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Cucurbit Seed Coat Composition

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Seed coats of domestic and xerophytic feral species of *Cucurbita* were investigated to determine composition and potential value as a ruminant feed source. These cucurbit seed coats had a 15–24% crude protein content which is considerably higher than that usually associated with seed coats. Acid detergent fiber and lignin ranges were 63–71 and 24–33%, respectively. Gross energies were in the range of 4600 to 5000 kcal/kg. Calculated cell wall digestibilities were found to be similar to those of other seed coats used for ruminant roughage.

The purpose of this work was to investigate the general composition of seed coats from several species of the genus *Cucurbita*. The genus contains 27 species which includes squashes, pumpkins, and gourds (Whitaker and Bemis, 1975). These species are native to the American continents and have adapted to many climatic conditions since their origin in the tropical regions of south central Mexico (Bemis and Whitaker, 1969). There are five domesticated extant species which are grown mainly for local markets or home consumption and thus have negligible international impact (Whitaker, 1968).

Three domesticated and two wild *Cucurbita* species were selected for this study. The three domesticated species have been described by Whitaker (1968). *Cucurbita pepo* and *C. maxima* are temperate annuals, while *C. ficifolia* is a tropical, high altitude perennial. *C. foetidissima* and *C. digitata*, two xerophytic perennial species which have been described by Whitaker and Bemis (1975), show considerable promise for domestication (Bemis et al., 1978). *C. foetidissima* ranges extensively through dry regions of the western United States and northern Mexico. The characteristics and composition of this plant have been described by Berry et al. (1976) and Bemis et al. (1978). *C. digitata* is an extreme xerophyte limited to hot, desert regions of southwestern United States and adjacent Mexico.

The recognition of cucurbit seeds as a potential food source will grow as the worldwide requirement for edible oil and protein increases. These seeds contain approximately 30% oil and 30% protein, and the yield per hectare is comparable to other commercially grown oilseeds (Jacks et al., 1972). During the processing of oilseeds, large quantities of residual seed coats are produced. They constitute 8–45% of the whole seed weight and are often considered byproduct wastes. If cucurbit seeds become edible oil sources, waste disposal regulations and process economics would make their possible utilization as a ruminant feed of considerable interest.

Table I. Physical Properties of *Cucurbita sp.* Seeds

	length × width, mm	seed wt per 100 seeds, g	seed coat in seed, %
C. foetidissima	9 × 5	4.0	33.0
C. digitata	9 × 5	5.0	45.0
C. pepo	15 × 9	10.0	21.0
C. maxima	18 × 11	22.0	20.0
C. ficifolia	17 × 12	20.0	25.0

PROCEDURE

Seeds from *C. foetidissima*, *C. digitata*, and *C. ficifolia* were obtained from the University of Arizona. Seeds from *C. pepo* (Gray Zucchini) and *C. maxima* (Green Hubbard) were obtained from the Asgrow Seed Co. Physical properties were determined in triplicate sets of 10–100 seeds. Seed coats were separated from embryos by hand and ground in a Wiley mill to –40 mesh.

Proximate composition of the seed coats was obtained by the following established methods: (a) dry matter by vacuum oven drying at 110 °C overnight, (b) lipid content using 2:1 (v/v) chloroform/methanol by Soxhlet extraction, (c) protein content by the Kjeldahl method, (d) ash content by use of an electric muffle furnace at 600 °C, (e) neutral detergent fiber (NDF) by the method of Southgate (1976), (f) acid detergent fiber (ADF) and acid detergent lignin (ADL) by the Klason method of Van Soest (1963).

Estimated cell wall digestibility was calculated by the method of Goering and Van Soest (1970), and gross energy (GE) was determined by oxygen bomb calorimetry.

Additional analytical properties were determined by the following standard methods: (a) free sugars by extraction with 80% ethanol, (b) water-soluble polysaccharide content

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Table II. Proximate Analysis of Seed Coats[a]

	dry matter, %	crude lipid, %	crude protein, %	ash, %	NDF, %	ADF, %	ADL, %	estimated cell-wall digestibility %	gross energy, kcal/kg
C. foetidissima	94	3.4	17	1.1	89	71	26	23	4600
C. digitata	96	4.1	18	2.1	81	64	24	22	4800
C. pepo	96	2.0	22	1.6	83	66	32	15	5000
C. maxima	96	2.6	15	0.2	88	69	30	18	4600
C. ficifolia	95	6.9	24	1.2	75	63	33	12	4600

[a] Data reported on a dry weight basis.

by extraction with boiling water, (c) pectin content by extraction with boiling 0.5% ammonium oxalate, (d) hemicellulose content by extraction with 10% potassium hydroxide both before and after delignification. Cellulose content was calculated by difference.

