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Assessment of the technological, physicochemical and microbiological characteristics of the fermented dough used to produce *O'moabu* in the Eastern region of Burkina Faso

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ABSTRACT

O'moabu is a traditional dough made from fermented cereal dough by the *Gourmachema* tribe in the East Region of Burkina Faso. The technological, physicochemical and microbiological characteristics of this food, have been poorly documented. This study aimed to evaluate the characteristics of the fermented dough used in the production of *O'moabu*. Data on production technology were collected through a survey. Physicochemical, microbiological and biochemical analyses were conducted using standard methods. The assessment enabled the generation of a typical production diagram for *O'moabu*. Concerning physicochemical characteristics, pH ranged from 5.57 ± 0.02 to 6.08 ± 0.02, while titratable acidity varied between 0.41 ± 0.01 and 1.04 ± 0.01 g lactic acid/100 g. Regarding microbiological characteristics, total aerobic mesophilic flora ranged from $1.1x10^5$ ± 27 to $4.6x10^7$ ± 10 CFU/g, yeasts from $5x10^2$ ± 37 to $9.5x10^4$ ± 33 CFU/g and lactic acid bacteria from $1x10^4$ ± 25 to $6.7x10^5$ ± 27 CFU/g. Morphological and biochemical tests showed that the yeast isolates belonged to the genera *Saccharomyces* sp. (50%), *Candida* sp. (18.75%), *Torulaspora* sp. (25%) and *Kluyeverommyces* sp. (6.25%). The lactic acid bacteria belonged to the genera *Lactobacillus* sp. (37.5%), *Streptococcus* sp. (12.5%), *Leuconostoc* sp. (25%) and others genera (25%). These yeasts and lactic acid bacteria work in symbiosis to ferment *O'moabu* dough.

Keywords: *O'moabu*, Fermented dough, Biochemical characteristics, Microbiological characteristics, Burkina Faso.

INTRODUCTION

The optimization and diversification of fermentative processes carried out in various parts of the world have been done without knowledge of the existence and role of microorganisms in these transformations (Lortal, 2015). The main advantages of fermentation are preserving certain foods for long periods at lower cost (Blandigo et al., 2003) and improving the nutritional and organoleptic qualities of foods (Saubade, 2016).

Cereal-based fermented foods are an important part of the diet of West African

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people, especially in Burkina Faso. For the 2020-2021 agricultural season, cereal production in Burkina Faso was estimated to be more than five million tons (INSD, 2021). The main cereals used for fermentation are millet, maize and sorghum (Kagambèga et al., 2019). Among the many fermented cereal-based foods, the most common in the West African sub-region are *Ben-saalga* (infant traditional fermented porridges made from Burkina Faso), *Donkounou* (fermented corn dough made from Togo) and *Togwa* (fermented porridge made from Tanzania) (Mugala et al., 2015; Songré et al., 2008). Most of these fermentations were made by lactic acid bacteria, yeasts and molds. Particularly, lactic acid bacteria can degrade a wide range of sugars, such as maltose, sucrose, glucose, fructose and α-galactosides, to produce plant products with lactic acid production (Turpin et al., 2011). Then, lactic acid acidifies the environment and inhibits the growth of undesirable and pathogenic microorganisms. So, lactic acid bacteria are widely used in the food industry because they play an important role in preserving and regulating microbial growth in fermented foods but also modify the sensory properties of the product (Maïwore et al., 2018; Khodja, 2018).

Most of the fermented foods are not yet known, as they have not been sufficiently documented. Thus, the traditional meal of the *Gourmantcheman* tribe called "*O'moabu*" has been least studied. No recent data are available on its production technology nor its physicochemical, nutritional or microbiological characteristics. Therefore, the present study was initiated to evaluate the technological, physicochemical and microbiological characteristics of the fermented dough used in the production of *O'moabu*.

MATERIALS AND METHODS

O'moabu production technology and sampling

The various unit operations in the production of *O'moabu* were recorded through a survey and then entered into a designed form. The information collected covered the processing of millet grain to fermented dough, the cooking of *O'moabu* and the storage method. Technology production data were collected from twenty (20) producers in the city of Fada N'Gourma from August to September 2021. Dough sampling was also made for physicochemical and microbiological analyses. A total of twenty (20) samples of 500 g each of dough were collected, preserved in sterile Falcon tubes and transported in a 4°C cooler to the Laboratory of Biochemistry and Applied Immunology of Josph KI-ZERBO University, Ouagadougou.

