THE JOURNAL OF AGRICULTURE
OF THE UNIVERSITY OF PUERTO RICO

Issued quarterly by the Agricultural Experiment Station of the University of Puerto Rico, for the publication of articles by members of its personnel, or others, dealing with any of the more technical aspects of scientific agriculture in Puerto Rico or the Caribbean Area

Vol. LXI JULY 1977 No. 3

Feeding Value of *Canna edulis* Roots for Pigs[1]

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ABSTRACT

Canna edulis roots grown in Guadeloupe were analyzed by proximate composition. The in vitro α-amylolysis of the canna starch was evaluated by the quantitative determination of the enzymatic hydrolysis products of starch with piglet pancreatic juice. The digestibility and the digestible energy content of canna roots for 55-kg pigs were determined by the addition method in a study using four pigs individually fed in metabolism crates. The studies were made on roots either raw or cooked in boiling water for 30 minutes.

Raw and cooked canna roots were found to contain (on dry weight basis) 81.0 and 75.6% starch, 6.0 and 13.9% alcohol soluble sugars and 3.7 and 3.4% crude protein, respectively. In vitro, less than 2% of raw canna starch was digested within two hours by the piglet pancreatic juice vs. more than 90% when cooked. In the pigs, the apparent digestibility of raw and cooked canna roots was 79.2 and 88.9% for dry matter and 76.0 and 87.6% for gross energy, respectively. Raw and cooked canna roots supplied 2,940 and 3,467 kcal digestible energy per kg (dry-matter basis), respectively.

INTRODUCTION

The *Canna edulis* plant, also called "queensland arrowroot," "toloman" (French West Indies), "archira" (Peru), "conflor" (Reunion), belongs to the botanic family of the Cannaceae. It comes from tropical America and is characterized by a purple and more or less ramified root system and a 1.5 to 2.5 m high aerial stalk with a great number of broad leaves. It is cultivated especially along the border of the Indian Ocean (5) and grows spontaneously in the West Indies. According to recent experimental studies made in Guadeloupe, increasing use of the canna crop can be expected especially on account of the high yield of roots (50 t/ha/year) and of stalks and leaves (50 to 100 t/ha/year). In Congo (16) and Brazil (1), the aerial parts and roots of canna are used in ruminant

[1] Manuscript submitted to Editorial Board March 24, 1976.

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Thanks are due to E. Calif and E. Despois for their technical assistance and to K. Rerat for the translation of the manuscript.

feeding. But, to our knowledge, no data are available about the feeding value of canna roots for pigs.

This experiment was designed to determine the proximate composition of canna roots and the effect of cooking on the in vitro rate of α-amylolysis of the starch and the energy value of the product for pigs.

MATERIALS AND METHODS

The canna roots came from an experimental culture propagated by the Plant Improvement Department of the Agricultural Research Center (Guadeloupe). The plants were harvested every week for the duration of the trial. The aerial part was cut immediately above the roots, which then were cleaned and stored. A portion of the roots was cooked every day in boiling water for about 30 min. The raw and cooked products were sliced into pieces before giving them to the pigs.

Chemical analysis of canna was made on samples freeze-dried either before or after cooking and ground in a shot grinder. The substances dissolved in the cooking water were not taken into account. The total alcohol-soluble sugars were assayed by the anthrone method (9) after two extractions with hot 80° G.L. ethanol, two washings and purification of the extract (3). They were qualitatively identified by thin-layer chromatography (7). Starch was determined by the enzymatic method (17) with glucoamylase after extraction of the alcohol-soluble sugars from the material. Phosphorus was determined by means of ammonium phosphovanadomolybdate photometry, sodium and potassium by flame spectrometry, and calcium and magnesium by atomic absorption spectrometry. Amino acid contents were determined according to the method of Moore, Spackman and Stein. Tryptophane, totally destroyed during the hydrolysis, was not determined. The content of sulphur amino acids was measured by the same technique after oxidation by performic acid.

