Analytical and biological studies of a high-yielding, high protein cassava[1]

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SUMMARY

Yucca and plantain have been considered solely as an energy source in diets of tropical populations. However, they represent 10% of the total protein intake in Colombia. Studies on several yucca cultivars detected one of them with a protein concentration three times higher than that of normal varieties. It was also a high-yielding type.

In spite of the very poor quality of its protein, as shown by analytical studies of this nutrient, it was demonstrated that in children recuperated from protein-calorie malnutrition, it represents an acceptable source of nonessential nitrogen, according to biological tests carried out.

INTRODUCTION

A large proportion of the population who live in the tropics depends mainly on energy-producing foods, low in protein content. One of them is *Manihot esculenta,* commonly called cassava or yucca, which is deeply rooted in the dietary habits of tropical populations.

Large quantities of this crop are now being produced under very poor agronomic conditions. Precise production figures are difficult to determine, as a large amount is grown and consumed on subsistence farms. Dietary surveys carried out in

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Colombia tend to give consumption figures higher than those cited in production reports for this staple (1, 2). The world production of cassava is 85 million metric tons per year, with Brazil as the largest producer in the world (3). This is a prevailing crop in tropical areas where it is used mainly for human consumption. In Colombia, cassava and plantain supply 20% of the calories and 10% of the protein in the diet (3, 4). These two products have been considered pure energy staples because of their low protein content; however (Table 1), they represent more than one-tenth of the total protein consumption of the Colombian population, and this figure may possibly be higher for other tropical countries (Tables 1 and 2). Furthermore, cassava supplies a good proportion of thiamine, riboflavin, niacin and ascorbic acid (3). The *per capita* consumption per day ranges from 10.2 to 103 g in urban areas, and from 80 to 242 g in rural communities (4, 5). One of the greatest disadvantages of this crop pertains to harvesting, handling, and storage. Since mechanical harvesting methods do not exist, this operation must be accomplished manually under most conditions. In small enterprises, this would not be a deterrent factor, but it might become limiting in large production units. Wet cassava cannot be stored for more than six days and must be harvested periodically once or twice per week.

Results obtained by the Instituto Colombiano Agropecuario (ICA) (6) indicate a normal distribution for total N in the analysis of 1,500 cultivars of the Colombian germ plasm collection, ranging from 0.16 to 0.64% nitrogen (dry basis). There is also a wide variation in the yielding capacity for the different cultivars. One of them, the CHCM 9 (Llanera) was found to have a crude protein content of 7.24 on a dry basis. This cultivar yields 78 metric tons per hectare (7) and reaches maturity at ten months. Because we feel that any effort addressed to increase the protein concentration of cassava and to improve the quality of this protein could have an inmediate favorable impact on low-income rural groups, studies of some of the nutritional characteristics of this cultivar were undertaken as follows.

TABLE 1

ADEQUACY OF AVERAGE CONSUMPTION AND AVAILABILITY OF NUTRIENTS PER CAPITA/DAY IN COLOMBIA*

Nutrients	Recommended allowance per capita/ day	Average consumption per capita/ day	Adequacy % of average consumption	Availability per capita/ day	Adequacy % of availability
Calories	2,130	1,812	85	2,293	107
Protein, g	59	46.1	78	53.5	91
Ca, mg	910	450	49	581	64
Fe, mg	10.7	12.5	117	14.9	139
Vitamin A, I.U.	3,989	2,747	69	3,223	81
Thiamine, mg	1.1	0.89	82	1.1	100
Riboflavin, mg	1.4	0.92	64	1.2	86
Niacin, mg	11.4	10.20	89	12.5	110
Vitamin C, mg	60	95	158	148	247

* Taken from dietary surveys carried out in Colombia from 1963 to 1966 by the Instituto Nacional de Nutrición (1).

