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Controlled fermentation of the zoom-koom dough using two isolates of lactic acid bacteria (LAB 1 and LAB 5) as starter cultures: Effect on hygienic, rheological, nutritional and sensorial characteristics of the final product

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Zoom-koom is a popular non-alcoholic beverage in Burkina Faso, which is based on cereals and mainly produced by women with important socio-economic implications. This study aimed to evaluate the effect of controlled fermentation using two selected isolates of lactic acid bacteria (LAB) as starter cultures, on the rheological and hygienic quality of zoom-koom. The starter cultures were used singly in monoculture and both in mixed culture. Microorganisms dynamic during the controlled fermentation were followed and enumerated using pour plate methods. The titratable acidity, pH, viscosity, water, ash, crude protein (N×6.25), crude fat and total carbohydrates contents were determined on the final zoom-koom by using standards methods. Sensory analyses of zoom-koom samples were performed by a panel of 30 tasters. The enterobacteria counts of all the controlled fermented zoom-koom samples using starters cultures decreased totally and significantly (p<0.05) from 6.4 (LAB 1), 5.5 log CFU/g (LAB 5) and 3.8 (LAB 1 and 5 in mixed culture) to < 1 log CFU/g after 24 h of fermentation. However, those of natural fermentation without inoculum decreased significantly (p<0.05) but not totally (1.4 log CFU/g after 24 h of fermentation). The zoom-koom from LAB 5 presented the best production of exopolysaccharides and was more viscous and homogenous than the others. All the zoom-koom samples presented a low fat (4.74, 5.21, 5.36 and 5.55%/DM) and ash (0.32, 0.53, 0.49 and 0.69%/DM) contents with a high total carbohydrate (74.18, 76.24, 68.86 and 76.09%/DM) and protein (20.75, 18.02, 25.30 and 17.66%/DM) contents. The most appreciated zoom-koom by the tasters was the controlled fermented zoom-koom from mixed culture (LAB 1 and 5).

Key words: Zoom-koom, starter cultures, fermentation, exopolysaccharides (EPS), hygienic quality.

INTRODUCTION

For Africans, the importance of traditional food fermentation lies in providing improved flavors to existing staples (for example cereals and root crops), and as a cheap way for food preservation and enhancement of the
nutritional quality and digestibility of the raw products (Olasupo et al., 2010). Frequently, fermented foods are considered to have health benefits, and in many regions, they are believed to aid in the control of some diseases, in particular intestinal disorders (Mathara et al., 2004). Traditional fermented foods still play a major role in the diet of numerous societies worldwide. The African dietary ethos includes both fermented and unfermented cereals and cassava products, wild legume seeds, but also meat, milk products and alcoholic beverages (Tamang and Samuel, 2010). Zoom-koom is one of common street-vended beverage and it is produced by crafts women. It is sold in all parts of Burkina Faso, mainly in cities such as Ouagadougou, Bobo-Dioulasso and Koudougou (Icard-Vernière et al., 2010). The grains of millet or sorghum are soaked overnight and then washed and mixed with spice (ginger and mint). The blend is ground into a dough, diluted with water, and then filtered using a clean muslin cloth to obtain zoom-koom, in which sugar and tamarind juice are added to give a sweet and sour taste. The production of zoom-koom is usually done in unhygienic environmental conditions (Besadjo-Tchamba et al., 2014; Soma, 2014; Tapsoba et al., 2017a).

Recently, a study on the traditional process of zoom-koom, showed the positive impact of the fermentation on the hygienic quality of this drink (Tapsoba et al., 2017a). Some isolates of lactic acid bacteria (LAB) involved in the zoom-koom production process identified as Weissella cibaria/confusa had shown their ability to produce exopolysaccharides and antimicrobial compounds (Tapsoba et al., 2017b). These technological properties are very important for the improvement of the safety and the texture of the zoom-koom in controlled fermentation. For example, the use of exopolysaccharides (EPS)-producing LAB strains as ferment during the production of fermented milks improved the texture and decreased the syneresis (Zannini et al., 2016). The success of EPS application in the food industry is generally dictated by its ability to bind water, interact with proteins, and increase the viscosity of the milk serum phase. EPS may act as texturisers and stabilisers, and consequently, avoid the use of food additives (Duboc and Mollet, 2001; Zannini et al., 2016). The availability of LAB starter cultures to produce exopolysaccharides in situ during fermentation could be a suitable alternative for products whose polysaccharides addition requires the specification as food additives, which is a condition not much appreciated by consumer. Zoom-koom is a suspension of millet fermented dough in water, which settles quickly. The use of EPS-producing LAB isolates, for controlled fermentation could improve the physical stability of this beverage. Moreover, LAB are generally recognized as safe (GRAS) due to their long history of safe use in food production, and many of them have the qualified presumption of safety (QPS) status (Lahtinen et al., 2011; Caggianiello et al., 2016). Controlled fermentation using starter cultures allowed improvement of the hygienic and nutritional quality of traditional fermented products (Egounlety et al., 2007; Sawadogo-Lingani et al., 2008; Yao et al., 2009; Soma, 2014).