Samples of 4 g of raw or cooked freeze-dried and ground canna root were dispersed in 200 ml of a buffer solution (pH 7.2) and kept with constant shaking for 2 hours at 37° C. One ml of pure piglet pancreatic juice was added to start the digestion. The sugars released in the reaction medium during the hydrolysis were continuously recorded by a Technicon[3] autoanalyzer (13) and expressed in terms of maltose equivalent. Final data were expressed in percentage of starch digested vs. digestion time.

Four castrated male pigs of a large white breed weighing initially 55 kg were placed in metabolism crates. After a 10-day period of adaptation

[3] Trade names are used in this publication solely for the purpose of providing specific information. Mention of a trade name does not constitute a guarantee or warranty of equipment or materials by the Agricultural Experiment Station of the University of Puerto Rico or an endorsement over other equipment or materials not mentioned.

TABLE 1.—*Plan of the experiment and amount of feed (kg of fresh material) allotted/pig/day*

Period	Pigs	
	1 and 2	3 and 4
1	Basal (.9 kg) + raw canna (3 kg)	Basal (.9 kg) + cooked canna (3 kg)
2	Basal (.9 kg)	Basal (.9 kg)
3	Basal (.9 kg) + cooked canna (3 kg)	Basal (.9 kg) + raw canna (3 kg)

the animals were grouped by pairs and subjected to the treatments during 3 successive experimental periods of 15 days each. The apparent digestibility of the main components of canna was estimated by the addition method. Description of the successive experimental periods is given in table 1.

The formulation and composition of the basal diet, which provided 3,692 kcal of gross energy per kg, are given in the following tabulation:

Ingredients	*Percent*
Ground yellow corn	58.2
Soybean oil meal (50% C.P.)	38.0
Dicalcium phosphate	2.1
Common salt	.7
Trace mineral mixture	.3
Vitamin mixture	.7
Composition	
Dry matter	87.7
Ash	6.7
Crude protein (N × 6.25)	23.9

The mineral mixture supplied the following per 100 kg diet: $MgCO_3$, 230 g; $FeSO_4 \cdot 7H_2O$, 30 g; $ZrSO_4$, 15 g; $MnSO_4 \cdot H_2O$, 18 g; $CuSO_4 \cdot 5H_2O$, 6.4 g; $CoSO_4 \cdot 7H_2O$, 300 mg, stabilized IK, 300 mg.

The vitamin mixture supplied the following per 100 kg diet: vitamin A, 560,000 I.U.; vitamin D_2, 50,000 I.U.; riboflavin, 280 mg; calcium pantothenate, 700 mg; choline chloride, 5.4 g; nicotinic acid, 1.4 g; vitamin B_{12}, 1.4 mg.

The amount of basal diet offerred per animal per day was constant (.9 kg) during the whole experiment; its digestibility was measured during the second experimental period. During periods 1 and 3, the animals received the basal diet and the same amount of either raw or cooked canna according to table 1. The animals were fed three times a day. After each meal refusals were collected, dried in the oven at 70° C and weighed. All feces were collected during the last 8 days of each experimental period, weighed and frozen at −15° C. At the end of each period, they were homogenized and their dry matter content was determined.

Dry matter content of the canna was measured every day. Using representative samples of the basal diet, feeds, refusals and feces, the contents of dry matter, ash, nitrogen and gross energy (adiabatic calorimetric bomb) were measured.

RESULTS AND DISCUSSION

Canna is an aqueous food the water content of which is fairly comparable to that of green banana and potato. It is also characterized by a

TABLE 2.—*Proximate chemical analysis of raw and cooked* **Canna edulis** *roots*

Analysis	Canna	
	Raw	Cooked
	%	%
Wet weight basis		
Dry matter[1]	22.8	25.4
Dry weight basis		
Protein (N × 6.25)	3.69	3.36
Fiber	2.67	–
Starch	81.20	75.60
Alcohol-soluble sugars	6.00	13.90
Ash	4.18	3.82
Ca	.15	.14
P	.10	.09
K	1.79	1.79
Mg	.03	.02
Na	.12	.12
Gross energy (kcal/kg dry matter)	3,869	3,958

[1] Mean of 12 analyses.

very high starch content representing about 80% of the dry matter (table 2). In addition, it contains a substantial amount of alcohol-soluble sugars, especially glucose and sucrose. Cooking seems to bring about a partial breakdown of the starch, leading to an increase in the content of alcohol-soluble sugars in the cooked product and to the presence of large amounts of maltose as revealed by the chromatographic study.