MATERIALS AND METHODS

Three cultivars were chosen for analysis of their protein content: low I, medium II, and high III (1.56, 3.59 and 5.78%). Whole root samples were collected at the Centro Internacional de Agricultura Tropical (CIAT) at a constant time, and delivered to the laboratory in sealed plastic bags not later than 3 hours after harvesting. The roots were then weighed and two roots per cultivar were immediately prepared for analysis. Two outer layers of the root were peeled off and both were chopped into pieces of 2-3 cm as separate samples and placed in an oven at 60°C until constant weight was obtained. The whole root was milled in a Willey Mill to a 60-mesh powder. Only CHCM 9 was analyzed at monthly intervals, after maturity at ten months. At twelve months other fresh roots were peeled and milled for human biological testing.

Aliquots of whole and peeled roots were analyzed for their total nitrogen content (micro-Kjeldhal method (8)) and precipitated several times with TCA until a clear supernatant was obtained. Nitrogen was determined in both precipitate and supernatant. The latter was placed directly in a chromatographic column for amino acids alpha-amino nitrogen, nitrates, and nitrites analysis, and the precipitate was hydrolized for the same determinations. Aliquots from the peeled sample were processed by the method of Landry and Moureaux (9) for protein fractionation. The first fraction obtained was hydrolized for amino acid analysis.

Twelve-month old plants were harvested, peeled, and processed for feeding studies. Diets were designed as follows:*

	Diets					
	1	2	3	4	5	6
Casein protein	1.0	0.50	0.50	—	—	—
Opaque-2 endosperm protein	—	—	—	1.00	0.75	—
CHCM 9 protein	—	—	0.50	—	0.25	—
Glycine-diammonium citrate (equal parts)	—	0.50	—	—	—	—

* Expressed as 1 g of protein/kg/day contained in the product and 100 calories/kg/day, minerals and vitamins added.

TABLE 2
NUTRIENT SOURCE IN THE DIETS OF URBAN AND RURAL COMMUNITIES IN COLOMBIA
(Expressed in %)

Urban communities	Cereals	Roots	Sugars	Legumes	Green vegetables	Plantains	Fruits	Meats	Eggs	Fish	Milk	Fats	Others
Calories	29	6	23	3	0	12	0	8	0	0	6	11	1
Proteins	32	4	1	7	1	4	0	33	5	1	13	1	—
Fats	8	—	—	—	—	1	—	22	1	1	13	49	5
Carbohydrates	35	9	32	3	1	17	1	0	—	—	2	—	—
Calcium	16	—	14	4	6	2	1	1	—	1	51	—	1
Phosphorus	29	5	5	8	2	6	—	20	—	2	20	1	2
Iron	26	8	14	11	3	8	1	22	2	—	3	—	2
Vitamin A	1	1	—	—	15	48	2	21	2	—	7	—	2
Thiamine	29	11	2	11	3	14	2	15	—	2	9	2	—
Riboflavin	13	7	5	2	2	5	1	28	2	—	32	1	1
Niacin	23	14	2	3	3	12	1	38	—	1	2	1	—
Vitamin C	1	29	2	1	12	33	18	1	—	—	3	—	—
Rural communities													
Calories	29	10	25	5	1	16	—	6	—	—	2	6	—
Proteins	33	5	1	14	1	6	—	30	1	1	8	—	—
Fats	9	1	1	2	—	—	—	31	1	—	3	50	1
Carbohydrates	31	12	31	4	1	20	4	—	—	—	1	—	—
Calcium	7	9	28	9	5	4	1	2	—	—	35	—	—
Phosphorus	32	7	8	15	2	8	1	16	1	1	10	—	—
Iron	19	9	23	18	2	9	1	17	—	1	1	—	—
Vitamin A	12	2	0	0	17	64	0	2	0	1	2	—	—
Thiamine	35	12	3	17	2	17	1	6	—	—	6	—	—
Riboflavin	13	12	11	5	3	10	1	22	1	—	21	—	—
Niacin	23	17	4	7	2	14	0	30	—	—	30	—	—
Vitamin C	1	39	4	1	8	44	3	—	—	—	1	—	—

Eight recuperated children with an average weight of 14.5 kg, 30-35 months old were placed on experimental diets and standard metabolic balance. Weight did not increase during the experimental periods.

