Food Chemistry, Vol. 57, No. 3, pp. 377–380, 1996

0308-8146/96 $15.00+0.00
0308-8146(95)00232-4

Indigenous fermentation and soy fortification: effects on protein quality and carbohydrate digestibility of a traditional Ghanaian corn meal

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(Received 17 July 1995; accepted 20 October 1995)

Studies were conducted into the effects of indigenous fermentation and soy fortification on the protein quality and carbohydrate digestibility of a traditional Ghanaian corn meal. Fermentation significantly ($P < 0.05$) improved protein quality as determined by a protein digestibility corrected amino acid score method and 2,4-dinitrofluorobenzene (DNFB)-available lysine of the corn meal cooked into a native Ghanaian weaning porridge. Addition of defatted soybean flour to the meal significantly ($P < 0.05$) improved protein quality and DNFB-available lysine. Indigenous fermentation also caused an increase in the *in vitro* carbohydrate digestibility of the non-fortified corn meal. Copyright © 1996 Elsevier Science Ltd

INTRODUCTION

Indigenous food fermentations are widely practised in several parts of the world and serve as significant sources of foods with improved organoleptic and preservative properties. In many African and Middle Eastern countries, corn (*Zea mays*) is used for various food preparations, mainly as a fermented sour dough or meal. These foods are major sources of calories and nutrients. '*Banku and Kenkey*' and '*Ogi*', for example, are traditional staple foods widely consumed in Ghana and Nigeria, respectively, and are prepared from naturally fermented corn doughs (Akinrele, 1970; Amoah & Muller, 1975; Plahar & Leung, 1982). When fortified with a high-quality vegetable protein such as soy flour, fermented corn meal could also serve as a major source of protein, especially in weaning foods for infants (Plahar *et al.*, 1983).

Important microorganisms such as *Saccharomyces cerevisae*, *Candida tropicalis*, *Candida krusei* and *Lactobacillus plantarum*, associated with corn meal fermentation, have been enumerated, isolated and identified (Akinrele, 1970; Obiri-Danso, 1994). In addition, major volatile carboxylic acids such as acetic, propionic and butyric acids produced during fermentation have been identified (Plahar & Leung, 1982). Previous studies into the nutritional qualities of fermented corn meals have focused primarily on the bioavailability of minerals, notably calcium and phosphorus (Amoah & Muller, 1975). Currently, there are no published reports on the effect of fermentation on starch or carbohydrate digestibilty of corn meal. The protein quality of fermented corn meals (with or without fortification) based on the more traditional protein efficiency ratio (PER) and relative nutritive value (RNV) methods have been reported (Plahar *et al.*, 1983; Hamad & Fields, 1979). However, the PER method is criticized for its inability to properly credit protein used for maintenance purposes, while the use of the RNV method becomes limited in samples severely lacking in lysine. The Codex Committee on Vegetable Proteins, which was established to develop international standards for vegetable protein products, has recommended amino acid scores, corrected for true digestibility of protein (as determined by the rat balance method), or protein digestibility corrected amino acid score (PDCAAS), as the most suitable routine method for evaluating protein quality of vegetable protein products and other food products (Sarwar & McDonough, 1990).

The present study was undertaken to determine the effects of natural fermentation and soy fortification on the protein quality of corn meals cooked into a traditional Ghanaian weaning food using the PDCAAS methodology. The effect of natural fermentation on *in vitro* carbohydrate digestibility of the non-fortified meal is also reported.

MATERIALS AND METHODS

Sample preparation and fermentation

Corn (white normal dent) was obtained from the Spindle Top Farm, Department of Agronomy, University of

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Kentucky. Defatted soy flour was obtained from Owensboro Grain (Owensboro, KY). Whole corn grains were milled to pass through a 1.0-mm screen in a Wiley mill (Arthur H. Thomas Co., Philadelphia, PA). Corn meal was prepared by mixing milled corn with distilled water (1:1.5, w/v). The meal was covered with aluminium foil and naturally fermented at room temperature (25°C) for up to 6 days. Fermenting meal samples were removed daily and cooked into '*akasa*' (a traditional Ghanaian weaning porridge) by the method of Andah & Muller (1973), and as reported by Plahar *et al.* (1983). Part of the meal was also mixed with defatted soy flour (9:1, w/w) and cooked by the same method. Samples were lyophilized in a Unitrap 10-100 freeze-dryer (Virtis Co., Gardiner, NY) and finely ground to pass a 1.0-mm screen in an Udy grinder (Udy Corporation, Fort Collins, CO) prior to analyses.

Proximate analyses

The moisture content of samples was determined by the official method of the American Association of Cereal Chemists (AACC, 1983). Samples were analyzed for levels of total nitrogen, fat and crude fiber using methods of the Association of Official Analytical Chemists (AOAC, 1984). The values were calculated on a dry weight basis.