The protein content (N × 6.25) is small and comparable to that of banana (9) or sweetpotatoes (6), but inferior to that of yam (12).

The levels of essential, "semi-essential" and non-essential amino acids are summarized in table 3, as a percentage of 16 g N. The quality of the protein is compared to that of whole egg. Threonine excepted, the essential amino acids content of canna, especially arginine and sulphur amino acids, is low. The biological value of canna protein, estimated from the sum of essential and semi-essential amino acids minus leucine (14), is low as compared to that of whole eggs. The percentage of ash is

TABLE 3.—*Amino acid contents (g/16 g N) in raw and cooked canna compared to that of eggs*

Item	Canna		Whole eggs
	Raw	Cooked	
Lysine[1]	3.9	4.2	7.1
Histidine	1.6	1.9	2.6
Arginine	3.1	3.6	6.4
Aspartic acid	20.7	18.4	9.9
Threonine	4.9	5.1	4.8
Serine	4.4	4.4	7.1
Glutamic acid	10.6	11.8	12.7
Proline	1.8	2.9	4.0
Glycine	4.0	4.4	3.2
Alanine	4.0	4.5	5.6
Valine	4.5	4.6	7.0
Isoleucine	3.7	4.1	5.5
Leucine	6.1	6.6	8.5
Tyrosine	3.7	4.2	3.8
Phenylalanine	3.4	3.7	4.8
Cystine	1.5	1.6	2.8
Methionine	1.7	1.8	3.3
Total essential and semi-essential amino acids minus leucine	32.0	34.8	48.1

[1] Essential amino acids are underlined.

low, and decreases after cooking (3.82% vs. 4.18%). The relative contents of calcium and phosphorus are very small, whereas that of potassium is large.

Starch of raw canna was very resistant in vitro to the α-amylase action of piglet pancreatic juice (fig. 1). In this respect it is similar to starches from raw tropical tubers and fruits (15). This behavior is in agreement with the nature of the X-ray diffraction spectrum which is of the type B for raw starch.[4] Cooking modifies the crystalline structure of starch and concomitantly increases starch susceptibility to the enzyme action. Thus, after cooking, more than 90% of the starch was digested within 2 hours vs. scarcely 2% of the raw product. A similar effect of cooking has also been noticed with tubers and tropical fruits rich in starch (4).

The animals fed the diet based on cooked canna, had an average of 7% higher dry matter intake than those fed raw canna (1,553 vs. 1,450 g/d). This difference in feed intake mainly depended on the difference in dry matter contents of raw and cooked canna, and probably accounts for the better growth performance of pigs receiving the diet based on cooked canna (494 vs. 432 g/d weight gain).

[4] Charbonnière, G. Personal communication, 1975.

The apparent digestibility coefficients of dry matter, organic matter, energy, and especially N, of the whole diet based on raw canna were significantly lower than those of the basal diet (table 4). On the other hand, the diet based on cooked canna was as digestible as the basal diet, the N fraction excepted. Thus, in agreement with results obtained in man (8), raw canna was less digestible for pigs. The improvement due to cooking may be explained, as in vitro, by a better digestion of canna starch by the pancreatic and intestinal enzymes. It results in a reduction of the excretion of fecal metabolic nitrogen (2, 18), and thus accounts for the improvement in apparent digestibility of N from the whole diet after cooking canna.

