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LWT 39 (2006) 1072–1079
LWT
www.elsevier.com/locate/lwt

Nutritional properties of tempeh flour from quality protein maize (*Zea mays* L.)

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Received 4 April 2005; received in revised form 30 June 2005; accepted 30 June 2005

Abstract

The objective of this investigation was to evaluate physico-chemical and nutritional properties of tempeh flour from a quality protein maize (QPM). In comparison to untreated QPM, the QPM tempeh flour showed a higher ($P \leqslant 0.05$) gelatinization temperature (81.7 vs 73.9 °C), and resistant starch (4.24 vs 1.9 g/100 g dry flour), and a lower ($P \leqslant 0.05$) gelatinization enthalpy (1.94 vs 2.74 J/g) and total starch content (56.9 vs 62.6 g/100 g dry flour). The essential amino acids (EAAs) content of raw QPM flour was improved by the solid-state fermentation process. The contents of His, Ile, and Leu increased ($P \leqslant 0.05$) in 0.81, 0.52, and 1.46 g/100 g protein, respectively. The total sulphur and total aromatic EAAs increased ($P \leqslant 0.05$) in 0.55 and 3.45 g/100 g protein, respectively. In untreated QPM flour, the first and second limiting EAAs were Lys and Trp, with EAAs score of 0.72. First and second limiting EAAs in QPM tempeh flour were Trp and Lys, with an EAAs score of 0.84. The SSF process increased ($P \leqslant 0.05$) nutritional indicators as follows: protein efficiency ratio (PER) from 1.78 to 2.10, calculated PER from 1.43 to 1.74, and protein digestibility corrected amino acid score from 0.55 to 0.83. It is concluded that based mainly on its nutritive value, fermented flour may be considered for the fortification of widely consumed cereal-based food product (tortillas, bread, cookies, atoles).

Keywords: Nutritional; Quality protein maize; Tempeh

1. Introduction

Maize (*Zea mays* L) is the third most important food crop in the world and a major source of energy, protein, and other nutrients for both human and livestock. Maize contains 7–13 g/100 g proteins (d.m.). However, the quality of maize proteins is poor, because they are deficient in the essential amino acids (EAAs) lysine and tryptophan (Paredes-López, Serna-Saldívar, & Guzmán-Maldonado, 2000). Due to the economic importance of maize, genetic improvements have played a key role in the development of genotypes that could grow in a wide range of environment, rainfall, and altitudes (CIMMYT, 1985). In México, extensive field trials have been

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0023-6438/$30.00
doi:10.1016/j.lwt.2005.07.003

carried out at the International Maize and Wheat Improvement Center (CIMMYT) to identify the most productive maize cultivars, high in lysine and tryptophan contents (Ortega & Bates, 1983). Through back crossing and several recurrent selections, maize breeders of CIMMYT and the National Research Institute for Forestry, Agriculture and Livestock (INIFAP) have successfully developed 26 hybrids and cultivars, similar in yield and other important agronomic properties to normal maize. These new high-quality protein genotypes are collectively called quality protein maize (QPM) (INIFAP, 1999). Solid-state fermentation (SSF) process represents a technological alternative for improving the nutritional value of a great variety of legumes and cereals maintaining acceptable sensory properties. Tempeh is a traditional fermented food produced by SSF of soybeans. Usually, the fermentation process is performed by *Rhizopus* strains belonging to the species *Rhizopus oligosporus*, *R. oryzae*, and *R. stolonifer*. An important function of the strains in the fermentation process of soybeans is the synthesis of enzymes, which hydrolyse its constituents and contribute to the development of a product with desirable texture, flavour, and aroma. Enzymatic hydrolysis also may decrease or eliminate antinutritional factors; consequently, the nutritional quality of the fermented product may be improved (Hachmeister & Fung, 1993; Paredes-López & Harry, 1988). The potential of using SSF to improve the nutritional quality of maize in developing countries has been evaluated (Egounlety & Aworh, 2003; Mugula, 1992; Mugula & Lyimo, 2000). There is, however ,still a need for more information on the nutritional effects of using SSF on QPM maize. The objective of this work was therefore to evaluate the nutritional properties of QPM tempeh flour made by SSF.