After a three-day adaptation period, endogenous, urinary and fecal nitrogen were determined for a three-day nitrogen-free diet period. Each one of the diets was administered to them for three consecutive three-day periods. Continuous collections of a duplicate diet, and of urine and feces were obtained and analyzed for nitrogen; the results were used to calculate biological value (BV) and net protein utilization (NPU) (10).

RESULTS AND DISCUSSION

Table 3 shows the proximal analysis for the three cultivars selected for the study on the basis of three levels of N: low, medium, and high. As the data reveal, there is little difference among the three samples except in protein concentration. When protein is precipitated with TCA, the nonprotein nitrogen is significantly lower in the low-protein cultivar; however, the increase in total nitrogen represents a three-fold net increase of protein nitrogen. The possibilities are that by increasing consumption of this type of cassava there would be a net increase of nitrogen from 46 g *per capita* per day to 50 g *per capita* per day. The amounts of HCN, method of preparation, and flavor, are similar for the three samples. Total national production of protein from casava using the same type of inputs would increase from 18,000 tons of protein (N x 6.25) to 54,000 tons, thereby helping close the protein gap.

Table 4 shows the variation of protein and nonprotein nitrogen of cassava at different stages of maturity. As has been reported (7), the concentration of N is higher in the outer layers of the root, and the outher skin has the highest concentration for all portions analyzed, of which nonprotein nitrogen (NPN) represents more than half of the total. Nevertheless, at least 50% of NPN is alpha-amino nitrogen, the remainder being nitrates, nitrites, ammonia, etc. Table 5 shows the results of protein fractionation. Again, 80% of the nitrogen is saline-soluble and is located in fraction I. Methods of preparation that require washing of the root starch with water may very well dispose of a good portion of the nitrogen, especially of that in the free amino acid form. Table 6 presents the amino acid composition of the edible part of the root, for the three cultivars studied. The quality of the protein is very poor, the amount of sulfur-containing amino acids is almost negligible, and other essential amino acids are low. Even by comparison with maize, it is obvious that the yucca protein is of very poor quality. Nevertheless, cassava contitutes only a portion of the diet and it can supply both nonspecific nitrogen and limited amounts of the essential amino acids and some vitamins, as well as energy.

When good-quality protein such as casein or Opaque-2 modified maize is diluted with poor-quality cassava protein, it seems possible to obtain a biological value and a net protein utilization very similar to those attained with casein and Opaque -2 alone. These results are better than those obtained using a mixture of glycine and diammonium citrate as a source of nonessential nitrogen. The "protein" calculations are based on total nitrogen times 6.25, disregarding the fact that at least 25% of the N is in nonutilizable forms. Part of the poor quality of the "crude protein" of cassava can be explained on this basis. Twenty-five percent of the protein from cassava in the diet represents more than twice the daily amount consumed *per capita* in Colombia. Yet this level does not produce a significant reduction in the protein quality of the diet.

It seems appropriate to maintain a clear perspective of staple foods accepting them as components of a diet where their real biological value can be demonstrated.

TABLE 3

ANALYTICAL STUDIES OF YUCCA VARIETIES

		Yucca varieties	
	I	II	III
Protein (N x 6.25)	2.30	3.59	6.40
Fat	0.82	0.68	0.50
Carbohydrate	79.46	77.1	76.08
Fiber	3.32	3.18	2.68
Ash	3.48	3.00	2.61
Moisture — Dried yucca	10.82	10.00	11.73
Moisture — Fresh yucca	63.52	65.31	67.90

