I-1505

NUTRITIONAL EVALUATION OF ROASTED, FLAKED AND POPPED *A caudatus*[1]

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SUMMARY

A study was carried out with a selection of *A. caudatus* CAC-064, which was processed in three different forms: popped, flaked and roasted. The popped sample was prepared by subjecting the grains to a temperature between 175 and 195°C for 15 - 25 seconds. The flaked sample was obtained by adjusting moisture content to 26°/o and using heated (200°C) rotating drums for a contact time of 1 - 3 seconds, and roasting was achieved by heating the grain at 150°C for a lapse of 60 - 90 seconds.

All samples, including a raw sample, were analyzed for proximate chemical composition, minerals, available lysine and tryptophan content, as well as damaged starch, calories, soluble and insoluble fiber, and protein quality. Differences in chemical composition due to the processing applied were small and insignificant, except for lower available lysine values, and insoluble fiber with higher values in the roasted sample than in the flaked and popped samples. Likewise, the roasted sample had higher levels of damaged starch. Protein quality was highest in the popped sample (NPR 3.19), followed by the flaked (NPR 2.78), the roasted (NPR 2.24) and the raw (NPR 1.73) samples. These values were related to available lysine. Protein digestibility was lowest in the roasted material followed by the flaked and the popped products. It is concluded that establishment of optimum processing conditions is necessary in order to achieve maximum utilization of amaranth grain.

Manuscrito modificado recibido: 2-4-87.

1 This work was supported with funds from the National Academy of Sciences - NAS/BOSTID Program (Grant-in-aid INC-NUT-380/PN/86-86-CA).

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INCAP Publication I-1505.

INTRODUCTION

Nutritional evaluation of a processed food from chemical data has the only disadvantage that it does not take into account the bioavailability of the nutrients. Therefore, biological assays should also be used. One of the most common ways to process amaranth grain for consumption is to heat it on a hot surface to induce popping. If such a process is extended in time, roasting also takes place (1). More recently, however, processing techniques such as flaking have also been applied (2,3). It is well known that processing, if not well controlled,. may reduce the nutritional quality of the product caused by destruction or binding of essential amino acids, particularly lysine (4,5). The purpose of the present study, therefore, was to evaluate the effect of these processing techniques on the nutritional quality of one cultivar of *Amaranthus caudatus.*

MATERIAL AND METHODS

The cultivar *A. caudatus* CAC-064, produced in Cuzco, Peru, was used for the study. The popped sample was prepared by subjecting the dry grains to a temperature of 175 - 195ºC for 15 - 25 seconds, condition which lead to a rapid grain expansion. A total of 1,213 g was produced. The flaked material was prepared by increasing moisture content in the grain to approximately 26º/o by immersing the grains in water for 10 minutes. The grain was then dropped into two rotating stainless steel drums, separated around 0.5 mm and heated at 200ºC with a contact time of 1 - 3 seconds. A total of 1,171 g of such a product was prepared. Finally, 1,365 g of roasted flour were prepared by heating the whole grain at 150ºC for 60 - 90 seconds. All samples, including the whole grain, were then ground to pass an 80-mesh screen. In a second study, the cultivar CAC-064 was cooked in water (1:1.5) to boiling for 30 min. Then it was dehydrated with hot air at 60ºC and ground into a flour. This sample was assayed for protein quality (NPR) and protein digestibility

All samples were analyzed for their moisture, ether extract, crude fiber, protein, and ash content by the standard AOAC methods of analysis (6). Minerals were attained by atomic absorption spectrophotometry on 6 *N* HCl solution of the ash. Crude calories were measured using a calorimeter, available lysine by the method of Carpenter (5), and tryptophan by the method of Villegas, Ortega and Bauer (7). The samples were also assayed for damaged starch as proposed by Farrand (8), and dietetic fiber by the method of Asp *et al.* (9).