Physicochemical analysis of the fermented dough

The pH was obtained using the AOAC (2005) method. Ten grams (10 g) of fermented dough was homogenized in an Erlenmeyer flask containing 90 ml of distilled water and then filtered. The resulting supernatant was used to measure the pH using a pH meter. Two replicates were performed for each sample to obtain the mean value.

Titratable acidity (TA) was measured using the AOAC (2000) method. Ten grams (10 g) of the dough was homogenized in 90 ml of distilled water. After stirring, 20 ml of the mixture was removed and centrifuged for 5 min. Next, 10 ml of the centrifuged supernatant was titrated with 0.1 N NaOH in an Erlenmeyer flask using three drops of phenolphthalein. Two replicates were performed for each sample to obtain the mean value. Titratable acidity was expressed in grams of lactic acid according to the following formula:

$$\text{TA (g Lactic Acid)} = \frac{C1 * Veq}{V} Mm$$

C1: Concentration of NaOH; **Veq:** Equivalent volume of NaOH; **V:** Volume of product titrated; **Mm:** Molar mass of lactic acid

Determination of microbial load

A stock solution (10^{-1}) was obtained by homogenizing 10 g of fermented dough in 90 ml of sterile physiological water. After homogenization, dilutions were made to enumerate the microorganisms involved in dough fermentation. Total aerobic mesophilic flora was counted on plate count agar (Liofilchem Diagnostic-ITALY) by the international standard ISO 4833-2 (2013), while yeasts and molds were counted on

Sabouraud chloramphenicol agar (Liofilchem srl Zona Ind. le-Roseto d. Abruzzi (TE)-ITALY) by the international standard ISO 21527-2 (2008). Lactic acid bacteria were counted on MRS media according to the international standard NF EN 15786 (2009) and NF EN 15787 (2021) methods.

The number of colony-forming units per gram (N) of product was calculated according to the international standard ISO 7218 (2007) method as an average using the following equation:

$$N = \frac{\sum C}{V.d(n1 + 0{,}1n2)}$$

ΣC: Sum of colonies on all plates of the two retained successive dilutions; **V:** Volume of inoculum; **n1** and **n2:** Number of plates for the 1st and 2nd dilutions, respectively; **d:** Dilution rate of the first plate producing countable colonies (low dilution).

Isolation and characterization of microorganisms involved in the dough fermentation

Cells observed on Petri dishes were isolated and purified on MRS, MSE and M17 media respectively for *Lactobacillus*, *Leuconostoc* and *Lactococcus* by the streaking method (Guiraud, 1998). As for yeasts and molds, they were isolated on PDA media (Botton et al., 1999).

Concerning physical characterization, the colony size, morphology, outline, density, surface appearance, color and clustering pattern of pure isolates were observed under a microscope fresh in a drop of water and recorded in tables.

Concerning biochemical characterization, urea production, indole production, glucose degradation, lactose degradation, citrate degradation, mannitol degradation, gas production, hydrogen sulfide production and mobility tests of pure isolates were also carried out through standard methods.

Statistical analysis

Data entry, processing and table management were performed using Excel 2016 software. The pH, titratable acidity and microbiological analysis data were subjected to analysis of variance (ANOVA) using XLSTAT 2019 software. Means were compared using the Student Newman Keuls (SNK) test, and the probability threshold was set at $p < 0.05$.

RESULTS

***O'moabu* process diagram**

Millet is the main cereal used for O'moabu dough production. The production process does not require the addition of other ingredients, but they can be added as required. The main production stages are shown in the diagram in Figure 1. The millet is first sorted to remove impurities and washed two or three times with clean water. The washed millet is then hulled to remove all impurities and anti-nutritional factors. The hulled millet is then soaked in water for 2 to 3 days before being drained out and ground into a moist powder. In the next step, a quantity of water is added to have a very fine paste, in a ratio of one volume of moist powder to two volumes of clean water. The fine paste is then filtered to remove impurities and left in fermentation naturally for 48 hours. During fermentation, the paste separates into two phases: a thick paste in the decanting phase and a liquid supernatant, which is recovered for further processing. After the fermentation, the thick fermented paste is then cooked for 1 hour to obtain a thick baked dough. During the cooking, the acid liquid supernatant is gradually added to the cooking paste until a more or less thick cooked dough is obtained. This cooked dough is then formed into balls of the desired size and put in fresh water. The balls are then cooked back into boiling water for 30 minutes and cooled again for 15 to 20 minutes to room temperature (25 to 35°C). Finally, the balls are stored in clean containers containing fresh clean water for consumption. The water must be changed every 24 hours to ensure good preservation. According to information reported by producers, the *O'moabu* produced can be kept for over a month if hygienic conditions are respected.