2. Materials and methods

2.1. Materials

The QPM (*Z. mays* L) V 537 variety was obtained from the National Research Institute for Forestry, Agriculture and Livestock (INIFAP) Culiacán, Experimental Station, Sinaloa, México. The grains were harvested, shelled, cleaned and stored in tightly sealed containers at 4 °C until used. *R. oligosporus* was obtained from the Microbiology Laboratory, National School of Biological Sciences, National Polytechnical Institute (Mexico, DF).

2.2. Methods

2.2.1. Manufacture of QPM tempeh flour

Tempeh flour was made by a procedure described by Cuevas-Rodríguez, Milán-Carrillo, Mora-Escobedo, Cárdenas-Valenzuela, and Reyes-Moreno (2004), with minor modifications. Whole seeds of QPM were soaked at 25 °C for 16 h in four volumes of 0.09 mol/l an acetic acid solution (pH 3.1). The seeds were then drained and cooked at 90 °C for 30 min, cooled at 25 °C, and packed in perforated polyethylene bags (15 × 15 cm). A suspension of *R. oligosporus* (1×10^6 spores/l) was used to inoculate the bags. SSF was carried out applying a fermentation temperature of 35.4 °C for a fermentation time of 54.6 h. The resulting QPM tempeh was dried at 52 °C for 12 h, cooled at 25 °C and milled (UD, Cyclone Sample Mill, UD Corp, Boulder, CO, USA) to pass through an 80-US mesh (0.180 mm) screen. QPM tempeh flour was kept in tightly sealed containers at 4 °C until used.

2.2.2. Proximate composition

The following AOAC methods (1998) were used to determine proximate composition: drying at 105 °C for 24 h for moisture (method 925.098); incineration a 550 °C for ash (method 923.03); defatting in a soxhlet apparatus whit 2:1 chloroform/methanol, for lipids (method 920.39C with minor modifications); and microKjeldahl for protein (Nx6.25) (method 960.52). Carbohydrate content was estimated by difference.

2.2.3. Total colour difference (Δe)

The surface colour of samples was measured using a Minolta Model CR-210 colour difference meter (Minolta LTD, Japan). L (0 = black, 100 = white), a (+value = red, −value = green) and b (+value = yellow, −value = blue) were recorded. The L, a, and b values of a white standard tile used as reference were 97.63, 0.78 and −2.85, respectively. ΔE was calculated as $\Delta E = [(\Delta L)^2 + (\Delta a)^2 + \Delta b)^2]^{1/2}$, where $\Delta L = L_{std} - L_{sample}$, $\Delta a = a_{std} - a_{sample}$, $\Delta b = b_{std} - b_{sample}$.

2.2.4. Particle size index (PSI)

Flour samples of 100 g were placed in a series of US standard sieves (WS Tyler Inc., Mentor, OH, USA) with the following sizes: No. 40 = 420 μm; No. 60 = 318 μm, No. 80 = 180 μm, No. 100 = 150 μm. Sieves were shaken by a Ro-Tap machine (WS Tyler Inc., Meter, OH, USA) for 10 min. The material retained on the sieves was expressed as percent over. To complete the particle size index of flours, the following formula was applied: $PSI = \sum a_i b_i$, where a_i is the percentage of overs on sieve i, and b_i the coefficient relative to sieve i. The b_i values for sieves numbers 40, 60 and 80 were 0.4, 0.6 and 0.8, respectively. Over from sieve No. 100 and the pan were added and on overall $b_i = 1.0$ was assumed (Bedolla & Rooney, 1982).

2.2.5. Bulk density (ρ_A)

The ground samples were placed in a known volume stainless cylinder until topped at 25 °C. The device was