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Intermediate moisture meat product: biological evaluation of charqui meat protein quality

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Abstract

Charqui is a typical salted and dry Brazilian meat product. A harsh condition for salting and drying during charqui processing could eventually damage its biological value. Therefore protein quality of raw and cooked charqui meat flours was chemically and biologically evaluated by rat growth and nitrogen balance studies. Proximate chemical compositions of desalted raw and cooked charqui flour samples showed protein content of 74.2 and 81.1%, respectively and lipid contents of 20.06 and 13.52%, respectively. There was a good balance of essential amino acids in both samples. Feeding of flour diets prepared from exhaustively desalted and dried cooked and raw charqui samples resulted in high protein efficiency ratios, in high net protein utilisations and high nitrogen balances thus showing a high biological value and also high true digestibility, with NPU similar to casein.

Keywords: Intermediate moisture meat; Biological evaluation; Charqui meat nutritive value

1. Introduction

Intermediate moisture (IM) meat products are processed almost everywhere in the world and each product has its own characteristics. Since there has been an increase in refrigeration costs, IM meat products have gained further interest (Chang, Huang, & Pearson, 1996). After drying, the IM product reaches an Aw of 0.6–0.90 equivalent to a relative humidity (RH) of 60–90% at ambient temperature (Ledward, 1981; Leistner, 1987). Charqui meat is the result of application of the so-called hurdle technology in its processing (Leistner, 1987). As recently described, salt, sodium nitrite, dehydration and packaging are hurdles sequentially applied to inhibit spoilage microorganisms (Shimokomaki, Franco, Biscontini, et al., 1998; Torres, Shimokomaki, & Franco, 1994). The conditions of charqui meat preparation were discussed elsewhere (Shimokomaki et al., 1998; Torres, Pearson, Gray, Ku, & Shimokomaki, 1989); essentially, a saline solution of 25°Baume is injected into the beef samples, which we exposed to the sun for drying. The final product reaches a constant Aw of 0.70–0.75 and is then ready for consumption and normally shelf-stable for 6 months and left unpacked (Torres et al., 1994). Since there is no need for refrigeration it is of great importance in rural areas. This product has been consumed in Brazil since the nineteenth century but only recently has it been partially characterised. Our group has evaluated it biochemically (Torres et al., 1994), ultrastructurally (Biscontini, Shimokomaki, Ferreira, & Zorn, 1996) and microbiologically (Shimokomaki et al., 1998) and this paper reports its biological evaluation using casein as control.

2. Materials and methods

2.1. Sample preparation

Charqui samples were processed in a commercial charqui meat Industry plant, FRIPAR, located in Londrina

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city, PR, Brazil. The preparation method closely followed the method already described (Shimokomaki et al., 1998). Essentially, *Vastus lateralis* muscle samples were consecutively salted in 20–25% brine, rock-salted and dried in the sun until the moisture reached a constant value of ca. 50.0% (Shimokomaki et. al., 1998). Samples were exhaustively desalted until NaCl content reached about 0.70% (AOAC, 1996). Part of this sample was cooked for 20 min in a boiling water bath. After cooling, samples, including raw material, were homogenised and dried in an air circulation oven at 45–50 °C for 3 days. Homogenised cooked and raw charqui samples were powdered in food micro homogeniser to pass through a 60-mesh sieve. These flours were stored at cold temperature for the subsequent chemical analysis and for preparation of the respective rations.

2.2. Animal tests

Young, 21–23 days old, white male Wistar rats, weighing 30.0–40.0 g, were obtained from the Central Animal House of Biological Sciences Centre, Londrina State University. Animals were randomly divided into three groups, each consisting of 10 rats. They were housed individually in metallic cages kept in an air-conditioned room maintained at 23.0 °C with a 12-h light and dark cycle.

2.3. Amino acid analysis

Amino acid composition was determined in replicate after acid hydrolysis with HCl 6 N for 24 h at 110 °C following the methodology described by Spackman, Stein, and Moore (1958) using a Beckman HPLC-amino acid analyser.

2.4. Basic chemical composition

Percentage of moisture, fat, protein, and ash was determined by the AOAC method (1996).

2.5. Composition of diets

Diets containing flours of raw and cooked charqui were offered to two groups of 10 rats each. The third group was fed on a casein (INLAB) diet as control. All three diets, having the calculated 10.0% protein level, are listed in Table 1. For the preparation of the diets, ingredients were homogenised and passed through a 60-mesh sieve to ensure uniform distribution of minerals and vitamins.

