino acids showed the pupae to be comparable to bone and fish meal and superior to soybean meal. The pupae also were a good source of fat and minerals. When dried fly pupae were substituted for soybean meal in the diet of chicks to the fourth week of age, there was no significant difference in weight gain, food consumption, or food conversion between chicks fed pupae and chicks fed a standard ration. Finally, there was no adverse effect on carcass quality or taste of birds fed the pupal diet.

In a study centered on utilizing the phosphorus in face fly, *M. autumnalis* De Geer, pupae for chicken feed supplementation, Dashefsky et al. (1976) found a high amount of phosphorus (5.73%, dry weight) and a bioassay revealed it, like other animal phosphorus sources, to be highly available (92 to 100%) to chickens. Protein content of the pupae was 53.4% (dry weight).

From these and other recent studies that involved amino acid analyses of various insect species (Phelps et al. 1975, Ramos and Bourges 1977), it is evident that insect protein is in general of high nutritional quality. This suggests that there should be an intensified search for exploitable systems so that this food resource can be utilized. An insect species of interest to us in this regard is the Mormon cricket, *Anabrus simplex* Haldeman. The crickets form large bands and it might be possible to develop management systems in which harvest would be a viable alternative to chemical control.

As the first step in a project to determine the potential of the Mormon cricket as a high protein source for poultry, we obtained mean dry weights, proximate and amino acid analyses of late-stage nymphs and adult crickets. The data reported here permit an estimate of the amount of crude protein potentially harvestable from a Mormon cricket band of given size, age, and density, and an evaluation of the nutritional value of cricket protein compared with that of soybean meal when fed to broiler chicks.

Materials and Methods

Mormon crickets were collected near Greystone, Colo., in early and late June 1978, in early July 1979, and in late July 1980. The area lies just outside the northeast boundary of Dinosaur National Monument, ca. 130 km northwest of Craig, Colo. The cricket population consisted mainly of 6th and 7th nymphal instars during the first week of June 1978, mainly of adults the last week of June 1978, and entirely of adults in July 1979 and 1980.

The topography of the study area, a north-facing slope, is typical mountain range and valley with elevation ranging from 1,700 to 2,000 m. The area was burned over in 1951 and again in 1968. Charred remnants of pinyon pine and Utah juniper trees still stand. Fallen snags make excellent cover for crickets during the hottest part of the day when they are not active. Evidently, grass seedings were applied on the valley floor after the fire occurred.

[1]Received for publication 28 July 1981.
[2]Dept. of Entomology.
[3]Dept. of Poultry Science.

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The most abundant shrub species was mountain big sagebrush, *Artemisia tridentata* Nutt., ssp. *vaseyane* (Rydberg) Beetle, average 4 to 6 years old, and the most abundant grass species were wheatgrass, *Bromus tectorum* L., and crested wheatgrass, *Agropyron cristatum* (L.) Gaertn. All plant species in the area were being eaten by the crickets.

Crickets for the weighed samples were collected by hand with the aid of an insect net. The crickets used in chick feeding trials, however, were collected by a variety of different methods, including fruit baits, in an effort to find a suitable method for obtaining large numbers of crickets. Crickets in samples collected for chemical analyses and determination of dry weight-fresh weight ratio were chilled on dry ice, weighed individually on a field torsion balance, then frozen over dry ice for shipment to Madison. In Madison, samples were dried in a radiant heat oven at 50°C until no further weight loss occurred during a 24-h period. Dry weights were then recorded (Table 1).

Protein, fat, ash, and fiber content of the various life stages (Table 2) were determined by methods prescribed by the Association of Official Analytical Chemists (Anonymous 1945). Upon completion of the proximate analysis, the next step was an amino acid analysis (Table 3). The first biological test involving Mormon crickets was designed to test palatability of corn-cricket (62 to 30%)-based diets (Table 4) for newly hatched broiler chicks. Growth on these diets was compared with that of chicks on a control diet (a conventional corn-soybean-based diet) (Table 5). The protein levels of all diets were equal and were based on the most recent NAS-NRC recommendations (Anonymous 1977).

For each treatment, 10 1-day-old broiler chicks were wing banded, group weighed, and placed in electrically heated chick starting batteries. Food and water were provided ad lib. The birds were then weighed individually at weekly intervals.

The compositions of the diets used in these studies are shown in Table 4. Diet 1 which served as a control, was a low-energy corn-soybean meal chick starter ration which is routinely used as a control for raising chicks at the University of Wisconsin. Supplementation of diet 1 with minerals, vitamins, and amino acids brought all dietary ingredients up to the levels recommended by the NAS-NRC (Anonymous 1977). Procaine penicillin, an antibiotic, was added to the diet at low levels to stimulate growth (Elam et al. 1953). Diets 2 and 3 were formulated to meet NAS-NRC recommendations (Anonymous 1977) for protein for broiler chicks but contained corn and crickets as the major dietary ingredients. Diet 3 differed from diet 2 only in that several amino acids were added to bring the level of all essential amino acids up to those recommended by the NAS-NRC (Anonymous 1977). For both cricket-based diets, vitamins were added as a total vitamin supplement, since we had no information on the vitamin content of the crickets. Similarly, availability of only a limited mineral analysis of crickets necessitated supplementing the diet with several of the essential minerals. Supplementation of this type insured that growth was dependent on the protein quality of the diet.