Physicochemical and microbiological characteristics of the fermented dough

Concerning physicochemical parameters, the results showed that the *O'moabu* dough was generally acidic, with a pH ranging from 5.57 ± 0.02 to 6.08 ± 0.02 (Table 1). The titratable acidity ranged from 0.41 ± 0.01 to 1.04 ± 0.01 g of lactic acid/100 g.

Concerning microbiological characteristics, total aerobic mesophilic flora varied from $1.1x10^5$ ± 27 to $4.6x10^7$ ± 10 CFU/g, while yeasts and mold ranged from $5x10^2$ ± 37 to $9.5x10^4$ ± 33 CFU/g. Lactic acid bacteria ranged from $1x10^4$ ± 25 to $6.7x10^5$ ± 27 CFU/g. These results revealed significant microbial activity during dough fermentation.

The results of the principal component analysis showed a correlation between the fermented dough samples and acidic pH (Figure 2). The results showed also a strong correlation between the presence of lactic acid bacteria and acidic pH.

Physical and biochemical characteristics of yeast isolates obtained from dough

Physical characteristics of the yeast isolates isolated from *O'moabu* dough are presented in Table 2, while biochemical characteristics are reported in Table 3. On sixteen (16) yeast isolates obtained from the fermented dough, the results indicated that all the yeast isolates were white, smooth in appearance, and creamy or milky in density. The observation of the morphology showed that all the isolates obtained were cocci. Concerning the clustering, cells were isolated or grouped in clusters. The size and outline observation revealed that cells were small, medium or large, with regular outlines.

By observing the biochemical characteristics of the yeast isolates, 50% of identified isolates in this study ferment glucose and lactose but not mannitol and citrate. They were all immobile, urea-, indole-, do not produce gas, nor hydrogen sulfide. The results also showed that 18.75% of the isolates ferment only mannitol and do not ferment glucose, lactose or citrate. They were all immobile, urea-, indole-, and did not produce gas or hydrogen sulfide. The results also showed that 25% of the isolates were all immobile and did not ferment any sugar. They were urea-, indole- and did not produce gas or hydrogen sulfide. Finally, 6.25% of the isolates ferment glucose, lactose, and mannitol and produce gas but did not ferment citrate, nor produce hydrogen sulfide.

Physical and biochemical characteristics of isolated lactic acid bacterial isolates

The physical and biochemical characteristics of the lactic acid bacteria isolates obtained from the fermented dough are shown in Table 4 and Table 5, respectively. A total of eight (08) isolates of lactic acid bacteria were obtained. Microscopically, they were all white, with regular outlines, smooth appearance and creamy density. Cells were grouped into chains, clusters or isolated cells. The cells were coccobacilli, small sticks, long sticks or cocci forms and their size was small, medium or large. The biochemical results showed that 37.5% of the isolates obtained were immobile, oxidase+, catalase+, gram+, urea-, and indole-. They ferment glucose and lactose but not citrate, nor mannitol, and produce neither gas nor hydrogen sulfide. The results showed also that 25% of the isolates obtained were immobile, oxidase+, catalase+, gram+, urea- and indole-. They ferment glucose, lactose and mannitol but not citrate and do not produce hydrogen sulfide, or gas. In addition, 12.5% of the isolates obtained in this study were all immobile, oxidase+, catalase+, gram+, urea-, indole-, and did not ferment any sugar. They did not produce gas or hydrogen sulfide. Finally, 25% of the isolates obtained were immobile, oxidase+, catalase+, gram-, urea-, and indole-. They ferment glucose, and lactose but not citrate and mannitol. They did not produce gas or hydrogen sulfide.

