Tapsoba *et al. Journal of Ethnic Foods* (2022) 9:47
https://doi.org/10.1186/s42779-022-00161-4

Journal of Ethnic Foods

ORIGINAL ARTICLE

Open Access

Microbiological characteristics of bread dough and nutritional quality of "*Tabnen-naow*," ethnic artisan bread in Burkina Faso

François Tapsoba[1*], Nicolas Ouédraogo[2], Boureima Kagambèga[3], Ali Ouédraogo[1], Oumarou Zongo[4], Fulbert Nikièma[5] and Aly Savadogo[1]

Abstract

This study aimed to evaluate the microbiological characteristics of bread dough and the nutritional quality of "*Tabnen-naow*," an ethnic artisan bread consumed mainly in Burkina Faso. Originating in Boussé, this bread is spreading to the outskirts of Ouagadougou for several reasons, such as the increase in the price of industrial bread and especially the supposed low glycemic index of artisan bread. However, there is insufficient information in the literature about the nutritional quality and technology of artisan bread in Burkina Faso. For this purpose, surveys were conducted among artisan bakers in five artisan bread production units in Ouagadougou, using survey forms to draw the production diagram. The microbiological characteristics of bread dough were evaluated using standard microbiology methods. Lastly, the nutritional quality of ethnic artisan bread was determined using standard techniques. All the bakers were male, between 22 and 34 years old, with an average age of 27.8 ± 5.1 years. They all used wheat flour, mainly (80%) from the Grand Moulin du Faso (GMF). The Baker's dough fermentation was done at room temperature using dry or lyophilized yeast. The interesting microorganisms (yeasts, lactic acid bacteria) were present in all the bread dough samples. The yeast (2.5 10^8 CFU/g) and lactic acid bacteria (2.27 10^7 CFU/g) were abundant apart from the one bread dough, which had a low lactic acid bacterial load. The ethnic artisan bread contains carbohydrates (88.20–89.05%), proteins (9.60–10.60%), and minerals such as iron (11.56 to 89.27 mg/kg), calcium (00.00–290.03 mg/kg), and zinc (69.18 ± 36.74 to 389.10 ± 32.89 mg/kg). The nutritional composition revealed that ethnic artisan bread could contribute significantly to a healthy diet and food security.

Keywords: Bread dough, Microbiological characteristics, Ethnic artisan bread, Tabnen-naow, Nutritional quality, Food security

Introduction

For more than 4000 years, man has known the art of bread production [1]. According to the union of bakers, bread consumption amounts to 600,000 loaves of bread per day in Burkina Faso [2], of which the population of Ouagadougou absorbs half of this production. Bread represents the main calorific intake of the population in general and for urban populations in particular in Burkina Faso [3]. The fermentation of wheat flour dough produces it by microorganisms such as yeasts and lactic acid bacteria. Indeed, the fermentation of dough is caused by beneficial microorganisms. Yeast is now emerging as a microorganism of choice in many applications due to its multiple health benefits [4]. Yeasts, particularly *Saccharomyces cerevisiae*, have better qualities in bread-making processes [5, 6]. Lactic acid bacteria have an exclusively fermentative energy metabolism and flavor production

*Correspondence: tapsobaf@gmail.com

[1] Laboratoire de Biochimie et Immunologie Appliquées (LaBIA), Université Joseph KI-ZERBO, 03 BP 7131 Ouagadougou, Burkina Faso
Full list of author information is available at the end of the article

thanks to biochemical compounds such as amino acids, fatty acids, vitamins, and minerals for their growth [7].

In Burkina Faso, the bread sector occupies an important place in daily life because bread is a staple food for all ages. Bread is available, more consumed by the urban population as breakfast, and appreciated at any time. Bread plays a vital role in the daily diet as a source of energy [1]. Bread is one of the high-consumption products in Burkina Faso. However, Boussé, located about fifty kilometers from Ouagadougou and extending over an area of 485 km^2, did not have modern or industrial bakeries at pass time. The local population has much more preference for artisan bread produced by the indigenous population and called "*Tabnen-naow*," from "*mooré*," meaning "to trample." Several artisanal bakeries in this locality are considered the capital of Mossi ethnic artisan bread because this food is unique and finds its origin there (Fig. 1). From Boussé, this bread is spreading to the outskirts of Ouagadougou for several reasons, such as the increase in the price of industrial bread in recent times and especially the supposed low glycemic index of artisan bread.

