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On the Nutritive Value of Mopanie Worms

The use of the caterpillar of the mopanie moth (*Conimbrasia belina*) as a food by the Pedi nation has been described in detail by Quin,[1] who also recorded data on the average weight and moisture, protein and fat contents of the fresh caterpillars. However, with the exception of the recording in 1968 of a figure for the digestibility of the protein component of one sample of traditionally prepared, dried mopanie caterpillars by Dreyer,[2] no further work has been done to assess the nutritive value of this indigenous foodstuff.

The mopanie 'worm' has, nevertheless, made impressive gains in importance as a product for sale in recent years. According to an estimate by the S.A. Bureau of Standards, annual sales through agricultural cooperative markets now amount to about 40 000 bags, each bag containing 40 kg of traditionally prepared, dried caterpillars. Furthermore, a considerable degree of sophistication has been introduced into the market by the recent establishment of a mopanie worm cannery at Pietersburg, northern Transvaal.

In view of the above, we considered it necessary to obtain additional information on certain aspects of the nutritive value of both the traditionally prepared, dried caterpillars and the same product after canning. The information included data on dry matter digestibility and protein digestibility and assimilability obtained in feeding experiments with monogastric animals (rats), as well as various figures on nutrient content obtained by means of the relevant chemical and physico-chemical methods of analysis.

Materials and methods

Samples. Traditionally, the gastrointestinal contents of the freshly harvested caterpillars are squeezed out by hand and what remains is dried slowly by exposure to direct sunlight. Frequently the drying process is accelerated by placing the material on a metal plate held over an open fire. The dried caterpillars are then transferred to bags for dispatch to the market. For our studies with the dried caterpillars 6 kg of material was obtained by the good offices of the Pietersburg company now engaged in canning mopanie caterpillars. Prior to use in the relevant trials, the test material was ground to a fine powder in a pin disc mill and stored in plastic bags in a cold room.

The canned material was obtained from the same source. It was prepared from dried caterpillars which had been soaked in water overnight and to which no condiments had been added. The soaking water was discarded. The material contained in 100 cans was combined, freeze-dried, ground and stored in the same way as the uncanned sample.

Dry matter digestibility (DMD) is an index of the total amount of digestible (or indigestible) material in a foodstuff. In this laboratory DMD is usually obtained through use of caecectomized rats, which are anatomically closer to man than uncaecectomized animals. However, in the present study a double trial was run using, separately, intact as well as caecectomized rats. The procedure employed in each case was essentially that proposed by Dreyer *et al.*,[3] involving the assumption that the DMD of glucose is 100%. Various other materials were tested at the same time, each material at two dietary levels. The other materials included in the trial were white bread, brown bread, cooked dry bean meal (Nep 2 cultivar), dried apple pomace, sorghum meal, and cooked soybean meal. In a given trial, the size of each rat group allocated to a particular test diet was 5 animals and that of the control or 'zero' group, 20 animals. The trial was run over a 4 + 8-day period, 4 days for adjustment and 8 for 'collection'.

Protein evaluation involved assessment of the digestibility and assimilability of the protein component according to a nitrogen metabolism method based on principles to be outlined more fully in a later publication.

Digestibility determination was based on the model:

$$(N_{intake} - N_{faecal})_{ij} = a + bF_{ij} + d\,(N_{intake})_{ij},$$

where $i = 1, 2, \ldots, k$; k = number of lines fitted = number of products tested; j refers to the j-th rat on the i-th test product; a = negative value of metabolic faecal nitrogen; F = dry food consumed in grams; and d = digestibility coefficient, all data being expressed per 100 g mean body mass (MBM) per 8 days.

Assimilability of the digestible protein fraction was assessed on the basis of the model:

$$Y_{ij} = a_1 + a_2F + b_i\,(N_{absorbed})_{ij},$$

where Y_{ij} = response = $(N_{absorbed} - N_{urine})$ of j-th rat on i-th test protein; a_1 = endogenous urinary N loss at food intake (F) = 0; a_2 = coefficient representing independent effect of food intake on endogenous urinary N loss; b_i = assimilability index of i-th test protein.

