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Digestibility and antinutrient properties of acidified and extruded maize–finger millet blend in the production of *uji*

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Abstract

Lactic and citric acids were used as alternatives to backslop fermentation in the manufacture of extruded *uji* (a thin porridge from eastern Africa). Acidity of the blends was reduced by fermentation or progressively lowered with 0.1, 0.5 and 1.0 mol/l lactic or citric acids before extrusion. The absence of ethanol soluble starch in the extrudates indicated that extrusion solubilizes starch without formation of maltodextrins. In vitro starch digestibility increased from 20 mg maltose/g starch in the raw blend to about 200 mg/g after extrusion. Extrusion reduced total dietary fibre by 39–68%, redistributed soluble to insoluble fibre ratios and had a negligible effect on the formation of resistant starch (less than 1 g/100 g). In vitro protein digestibility increased after fermentation or acid treatment followed by extrusion. Nitrogen solubility index decreased by 40–50% when the unfermented, lactic or citric acid treated blends were extruded, but increased by 20% when the blend was fermented before extrusion. Amino acid analysis showed that histidine, lysine and arginine contents were lowest in the fermented-extruded blends. Tannin content decreased from 1677 mg/100 g in the raw blend to between 551 and 1093 mg/100 g in the extrudates whereas phytate content remained unaffected by extrusion (248–286 mg/100 g).

Keywords: Maize; Finger millet; Organic acids; Extrusion; Digestibility; Antinutrients

1. Introduction

Uji is a thin lactic fermented porridge prepared from cassava flour or whole milled cereals of maize, sorghum and finger millet and is widely consumed in eastern Africa as a refreshing drink. A lot of flexibility exists in the formulation of the raw materials but the maize–-finger millet blend is especially preferred because of the chocolate-brown colour of the end-product. This blend is first diluted with water to give a 30–40 g/100 ml slurry which is then spontaneously or backslop fermented for 24 h at 25–35 °C (Onyango, Henle, Hofmann, & Bley, 2004a). The fermented slurry is further diluted to 10 g/100 ml, cooked for 30 min, sweetened with sugar and served warm. Despite its low energy and nutrient content (Onyango, Noetzold, Bley, & Henle, 2004b), and high levels of polyphenols and phytates in the raw materials (Lorri & Svanberg, 1993; Mbithi-Mwikya, van Camp, Yiru, & Huyghebaert, 2000), *uji* remains the most important and affordable weaning food among the poor in eastern Africa. Lactic acid, resulting from the predominance and metabolic activities of lactic acid bacteria, is the main nonvolatile aroma compound in fermented *uji* although an extensive range of branched alcohols, carboxylic acids, esters and aldehydes are also produced and contribute to flavour (Masha, Ipsen, Petersen, & Jakobsen, 1998; Onyango, Bley, Raddatz, & Henle, 2004c). Flavour differences exist between

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different batches of fermented *uji* and are influenced by the prevailing temperature, humidity, duration of fermentation, method of inoculation (i.e. backslop or spontaneous fermentation), chemical composition of the substrate and its buffering capacity, added ingredients and the compatibility and interactions of the microbial flora. The laboriousness associated with the preparation of *uji*, inconsistent flavour and unreliability of spontaneous fermentation forces many urban-based and increasingly time conscious consumers to simply add lemon extract to unfermented *uji* during cooking in order to reproduce a standard sour tasting product. The use of lemon juice as an acidulant is due to its high content of citric acid which however is not a naturally occurring flavour compound of fermented *uji*.