For biological evaluation, diets were prepared containing 10º/o protein from the various samples based on their respective protein content (N x 6.25). The amaranth flour samples were supplemented with 4.0º/o of a mineral mixture (10), 5.0º/o refined cottonseed oil, 1.0º/o cod liver oil, and 5 ml of a complete vitamin solution per 100 g of diet (11). Refined corn starch was used to adjust all diets to 100º/o. Two additional diets were prepared, a 10º/o protein diet using casein and a nitrogen-free diet. The assay used was the NPR (12) run for 14 days. During the second seven days of the assay, feces were collected, dried, weighed, and ground for digestibility measurements of dry matter, protein and energy of the diets. A total of 48 young rats, 21 - 22 days of age, with an initial weight of 45 ± 1 g of the Wistar strain from INCAP's animal colony were distributed by weight among six groups, assigning four males and four females per group. The animals were placed in individual all-wire screen cages with raised screen bottoms. Diet and water were provided *ad libitum* and weight changes and diet consumed were measured every seven days.

RESULTS AND DISCUSSION

Chemical composition of the raw and processed samples is shown in Table 1. As the data reveal, ether extract, protein and ash content of the various materials are essentially alike, and the differences observed are partially due to the differences in moisture content. Crude fiber content in the roasted material is higher than in the raw, flaked and popped samples, probably due to the effect of processing, as can be seen from the dietetic fiber values. The insoluble fiber is significantly higher in the roasted sample, as compared with the other materials. On the other hand, the soluble fiber is similar among samples. As would be expected, there are no differences between samples in regard to calories and minerals. Available lysine content is lower in the roasted samples, as well as their tryptophan content. The higher value of available lysine of the flaked sample as compared to the popped and raw samples cannot be explained, since repeated analysis of the samples gave the same values. Dietetic fiber and the lower levels of lysine and tryptophan suggest, therefore, that the roasted material should be lower in nutritional quality than the popped and flaked samples. Although damaged starch is not a nutritional indicator, the data show the roasted sample to have undergone greater changes in its starch molecule.

Results of the NPR assay are shown in Table 2. Animals fed on raw flour showed low weight gain due to a low feed intake, probably caused by antiphysiological substances, with a relative NPR to casein of 47.4o/o. The increasing order of nutritive quality was roasted, flaked and popped samples. Hence, processing increases the nutritive value of amaranth grain protein when comparisons are made between raw and processed samples. Nevertheless, the three types of processes affect protein quality differently. The roasting process gave a nutritionally better product than the raw sample, but inferior to the flaked and the popped samples. Lysine and tryptophan contents are in agreement in values. Although the beneficial effect of appropriate processing in increasing protein quality of raw amaranth has been stated before (2,13), it must be emphasized again. At the present time no explanataion is available; however, it is doubtful that it could be due to the classical growth inhibitions, since concentrations found were very small (14,15). More likely, it could be caused by an increase in the bioavailability of nutrients, particularly amino acids.

Table 3 summarizes digestibility of the dry matter ingested, as well as of protein, and total diet energy. While the digestibility of dry matter, energy and protein of the processed amaranth flours was below values for

TABLE 1

CHEMICAL COMPOSITION OF SAMPLES
(o/o)

Nutrient	Raw	Process		
		Roasted	Flaked	Popped
Moisture	11.9	5.5	9.2	6.2
Ether extract	7.6	7.3	7.5	7.6
Crude fiber	2.7	3.7	2.3	2.4
Protein	12.1	14.6	12.9	13.3
Ash	1.9	2.7	2.5	2.5
Available lysine g/16 g N	5.3	4.3	6.5	5.7
Tryptophan* g/16 g N	0.96	0.86	1.19	1.11
Calories, kcal/g	3.98	4.28	4.31	4.53
Damaged starch, g	0	97.0	68.0	63.5
Phosphorus, mg o/o	—*	43.3	46.4	41.1
Calcium, mg o/o	—*	24.5	21.7	23.6
Potassium, mg o/o	—*	40.4	43.8	35.5
Dietary fiber:				
Insoluble fiber	7.0	20.7	14.3	13.9
Soluble fiber	6.5	4.1	4.0	5.2

* Not analyzed.

