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Effect of different process combinations on the fermentation kinetics, microflora and energy density of *ben-saalga*, a fermented gruel from Burkina Faso

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Abstract

Three different processes combining cooking (C), addition of malt (M) and/or backslop inoculation (I) were investigated to increase the energy density (ED) of *ben-saalga*, a millet-based fermented gruel and their effects on fermentation kinetics and microbiological characteristics were assessed. In the process combining cooking and inoculation (CI) and in the control (traditional processing methods), glucose and fructose were the main sugars and their concentrations decreased during the settling step (fermentation). In the process combinations that included the addition of malt (CM and CMI), maltose was the main sugar that accumulated during settling. In the CM process combination, the start of fermentation was considerably delayed due to the marked reduction in natural microflora during cooking. In contrast, in the CI and CMI process combinations, inoculation by back slopping accelerated acidification, resulting in a pH value of below 4.0 after 7 h of fermentation. Although malt was added at a very low rate (0.125%), gruels made using CM and CMI process combinations, and prepared at a suitable consistency, had an ED close to or above 84 kcal/100 g of sweetened gruel, the minimum value required for complementary food.

Keywords: Pearl millet; Lactic acid fermentation; Sugars; Organic acids; Complementary food; Energy density; Malt

1. Introduction

Traditional cereal-based fermented foods, such as *poto-poto*, *ogi*, *kenkey* and *ben-saalga*, are well accepted and widely consumed in Africa (Blandino, Al-Aseeri, Pandiella, Cantero, & Webb, 2003; Oyewole, 1997). Some of these traditional cereal-based fermented gruels are frequently used as complementary foods for infants and young children. However, they are characterized by a low energy and nutrient density (Lorri & Svanberg, 1994), well below the values recommended by Dewey and Brown (2003) for complementary foods. The consumption of high energy density (ED) gruels enables improvement of the infant's energy and nutrient intakes (Brown et al., 1995; Den Besten, Glatthaar, & Ijsselmuiden, 1998; Moursi, Mbemba, & Trèche, 2003; Vieu, Traoré, & Trèche, 2001).

The ED of cereal-based gruels depends on their flour content. However, this flour content is limited by the thickening of the gruels due to the swelling of the starch during cooking, which results in gruels with low EDs. One of the ways to obtain a thin cereal-based gruel with a high ED is to achieve partial hydrolysis of the starchy fraction. The effect of natural fermentation on the viscosity of cereal-based gruels has already been assessed. It has been shown that natural lactic acid fermentation of cereal gruels has a slight viscosity-reducing effect that cannot result in thin gruels with high ED (Lorri & Svanberg, 1993; Westby & Gallat, 1991).

Different technological methods have been tested to increase the ED of fermented and unfermented

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complementary foods for infants. The addition of α-amylase from commercial sources or produced from germinated cereals to gelatinize starch proved to be an efficient method (Kitabatake, Gimbi, & Oi, 2003; Mosha & Svanberg, 1983; Thaoge et al., 2003). Recently, several studies tested the combination of the use of germinated cereals and fermentation to increase gruel ED (Thaoge et al., 2003).

Ben-saalga is a pearl millet-based fermented gruel widely consumed by infants and young children in Ouagadougou (Burkina Faso). As it is the case in many other traditional cereal-based fermented gruels, the dry matter content of *ben-saalga* is very low (Guyot et al., 2003) and consequently its ED is not high enough to meet the energy requirements of infants and young children. Modifications of the traditional processing method are required to produce an improved gruel with the suitable characteristics.

The present work aimed at increasing the ED of this fermented gruel by implementing three different combinations of processes (pre-cooking, addition of malt flour and inoculation by back-slopping) in addition to the processes traditionally used to produce *ben-saalga*. These processes were chosen according to their potential ability to favour partial starch hydrolysis (pre-cooking and addition of malt) and also to promote rapid acidification by lactic acid fermentation (back-slopping) to improve hygienic conditions (Nout, Rombouts, & Havelaar, 1989). In addition to the assessment of the influence of these processes on the fermented gruel ED, special attention was paid to their effects on fermentation kinetics and on microflora.

2. Materials and methods

2.1. Materials

Pearl millet (*Pennisetum glaucum*) and aromatic ingredients such as ginger and mint used in the preparation of *ben-saalga* were purchased on the retail market in Ouagadougou. Malted grains of barley were obtained from Brakina, an industrial brewery in Ouagadougou.

2.2. Description of the processing conditions

The traditional processing of pearl millet into *ben-saalga* has been previously described in details (Tou et al., in press). It comprises the following main steps: washing, soaking the pearl millet grains and milling them in wet conditions, kneading and sieving the dough, settling the diluted slurry to allow natural fermentation to occur (fermentation step) and cooking the fermented slurry to obtain the gruel *ben-saalga*. The flow chart of traditional processing method (used as control), and the process combinations including new processes are presented in Fig. 1. These experiments were performed at pilot-scale using the facilities of the University of Ouagadougou, in the same conditions and with the same raw materials as local producers. Results are means of triplicate experiments for control and process combinations. The innovations introduced in the traditional process consisted in different process combinations: pre-cooking, addition of malt and inoculation by back-slopping of the slurry obtained after the sieving/kneading step. The process combinations were called "CI" for the combination of pre-cooking and inoculation, "CM" for the combination of pre-cooking and addition of malt and "CMI" for the combination of the three processes. The conditions for each process (pre-cooking, addition of malt and inoculation) are described below.

2.2.1. Pre-cooking step (C)

The pre-cooking step consisted in boiling the unfermented slurry resulting from sieving for 10 min to gelatinize the starch and to allow either the action of malt amylase in CM and CMI process combinations or the possible action of amylases produced by the natural microflora introduced by the inoculation.

2.2.2. Incorporation of malt (M)

Malted grains of barley were milled and sieved to obtain the malt flour used as the source of amylase. The malt flour was used at the rate of 0.125 g/100 g of the dry matter (DM) of the wet flour. It was added to the unfermented paste, when it had cooled down to 65 °C, 10–20 min after cooking.

2.2.3. Inoculation (I)

Inoculation of the paste by the back-slopping technique was used to favour fermentation after pre-cooking. A portion of fermented paste prepared the day before according to the traditional processing method was used as inoculum. It was added at a rate of 10% (w/w) to the unfermented paste after the addition of malt, when it had cooled down to 35 °C, after 2–3 h.

2.3. Preparation of gruels

For each experiment, five gruels were prepared at different DM contents by boiling the fermented paste for at least 5 min. The dry matter content of gruels was determined by oven-drying at 105 °C to constant weight. The consistency of the gruels was assessed by measurement in a Bostwick consistometer (CSC Scientific Company Inc., Fairfax, VA, USA) (Bookwalter, Peplinski, & Pfeifer, 1968). Measurements were made at 45 °C and the Bostwick flow value was expressed in mm/30 s. The ED of gruels was calculated by multiplying their dry matter content by 4 kcal, which was taken as the mean energy value of 1 g of DM. This ED was calculated for gruels with a suitable consistency, corresponding to a Bostwick flow of 120 mm/30 s (Vieu et al., 2001).

2.4. Fermentation kinetics

Samples were taken during the fermentation step (from 0 to 24 h) of the different process combinations and of the control experiment. The pH was recorded on-line using a pH-meter register (WTW 340i, Fisher Bioblock Scientific,