This study aimed to use two isolates of LAB producing EPSs and antimicrobial compounds (LAB 1 and 5) as starter cultures, to improve the rheological, nutritional, sensory and hygienic quality of zoom-koom.

**MATERIALS AND METHODS**

**Origin of starters’ cultures**

The LAB isolates (LAB 1 and 5) used as starters cultures (pure cultures) were obtained from traditional fermentation process of zoom-koom (Tapsoba et al., 2017a). These isolates were previously characterized and identified as W. confusa/cibaria by using 16S rRNA gene sequencing and were able to produce EPSs and antimicrobial compounds against Escherichia coli; Pseudomonas aeruginosa and Salmonella typhimurium (Tapsoba et al., 2017b).

**Preparation of LAB inoculums**

The two selected LAB isolates (previously stored in MRS-broth + glycerol at -20°C) were subcultured onto mMRS agar and incubated for 48 h at 37°C. The isolated colonies were then subcultured in 10 mL of MRS-broth and incubated for 24 h at 37°C. 0.1 mL of culture broth of each tube initially prepared was subcultured in MRS-broth (10 mL) and then incubated for 16 to 18 h at 37°C. For each isolate, the culture broth obtained after 16-18 h of incubation was distributed in sterile cryotubes (1 mL/tube) then centrifuged at 5000 g for 10 min. The supernatant of each tube was removed and the pellet (cells) of the tube was retained. To this pellet was added 1 mL of sterile diluent [0.1% (w/v) peptone (Difco), 0.85% (w/v) NaCl (Sigma), pH 7.2 ± 0.2] after vortexing, a further centrifugation was carried out at 5000 g for 10 min. The supernatant was again removed and the pellet was kept. One millimeter (1 mL) of sterile diluent was added to the pellet and, after stirring, the suspension of cells which constitutes the inoculum was stored in the refrigerator at 4°C. The concentration of viable cells of the inoculum was determined by enumeration on mMRS agar. The inoculum was used at a rate of 1% (v/v) (Sawadogo-Lingani et al., 2008; Soma, 2014) in the millet dough for controlled fermentation.

**Controlled fermentation using the isolates**

Controlled fermentation in monoculture was carried out at 30°C in an incubator (Binder 78532 Tuttinglen, GERMANY) using separately LAB 1 and 5. For each isolate, 20 mL of inoculums were prepared to inoculate 2 L of millet dough made with millet. For controlled fermentation in mixed culture (with both LAB 1 and 5), 20 mL of mixed inoculum (10 mL of LAB 1 inoculum + 10 mL of LAB 5 inoculum) was used to inoculate 2 L of millet dough. The controlled fermentation of the millet dough with the isolates were followed by...
sampling at intervals of: 0, 4, 6, 8, 10 and 24 h for laboratory analyses. For each sample, pH, titratable acidity, mesophilic microorganisms, lactic acid bacteria, enterobacteria, yeasts and molds were measured or counted. A natural fermentation of the millet dough without inoculum was carried out simultaneously to serve as a control at each fermentation trials. For each isolate, the trial fermentation was done in duplicate. The flow diagram (Figure 1) of zoom-koom previously described (Tapsoba et al., 2017a) was adapted for the production with controlled fermentation.