The dose-response relationship in respect of assimilability determinations is frequently biphasal, particularly in the case of proteins deficient in lysine, and when nitrogen absorption exceeds the 1200 mg per 100 g MBM per 8 day mark. To solve the latter problem all dosage levels were chosen to yield absorption levels of less than the above figure. The complications arising from biphasal dose-response relationships occurring at absorption levels < 1200 mg were eliminated through use of the following model:

$$Y_{ij} = a_2F + b_{1i}\,(N_{abs})_{ij} \text{ for } N_{abs} \le \theta_i;$$
$$Y_{ij} = a_1 + a_2F + b_{1i}\theta_i + b_{2i}\,(N_{abs} - \theta)_{ij} \text{ for } N_{abs} > \theta_i;$$

where θ = point of deflection relative to the X-axis of a biphasal linear regression of response on dosage; b_{1i} and b_{2i} the assimilability indices at absorption levels of respectively $\le \theta$ and $> \theta$. Whenever the dose-response relationship was found to be biphasal, b_2 was considered the true index of protein assimilability.

Elimination of cases of inadequate food (energy) intake was based on the equation recently proposed by Dreyer,[4] namely,

Minimum amount of dry laboratory diet (in g per 100 g MBM per 8 days) to be consumed for optimal protein assimilation = $378 + 0.01077\,(\text{N balance in mg} + 187)^{1.16}$.

Each test protein was fed to one of 7 separate but equal groups of 5 weanling rats, in each case at a given dietary level. Those proteins expected to be of high nutritive value were fed at dietary nitrogen levels of 0.4, 0.6, . . ., 1.6%; and those expected to be of poor quality at 0.8, 1.0, . . ., 2.0%. The protein digestibility and assimilability data were obtained in the same trial over a 4 + 8-day period. For comparison, certain other materials were tested together with the mopanie caterpillars, namely, cooked whole egg protein, three cultivars of dry beans (cooked), gluten, casein and cooked, defatted beef.

Determination of nutrient contents. Moisture, lipid, fibre and ash contents of samples were determined according to official methods of the A.O.A.C.[5] For determination of mineral contents, excluding phosphorus, atomic absorption methods were employed according to the routines recommended by the Perkin-Elmer Corporation.[6] For phosphorus determination the spectrophotometric heteropoly blue method[7] was used. The B-complex vitamins were determined according to the routines described by the Association of Vitamin Chemists.[8]

Vitamin A and carotene determinations were based on modifications of the HPLC routines proposed by Van Niekerk and Du Plessis.[9] In vitamin A determinations hexane instead of pentane was used for extraction and the extract was washed with water in-

Table 1. Nutrient contents on moisture-free basis of the caterpillars of the mopanie moth (*Conimbrasia belina*). The one sample (A) was prepared in the traditional way and ground, whilst the other (B) was of similar origin but afterwards soaked in water, steamed, canned, freeze-dried and ground.

Nutrient	Sample		Nutrient*	Sample		Nutrient*	Sample	
	A	B		A	B		A	B
Protein (N × 6.25), %	62	63	Na	1032	517	Mn	3.95	4.05
Ash, %	7.6	5.0	K	1024	668	Thiamine	0.58	0.09
Fat, %	16	18	Cu	0.91	0.95	Riboflavin	4.98	3.96
Crude fibre, %	11.4	13.3	Fe	31	33	Nicotinic acid	11.9	6.96
Ca, mg/100 g	174	231	Zn	14	17	Vitamin A	21.6	20.7
Mg, mg/100 g	160	119	P	543	470	β-Carotene	1.71	1.81

*Contents are in units of mg/100 g with the exception of vitamin A and β-carotene, which are in i.u./100 g.

stead of KOH. The column was a LiChrosorb S.I. 60, 5 μm, instead of a Corasil II, and the mobile phase 8% dioxane in hexane instead of 1:1 chloroform:hexane mixture. A Nucleosil 5 C_{18} instead of a Corasil C_{18} column was used for carotene determination. The mobile phase was 4% chloroform in acetonitrile.