Thus, in recent times, the majority of the population has turned more and more toward the consumption of artisan ethnic food, and artisan bakeries have become more and more widespread on the outskirts of Ouagadougou (Fig. 1). Ethnic artisan bread, commonly known as "*Tabnen-naow*" in the mooré language, is bread made by hand. The production of this type of bread amounts to 400 to 1000 loaves per unit per day in Ouagadougou, i.e., 0.13 to 0.17% of total production. This bread comes from the artisan processing of flour by artisan bakers. The consumers much appreciate it, but access to it remains uncertain because the production sites are far away. From a health point of view, ethnic artisan bread has an appreciable density with a supposed lower glycemic index and poses less risk to consumers. It provides a vital income, according to the artisan bakers. Artisan bread is widely consumed and highly appreciated by the indigenous and urban populations. Its production and sale constitute another important source of income for artisan bakers.

Produced in an artisan way, it is difficult to predict its microbiological characteristics and nutritional quality. However, the production technology of artisan bread and

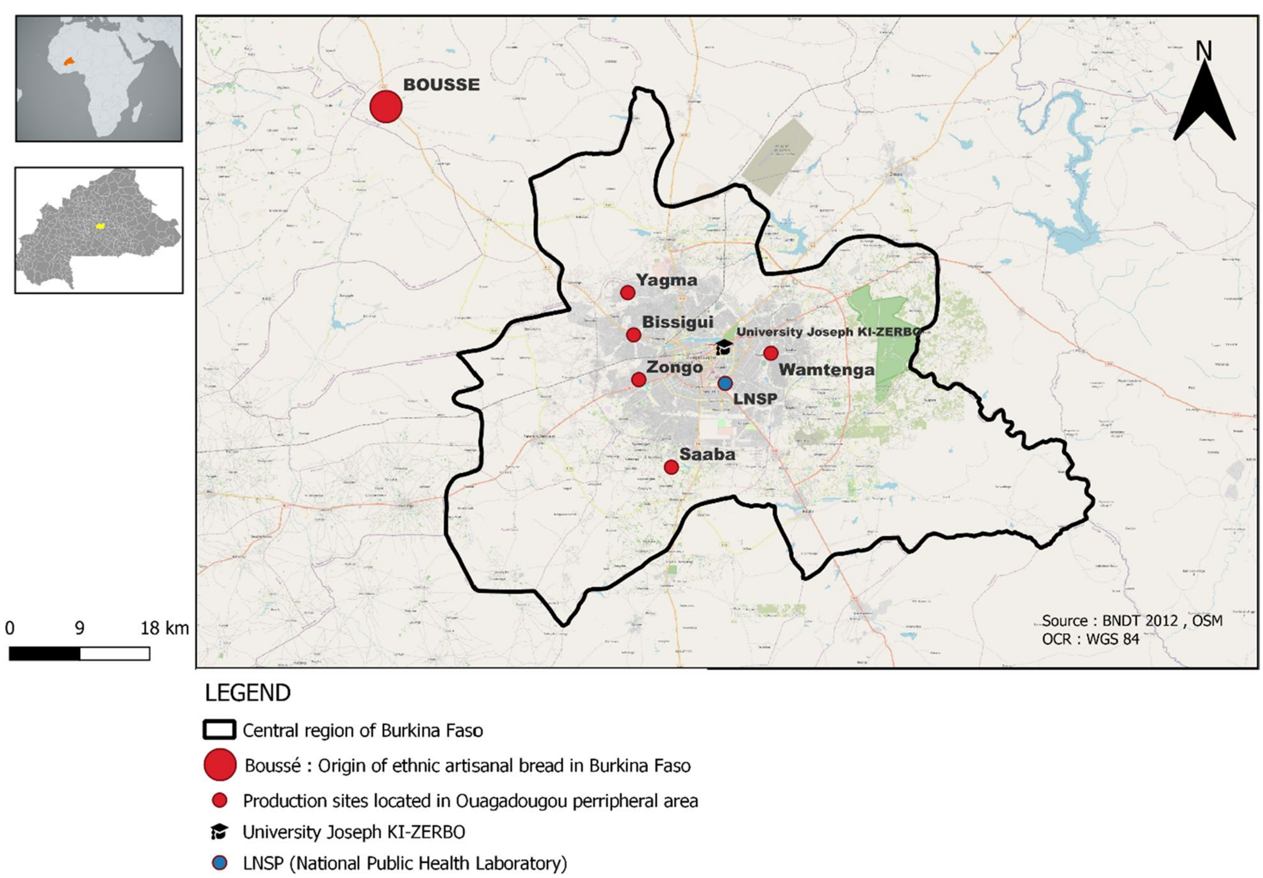

Fig. 1 Historical expansion of ethnic artisan bread production units in Ouagadougou/Burkina Faso

its nutritional quality still need to be discovered in Burkina Faso. For the future implementation of healthy food production in areas of high insecurity, this study aimed to answer the following research questions: (1) What is the production technology of artisan ethnic food in Burkina Faso?; (2) What are the microorganisms in bakery dough?; and (3) What is the nutritional quality of artisan ethnic food?

Thus, the objective of this study was to evaluate the microbiological characteristics of bread dough and the nutritional quality of ethnic artisan bread in Burkina Faso.

Material and methods

Study period and areas

The present study was carried out at the Laboratory of Applied Immunology and Biochemistry (LaBIA) of the University Joseph KI-ZERBO and the National Laboratory of Public Health (LNSP) (Fig. 1) from May 2020 to December 2020.

Ethnic artisan bread production surveys and sampling