The results from these studies were analyzed by the Newman-Keul test for multiple comparisons among means based on equal sample sizes (Sokal and Rohlf 1969).

Results and Discussion

Mean fresh and dry weights and proximate analyses of the various cricket age groups are shown in Tables 1 and 2, respectively. Assuming a 1:1 male-female sex ratio, the mean dry weight under conditions of these tests was 0.19 g for 6th instars, 0.36 g for 7th instars, and 0.97 g for adults collected in 1978, 1.18 g for adults collected in 1979, and 1.09 g for adults in 1980. The mean crude protein content on a dry weight basis (determined on samples collected in 1978) was ca. 58% for both adults and 7th instars.

Table 3 shows the mean of four amino acid analyses performed on crickets with a comparison to 44% soybean meal and the requirements for young broiler chicks and laying hens. It appears that the cricket protein is deficient in methionine and may be slightly low in ar-

Table 1.—Metric tons of Mormon cricket protein per km² at a cricket density of 10/m² (crude protein content = 58%)

Instar and sex	Date collected	No. weighed	Mean wt (g) Fresh	Dried	% Dry wt	Metric tons/km² Cricket powder	Crude protein
6th ♂	3-VI–4-VI-78	60	0.85	0.19	22		
♀		60	0.87	0.19	22		
				0.19		1.90	1.10
7th ♂	3-VI–4-VI-78	60	1.48	0.33	23		
♀		60	1.61	0.39	24		
				0.36		3.60	2.09
Adult ♂	27-VI-78	60	2.94	0.77	26		
♀		60	3.66	1.17	32		
				0.97		9.70	5.63
Adult ♂	5-VII–6-VII-79	50	3.43	0.95	28		
♀		50	4.27	1.41	33		
				1.18		11.80	6.84
Adult ♂	17-VII–18-VII-80	30	2.87	0.71	25		
♀		28	4.41	1.50	34		
				1.09		10.90	6.32

Table 2.—Proximate analysis (percent, dry weight) of Mormon crickets collected near Greystone, Colo., June 1978

Component	Adult[a] ♂♂	Adult[a] ♀♀	7th Instar ♂♂ and ♀♀
Water	6.2	6.3	6.0
Protein[b]	60.3	56.0	57.7
Fat	12.9	19.9	12.4
Ash	6.9	5.4	9.0
Fiber	9.8	8.2	7.6

[a]Sampled ca. 3 weeks after adults first appeared in the population.
[b]N × 6.25

Table 3.—Comparison of the essential amino acids of the Mormon cricket with the requirements for young broiler chicks and laying hens (NAS-NRC)[a]; values represent mg/g of protein

Amino acid	Composition of Mormon cricket	Soybean meal 44%	Requirements for: Broiler chick	Requirements for: Laying hen
Arginine	45	75	63	53
Glycine-serine	110	108	65	33
Histidine	33	26	15	15
Isoleucine	53	54	35	33
Leucine	86	80	59	80
Lysine	62	67	52	40
Methionine-cysteine	14	30	40	33
Methionine	13	15	22	18
Phenylalanine-tyrosine	90	81	58	53
Phenylalanine	28	52	31	27
Threonine	48	41	33	27
Tryptophan	5	14	10	7
Valine	60	53	36	33

[a]Anonymous (1977).

ginine and tryptophan. However, preliminary feeding trials (see following) cast some doubt on the accuracy of these analyses.

Broiler chicks apparently experienced no palatability problems with any of the diets described in Table 4, and Table 5 shows the results from our initial feeding trials. Note that the chicks on the conventional corn-soybean meal diet (Diet 1) grew more slowly than those on either corn-cricket diet (diets 2 and 3). Even without the addition of an antibiotic to the cricket diets some of this difference is probably due to the higher metabolizable energy content of the corn-cricket diets because of the high fat content of crickets. Supplementing the corn-cricket diet with additional amino acids resulted in no significant increase in growth. These results indicate that ground dried Mormon crickets are an excellent source of protein for young chicks. In addition, the amino acid quality appears to be higher than that indicated by amino acid analysis, since supplementation of the diet with purified amino acids did not significantly increase the weight of chicks feeding on that diet over those on an unsupplemented diet.

Currently, more detailed nutritional studies using both rats and chickens are under way to assess the nutritional value of ground crickets more accurately.

The average wholesale price of soybean meal (44%) and no. 2 yellow corn quoted in January 1981 was 11.18 and 6.47 cents/lb, respectively (Anonymous 1981). The use of feedstuff composition tables and current market prices allowed us to calculate the values of all the ingredients in these feedstuffs. This permits one to determine the values of the energy and protein in these feedstuffs, and hence the value of ground crickets based solely on their protein and energy content (metabolizable energy (ME) conservatively estimated at 2,800 kcal/kg from proximate analysis). By these methods, the value of crickets is ca. $300/metric ton (13.6 cents/lb).