**Enumeration of microorganisms**

For all the samples, 10 g of the product were soaked in 90 mL of sterile diluent (0.1% peptone, 0.8% NaCl, pH 7.0 ± 0.2) in a stomacher bag and homogenized in a stomacher (stomacher 400 lab blender, England) for 2 min at normal speed. From appropriate ten-fold dilutions, total mesophilic microorganisms were enumerated by pour plate on plate count agar (Liofilchem, Spain) incubated at 30°C for 72 h (ISO 4833, 2003). Yeasts were enumerated by pour plate on Dextrose Chloramphenicol Agar (Liofilchem, Spain), pH 6.6 ± 0.2, and incubated at 30°C for 3–5 days according to ISO 7954 (1988). Lactic acid bacteria (LAB) were enumerated on modified Man, Rogosa and Sharpe (mMRS: MRS-IM agar + maltose) agar (Liofilchem, Spain), incubated anaerobically in an anaerobic jar with anaerocult A at 37°C, for 72 to 96 h according to ISO 15214 (1998). Enterobacteria were enumerated on Violet Red Bile Glucose (VRBG) agar (Liofilchem,
Spain), and incubated at 37°C for 24 h according to ISO 7402 (1993). The results were given as CFU/g or mL of sample. The trial were done in duplicate.

Physico-chemical and nutritional analyses

The pH of the samples was measured with an electronic pH meter (Model HI 8520; Hanna Instrument, Singapore). For solid samples, 10 g of product were mixed with 20 mL of distilled water prior to pH measurement. For liquid samples, the pH was measured directly (Sawadogo-Lingani et al., 2007). For titratable acidity determination, 5 g or 5 mL of sample suspended in 30 mL of ethanol (90°) was mixed 1 h, using an automatic agitator, and centrifuged for 5 min at 3500 g. From the supernatant, 20 mL was transferred to a 50 mL measuring flask and was titrated with NaOH 0.1 N using 1% phenolphthalein as indicator (Soma, 2014). The titratable acidity (as g lactic acid per 100 mL or g of sample) was calculated according to Amoa-Awua et al. (1996). Water content was determined by oven drying the sample at 105 ± 2°C for 12 h (NF V03-707. July 2000); ash content was determined by incineration at 650°C overnight according to the French standard V03-760 (1981); crude protein content (N×6.25) was determined by the Kjeldahl method after acid digestion (NF V03 50, 1970); crude fat content was determined by soxhlet extraction using n-hexane (ISO 659, 1998). Total carbohydrates content were determined by spectrophotometric method at 510 nm using orcinol as reagent (Montreuil and Spik, 1983). The values were expressed in g/100 g of dry matter. The trial were done in duplicate.

Determination of viscosity

The viscosity measurement of the zoom-koom samples resulting from the controlled fermentations by the LAB 1 and LAB 5 isolates, was carried out by using a viscometer (CSC scientific 1-800-458-2558). This measure consisted sinking 10 mL of the zoom-koom samples on a viscometer and measuring the flow rate. The result was expressed in cm/s. The types of zoom-koom were left for settling to observe their homogeneity at different times (25 min and 24 h).

Sensory analysis of zoom-koom samples

The sensory analysis consisted of evaluating the sensory profile of zoom-koom samples: A test of differentiation of the controlled fermented zoom-koom samples compared to the unfermented zoom-koom; used as control sample; a test of the classification of the zoom-koom samples according to the tasters were also performed. Thirty (30) members tasting panel were composed of men and women aged between 15 and more, who had already consumed the zoom-koom. The sensory profile was related to the color (nice, acceptable and mediocre), mouthfeel (very pleasant, pleasant and unpleasant), sweetened taste (very sweet, sweet and little sweet), aroma (very good, good and fair) and acidity (very acidic, acidic and fair acidic).

Statistical analysis

All the data (except sensorial analyses data) were subjected to Analysis of Variance (ANOVA) with the statistical software XLSTAT-Pro 7.5.2 and the means were compared using the test of Student Newman-keuls to the probability level p<0.05. The curves were obtained using Microsoft Excel 2013. The data of sensorial analyses were performed using the Chi² test with the statistical software SPSS.

RESULTS

Microbial growth during fermentation

The inoculum counts were 10⁶ CFU/mL. All the control samples showed the same trend with their corresponding controlled fermentation trials. In this study, one control was presented to illustrate the other controls.