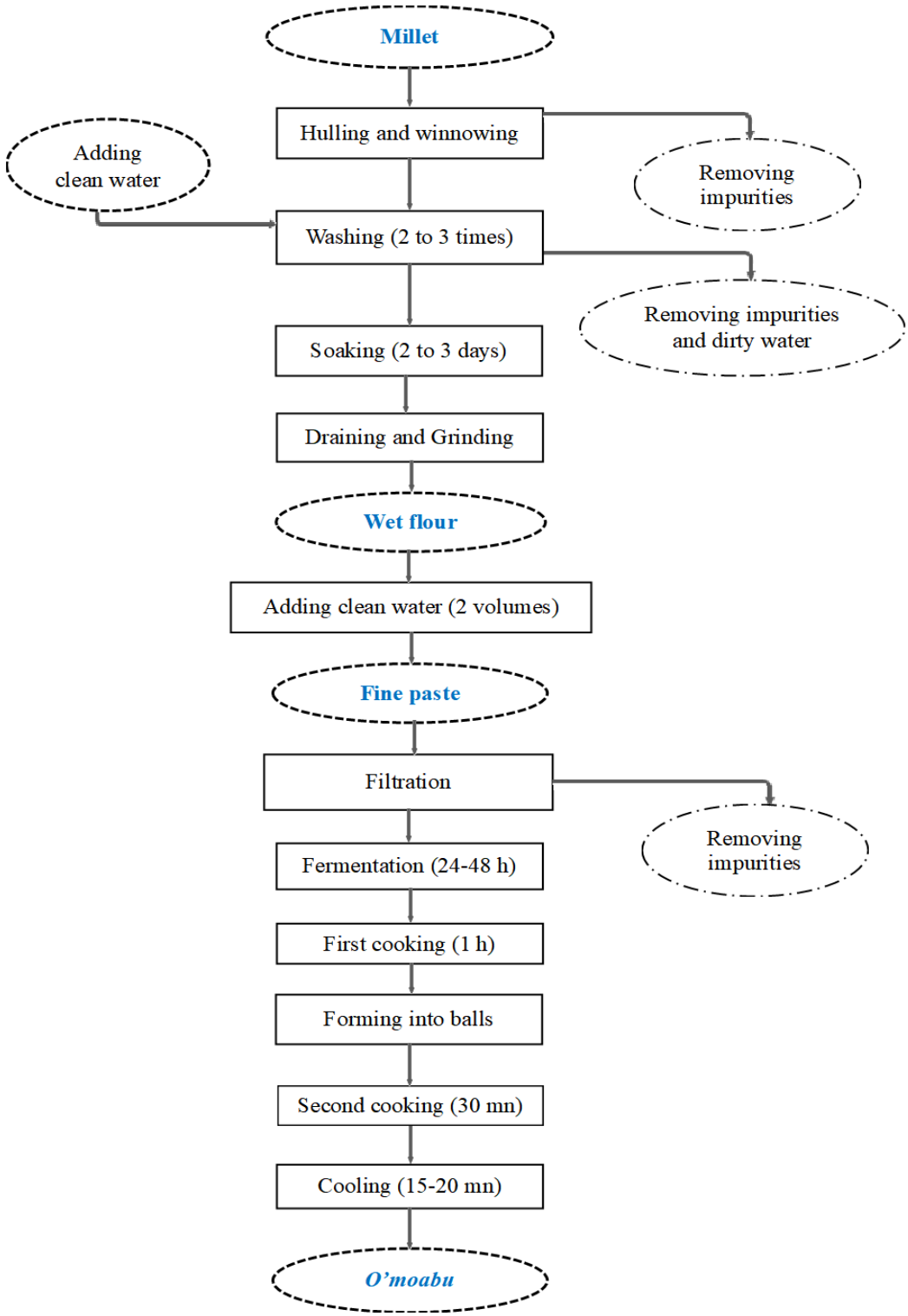

Figure 1: *O'moabu* production process diagram.

Table 1: Physicochemical and microbiological characteristics of the fermented dough.