TABLE 4

NITROGEN ANALYSIS OF YUCCA LLANERA CHCM 9 (ABANICOS) AT DIFFERENT AGES OF HARVESTING

Harvesting		Total N	Nonprotein nitrogen	Protein
Jan. 10/70 (10th mth)	A	1.48	0.86	9.25
	B	0.94	0.63	5.90
	C	1.08	1.00	6.75
Feb. 23/70	A	1.35	0.53	8.43
	B	0.72	0.25	4.50
	C	0.87	0.62	5.45
Mar. 10/70	A	1.07	0.55	6.69
	B	0.72	0.42	4.51
	C	0.88	0.47	5.50
Mar. 30/70	A	1.40	0.74	8.75
	B	0.72	0.55	4.51
	C	0.84	0.56	5.25
Apr. 17/70	A	1.92	1.06	12.00
	B	0.82	0.52	5.15
	C	1.01	0.57	6.35
May 4/70	A	1.92	0.94	12.00
	B	0.84	0.51	5.20
	C	0.94	0.63	5.90
Low protein cultivar I		0.25	0.16	0.09
Medium protein cultivar II		0.57	0.45	0.125
High protein cultivar III		0.92	0.65	0.270

A = Yucca shell - peel; B = Flesh - medulla; C = Whole.

TABLE 5

PROTEIN FRACTIONS OF THREE PEELED CASSAVA CULTIVARS*

	Cultivars		
	CHCM 4	CHCM 9 "R"	CHCM 9
Total percent	1.56	3.59	5.78
I NaCl,0.5M	11.68 (93.6%)	23.77 (82.8%)	35.11 (82.5%)
II Isopropyl alcohol, 55%	0.82 (0.65%)	0.21 (0.71%)	0.41 (0.89%)
III Isopropyl alcohol-2 mercaptoethanol	0.33 (0.26%)	0.411(1.3%)	0.082(0.177%)
IV Buffer pH10-2 mercaptoethanol	0.205(1.64%)	0.205(0.71%)	0.61 (1.32%)
V Buffer pH10-lauryl sodium sulfate	0.49 (3.92%)	0.83 (2.87%)	1.86 (4.02%)
Residue	—	0.93 (3.24%)	2.40 (5.19%)

* Landry and Moureaux (9).

TABLE 6

AMINO ACID ANALYSIS OF THREE PEELED VARIETIES OF YUCCA IN COMPARISON WITH MAIZE

Amino acids*	Yucca cultivars			Maize
	I	II	III	
Isoleucine	184	150	107	336
Leucine	204	132	129	848
Lysine	204	190	165	174
Methionine	Trace	Trace	Trace	100
Threonine	429	420	390	425
Valine	133	90	75	425

* Expressed in mg per g of nitrogen.

TABLE 7
NITROGEN BALANCE WITH DILUTIONS OF CASEIN AND OPAQUE-2 MAIZE WITH YUCCA PROTEIN: AVERAGE FOR 4 CHILDREN (INTAKE AND RETENTION ARE GIVEN IN GRAMS OF NITROGEN PER BODY WEIGHT) (14.5 kg)

	Casein 100%	Casein 50 yucca 50	Casein 50 Diammonium citrate 50	$0_2$100	$0_2$75 yucca 25
Intake	2.4	2.08	2.33	2.55	2.30
Digestibility	99.0	92.5	98.5	95.0	91.0
NPU	85.5	73.0	44.5	80.0	76.0
Biological value	86.5	82.5	45.5	86.0	84.0
Retention	2.12	1.57	1.04	2.03	1.75

RESUMEN

Estudios analíticos y biológicos de cultivares de yuca de alto rendimiento y ricos en proteína

La yuca y el plátano han sido considerados sólo como fuente de energía en las dietas habituales de las poblaciones del trópico. Sin embargo, estos alimentos constituyen 10% del total de proteína ingerida en Colombia. El estudio de cultivares de yuca en el país permitió detectar uno de alto rendimiento y con una concentración proteínica tres veces superior a los de consumo común. Se presentan datos de composición de este cultivar comparados con otros de menor concentración proteínica. A pesar de la calidad biológica pobre de su proteína, se demuestra que, según pruebas biológicas practicadas en niños de edad preescolar recuperados de desnutrición proteínico-calórica, constituye una fuente aceptable de nitrógeno no esencial.

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