From the results, it is shown that during all the fermentation trials, the enterobacteria counts decreased significantly (P<0.05) after 24 h of incubation (Figures 2, 3, 4 and 5). Thus, from the fermentation using LAB 1 and 5 isolates (singly) as starters cultures in monoculture, the enterobacteria counts decreased from 6.4 (0 h) to < 1 log CFU/g (24 h) (LAB 1 in monoculture) and from 5.5 (0 h) to < 1 log CFU/g (24 h) (LAB 5 in monoculture) as shown in Figures 2 and 3. From the fermentation using both isolates LAB 1 and 5 in mixed culture, the enterobacteria counts decreased from 3.8 (0 h) to < 1 log CFU/g (24 h) as shown in Figure 4. The natural fermentation of millet dough (control) also showed a significant decrease (P<0.05) in enterobacteria counts (Figure 4). However, the enterobacteria counts at 24 h of fermentation were not < 1 log CFU/g. These counts were 1.3 log CFU/g for the natural fermented millet dough samples at 24 h of fermentation (Figure 4). All the final products (zoom-koom) did not contain enterobacteria except the natural fermented zoom-koom samples (Table 1). The yeasts, LAB and mesophillic microorganisms counts increased significantly (P<0.05) after 24 h of fermentation (Figures 2, 3, 4 and 5). Thus, the yeasts counts increased from 4.2 (0 h) to 7.1 log CFU/g (LAB 1 in monoculture) as shown in Figure 2, from 5.3 (0h) to 7.2 log CFU/g (LAB 5 in monoculture) as shown in Figure 3 and from 5.0 (0 h) to 6.8 log CFU/g (both LAB 1 and 5 in mixed culture) as shown in Figure 4. The natural fermentation showed the same trend. The LAB counts increased from 8.3 (0 h) to 8.7 log CFU/g (LAB 1 in monoculture), from 7.9 (0 h) to 8.6 log CFU/g (LAB 5 in monoculture) and from 6.7 to 8.7 log CFU/g (both in mixed culture). The natural fermentation showed the same trend. No moulds were observed after 24 h of fermentation for all the fermentation trials. For all the fermentation trials (natural and controlled fermentation) the LAB, mesophillic microorganisms and yeasts counts decreased a little in the final product (zoom-koom) after diluting and filtering of the dough (at 24 h of fermentation) as shown in Table 1.

From the means comparison of all the controlled fermentation trials, the LAB, mesophillic microorganisms and yeasts counts at 24 h of fermentation were significantly different (P<0.05) from those of 0 h (Figures 2, 3 and 4). The enterobacteria, mesophillic microorganisms, LAB and yeasts counts of natural fermentation at 24 h of fermentation of the dough, were significantly different (P<0.05) from those of 0 h as shown in Figure 5.
Physicochemical parameters during fermentation

**pH**

The pH of controlled fermented samples evolved similarly during all the trials fermentation processes. The pH values decreased significantly after 4 h of fermentation (p<0.001). The pH obtained with the fermentation in mixed culture (LAB 1 and LAB 5) showed the lowest decrease after 4 h of fermentation (from 6.2 to 5.4). The pH decreased slowly (from 6 to 10 h) before stabilizing at pH 4.0 (10 to 24 h) for monoculture fermentation (Figure 6). It should also be noted that the pH measured during the natural fermentation of the *millet* dough without inoculum (control) showed a similar evolutionary trend as that performed with the LAB 1 and LAB 5 isolates (Figure 6).
**Figure 4.** Evolution of the microbial population during the controlled fermentation of millet dough using both isolate LAB 1 and LAB 5 as inoculum (mixed culture): each parameter having a common letter during the fermentation time, are not significantly different according to the Student Newman Keuls test threshold of 5%.

**Table 1.** Microbiological and physicochemical analyses of zoom-koom samples after diluting and filtration of the millet dough from 24 H of fermentation.

| Parameters          | Samples | Microorganisms counts (log CFU/ml) | Titratable acidity (g/100g of lactic acid) |
|---------------------|---------|-----------------------------------|-------------------------------------------|
|                     | Zoom-koom LAB 1 | Zoom-koom LAB 5 | Zoom-koom LAB 1 + LAB 5 | Zoom-koom control |
| Enterobacteria      | < 1      | < 1                              | < 1                                       | 1.1 ± 0.6          |
| Yeasts              | 5.1 ± 4.4 | 6.9 ± 5.7                        | 5.2 ± 4.3                                | 6.3 ± 5.8          |
| Moulds              | < 1      | < 1                              | < 1                                       | < 1                |
| LAB                 | 8.1 ± 7.4 | 8.2 ± 7.3                        | 8.1 ± 7.2                                | 8.0 ± 7.3          |
| Mesophillic microorganisms | 8.3 ± 7.8 | 8.6 ± 7.2                        | 8.2 ± 7.2                                | 8.1 ± 7.5          |
| pH                  | 4.0 ± 0.1 | 4.0 ± 0.1                        | 4.0 ± 0.1                                | 4.0 ± 0.1          |
| Titratable acidity  | 0.29 ± 0.03 | 0.33 ± 0.02                       | 0.33 ± 0.03                              | 0.3 ± 0.01         |