Nitrogen determinations were performed on foodstuffs, rations and excreta with the aid of a Kjel-Foss instrument according to routines described elsewhere.[10]

Results and discussion

Analytical data. The figures recorded in Table 1 reveal a limited number of differences in the concentration of some of the components between the two samples of caterpillars investigated. These differences pertain especially to water-soluble components such as magnesium, sodium, potassium and the B-complex vitamins, which were found in smaller quantities in the canned than in the uncanned product. They were most probably due to loss in the soaking water used in preparation of the canned product, this water usually being discarded. Another possible cause of nutrient loss was undoubtedly the heat treatment applied during the canning; the concentration of the heat-labile vitamin thiamine in the canned sample was only about 16% of that in the uncanned sample.

In spite of the above losses it can be said that most of the nutrients listed in the table are present in concentrations sufficiently high to make substantial contributions to the traditional, predominantly cereal diet of the people using the mopanie caterpillar as a food. For example, according to unpublished results obtained by one of us (A.S.W.), the traditional maize porridge made from unsifted meal yields only the following per 100 g solids: protein 9.0 g, fat 4.33 g, Ca 3.67 mg, Fe 3.13 mg, P 224 mg, Cu 0.3 mg, and Zn 2 mg.

It is pertinent to note, however, that analytical data of the type considered here seldom provide all the information required for assessment of nutritive value. The bioavailability of the nutrient in question also needs to be considered. In another report from this laboratory[11] it was stressed that the bioavailability of certain nutrients in a commonly used foodstuff, wheaten bran, had been found to be poor and that suitable laboratory methods are urgently needed to determine nutrient bioavailability.

Dry matter digestibility. The relevant figures are shown in Table 2. It can be seen that, in spite of the heat treatment applied in the canning, the indigestible dry matter (IDM) content of the moisture-free caterpillar material is comparatively high. As will be shown later (Table 3), this is partly due to a relatively low protein digestibility value, but since DMD is even lower than protein digestibility, it follows that the non-protein fraction of the moisture-free material must be particularly indigestible. From the data obtained with the caecectomized rats this figure can be calculated thus:

1) Protein content (Table 3): 65.8%;
2) non-protein fraction: 100 − 65.8 = 34.2%;
3) digestible protein (Table 3): 65.8 × 0.84 = 55.3%;
4) indigestible protein: 65.8 − 55.3 = 10.5%;
5) total amount indigestible material (caecectomized rats; Table 2): 31.3%;
6) non-protein indigestible fraction: 31.3 − 10.5 = 20.8%;
7) non-protein digestible fraction: 34.2 − 20.8 = 13.4%;
8) digestibility of non-protein fraction: (13.4/34.2) × 100 = 39.2%;
9) indigestible fraction of non-protein component: 100 − 39.2 = 60.8%.

From the value recorded in Table 1 for crude fibre content (13.3%), it appears that (13.3/20.8) × 100 = 64% of the non-protein indigestible fraction is cellulose. This indicates that the plant material in the digestive tracts of the caterpillars was not completely cleaned out in the preparation of the samples investigated.

A noteworthy feature of the data listed in Table 2 is the marked difference in the results obtained for DMD between intact and caecectomized rats. The values secured with intact animals are consistently higher than those representing the caecectomized rats. This phenomenon has frequently been observed in our

Table 2. Comparison of dry matter digestibility of canned mopanie worm caterpillars with certain other foodstuffs. One set of results was secured with use of caecectomized rats and another with intact animals.

Material tested	Intact rats		Caecectomized rats	
	Digestible dry matter (%)	Indigestible dry matter (%)	Digestible dry matter (%)	Indigestible dry matter (%)
Mopanie caterpillars (canned)	79.9 ± 2.29	20.1*	68.7 ± 3.25	31.3*
White bread (freeze-dried)	96.1 ± 1.12	3.9	94.1 ± 1.60	5.9
Sorghum meal	91.8 ± 1.22	8.2	88.4 ± 1.74	11.6
Apple press cake (dried)	71.4 ± 1.55	28.6	40.8 ± 2.22	59.2
Soybean (cooked and freeze-dried)	85.5 ± 1.49	14.5	67.4 ± 2.12	32.6
Brown bread (freeze-dried)	91.3 ± 1.11	8.7	85.9 ± 1.61	14.1
Dry beans (cooked and freeze-dried)	87.0 ± 1.47	13.0	70.7 ± 2.14	29.3

*The standard errors of these values are the same as those of the corresponding digestible dry matter values.