2.6. Growth experiment

Protein efficiency ratio (PER) was determined according to AOAC (1996). Animals were initially weighed and food and water were given ad libitum. The rats fed on different experimental diets and control diet were weighed for four weeks and the gain in weight during this period was recorded. The consumed protein was calculated from the consumed nitrogen, based on the diet's nitrogen content. PER was calculated by the formula below:

$$\text{PER} = \text{gain in body weight (g)/protein consumed (g)}$$

2.7. Nitrogen balance studies

Nitrogen balance studies were carried out during the experiment. During the second and third consecutive weeks, faeces and urine of each rat were collected separately. The concentration of nitrogen in urine and faeces were estimated by the microKjeldahl method according to AOAC (1996). The data obtained from this experiment were used to calculate true digestibility (TD; Urbano, Lopez-Jurado, Hernandez et al., 1995), biological value (BV; Hackler, 1977), net protein retention (NPR; Walker, 1983) and net protein utilisation (NPU; Sgarbieri, 1996) by employing the following formulas:

$$\text{TD} = (\text{Ni} - \text{NF}_1 - \text{NF}_2/\text{Ni}) \times 100$$

Table 1
Composition of the experimental diets for calculated protein as 10.0% and metabolisable energy as 36.00 $MJkg^{-1}$

Ingredients	Casein	Diets protein-free	Raw charqui flour	Cooked charqui flour
Casein	12.22		–	–
Raw charqui flour	–		12.95	–
Cooked charqui flour	–			11.76
Sucrose	10.00	10.00	10.00	10.00
Corn oil	3.50	4.00	3.50	3.50
Mineral mix[a]	2.10	2.10	2.10	2.10
Vitamin mix[b]	0.10	0.10	0.10	0.10
Cellulose	5.67	4.70	6.90	7.71
Corn starch	66.41	79.10.4	64.45	64.83

[a] Containing per kg mix (g/kg): Ca_2PO_4 490.83, NaCl 32.63, K_2SO_4 75.51, $MgSO_4$ 151.03, $MnSO_4 \cdot H_2O$ 60; ZnO 60; $FeSO_4 \cdot 7H_2O$ 50, $CuSO_4 \cdot 5H_2O$ 10; KIO_3 2.0, Na_2SeO_3 0.005, Cobalt Oxide 1.5.

[b] Containing per kg mix: retinol 12.0 IU, cholecalciferol 1.8 IU, α-tocopheryl acetate 30.0 IU; vitamin K_3 3.0 g riboflavin 6.0 g; d-panthotenic acid 20.0 g, niacin 60.0 g, cianocobalamine 0.02 g; biotin 0.05 g, folic acid 1.0 g; thiamine 6.0 g, pyridoxine 7.0 g, choline chloride 600.0 g.

$BV = Ni-(NF_1-NF_2)-(NU_1-NU_2)/Ni-(NF_1-NF_2) \times 100$

Ni = Nitrogen intake of animals fed test diet

NF_1 = Nitrogen excreted in faeces of animals fed test diet

NF_2 = Nitrogen excreted in faeces of animals fed protein free diet

NU_1 = Nitrogen excreted in urine of animals fed test diet

NU_2 = Nitrogen excreted in urine of animals fed protein free diet

NPR = Weight gain of test group + weight loss of protein-free group/weight of test protein consumed

$NPU = BV \times TD/100$

2.8. Statistical analysis

The data were subjected to analysis of variance (ANOVA) in a completely randomised design to determine the significant differences among various groups (Statistical Analysis Systems, 1989).

3. Results and discussion

3.1. Charqui meat approximate chemical composition

After exhaustive desalting and drying, flour prepared from raw and cooked samples presented the final chemical composition as shown in Table 2. The chemical composition was similar for both samples with slight predominance of the protein fraction and less fat in cooked sample.

Table 2
Proximate chemical composition of raw charqui meat flour (RCMF) and cooked charqui meat flour (CCMF) (%) on dry basis[a]

Samples	Moisture	Protein	Ash	Lipid
RCMF	3.95±0.10	74.2±0.32	0.71±0.05	20.06±0.26
CCMF	4.70±0.09	81.1±0.01	0.58±0.01	13.52±0.06

[a] Values are means±S.D. of triplicate analysis.

3.2. Essential amino acid profile

Table 3 presents the determined essential amino acid composition for raw and cooked charqui flour samples. Despite heat treatment, no substantial difference was noticed.