Surveys were conducted among artisan bakers in five sites located in Ouagadougou's peripheral area (Fig. 1), and survey forms were to be able to note the production techniques. One artisan baker was selected in each site, with regularity and quantity in production as criteria for the selection. The production process was followed case by case, from the flour bags to the baguette nets. Sampling was done aseptically and randomly. Approximately 40 to 50 g of dough were taken and put into Falcon tubes at the end of the kneading process (after Step 3). Two baguettes were taken and packaged in sterile bags when the bread came out of the oven.

Determination of the microbiological characteristics of ethnic artisan bread dough

Ten g of ethnic artisan bread dough was placed into vials containing 90 mL of sterile physiological water (9 ‰). Decimal dilutions ranging from 10^{-1} to 10^{-7} were prepared from the same diluent and used for the yeasts and lactic acid bacteria enumeration. Yeast and lactic acid bacteria (LAB) were enumerated using culture media and incubation conditions presented in Table 1.

The enumeration of yeasts associated with ethnic artisan bread was carried out according to the NF V08-59 (2003) standard [8]. Lactic acid bacteria were counted in MRS medium according to ISO 15,214 [9].

Determination of the biochemical composition of ethnic artisan bread

Moisture content

The water content of the samples was determined by weighing them before and after the oven drying at 105 ± 2 °C for 4 h according to NF EN ISO 712, V03-707 [10]. 5 g of crushed material (PE) was weighed into a sample scoop (PV) previously dried in the oven at 105 °C for 30 min and cooled in a desiccator, then weighed (PO). The sample carriers were placed in the oven at 105 °C. After 4 h, the pods were removed from the oven and cooled in the desiccator for 30 min; then weighed, the final weight (Pf) was recorded. The percentage of the mass of water was obtained using the following formula:

$$H = \frac{PE - (PF - P0)}{PE} \times 100$$

H = moisture (%); P0 = weight of pods; PE = test plug; Pf = final weight (pod + test plug).

Total ash

Total ash was obtained by differential weighing the sample before and after firing at 550 °C for 12 h according to ISO 2171 [11]. 5 g of grinding material (Pe) was weighed into a pre-weighed porcelain crucible (Po). The crucible containing the sample was placed in the muffle furnace at 550 °C for 12 h. After incineration, the crucibles were removed and cooled in the desiccator for 1 h and then weighed again (pf). The ash content was calculated according to the following formula:

$$\%C = \frac{Pf - Pv}{Pe} \times 100 \times \frac{100}{100 - H}$$

% C: ash content; Pe: test sample; Pf: final weight (crucible + calcined sample); PV: empty weight of crucibles; and %H: percentage of mass of water.