TABLE 2

PROTEIN QUALITY OF *A. Caudatus* (Cuzco 064) SUBMITTED TO DIFFERENT PROCESSES

Process	Protein in diet, g	Ave. weight gain, g	Food intake, g	NPR	R-NPR, o/o
Raw	8.6	7 ± 5.3	101	$1.73^c \pm 0.56$	47.4
Roasted	9.1	17 ± 6.7	131	$2.24^c \pm 0.81$	61.4
Flaked	9.3	26 ± 7.6	126	$2.78^b \pm 0.30$	76.2
Popped	9.1	37 ± 6.3	149	$3.19^b \pm 0.35$	87.4
Wet cooking	9.2	42 ± 8.2	177	$3.07^b \pm 0.29$	84.1
Casein	9.6	52 ± 7.9	166	$3.65^a \pm 0.23$	100.0

Initial weight: 45 ± 1 g.
Different letters in the same column, indicate significant differences.

TABLE 3

DRY MATTER, ENERGY AND PROTEIN DIGESTIBILITY IN PROCESSED *A. caudatus*

Process	Dry matter %	Energy %	Protein %
Raw	—	—	76.0 ± 2.80
Roasted	88.1 ± 0.52	89.6 ± 0.50	62.2 ± 1.88
Flaked	91.3 ± 0.70	92.4 ± 0.60	79.5 ± 3.49
Popped	91.4 ± 0.79	92.4 ± 1.19	78.7 ± 2.37
Casein	97.8 ± 0.37	98.6 ± 0.18	92.9 ± 1.24

the casein diet, the roasted flour gave the lowest figures. These results confirm the higher content of insoluble dietary fiber shown in Table 1, which indicate that these lower digestibility figures for the roasted flour are due to the process employed. Apparently, protein was more affected, since the digestibility of the protein in the roasted samples was 62.2% as compared to 79.5 and 78.7% for the flaked and popped samples, respectively. Results indicate that of the four cooking methods, popping, flaking and wet-cooking processes yield the best quality products from the nutritional point of view. The popping process does not differ greatly from the roasting process except for the time of residence at the chosen temperature; therefore, care must be taken not to exceed the residence time. It would be advantageous, however, to test the temperature and time relationship so as to be consistent in preparing lots of popped amaranth with the same nutritive quality every time. Likewise, underprocessing may result in products of a protein quality between the maximum and that of the raw grain, since, raw amaranth grain does not promote good animal growth, as shown in this and other studies (2, 13, 16, 17). The increase in protein quality observed with the flaking and popping processes, as carried out in this study, is similar to those increments observed for wet-cooking (13), drum-drying (2, 16), and extrusion-cooking (17).

RESUMEN

EVALUACION NUTRICIONAL DE *A. caudatus* TOSTADO, EN FORMA DE HOJUELAS Y REVENTADO

En el presente estudio se procesó una selección de *A. caudatus* CAC-064 en tres diferentes formas: reventada, en forma de hojuelas y tostada. La muestra reventada se preparó sometiendo el grano a una temperatura que oscilaba entre 175 - 195°C durante 15 - 25 segundos. La muestra en forma de hojuelas se obtuvo ajustando la humedad a 26% y sometiendo el producto a cocción en cilindros rotatorios a 200°C durante 1 - 3 segundos. El producto tostado se obtuvo calentando el grano a 150°C por un lapso de 60 a 90 segundos.

Todas las muestras procesadas, y una cruda, fueron analizadas con respecto a composición química proximal, contenido de minerales, lisina disponible, triptofano, almidón dañado, calorías, fibra soluble e insoluble, y calidad proteínica. Las diferencias en composición química debido al proceso utilizado fueron pequeñas y no significativas, excepto en la lisina disponible. La muestra tostada acusó valores más bajos en lisina disponible y valores más altos en fibra insoluble que el producto reventado y que el producto en forma de hojuelas. El material tostado mostró valores mayores de almidón dañado. La calidad de la proteína fue mayor en las muestras reventadas (NPR 3.19) seguido por las hojuelas (NPR 2.78), el material tostado (NPR 2.24), y el crudo (NPR 1.73). Estos valores están relacionados directamente con la lisina disponible. La digestibilidad de la proteína fue menor en el material tostado, seguido por las hojuelas y el producto reventado. Se concluye que deben establecerse las condiciones óptimas de procesamiento para lograr la máxima utilización biológica del grano de amaranto.

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