3.3. PER and NPR

Food intake and body weight gain on the casein (control) were the highest (59.92 and 123.52 g per rat, respectively) and differed significantly ($P<0.05$) from other diets where food intake and body weight ranged from 37.08 to 42.91 g per rat and 73.98 to 87.76 g, respectively (Table 4). Although the body weight gain was higher in the group fed on cooked charqui meat flour diet, the difference was not significant ($P>0.05$) in comparison to raw charqui meat flour. Food intake results were significant ($P<0.05$), being higher on the control diet, followed by cooked sample diet. Cooked samples would improve the digestibility properties although earlier reports stated that heat treatment decreased biological value due to losses of available amino acids (Danoso, Lewis, Miller, & Payne, 1962; Dvorak & Vognarova, 1965). However, Brinckman and McNeil (1976) reported that diets rich in collagen, such as deboned meat, presented higher values for cooked than raw samples. Casein diet had a PER of 2.33; although not significant, this value was higher than raw and cooked charqui meat flour diets (1.99 and 1.91, respectively). The corrected PER values followed a similar pattern of 2.50, 2.15 and 2.07, respectively for casein, raw charqui meat and cooked charqui meat flour

Table 3
Essential amino acid composition (mg/g protein) of desalted raw charqui meat flour (RCMF) and cooked charqui meat flour (CCMF) in comparison to FAO standard

Essential amino acids	RCMF[a]	FAO reference[b]	CCMF[a]
Histidine	27.1	19.0	22.8
Isoleucine	59.8	28.0	57.4
Leucine	112	66.0	106
Lysine	105	58.0	102
Methionine + Cystine	37.6	34.0	35.0
Phenylalanine + Tyrosine	99.3	63.0	92.3
Treonine	56.6	34.0	54.4
Tryptophan	ND[c]	11.0	ND[c]
Valine	58.8	35.0	55.6

[a] Average of two analyses.
[b] FAO/WHO/ONU (1985).
[c] ND: Not Determined.

Table 4
Food intake, protein intake, body weight gain of rats; PER[a] and NPR of raw (RCMF) and cooked charqui meat flours (CCMF)

Dietary groups	Body weight gain (g)	Food intake (g)	Protein intake (g)	PER	Corrected PER[b]	NPR
Casein	123.52a±2.36	59.92a±0.79	5.38a±0.12	2.33±0.61	2.50	2.26±1.02
RCMF	73.98b±7.53	37.08c±1.92	3.64a±0.19	1.99±1.29	2.15	1.67±1.46
CCMF	87.76b±4.30	42.91b±1.24	5.78a±1.10	1.91±2.81	2.07	1.89±4.82

[a] Values are means±S.D. of 10 rats in each group throughout 28 days of experimental period.
[b] Based on values of 2.5 as standard for casein RCMF, raw charqui meat flour; CCMF, cooked charqui meat sample.

Table 5
Nitrogen consumed, nitrogen absorbed, nitrogen retained, TD, BV and NPU values[a] of raw and cooked charqui meat flours (RCMF and CCMF, respectively) fed to rats, measured after second and third weeks of experiment

Dietary group	Nitrogen consumed (g)	Nitrogen absorbed (g)	Nitrogen retained (g)	BV	NPU	TD
Casein	0.44a±0.01	0.42a±0.01	0.41a±0.01	96.9a±1.90	94.6a±1.99	97.6ab±0.68
RCMF	0.27c±0.01	0.25c±0.01	0.21c±0.01	84.5b±1.90	81.4b±1.99	96.3b±0.68
CCMF	0.33b±0.01	0.32b±0.01	0.28b±0.01	88.1b±1.90	87.7ab±1.99	99.6a±0.68

[a] Values are means±S.D. of 10 rats in each group.

diets. These results were somewhat unexpected because there was a possibility of influence from some components derived from cholesterol oxidation, formed during charqui meat processing in particular (Torres et al., 1989). These substances have been described as toxic and it seems that the preparation of charqui flour by exhaustive washing steps, would remove them. This assumption was corroborated by microscopic observation of several animal organs after feeding with both flours and no abnormal condition was observed (not shown).

NPR was shown to be higher for casein (2.26) than for raw or cooked charqui meat flours (1.67 and 1.89, respectively), although these values were not significantly different ($P > 0.05$).