Table 1 Culture media and incubation conditions for enumeration

Microorganisms	Media	T (°C)	Duration (hours)	Incubation conditions
Yeasts	Sabouraud chloramphenicol (Sigma-Aldrich, USA)	30 °C	24–48	Aerobiosis
LAB	MRS (Sigma-Aldrich, USA)	30 °C	48	Anaerobiosis

Determination of proteins content
Infrared analysis (Infra Neo, Chopin's technology) was used to determine the total protein content of the samples according to NF EN 15 948 [12].

The bread powder, after dehydration, is introduced into a small shuttle of a lower dish. Using a scraper, the upper part was leveled by positioning the scraper at 45° to the lower cup. Then, the upper cup was rotated by 90° until it reached the stop. Then, the scoop was removed and inserted into the measuring cell. The analysis was started by switching on the instrument. The results of the different parameters were expressed as a percentage of the dry matter. These results from sixteen replicates form an average. The result was shown on the infra Neo screen.

Determination of lipids content
Fat was determined by the Soxhlet extraction method according to ISO 659 [13]. Lipid extraction was done at warm temperatures (60–70 °C) by soaking and rinsing the sample with hexane. The lipid content was determined by weighing after the evaporation of the hexane. Five g of crushed material (PE) was collected in an extraction cartridge. The cartridge was capped with cotton and placed in the Soxhlet. Soxhlet was mounted between a flask containing 200 mL of pre-weighed hexane (PV) and a refrigeration system. The latter was connected to a cryostat to condense the solvent vapors intended to carry the lipids away. The extraction was carried out for 4 h. The solvent was separated from the lipids by rota vapor evaporation. The flask containing the free lipids was then placed in an oven for 1 h at 40 °C and then in a desiccator for 30 min. After cooling, the flask was weighed (pf), and the percentage of lipids were obtained according to the following formula:

$$\mathrm{Lipid}(\%) = \frac{pf - pv}{pe} \times 100 \times \frac{100}{100 - H}$$

pf = final weight (flask + fat); *pv* = empty weight of the flask; *pe* = test plug; Lipid (%) = fat content; and H = moisture.

Determination of carbohydrates content
Total sugars (TS) were determined by differential calculation according to the method of Al-Hooti et al. [14] using the following formula:

$$\mathrm{ST}(\%) = 100 - (\mathrm{P} + \mathrm{L} + \mathrm{Ce})$$

ST = Total sugars; P = Protein; L = Lipids; and Ce = Ash.

Determination of the energy value
The energy values of the ethnic artisan bread samples were determined using the Atwater coefficients by multiplying the protein content by 4 kcal/g, the fat content by 9 kcal/g, and the total carbohydrate content by 4 kcal/g [15].

$$\mathrm{VE} = \sum (4\mathrm{P} + 9\mathrm{L} + 4\mathrm{ST})$$

VE = Energy Value; P = Protein; L = Fat; ST = Total Sugar.

Determination of the minerals
Ca, Fe, and Zn contents were determined according to ISO 13 312 [16]. The extraction of minerals was done after calcination of the crushed material in the muffle furnace at 550 °C for 10 h, followed by the dissolution of the ash obtained. 0.20 g of the sample was weighed into a glass test tube. 5 mL of concentrated nitric acid (HNO_3) was withdrawn and placed in a tube containing 0.20 g of bread. This test tube was placed in a mineralizer for 2.5 h at 150 °C to ensure acid digestion. The mineralized contents of the tube were transferred to a 25-mL volumetric flask and made up to the mark with distilled tube rinse water. This solution was filtered through a 0.45-μm-diameter filter. The calcium, iron, and zinc contents were determined using a flame atomic absorption spectrometer. For each determination, three replicates were performed.

$$\mathrm{CF} = \frac{\mathrm{Cins} \times \mathrm{V}}{\mathrm{PE}} \times \mathrm{FD}$$

CF: Final Concentration; V = Volume; Cins = Instantaneous Concentration; PE = Test Point; and FD = Dilution Factor.

Data analysis
Excel 2013 was used for data entry. XLSTAT version 2016 was used for the analysis of variance (ANOVA). The Tukey test was used to compare the means of the parameters evaluated (at the probability $p = 5\%$).

Results and discussion
This study was carried out through contact with producers during a survey period. Boussé is the city of "*Tabnen-naow*" because there were no modern or industrial bakeries in the past, and several artisanal bakeries were developed there. The artisan bread is baked in a traditional artisan oven built from local earthen material (Fig. 3c). The baking conditions were assessed thanks to the experience of the artisan bakers.