Sugar composition of hemicellulose samples was determined after hydrolysis in sulfuric acid and neutralization with barium carbonate. The sugars were trimethylsilylated (Dutton, 1973) and analyzed on a Beckman GC-5 gas–liquid chromatograph (6 ft column; 3% SE-30 on Gas-Chrom Q, 80–100 mesh; N_2 gas 40 mL/min). The column was programmed to rise from 100 to 250 °C in 16 min. Inositol was used as an internal standard.

The amino acids as percent of protein were determined after hydrolysis with 6 N HCl by using a Beckman 121 automatic amino acid analyzer (Zacharius and Talley, 1962).

RESULTS AND DISCUSSION

Physical data for seeds and seed coats are listed in Table I. The xerophytic cucurbit seeds were less than half the size and weight of other cucurbit seeds, and they had a higher ratio of seed coat per seed than the others. The processing of these cucurbits would resemble that of cotton and sunflower in that large amounts of residual seed coats would be produced.

The proximate values of the seed coats were generally similar, but some specific differences were apparent (Table II). The crude lipid content of *C. ficifolia* was higher than that of the others. The crude protein ranged from 15 to 24% with the xerophytic species having values of 17 and 18%. In contrast, cottonseed hulls and sunflower seed coats have values from 4 to 5% (Hale et al., 1969; Sabir et al., 1975). The cucurbit seed coat protein values are also much higher than those reported for other common seed coats (National Academy of Sciences, 1972). The feeding of *C. foetidissima* seed coats to mice as the sole source of protein in the diet resulted in a loss of weight and a negative PER, indicating that the seed coat protein was largely unavailable for digestion by monogastric animals (Bemis et al., 1977).

The crude fiber was determined by two different methods, NDF and ADF. Different values were found using the two methods, but they gave the same ranking for the fiber content. *C. foetidissima* and *C. maxima* had the highest values, while *C. ficifolia* had the lowest. The ADL values were not related to either the NDF or ADF levels. *C. ficifolia* had the lowest ADF and highest ADL value. The ADL values of these five species indicate potential feed value for ruminants. A qualitative test for tannin was negative in all species. The sum of crude protein and NDF values approaches or exceeds 100% in these seed coats, suggesting an association of protein with the cell wall matrix. Investigation of the association is being made.

Extensive use is made of proximate analyses of this type in evaluating ruminant feedstuffs. The equation of Goering and Van Soest (1970) was used to predict the digestibility of the seed coats from their ADL and ADF values (Table II). The ranking in order of decreasing digestibility was as follows: *C. foetidissima*, *C. digitata*, *C. maxima*, *C. pepo*, and *C. ficifolia*.

Table III. Carbohydrate Composition of Seed Coats[a]

	free sugars, %	water-soluble polysaccharides, %	pectin, %	hemicellulose, %	cellulose,[b] %
C. foetidissima	1.0	2.7	1.0	18	27
C. digitata	2.2	7.4	1.2	17	22
C. pepo	1.3	6.0	1.7	17	20
C. maxima	1.8	1.5	0.1	19	31
C. ficifolia	1.8	5.9	5.3	12	15

[a] Data reported on a dry weight basis. [b] Values determined by difference.

Table IV. Component Sugars of Hemicellulose

	xylose, %	arabinose, %	glucose, %	galactose, %	mannose, %
C. foetidissima	64	22	7	4	3
C. digitata	44	33	11	6	6
C. pepo	37	20	34	6	3
C. maxima	73	7	11	5	3
C. ficifolia	64	10	18	6	1

The data of Hale et al. (1969) and Sabir et al. (1975) can be used to calculate cell wall digestibilities of 26% for cottonseed hulls and 20% for sunflower seed coats. Thus, the values of 22 and 23% for the xerophytic cucurbit seed coats make them comparable to currently used ruminant roughages.

Gross energy values fluctuated unexplainably from 4600 to 5000 kcal/kg. *C. pepo* had the highest value, despite the relatively high crude lipid level in *C. ficifolia*. The xerophytic species had values of 4600 and 4800 which compare closely with 4600 reported for cottonseed hulls (Hale et al., 1969) and sunflower seedcoats (National Academy of Sciences, 1972).