Samples code	pH	TA (g lactic Acid/100 g)	TAMF (CFU/g)	YM (CFU/g)	LAB (CFU/g)
OM1	5.93 ± 0.02^{e}	0.59 ± 0.05^{bcd}	$2.5x10^{5} \pm 37^{a}$	$5.3x10^{4} \pm 12^{bc}$	$1x10^{4} \pm 25^{a}$
OM2	5.68 ± 0.01^{b}	0.86 ± 0.01^{ef}	$1.3x10^{5} \pm 27^{a}$	$1.4x10^{4} \pm 17^{ab}$	$4x10^{5} \pm 13^{a}$
OM3	5.62 ± 0.02^{a}	0.99 ± 0.03^{fg}	$2.7x10^{6} \pm 32^{a}$	$7.1x10^{4} \pm 33^{cd}$	$6.7x10^{5} \pm 27^{a}$
OM4	5.90 ± 0.02^{e}	0.86 ± 0.05^{ef}	$4.6x10^{5} \pm 67^{a}$	ND	$7.6x10^{4} \pm 25^{a}$
OM5	5.92 ± 0.01^{e}	0.81 ± 0.01^{e}	$6.9x10^{5} \pm 10^{a}$	ND	$2.8x10^{5} \pm 17^{a}$
OM6	5.89 ± 0.02^{e}	0.72 ± 0.03^{cde}	$1.2x10^{5} \pm 37^{a}$	ND	$1.5x10^{4} \pm 5^{a}$
OM7	5.87 ± 0.02^{de}	0.72 ± 0.05^{cde}	$1.1x10^{5} \pm 27^{a}$	ND	$6.9x10^{4} \pm 10^{a}$
OM8	5.61 ± 0.01^{a}	0.41 ± 0.01^{a}	$2.9x10^{6} \pm 32^{abc}$	$9.5x10^{4} \pm 33^{d}$	$2.7 \pm x10^{5} \pm 25^{a}$
OM9	5.6 ± 0.02^{a}	0.77 ± 0.03^{de}	$5.3x10^{5} \pm 67^{a}$	$7.5x10^{4} \pm 37^{cd}$	$4.7x10^{4} \pm 13^{a}$
OM10	5.59 ± 0.02^{a}	0.72 ± 0.05^{cde}	$4.6x10^{7} \pm 10^{c}$	$1.5x10^{4} \pm 37^{ab}$	$8.5x10^{4} \pm 27^{a}$
OM11	5.59 ± 0.01^{a}	0.72 ± 0.01^{cde}	$5.9x10^{5} \pm 37^{a}$	$3x10^{4} \pm 12^{ab}$	$1.5x10^{4} \pm 25^{a}$
OM12	5.59 ± 0.02^{a}	0.5 ± 0.03^{ab}	$2.2x10^{5} \pm 27^{ab}$	$2.4x10^{4} \pm 17^{ab}$	$5x10^{5} \pm 17^{a}$
OM13	5.57 ± 0.02^{a}	0.68 ± 0.05^{cde}	$2.2x10^{6} \pm 32^{a}$	$1.5x10^{4} \pm 33^{ab}$	$4.1x10^{5} \pm 5^{a}$
OM14	5.8 ± 0.01^{c}	1.04 ± 0.01^{g}	$7.7x10^{5} \pm 67^{bc}$	$1.3x10^{4} \pm 29^{a}$	$4.2x10^{5} \pm 10^{a}$
OM15	5.83 ± 0.02^{cd}	0.54 ± 0.03^{abc}	$5.8x10^{5} \pm 10^{ab}$	$5x10^{2} \pm 37^{ab}$	$1.5x10^{5} \pm 25^{a}$
OM16	5.88 ± 0.02^{de}	0.68 ± 0.05^{cde}	$3.2x10^{6} \pm 37^{a}$	ND	$2.4x10^{5} \pm 13^{b}$
OM17	5.78 ± 0.01^{c}	0.81 ± 0.01^{e}	$1.1x10^{6} \pm 27^{a}$	$1.9x10^{4} \pm 17^{a}$	$5.7x10^{5} \pm 27^{a}$
OM18	6.06 ± 0.02^{f}	0.72 ± 0.03^{cde}	$6.5x10^{5} \pm 32^{a}$	$2.5x10^{4} \pm 33^{ab}$	$5.4x10^{5} \pm 25^{a}$
OM19	6.08 ± 0.02^{f}	0.59 ± 0.05^{bcd}	$9x10^{5} \pm 67^{a}$	$2.8 \pm x10^{4} \pm 27^{ab}$	$3.3x10^{4} \pm 17^{a}$
OM20	6.04 ± 0.01^{f}	0.54 ± 0.01^{abc}	$3.0x10^{5} \pm 10^{a}$	$1.3x10^{4} \pm 23^{ab}$	$4.3x10^{6} \pm 15^{a}$

TA: titratable acidity; **LAB:** lactic acid bacteria; **TAMF:** total aerobic mesophilic flora; **YM:** yeast and mold. Means with identical letters in each column are not significantly different according to the Newman Keuls test at the 5% probability threshold.