For several reasons, this ethnic artisan bread dough is spreading to the outskirts of Ouagadougou and especially the supposed low glycemic index of artisan bread. Some consumers were considering "*Tabnen-naow*" as an alternative to industrial bread prices increasing in Burkina Faso.

The technology for ethnic artisan bread production is presented in Fig. 2. The production technology of ethnic artisan bread was carried out by kneading. This step was followed by a pre-fermentation (punching) which lasted forty to sixty minutes. The manual shaping of the dough pieces was carried out using a table. The artisan dough pieces obtained were packed in nets. They were then placed on a raised support in a relatively ventilated room at room temperature (priming) for 1 to 2 h. Scarification and baking of the ethnic artisan bread were carried out successively in a short time.

For this purpose, a questionnaire was drawn to collect information on ethnic artisan bread dough composition. Table 2 presents the survey results among five ethnic artisan bread producers. The bakers were all males between 22 and 34 years old, averaging 27.8 ± 5.1 years. They all used wheat flour, mainly (80%) from the Grand Moulin du Faso (GMF). For the fermentation of the Baker's dough carried out at room temperature, they use Baker's dry or lyophilized yeasts. No chemical additives were used during the process.

The bread-making quality of the dough was determined by evaluating the characteristics of the bread dough and ethnic artisan bread presented in Table 2.

Production of ethnic artisan bread

The formulation consisted of adjusting the composition of the flour and the ingredients necessary to meet not only the technology of the bread but also the nutritional and organoleptic needs of the consumer. The dough was obtained by kneading a mixture of flour, water, and salt and subjected to fermentation by yeast *Saccharomyces cerevisiae*. It was kneaded well to homogenize and soften the gluten. The dough was incubated for a minimum of 45 min before shaping and then 1 to 2 h for the second fermentation. The fermented dough was baked in an artisan oven. The evolution of the fermenting dough during the production of ethnic artisan bread is shown in Fig. 2.

Figure 3 presents the evolution of the dough during ethnic artisan bread production.

Microbiological characteristics of ethnic artisan bread dough

Table 3 shows the enumeration of the interesting microbiota (yeasts, lactic acid bacteria) of the five ethnic artisan bread production units.

In general, all microbial microbiota were present in all samples. The average yeast population was $2.50.10^8$. CFU/g for ethnic artisan bread dough from Ouagadougou