The carbohydrate composition of the seed coats is shown in Table III. While free sugars showed little variation, water-soluble polysaccharides ranged from 1.5% in *C. maxima* to 7.4% in *C. digitata*. Pectin content was extremely high in the tropical cucurbit *C. ficifolia*. The hemicellulose and cellulose contents showed little variation except in *C. ficifolia* which had much lower values for each.

The sugar composition of hemicellulose residues for the seed coats is listed in Table IV. All had different proportions of sugars, and xylose was predominant in each case. Hemicellulose from the xerophytic seed coats had considerable arabinose, suggesting the presence of arabinoxylan. Xylan probably predominates in the hemicellulose of *C. maxima* and *C. ficifolia*, while *C. pepo* may

Table V. Amino Acid Content of Seed Coat Protein[a]

	C. foetidissima	*C. digitata*	*C. pepo*	*C. maxima*	*C. ficifolia*
Lys	7.7	5.3	7.3	5.0	7.5
His	2.6	3.1	2.6	3.2	5.4
Arg	9.3	13.2	6.4	3.7	2.7
Asp	12.5	11.4	9.8	9.2	11.4
Thr	1.1	2.1	1.0	0.5	0.4
Ser	3.3	3.0	2.1	1.3	2.6
Glu	15.1	17.4	9.1	9.0	10.8
Pro	2.5	1.2	1.2	0.5	0.7
Gly	14.2	9.6	10.1	11.9	20.6
Ala	1.8	3.1	2.5	1.2	1.6
Val	2.0	3.7	1.0	1.0	1.3
Met	0.6	1.3	0.5	0.3	0.3
Ile	1.5	3.2	1.5	0.7	0.7
Leu	2.5	5.3	2.7	1.0	1.0
Tyr	6.6	5.0	5.3	6.9	12.0
Phe	1.4	3.2	1.7	0.5	0.6
Cys	0.5	0.1	Tr[b]	Tr	Tr

[a] Data are reported as percent of protein. [b] Trace.

contain a mixture of heteropolymers consisting of xylose and arabinose, and xylose and glucose.

A possible way to utilize the carbohydrates of waste seed coats would be to hydrolyze them with microbial enzymes to form free sugars (Conrad and Palmer, 1976). Such treatments generally produce glucose and xylose.

Amino acid values (Table V) demonstrate that the crude protein levels in the xerophytic species are primarily protein nitrogen. The high levels of protein nitrogen found in these species suggest that a considerable portion of the protein may be present as glycoprotein. All seed coats had very low levels of leucine, phenylalanine, and the sulfur amino acids. In contrast, their lysine levels ranged from 5.0 to 7.7%.

A variety of technical studies involving processing and handling of these seed coats will be necessary before commercial feasibility can be demonstrated. In the case of the *C. foetidissima*, sufficient land is under cultivation to produce seed and plant material for evaluation as a ruminant feedstuff.

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Conversion of Parathion to Paraoxon on Soil Dusts and Clay Minerals as Affected by Ozone and UV Light

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The persistence of parathion and its conversion to the highly toxic paraoxon on soil dusts and monoionic clay minerals were measured in environmental chambers with various rates of atmospheric ozone with and without ultraviolet (UV) light. The oxidation of parathion to paraoxon on soil dust was controlled mainly by ozone concentrations and the type and thickness of soil dust. Rates of paraoxon production were maximum at high ozone levels in the presence of UV light. Neither ozone alone, nor UV light alone, effectively produced paraoxon on the soil dust. When dry monoionic clays were exposed to 300 ppb oxone and UV light, the kaolinite clays more effectively catalyzed the oxidation of parathion to paraoxon than the montmorillonite clays. In oxidizing parathion to paraoxon the Cu-saturated clays were most effective, and the Ca-saturated montmorillonite clay (the dominant species in many agricultural soils of California) was least effective.

The worker reentry problem associated with using organophosphate insecticides has been the topic of several studies and a recent review (Gunther et al., 1977). The infrequent episodes of workers becoming ill from exposure to residues of parathion under hot, dry, California conditions has been found to be caused mainly by the highly toxic alteration product, paraoxon, carried on dust particles to the worker's clothing or skin, from which it is dermally absorbed (Spear et al., 1977a,b). Considerable quantities of insecticides ultimately reach the soil surface—either by direct application or by runoff from crops in excess water applied with the insecticide. Parathion can persist on dry soil for long periods and can be oxidized to the highly toxic

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