Evaluation of protein quality

Protein quality of samples was evaluated using the PDCAAS (true protein digestibility×the lowest amino acid ratio) procedure of Sarwar & McDonough (1990). True protein digestibility was by the rat balance method as standardized by McDonough *et al.* (1990). Amino acid ratios [(mg of an essential amino acid in 1.0 g of test protein)/(mg of the same amino acid in 1.0 g of reference protein)×100] were calculated using the FAO/WHO/UNU (1985) suggested pattern, based on lysine and threonine as first limiting amino acids in the corn meals and corn meal–defatted soybean flour mixtures, respectively. Amino acid profile was by the AOAC approved method (AOAC, 1990). 2,4-Dinitrofluorobenzene (DNFB)-available lysine was determined by the modified Carpenter method (Booth, 1971).

In vitro carbohydrate digestibility

The *in vitro* carbohydrate digestibility procedure of Dahlin & Lorenz (1993) was used. Total carbohydrate content of digested samples was analyzed using the phenol–sulfuric acid method (Dubois *et al.*, 1956).

Statistical analysis

Data were analyzed statistically, where applicable, by analysis of variance. Means were separated using Tukey's standardized range test (SAS, 1990).

RESULTS AND DISCUSSION

Protein quality

Protein quality of the fermented corn meals was determined using the protein digestibility corrected amino acid scores (PDCAA scores). The effects of fermentation and soy fortification on PDCAA scores of samples of corn meals are presented in Fig. 1. Natural fermentation caused a steady increase in PDCAA scores of the corn meals. The increase was significant ($P < 0.05$) after 3 days of fermentation, and continued to increase as fermentation progressed. The improvement in protein digestibility as a result of fermentation is caused by the

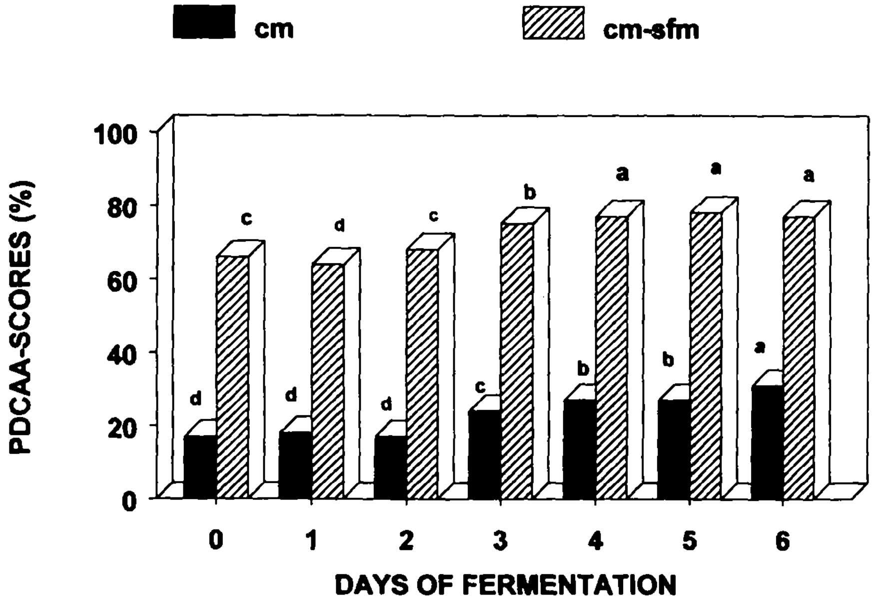

Fig. 1. Effects of fermentation and soy fortification on protein digestibility corrected amino acid (PDCAA) scores of cooked corn meal. Values are means of two determinations. Different letters for the same measurement among samples show significance ($P < 0.05$). cm, corn meal; cm–sfm, corn meal–soy flour mixture.

enhanced proteolytic activity of fermenting microflora. Proteolytic enzymes cause a partial breakdown of protein to peptides and amino acids, resulting in improved protein digestibility (Kao & Robinson, 1978). Addition of defatted soy flour (10%) to the fermenting meals caused further significant improvement in the PDCAA scores. The results are consistent with other reports on the improvement in quality of corn protein by protein complementation or supplementation as determined by the more traditional evaluation methods (Ekpenyong *et al.*, 1977; Adeniji & Potter, 1978; Plahar *et al.*, 1983). Higher levels of soy flour (>10%) imparted a strong undesirable flavor to the mixture. Plahar *et al.* (1983) reported only a slight increase in protein quality when the amount of soy flour was increased from 10% to 20%. The higher concentration of soy flour also reduced its preference by sensory testing. Extending the fermentation period beyond 3 days appears to enhance the protein quality further.