3.4. Nitrogen consumption, absorption, digestibility, BV and NPU

Nitrogen consumed, nitrogen absorbed and nitrogen retained were significantly ($P < 0.05$) higher in animals fed with casein, and those fed with cooked charqui meat presented higher values than those fed with raw charqui meat flour.

True digestibility was lower ($P < 0.05$) for the raw sample than the cooked flour which was not different from casein diet. It seemed that heat treatment improved digestibility by changing some protein components, in particular the collagen fraction, which was denatured. Insoluble collagen is an important component of charqui meat (Shimokomaki et al., 1998) and gelatinising would make it more easily metabolised. It is fair to conclude that, since there was no substantial change, it is unlikely that essential amino acid content would have any influence on digestibility (Table 5).

Biological value was observed to be significantly ($P < 0.05$) higher in the control sample (96.9%) than in raw charqui meat or cooked charqui meat (84.5 and 88.1%, respectively).

4. Conclusions

Although during charqui meat processing severe hurdles are applied, such as a relatively high salt and temperature, these dramatic processing conditions did not substantially change the biological values of the desalted charqui meat.

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References

AOAC. (1996). *Official methods of analysis*. Arlington, VA: Kenneth Hilrich.

Biscontini, T. M. B., Shimokomaki, M., Ferreira, S. O., & Zorn, T. M. T. (1996). An ultrastructural observation on charquis, salted and intermediate moisture meat products. *Meat Science*, *43*, 351–358.

Brinckman, G. L., & McNeil, J. H. (1976). Protein quality of mechanically deboned poultry meat as measures by rat PER. *Nutritional Report International*, *14*, 365–369.

Chang, F. S., Huang, T. C., & Pearson, A. M. (1996). Control of the dehydration process in production of intermediate moisture meat products: a review. *Advance in Food Nutrition Research*, *29*, 71–161.

Danoso, G., Lewis, O. A. M., Miller, D. S., & Payne, P. R. (1962). Effect of heat treatment on the nutritive value of proteins: chemical and balance studies. *Journal of Science and Food Agriculture*, *13*, 192–196.

Dvorak, Z., & Vognarova, I. (1965). Available lysine in meat and meat products. *Journal of Science and Food Agriculture*, *16*, 305–312.

FAO/WHO/UNU. (1985). Energy and Protein Requirements. Report of a Joint FAO/WHO/UNU Expert Consultation. World Health Organisation Technical Rpt. Series 724. World Health Organisation, Geneva.

Hackler, L. R. (1977). Methods of measuring protein quality: a review of bioassay procedure. *Cereal Chemistry*, *54*, 984–995.

Ledward, P. (1981). Intermediate moisture meats. *Developments in Meat Science*, *2*, 159–194.

Leistner, L. (1987). Shelf stable product and intermediate moisture foods based on meat. In L. Rockland, & L. B. Beuchat (Eds.), *Water activity theory and application to food* (pp. 295–328). New York: Marcel Dekker Inc.

Sgarbieri, V. C. (1996). *Proteinas em alimentos proteicos: propriedades, degradações*. São Paulo: Editora Varila.

Shimokomaki, M., Franco, B. D. G. M., & Biscontini, T. M. B., et al. (1998). CHARQUI meats are hurdle technology meat products. *Food Reviews International*, *14*, 339–349.

Spackman, D. H., Stein, W. H., & Moore, S. (1958). Automatic recording apparatus for use in the chromatography of aminoacids. *Analytical Chemistry*, *30*, 1190–1206.

Statistical Analysis Systems. (1989). *SAS user's guide* (5th ed.). NC: Cary.

Torres, E., Pearson, A. M., Gray, J. I., Ku, P. K., & Shimokomaki, M. (1989). Lipid oxidation in charqui (salted and dried beef). *Food Chemistry*, *32*, 257–268.

Torres, E. A. F. S., Shimokomaki, M., Franco, B. D. G. M., Landgraf, M., Carvalho Junior, B. C. C., & Santos, J. C. (1994). Parameters determining the quality of charqui, an intermediate moisture meat product. *Meat Science*, *38*, 229–234.

Urbano, G., Lopez-Jurado, M., & Hernandez, J., et al. (1995). Nutritional assessment of raw, heated and germinated lentils. *Journal Agriculture Food Chemistry*, *43*, 1871–1877.

Walker, A. F. (1983). The estimation of protein quality. In B. E. F. Hudson (Ed.), *Developments in food protein, Vol. 2* (pp. 293–323). London: Applied Sciences Publishers Ltd.