Table 3. Comparison of the nutritive value (digestibility and assimilability) of the protein in mopanie caterpillars with that in certain other foodstuffs.

Foodstuff	'Crude' protein content (dry basis, %) (N × 6.25)*	Digestibility (D, %) ± S.E.	Assimilability (Assim, %) ± S.E.	(N)et (P)rotein (U)tilization, % (= D × Assim/100)	(N)et (P)rotein (V)alue, % (= NPU × crude protein*/100)
Mopanie caterpillars (dried)	65.8	85.8 ± 0.40	78.8 ± 1.22	67.6	44.5
Mopanie caterpillars (dried, soaked and canned)	65.8	83.9 ± 0.37	79.1 ± 1.21	66.4	43.7
Defatted cooked and dried egg	85.1	94.5 ± 0.42	90.1 ± 1.18	85.1	72.4
Casein	89.1	98.0 ± 0.49	80.5 ± 1.34	78.9	70.3
Defatted cooked and dried beef	90.4	98.8 ± 0.52	84.5 ± 1.45	83.5	75.5
Cooked dry bean 1	34.7	85.0 ± 0.41	52.2 ± 1.03	44.4	15.4
Cooked dry bean 2	31.1	80.6 ± 0.36	56.7 ± 1.09	45.7	14.2
Cooked dry bean 3	27.2	80.5 ± 0.38	53.2 ± 1.04	42.8	11.6
Wheat gluten	81.8	97.2 ± 0.37	27.6 ± 2.28	26.8	21.9

*Since the bioassay employed is based on total amino N (including non-protein amino N) consumed and excreted, the appropriate conversion factor is N × 6.25 in all cases and not the conventional tabulated values which vary from foodstuff to fodstuff, e.g. 5.71 for soybean, 6.38 for milk, etc.

laboratory.[12] It indicates further degradation and absorption of the undigested material passed through the ileo-caecal valve into the caecum. First thought suggests that the degradation is due to microbial fermentation, but according to results which we intend to publish at a later stage, the role of microbial fermentation is insignificant.

Protein value. According to the data listed in Table 3 a major advantage of the moisture-free mopanie caterpillar products is their high protein content. In comparison with the protein from the other products of animal origin, digestibility of this protein was found to be relatively low. However, the above weakness was compensated for to a considerable degree by an assimilability index which compares favourably with those of the high-class products such as casein and beef. The net effect of the digestibility and assimilability, as given by the NPU values, is such that, quality-wise, the mopanie product protein occupies a position well above the midpoint between the bottom end (gluten, 27%) and the uppermost point on the scale of natural proteins as exemplified by whole hen's egg protein (85%).

We suspect the low values obtained for mopanie protein digestibility to be due to the fact that in insects some of the nitrogenous components are present in the form of chitin. This compound is not hydrolyzed in the intestinal tracts of mammals because of the absence of the relevant enzyme, chitinase.

The NPVs listed in the last column of Table 3 can be used to estimate those amounts of the various products that would be required to meet specific demands. For example: if we assume the assimilable protein requirement for nitrogen equilibrium in a 70 kg man to be about 30 g per day,[13] it can be said that (100/44.5) × 30 = 67.4 g of moisture-free caterpillars will be needed to furnish this requirement. According to Quin[1] the average moisture content of the fresh, whole caterpillars is 83.1%. The above amount of moisture-free material is therefore obtainable from about (100/16.9) × 67.4 = 399 g fresh caterpillar material, or 399 ÷ 5.8 ≅ 69 fresh caterpillars.

From the above results we conclude that the consumption of mopanie caterpillars can to a substantial degree supplement the predominantly cereal diet with many of the protective nutrients. The main advantage of this foodstuff is its high protein value, in spite of the fact that the digestibility of this protein is lower than that of most proteins of animal origin. The traditional method of degutting does not yield a product completely free from gut contents, a considerable amount of cellulosic material still being detectable in the samples investigated.

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