**Titratable acidity**

The titratable acidity of all the samples showed the same evolutionary trend during the trials fermentations. The results show that titratable acidity evolved significantly from 0 to 24 h for all trials fermentations. The highest acidity value was recorded with the monoculture fermentation using the LAB 1 isolate at 24 h (1.24 g of lactic acid/100 g). After dilution and filtration of the 24 h fermented dough, the titratable acidity values of all the fermentations decreased significantly (p<0.001) as shown in Figure 10. It should also be noted that the titratable acidity measured during natural fermentation of the millet dough without inoculum (control) showed a similar evolutionary trend as that performed with the LAB 1 and LAB 5 isolates (Figure 7).

**Viscosity**

From the results of viscosity, the flow tests showed that the zoom-koom fermented by the isolate LAB 5 was the most viscous and homogeneous with a flow of 0.22 cm/s as compared to the natural fermented zoom-koom (control for LAB 5) without inoculum (0.14 cm/s). The flow of the other types of zoom-koom fermented in monoculture with the isolate LAB 1 and in mixed culture with the isolates both LAB 1 and 5 were different from that of the control and less homogeneous than the zoom-koom with the isolate LAB 5. The unfermented zoom-koom was the least viscous and decanted faster than other fermented types. After 25 min and 24 h of settling, the control (natural fermented) zoom-koom settled faster than the controlled fermented zoom-koom using LAB 5.
Figure 5. Evolution of the microbial population during the natural fermentation process of the millet dough without inoculum (control): each parameter having a common letter during the fermentation time are not significantly different according to the Student Newman Keuls test threshold of 5%.

Figure 6. Evolution of the pH during the natural fermentation of the millet dough without inoculum (control) and the controlled fermentation of millet dough using LAB 1 and LAB 5 isolates in monoculture and mixed culture.

The last one was more viscous and cloudy.

Nutritional characteristics of fermented zoom-koom samples

The fermented zoom-koom sample from monoculture with the isolate LAB 5 contained less water and more dry matter content than the others, but not significantly different on statistical plan (p<0.05) (Table 2). This sample contained more fat, total carbohydrates and ash than the zoom-koom sample with isolate LAB 1. However, the zoom-koom sample with isolate LAB 1 contained more proteins as compared to the zoom-koom with isolate LAB 5. Both samples contained more sugars than the mixed culture fermentation sample. The control sample (natural fermentation without inoculum) contained more fat and ash than the others. The highest ash contents were obtained with the zoom-koom LAB 5 samples and the natural fermented zoom-koom sample.
Figure 7: Evolution of titratable acidity during the natural fermentation of the millet dough without inoculum (control) and the controlled fermentation of millet dough using LAB 1 and LAB 5 isolates in monoculture and mixed culture.

Table 2. Nutritional characteristics of fermented zoom-koom samples.

| Samples                        | Water content (%/DM) | Dry matter (%/DM) | Crude fat (%/DM) | Total carbohydrates (%/DM) | Crude proteins (%/DM) | Ash (%/DM) |
|--------------------------------|----------------------|-------------------|------------------|---------------------------|-----------------------|------------|
| Zoom-koom LAB 1                | 81.51 ± 0.00a        | 18.49 ± 0.00a     | 4.74 ± 0.31a     | 74.18 ± 0.02a             | 20.75 ± 0.01a         | 0.32 ± 0.00a |
| Zoom-koom LAB 5                | 81.04 ± 1.10b        | 18.96 ± 1.10b     | 5.21 ± 0.05b     | 76.24 ± 0.12b             | 18.02 ± 0.02b         | 0.53 ± 0.00b |
| Zoom-koom LAB 1 and LAB 5     | 81.49 ± 0.01c        | 18.51 ± 0.01c     | 5.36 ± 0.28c     | 68.86 ± 0.01c             | 25.30 ± 0.05c         | 0.49 ± 0.01c |
| Zoom-koom control (without inoculum) | 81.25 ± 0.02d       | 18.75 ± 0.02d     | 5.55 ± 0.34d     | 76.09 ± 0.04d             | 17.66 ± 0.05d         | 0.69 ± 0.01d |