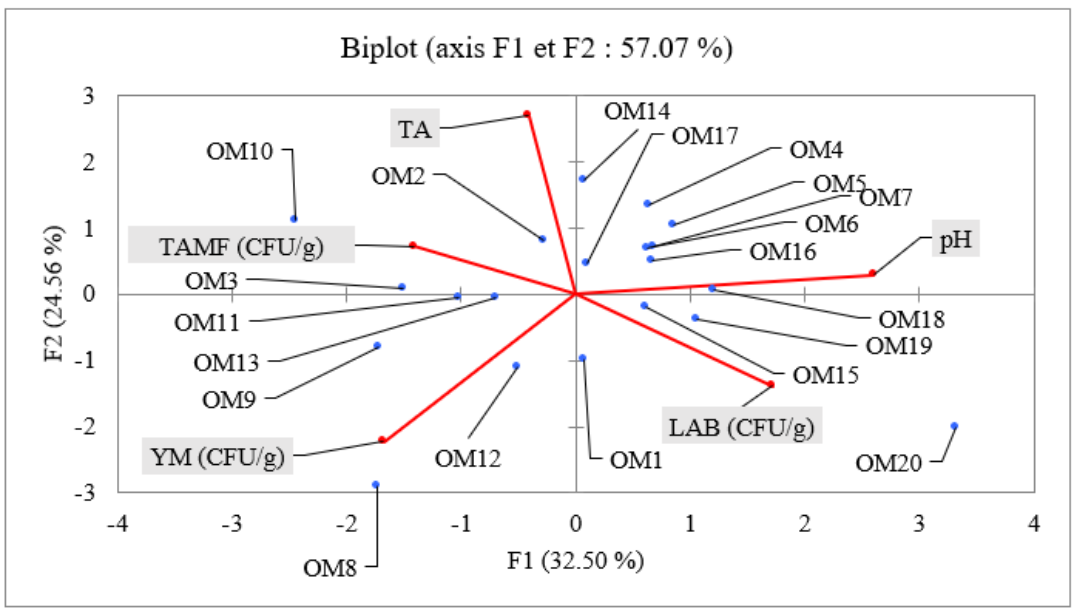

Figure 2: Principal component analysis of the physicochemical and microbiological characteristics of *O'moabu* fermented dough.

Table 2: Physical characteristics of the yeast isolates.

Samples	Morphology	Outline	Appearance/Density	Size	Color	Clustering	Genera
YS1	Cocci	Regular	Smooth/Milky	Medium	White	Isolated	Toru
YS2	Cocci	Regular	Smooth/Creamy	Medium	White	Isolated/Cluster	Sach
YS3	Cocci	Regular	Smooth/Milky	Medium	White	Isolated/Cluster	Toru
YS4	Cocci	Regular	Smooth/Milky	Medium	White	Isolated	Cand
YS8	Cocci	Regular	Smooth/Creamy	Medium	White	Isolated/Cluster	Sach
YS9	Cocci	Regular	Smooth/Milky	Small	White	Isolated	Toru
YS10	Cocci	Regular	Smooth/Milky	Medium	White	Isolated/Cluster	Sach
YS11	Cocci	Regular	Smooth/Creamy	Medium	White	Isolated/Cluster	Sach
YS12	Cocci	Regular	Smooth/Creamy	Medium	White	Isolated	Klu
YS13	Cocci	Regular	Smooth/Milky	Large	White	Isolated	Sach
YS14	Cocci	Regular	Smooth/Milky	Medium	White	Isolated/Cluster	Cand
YS15	Cocci	Regular	Smooth/Milky	Large	White	Isolated/Cluster	Sach
YS16	Cocci	Regular	Smooth/Milky	Medium	White	Isolated	Toru
YS18	Cocci	Regular	Smooth/Milky	Small	White	Isolated/Cluster	Cand
YS19	Cocci	Regular	Smooth/Creamy	Small	White	Isolated/Cluster	Sach
YS20	Cocci	Regular	Smooth/Creamy	Medium	White	Isolated/Cluster	Sach

PGen: Presumptive genera; **Klu:** *Kluyeveromyces* sp; **Toru:** *Torulaspora* sp; **Cand:** *Candida* sp; **Sach:** *Saccharomyces sp*

Table 3: Biochemical characteristics of the isolated yeast isolates.

Isolates	Ur	Ind	Glu	Lac	Citr	Man	Gas	Hydro	Mob	PGen
Y1S1	-	-	-	-	-	-	-	-	-	Toru
Y2S2	-	-	+	+	-	-	-	-	-	Sach
Y3S3	-	-	-	-	-	-	-	-	-	Toru
Y4S4	-	-	-	-	-	+	-	-	-	Cand
Y5S8	-	-	+	+	-	-	-	-	-	Sach
Y6S9	-	-	-	-	-	-	-	-	-	Toru
Y7S10	-	-	+	+	-	-	-	-	-	Sach
Y8S11	-	-	+	+	-	-	-	-	-	Sach
Y9S12	-	-	+	+	-	+	+	-	-	Klu
Y10S13	-	-	+	+	-	-	-	-	-	Sach
Y11S14	-	-	-	-	-	+	-	-	-	Cand
Y12S15	-	-	+	+	-	-	-	-	-	Sach
Y13S16	-	-	-	-	-	-	-	-	-	Toru
Y14S18	-	-	-	-	-	+	-	-	-	Cand
Y15S19	-	-	+	+	-	-	-	-	-	Sach
Y16S20	-	-	+	+	-	-	-	-	-	Sach