Extrusion cooking is one of the most efficient and versatile food processing technologies that can be used to produce pre-cooked and dehydrated foods. We have previously reported that extrusion cooking of fermented *uji* improves in vitro protein and starch digestibility (Onyango et al., 2004b). Improved protein digestibility is due to degradation of complex storage proteins by endogenous and microbial proteases during fermentation and thermal denaturation of protein by extrusion whereas improved starch digestibility results from increased susceptibility of starch to amylase hydrolysis, loss of structural integrity and partial solubilization of starch molecules. Extrusion also influences the amount of dietary fibre and resistant starch (RS) in foods. Unlu and Faller (1998) have reported that adding certain forms of starch or citric acid to corn meal prior to extrusion modifies RS and dietary fibre. Fermentation of sorghum-based foods before extrusion has also been reported to counteract the formation of RS whereas direct acidification does not (Knudsen & Munck, 1985). The possible formation of RS in fermented or directly acidified and extruded *uji* warrants investigation because consumers value the porridge as a dietary source of highly digestible carbohydrate.

The most important antinutrients in *uji* prepared from maize–finger millet blend are polyphenols and phytates. Finger millet varieties from eastern Africa have varying amounts of tannins (270–2000 mg/100 g) whereas both maize and finger millet are rich sources of phytic acid (Lorri & Svanberg, 1993; Mbithi-Mwikya et al., 2000; Egli, Davidsson, Juillerat, Barclay, & Hurrell, 2002). These antinutrients form complexes with micronutrients such as iron, calcium and zinc and reduce their solubility and bioavailability. Tannins also complex enzymes of the digestive tract adversely affecting utilization of proteins and carbohydrates and resulting in reduced growth, feeding efficiency, metabolizable energy and bioavailability of amino acids. Traditional artisanal technologies such as decortication, soaking, germination and fermentation of cereal-based foods reduce the levels of tannins and phytates, increase bioavailability of amino acids and mineral elements and improve protein and starch digestibility (Lorri & Svanberg, 1993; Mbithi-Mwikya et al., 2000; Mamiro, van Camp, Mbithi-Mwikya, & Huyghebaert, 2001); but these technologies are limited by their laborious and time-demanding nature. The effect of extrusion cooking on phytic acid has not been clearly elucidated. Some authors (Sandberg, Andersson, Kivistö, & Sandström, 1986; Ummadi, Chenoweth, & Uebersax, 1995; Gualberto, Bergman, Kazemzadeh, & Weber, 1997) reported no change whereas Le Francois (1988) reported a decrease in phytic acid content in extruded products. Very little has been published on the effects of extrusion on tannins in cereals (Camire, 2001), but El-hady and Habiba (2003) have reported significant reduction in tannin content after extruding legume seeds at different moisture contents.

Although processing of *uji* has remained a largely home-based or at best artisanal activity using rudimentary equipments and techniques, untapped potential exists for its commercialization. It is with this background in mind that this study considers the application of a single-screw laboratory extruder to produce ready-to-eat *uji* from maize–finger millet blend. In order to control the souring process and obtain a standard product, backslop fermentation was replaced with different molarities of citric or lactic acids before extrusion. The effect of these processing conditions on in vitro starch and protein digestibility, amino acid content, phytates, tannins, resistant starch and different fractions of dietary fibre was evaluated.

2. Materials and methods

2.1. Preparation of flour blends and extrusion

Maize (*Zea mays*) and finger millet (*Eleusine coracana*) were purchased in Migori district, Kenya. The cereals were cleaned and hammer milled through a mesh having 1000 μm sized pores (KIRDI, Kenya) before blending in 1:1 ratio and sifted through a 600 μm sieve. We have reported the proximate composition of this blend in a previous publication (Onyango et al., 2004b). Moisture content of the blend was adjusted to 19 g/100 g by pipetting appropriate amounts of 0.1, 0.5 and 1.0 mol/l food-grade citric acid monohydrate (Applichem GmbH, Darmstadt, Germany) or lactic acid (Grüssing GmbH, Filsum, Germany) and manually mixing in a wide bowl. The fermented slurry was prepared by adding 66 g flour to 100 ml distilled water. This slurry was inoculated with 10 ml/100 ml of previously fermented maize–finger millet slurry (backslop culture) and incubated in a Memmert Cabinet (Memmert GmbH, Schwabach, Germany) at 30 °C for 24 h. The fermented slurry was spread thinly on an