For each column, the values with a common letter are not significantly different according to the Student Newman Keuls test at the 5% threshold. DM, Dry matter.

without inoculum (control). Natural fermented zoom-koom (without inoculum) showed the best fat levels and the lowest value of proteins. All the samples showed a low level of fat. The highest protein content was obtained with the zoom-koom sample from fermentation in mixed-culture (Table 2), probably due to the high contribution of isolate LAB 1. No significant difference (p<0.05) was observed for water content. The protein content of the zoom-koom sample from the fermentation in mixed-culture was significantly different from that of the other samples (p<0.05). The ash contents of the different samples were significantly different from each other (p<0.05). The total carbohydrates in the zoom-koom from mixed culture fermentation were significantly different from the others (p<0.05).

Sensorial characteristics of fermented zoom-koom samples

From the sensory analysis results, it appeared that 70% of the tasters found that the zoom-koom resulting from the monoculture fermentation with the isolate LAB 1 and the zoom-koom resulting from the fermentation in mixed culture with both isolates LAB 1 and LAB 5 had a nice color. However, 50 and 13.3% of the tasters found that the zoom-koom from the monoculture fermentation with the isolate LAB 5 and the control zoom-koom showed a nice color (Figure 8). The zoom-koom with the isolate LAB 1 and the zoom-koom from the fermentation in mixed-culture showed a better aroma (46.7 and 46.7% of the tasters, respectively) than the zoom-koom with the isolate LAB 5 and the control zoom-koom (40 and 43.3%, respectively) according to the tasters (Figure 8). The mouth feel after tasting the zoom-koom in mixed culture (both LAB 1 and Lab 5) and the control zoom-koom appeared pleasant (63.3 and 63.3%, respectively). Approximately 60% of the tasters appreciated pleasant mouth feel after tasting the zoom-koom resulting from monoculture fermentation with isolate LAB 1 on one hand and isolate LAB 5 on the other hand. The tasters (73.3%) also found that the zoom-koom with isolate LAB 1 and
Figure 8. Organoleptic characteristics of zoom-koom samples according to the tasters.

DISCUSSION

The enterobacteria, mesophilic microorganisms and LAB counts increased after 4 h of fermentation, while the yeast counts remained almost unchanged. This increase could be due to the fact that at the beginning of the fermentation, the medium was rich in nutrients with a favorable temperature which allowed the growth of microorganisms. Indeed, water activity and the presence of nutrients could promote the activation of spores, the growth of bacteria, yeasts and molds (Tawaba et al., 2013). LAB are generally described as mesophilic microorganisms with an optimal growth temperature of 30°C (van de Guchte et al., 2002). Gymnase (2011) also indicated that cereals contain prebiotics which stimulate the growth of enterobacteria and LAB for the present study and zoom-koom is a cereal based beverage. The decrease in enterobacteria counts during the fermentation (8, 10 and 24 h) is probably due to the growth of LAB which are well known to produce antimicrobial substances such as organic acids (lactic, acetic, formic and caproic phenolic), carbon dioxide, hydrogen peroxide, ethanol and bacteriocins during fermentation (Messens and De Vuyst, 2002).

The pH of the fermented dough remained stable at pH 4.0 from 10 to 24 h and this induced an effective action of the acidity on enterobacteria. The results corroborate those of Soma (2014) who observed a decrease in enterobacteria counts in the fresh zoom-koom after 24 h of fermentation, using a strain of Lactobacillus fermentum as starter. This result also confirmed previous study of Tapsoba et al. (2017a) where a decrease in
enterobacteria and yeasts counts was found after 10 h of natural fermentation of the zoom-koom based on millet and red sorghum dough. In addition, the LAB isolates used as starter in this study have been selected on the bases of their antibacterial and antifungal activities (Tapsoba et al., 2017b).