Ur: Urea; **Ind:** Indole; **Glu:** Glucose; **Lac:** Lactose; **Citr:** Citrate; **Man:** Mannitol; **Gas:** Gas production; **Hydro:** Hydrogen sulfide; **Mob:** Mobility; **PGen:** Presumptive genera; **Klu:** *Kluyeveromyces* sp; **Toru:** *Torulaspora* sp; **Cand:** *Candida* sp; **Sach:** *Saccharomyces sp.*

Table 4: Physical characteristics of the lactic acid bacterial isolates.

Isolates	Morphology	Outline	Appearance/Density	Size	Color	Clustering	Genera
LABS3	Coccobacilli	Regular	Smooth/Creamy	Small	White	Isolated/Chains	Lacto
LAB1S8	Small stick	Regular	Smooth/Creamy	Medium	White	Isolated/Chains	ND
LAB2S8	Long stick	Regular	Smooth/Creamy	Medium	White	Isolated/Chains	ND
LABS9	Stick	Regular	Smooth/Creamy	Medium	White	Cluster	Lacto
LABS10	Cocci	Regular	Smooth/Creamy	Medium	White	Isolated/Chains	Strepto
LABS11	Stick	Regular	Smooth/Creamy	Small	White	Isolated/Chains	Leuco
LABS15	Cocci	Regular	Smooth/Creamy	Medium	White	Isolated/Cluster	Leuco
LABS17	Stick	Regular	Smooth/Creamy	Large	White	Isolated/Chains	Lacto

PGen: Presumptive Genera; **Lacto:** *Lactobacillus* sp; **Leuco:** *Leuconostoc* sp; **Strepto:** *Streptococcus* sp; **ND:** not determined.

Table 5: Biochemical characteristics of the isolated bacterial isolates.

Isolates	Ox	Cat	Gram	Ur	Ind	Glu	Lac	Citr	Man	Gas	Hydro	Mob	PGen
LABS3	+	+	+	-	-	+	+	-	-	-	-	-	Lacto
LAB1S8	+	+	-	-	-	+	+	-	-	-	-	-	ND
LAB2S8	+	+	-	-	-	-	-	-	+	-	-	-	ND
LABS9	+	+	+	-	-	+	+	-	-	-	-	-	Lacto
LABS10	+	+	+	-	-	-	-	-	-	-	-	-	Strepto
LABS11	+	+	+	-	-	+	+	-	+	-	-	-	Leuco
LABS15	+	+	+	-	-	+	+	-	+	-	-	-	Leuco
LABS17	+	+	+	-	-	+	+	-	-	-	-	-	Lacto

Oxi: Oxidase; **Cat:** Catalase; **Gram:** Gram; **Ur:** Urea; **Ind:** Indole; **Glu:** Glucose; **Lac:** Lactose; **Citr:** Citrate; **Man:** Mannitol; **Gas:** Gas production; **Hydro:** Hydrogen sulfide; **Mob:** Mobility; **PGen:** Presumptive Genera; **Lacto:** *Lactobacillus* sp; **Leuco:** *Leuconostoc* sp; **Strepto:** *Streptococcus* sp; **ND:** not determined.

DISCUSSION

The results showed that the dough was generally acidic. The pH obtained in this study was high compared to that of *Anango baca*, a traditional porridge made from fermented maize which was between 2.98 and 3.75 (Aka-Gbezo et al., 2017). This acidity ensures that the product is preserved against microbial deterioration and is valuable to consumers. Several studies have also indicated that fermented doughs are acidic, notably those by N'goran-Aw et al. (2017) in Ivory Coast, who showed that the fermented millet dough used to produce *Gnomy* cakes has an acidic pH of 4.47. Similarly, Bokossa et al. (2016) reported an acidic pH of 4.28 for the fermented corn dough used for the production of *Ablo* in Benin. The acidic pH of fermented doughs therefore

enables the growth of lactic acid bacteria and simultaneously inhibits the growth of pathogens (Owusu-Kwarteng et al., 2012; Adamasie, 2018). The titratable acidity of the fermented dough in this study was low compared to that of the fermented dough used for *Ablo* production, with an acidity of 2.72 g of lactic acid/100 g (Bokossa et al., 2016) but high compared to those of *Attiéké*, with acidity of 0,06 g of lactic acid/100 g (Gnagne et al., 2016). This difference in acidity could be explained by the difference in the microbial flora involved in the fermentation of the two types of doughs but the raw material used, as *Ablo* is made from a mixture of rice and maize, whereas the *O'moabu* was made from millet flour only.