Figure 2 shows the effects of fermentation and soy fortification on available lysine in both the corn meal and corn meal–soy flour mixture. Lysine is the first limiting amino acid in corn and most other cereals. Natural fermentation improved the available lysine content of the cooked corn meal. This result is in contrast with the findings of Plahar *et al.* (1983), who reported an 18.1% loss in the available lysine content of a maize meal fermented for 3 days and dehydrated by air-drying. In this study, the available lysine content of the lyophilized corn meal increased about 14% after 3 days

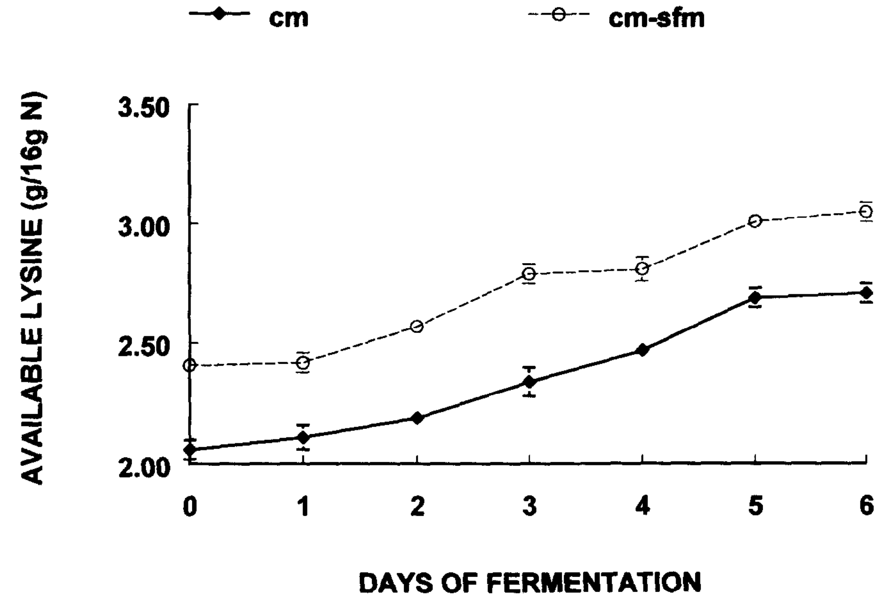

Fig. 2. Effects of fermentation and soy fortification on available lysine content of cooked corn meal. Values are means of two determinations. Error bars represent standard deviations of the means. Other details as in Fig. 1.

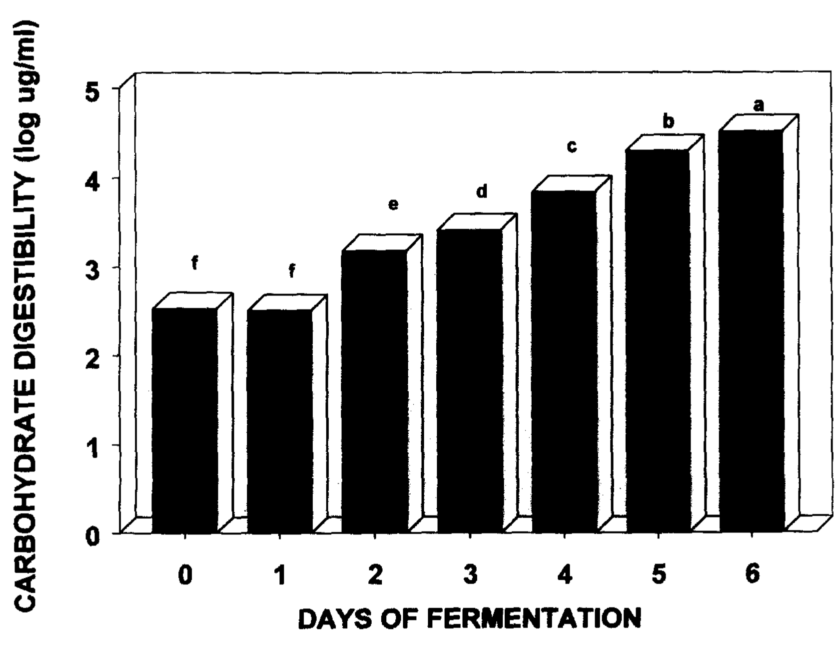

Fig. 3. Effect of fermentation on carbohydrate digestibility and of cooked corn meal. Values are means of three determinations. Different letters show significance ($P < 0.05$).

of fermentation, and to more than 30% after 6 days of fermentation. The difference could be attributed to the mode of drying (air-drying versus freeze-drying), and to the extent of fermentation. Hamad & Fields (1979) reported increases in the available lysine contents of several cereals (including maize) after 6 days of fermentation. Fortifying the corn meal with defatted soybean flour caused a further significant improvement of the available lysine content (Fig. 2).

Carbohydrate digestibility (*in vitro*)

The effect of fermentation on *in vitro* carbohydrate digestibility of corn meal samples is shown in Fig. 3. An increase in the fermentation period resulted in a gradual increase in carbohydrate digestibility. The effect became much more significant after 3 days of fermentation, and continued to increase tremendously afterwards. This increase in carbohydrate digestibility may be due to the breakdown of starch as a result of the activity of the naturally fermenting microorganisms, or enzymes inherent in the corn grain.

CONCLUSION

Traditional indigenous fermentation combined with soy fortification improved protein quality as measured by the protein digestibility corrected amino acid score method, and the available lysine content of corn meal. Fermentation also improves the carbohydrate digestibility. Both the improvement in protein quality and carbohydrate digestibility are dependent on the extent of fermentation.

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