The presence of enterobacteria in the control dough at 24 h and their absence in the dough with the inocula, means that the selected isolates have maintained and expressed their antibacterial properties. In fact, these selected isolates were able to produce bacteriocins like compounds or similar metabolites according to the antimicrobial activities performed (Tapsoba et al., 2017b). It was also observed in previous study that the bacteriocin produced by W. confusa had a broad spectrum of antimicrobial activity inhibiting both Gram-positive and negative bacteria (Hweh and Koshy, 2015). The results also highlighted an increase of yeasts population after 24 h of fermentation, while those of LAB decreased; this could be due to the fact that LAB by their
carbohydrates metabolism acidify the medium which becomes favorable to the growth of yeasts and molds (Tchekessi et al., 2014). According to Yao et al. (2009), the acid environment created by LAB promoted yeasts growth. From a hygienic point of view, this acidification is a major asset because it prevents the growth of most pathogenic bacteria (Tchekessi et al., 2013). After 24 h of fermentation, the population of enterobacteria decreased totally during the controlled fermentation with the selected isolates. In general, the manufacturing of foods and beverages sold on the streets involves manual processes without any good hygiene practices and are subject to numerous contaminations (Sunday et al., 2011; Bsadjo-Tchamba et al., 2014). This contamination was not observed in our zoom-koom produced from controlled fermentation with starter cultures where the conditions were better controlled than previous productions.

The low water content of zoom-koom samples could be due to EPS produced during the dough fermentation with the isolates. Indeed, exopolysaccharides have been shown to increase the viscosity and softness of the milk product and have the ability to retain water molecules, thereby reducing the separation of whey and milk coagulated caseins (Zannini et al., 2016). The water contents of the samples were lower than those of Soma (2014) on unfermented zoom-koom and fermented zoom-koom using a strain of Lactobacillus fermentum as starter. The fermented zoom-koom samples also contained more total carbohydrates but less protein and ash than the zoom-koom samples produced by Soma (2014). The crude fat content of this fermented zoom-koom samples had approximately the same levels than the zoom-koom samples produced by Soma (2014). This difference could be explained in part by the dilution rate and the fact that the zoom-koom samples were produced from whole grains of millet, while those of Soma (2014) were produced from dehulled millet grains.

All the controlled fermented zoom-koom samples were a good source of energy and nutrients. Concerning the sensory characteristics, overall, the fermented zoom-koom samples were found to be more acidic than the unfermented zoom-koom which was slightly acidic, due to the effect of fermentation. All the zoom-koom samples showed a nice color, pleasant taste and good aroma. The best flavor was obtained with the unfermented zoom-koom sample, followed by the zoom-koom from the mixed-culture fermentation. This difference in flavor is due to the fact that with the addition of the tamarind, the zoom-koom presents a better aroma. Nevertheless, LAB allows the development of aroma in the fermented products. These bacteria in mixed cultured during fermentation could diversify aroma production better than when they are in monocultures. Indeed, LAB are well known to produce a variety of compounds that contribute to the taste, flavor, color, texture, consistency, nutritional quality and safety of fermented products (Davidson, 1997; Ayad et al., 2004; Sawadogo-Lingani et al., 2008).

Because they are different from the unfermented zoom-koom, the zoom-koom from the mixed-culture fermentation was preferred by the tasters, followed by the zoom-koom in monoculture with the isolate LAB 1 and then the isolate LAB 5 and finally the unfermented zoom-koom, on the basis of their organoleptic qualities. Since the strains of Weissella spp. occupy an important place in certain African fermented foods, or in European fermented dough, the use of these specific strains as starter cultures can be envisaged (Fusco et al., 2015).

Conclusion

This study showed the efficacy of selected LAB isolates (EPS producer and antimicrobial properties) for controlled fermentation of zoom-koom dough. During this fermentation, the enterobacteria counts reduced to maximum after 24 h of fermentation. Overall, the LAB counts in controlled fermented zoom-koom with inocula were higher than that of natural fermented zoom-koom without inoculum. The zoom-koom obtained with isolate LAB 5 was the most homogeneous and viscous as compared to the other types of zoom-koom. All the types of zoom-koom contained more carbohydrates and protein than fat and ash. The fermented zoom-koom in mixed culture and the zoom-koom control (unfermented) presented the best aromas. From the acid taste point of view, the unfermented zoom-koom was not very acidic as compared to fermented zoom-koom. All zoom-koom types have a good taste after tasting and a nice color. The preferred zoom-koom of the tasters was that resulting from the fermentation in mixed culture. The controlled fermentation using selected LAB isolates allows (i) scaling up of the production of zoom-koom by moving from household to semi-industrial level, (ii) standardizing of the flow diagram of zoom-koom and (iii) improvement of the hygienic, nutritional and organoleptics characteristics of zoom-koom.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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