Concerning microbiological characteristics, the results revealed significant microbial activity during dough fermentation. The microbial loads obtained in this study were similar to those of millet dough fermented for the production of *Gnomy* in Ivory Coast, in which the mean of total aerobic mesophilic flora was $8.5x10^7$ CFU/g (N'goran-Aw et al., 2017), but low compared to those of maize fermented dough for the production of *Poto-poto* in Congo, in which the total aerobic mesophilic flora ranged from $5x10^9$ to $4x10^{10}$ CFU/g (Louembé et al., 2003). However, the lactic acid bacteria, yeast and mold in the fermented corn dough used for *Poto-poto* production were greater than those of *O'moabu* dough, with loads ranging respectively from $1.8x10^{10}$ to $1.3x10^{11}$ CFU/g for lactic acid bacteria and from $3.2x10^7$ to $4x10^9$ CFU/g for yeast and mold (Louembé et al., 2003; N'Gan-Aw et al., 2017). The presence of lactic acid bacteria leads to dough acidification through carbohydrate metabolism, which then becomes favorable for yeast development but inhibits the growth of pathogenic microorganisms (Nasrollahzadeh et al., 2022). Thus, the results of the principal component analysis showed a correlation between the presence of lactic acid bacteria and acidic pH.

By observing the physical and biochemical characteristics of the yeast isolates, four genera were presumed (*Saccharomyces* sp., *Torulaspora* sp., *Candida* sp. and *Kluyeveromyces* sp.). According to the description given by Haingomalalariso (2016) and Sulmiyati et al. (2019), 50% of the isolates obtained in this study belonged to *Saccharomyces* sp., and 18.75% had characteristics corresponding to *Candida* sp. The results showed also that 25% of the isolates had characteristics of *Torulaspora* sp. as described by Marson (2015), and 6.25% corresponded to the characteristics of *Kluyeveromyces* sp. described by Ahmed (2015).

The physical and biochemical characteristics of the lactic acid bacteria isolates obtained from the fermented dough showed that they corresponded to three lactic acid genera (*Lactobacillus* sp., *Leuconostoc* sp. and *Streptococcus* sp.). The results obtained in this study are similar to those of other authors who also found that the main lactic acid bacteria encountered in fermented cereal doughs belong mainly to the genera *Lactobacillus* sp. and *Leuconostoc* sp. (Yao et al., 2009; Turpin et al., 2011). In detail, the results of this study showed that 37.5% of the isolates obtained corresponded well to the descriptions of *Lactobacillus* sp. and 25% corresponded to *Leuconostoc* sp. made by some authors (Savadogo et Traoré, 2011; Bouzaid et al., 2016; Boulouf and Zidoune, 2017). The results also showed that 12.5% of the isolates obtained in this study corresponded to the characteristics of the *Streptococcus* sp. reported by the authors (Savadogo et Traoré, 2011; Bouzaid et al., 2016; Boulouf and Zidoune, 2017). However, the results indicated that 25% of the isolates obtained did not correspond to any of the characteristics of lactic acid bacteria.

Conclusion

The results showed the high acidity of the dough and the diversity of microorganisms responsible for fermentation, such as lactic acid bacteria and yeast. The characterization of lactic acid bacteria and yeast isolates revealed four main yeast genera (*Saccharomyces* sp., *Torulaspora* sp., *Candida* sp. and *Kluyeveromyces* sp.) and three lactic acid bacteria genera (*Lactobacillus* sp.,

Leuconostoc sp. and *Streptococcus* sp.). This study showed that the fermentation of *O'moabu* dough results from symbiosis between yeast and lactic acid bacteria. To increase the value of this little-known meal, it would be interesting to evaluate the probiotic potential of the isolates responsible for the fermentation of *O'moabu* dough to produce starters to optimize dough fermentation.

COMPETING INTERESTS

The authors declare that they have no competing interests.

AUTHOR'S CONTRIBUTIONS

All authors participated equally in designing the study and collecting data and the samples. FT, SWC, SB and HC participated in analyzing and writing the manuscript. HC, CZ and AS participated in revising the manuscript. All authors read and checked the final version of the manuscript.

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