Based on Cowan and Shipman (1947), Mormon cricket bands ''covering 640 acres at the rate of 10 crickets per square yard'' are not uncommon. Assuming a cricket density of 10 adults per m^2 and a mean dry weight of 1.09 g per cricket, which was the mean dry weight observed in our 1980 sample and about the average for our 3-year sample of adults, it can be calculated that the dry weight of crickets in a 1-km^2 band is ca. 11 metric tons. Based on the aforementioned quoted prices for corn and soybean meal, the wholesale value of crickets at 10/m^2 in a 1-km^2 band, if harvested for use as a high-protein feed, would be $3,300.

Harvestable amounts increase, of course, with increasing cricket density. We have seen bands with cricket densities of 15 to 20/m^2, and higher densities have been reported in the older literature. At a density of 20 crickets per m^2, the dry weight of crickets in a 1-km^2 band would be ca. 22 metric tons, and the wholesale value at the aforementioned prices would be $6,600.

Table 4.—Compositions of corn-Mormon cricket and corn-soybean diets fed to chicks (values in g/kg of diet, except as otherwise indicated)

Ingredients	Diet 1	Diet 2	Diet 3
Ground corn	555.8	619.6	619.6
44% Soybean meal	280.4	—	—
Wheat middlings	50.1	—	—
17% Alfalfa meal	30.0	—	—
Fish meal	30.0	—	—
Meat meal	30.0	—	—
Ground crickets	—	300.0	300.0
Iodized salt	5.6	5.0	5.0
White grease	—	20.0	20.0
Dicalcium phosphate	7.5	20.0	20.0
$CaCO_3$	10.0	15.0	15.0
$ZnCO_3$	—	0.1	0.1
$MnSO_4$	—	0.33	0.33
MnO	0.11	—	—
Vitamin mix[a]	—	5.0	5.0
Riboflavin (220 g/kg)	0.01	—	—
Vitamin B_{12} (660 mg/kg)	0.02	—	—
Vitamin A	2,200 IU/kg	—	—
Vitamin D_3	800 ICU/kg	—	—
Vitamin E	—	20 IU/kg	20 IU/kg
Choline (50%)	—	2.0	2.0
L-Arginine	—	—	5
L-Lysine	—	—	3
L-Phenylalanine	—	—	1
L-Tryptophan	—	—	1
DL-Methionine	5	—	5
Sucrose	—	15	—
Procaine penicillin (2 g/lb)	0.1	—	—

[a]Vitamin mixture supplied the following (in mg per kg of diet): thiamin HCl, 100; niacin, 100; inositol, 100; Ca pantothenate, 20; riboflavin, 16, pyridoxine HCl, 6; menadione, 5; folic acid, 4; biotin, 0.6; cyanocobalamin, 0.02; vitamin A palmitate, 10,000 IU; vitamin D_3, 1,000 ICU (Maruyama et al. 1976).

Table 5.—Weights (in g) of chicks fed experimental diets (values are presented as means ± SE[a]

Age (wk)	Diet 1	Diet 2	Diet 3
Initial	46	46	46
1	107 ± 4a	109 ± 4a	115 ± 4a
2	241 ± 7a	258 ± 6a	267 ± 10a
3	396 ± 7a	441 ± 12b	471 ± 16b

[a]Letters indicate significant differences between the means at $P = 0.05$ level, by Newman-Keul procedure (Sokal land Rohlf 1969).

These estimates do not take into account factors that additionally enhance the value of Mormon cricket meal, such as high protein quality, mineral and vitamin content, and possible reduction of the costs of chemical control. The latter might be offset, however, by the cost of cricket harvest, satisfactory methods for which have not yet been worked out. Although the costs of harvest cannot be estimated as yet, even roughly, problems of harvest do not seem formidable, because of the banding habits of the cricket.

An unanswered question is whether management practices that include cricket harvest would tend to insure a reasonably dependable cricket crop, a factor that would be important in gaining access to the market. Also, realization of the full economic potential of the Mormon cricket as a protein source would be influenced by its efficiency of utilization of rangeland vegetation in relation to, or in comparison with, other rangeland livestock production systems. Cowan and Shipman (1947), quoting studies by R. B. Swain (unpublished data), reported that cricket food preferences placed them in direct competition with cattle in northern Nevada and other areas where the northern desert shrub type of vegetation prevailed. There was little damage to forage, however, even in outbreak years in the grassland types of range in Montana, Wyoming, and eastern Idaho. In an arid ponderosa pine-bunchgrass community in northern Colorado, Ueckert and Hanson (1970) found that the crickets, although primarily herbivorous, also were carnivorous and fungivorous, with forbs contributing ca. 50% of the diet, arthropods, and fungi ca. 37% of the diet, and grasses, clubmoss, and grasslike plants ca. 13%.

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