The apparent digestibility coefficients of dry matter and energy of canna were estimated by means of the addition method, assuming the absence of any interaction between basal diet and feed tested. The values calculated in this way are reported in table 5 and compared with those obtained with whole green banana (9), sweetpotatoes (6) and yam (11). Cooking significantly improved the apparent digestibility of canna dry matter and energy. Consequently, the energy value of cooked canna expressed in digestible energy per kg of dry matter exceeded by 18% that

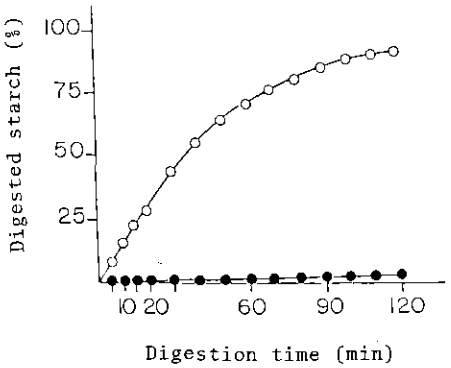

FIG. 1.—In vitro α-amylolysis of raw ● and cooked ○ *Canna edulis* starch.

TABLE 4.—*Mean apparent digestibility coefficient percentage of basal and whole diet (basal + test feed)*

Apparent digestibility coefficient %	Basal diet	Basal diet plus	
		Raw canna	Cooked canna
Dry matter	88.1[a1]	84.0[b]	88.4[a]
Organic matter	90.5[a]	85.8[b]	90.4[a]
Nitrogen	90.9[a]	77.3[b]	84.2[c]
Gross energy	89.0[a]	83.3[b]	88.3[a]

[1] Means followed by the same letter do not differ significantly at the 1% level.

TABLE 5.—*Effect of cooking on the dry matter and energy digestibility coefficient (%) and digestible energy content of canna roots as compared with other starchy tropical foods*

Apparent digestibility coefficients %	Canna		Green whole banana[1]		Sweetpotatoes[1]		Yam[1]
	R[2]	C	R	C	R	C	R
Dry matter	79.2	88.9**[3]	83.5	87.9*	90.4	93.5	68.8
Gross energy	76.0	87.6**	79.5	84.3*	89.1	91.9	61.1
Digestible energy content (kcal/kg D.M.)	2,940	3,467**	3,181	3,439*	3,373	3,463	2,505

[1] According to Le Dividich (9), Corring (6), and Marin (12).

[2] R = raw; C = cooked.

[3] Significant effect of cooking, * $P < .05$; ** $P < .01$.

of the raw product. The digestibility coefficients as well as the energy value of raw canna were higher than those obtained with raw yam, but lower than those obtained with raw banana, and especially with raw sweetpotato. However after cooking, the energy value of canna was very similar to that of cooked banana and sweetpotato.

It is concluded that canna, like many starch-rich tropical tubers and fruits, may constitute a basal energy feed for pigs. However, it should be supplemented with proteins and minerals. Cooking enhances the energy value of the product by 18% and improves the apparent digestibility of the dietary N by about 10%.

RESUMEN

La composición química de las raíces de la *Canna edulis*,[5] cultivadas en Guadalupe, arroja de 75 a 78% de agua. Las raíces crudas o hervidas en agua por 30 minutos contienen (en porcentaje de materia seca) 81 y 76% de almidón, respectivamente, y 6 y 14%, en el mismo orden, de azúcares solubles en alcohol. El contenido en proteína bruta, aminoácidos esenciales, calcio y fósforo es bajo. *In vitro*, el almidón de la *Canna* cruda es muy resistente a la acción de la α-amilasa del jugo pancreático del cerdo joven. La susceptibilidad a la enzima aumenta mucho al cocerse: 90% del almidón se digiere en dos horas, en contraste con 2% si la raíz está cruda.

El valor energético expresado en kilocalorías por kilogramo (kcal./kg.) de materia seca digestible de la raíz cruda y hervida se estimó por el método aditivo usando cuatro cerdos castrados de una raza "Large White" con un peso medio de 55 kg. y alojados en jaulas de digestibilidad. El valor de 2,940 kcal./kg. de materia seca de la raíz cruda representa 3,467 kcal./kg. en la raíz cocida; o sea, un aumento de 18% debido a la cocción. Los coeficientes de digestibilidad aparente de la proteína bruta fueron 77 y 84%, respectivamente en dietas a base de la raíz cruda y cocida.

[5] Maraca, imocona, achira, platanillo, cañacoros. N. del E.

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