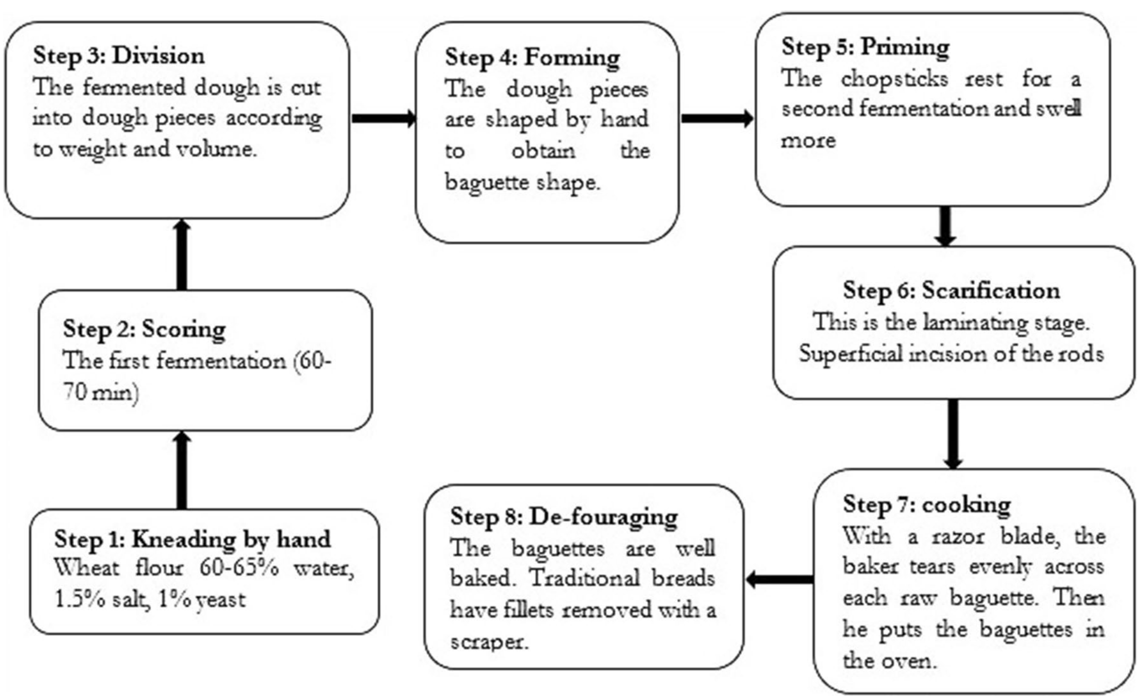

Fig. 2 Diagram of ethnic artisan bread production

Table 2 Characteristics of bread dough and ethnic artisan bread

Characteristics	UPY	UPB	UPS	UPW	UPZ
Dough weight (g)	102.0 ± 3.0	98.0 ± 1.2	101.0 ± 1.3	105.0 ± 1.5	108.0 ± 1.3
Dough temperature (°C)	35.7 ± 0.2	36.3 ± 0.1	35.8 ± 0.2	35.9 ± 0.1	36.5 ± 0.3
Pre-fermentation (min)	45.0 ± 2.0	50.0 ± 1.0	70.0 ± 3.0	55.0 ± 2.0	47.0 ± 4.0
Fermentation (min)	30.0 ± 0.0	45.0 ± 2.0	32.0 ± 3.0	34.0 ± 2.0	38.0 ± 2.0
Flour daily used (kg)	50.0 ± 0.0	45.0 ± 0.0	50.0 ± 0.0	50.0 ± 0.0	30.0 ± 5.0
Smoothing (1 to 10*)	4.0 ± 0.0	7.0 ± 0.0	4.0 ± 0.0	7.0 ± 0.0	7.0 ± 1.0
Consistency (1 to 10*)	7.0 ± 0.0	7.0 ± 0.0	7.0 ± 0.0	7.0 ± 0.0	4.0 ± 0.0
Tights (1 to 10*)	10.0 ± 0.0	7.0 ± 2.0	10.0 ± 0.0	7.0 ± 1.0	10.0 ± 0.0
Extensibility (1 to 10*)	7.0 ± 0.0	7.0 ± 2.0	7.0 ± 0.0	7.0 ± 1.0	7.0 ± 2.0
Elasticity (1 to 10*)	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0	10.0 ± 0.0	10.0 ± 0.0
Loaf of bread weight (g)	80.2 ± 0.7	82.1 ± 1.2	80.1 ± 1.0	77.5 ± 1.5	76.1 ± 0.7
Bread quantity (loaves)	203.0 ± 8.0	220.0 ± 10.0	205.0 ± 3.0	196.0 ± 5.0	208.0 ± 3.0
Baguette price (FCFA)	50.0 ± 0.0	50.0 ± 0.0	50.0 ± 0.0	50.0 ± 00	50.0 ± 0.0
Production costs (FCFA)	10,150.0 ± 200.0	11,000.0 ± 1000.0	10,250.0 ± 150.0	9800.0 ± 250	10,400 ± 150.0

UPY: Yagma Production Unit; UPB: Bissigui Production Unit; UPS: Saaba Production Unit; UPW: Wamtenga Production Unit; UPZ: Zongo Production Unit; 1 = Poor; 4 = Passable; 7 = Good; and 10 = Very Good

and Saaba (Table 3). These yeast contents are similar to those of the crushed wheat sourdough (1.5.10^8 CFU/g) reported by Taupier-Létage et al. [17]. The yeast strains of artisan dough were higher than those of commercial liquid sourdough (1.37.10^7 CFU/g) and industrial sourdough (3.6.10^7 CFU/g), reported by Taupier-Létage et al. [17]. The lactic acid bacteria, through their carbohydrate metabolism, cause the acidification of the dough, which thus becomes favorable to the growth of yeast. This symbiosis during dough fermentation has also been reported by Bokossa et al. [18] on ablo, a fermented dough from Benin. *Saccharomyces cerevisiae* is responsible for the production of alcohol (fermentation) [19]. According to Taupier-Létage et al. [17], this average yeast value (2.50 10^8 CFU/g) explains a better application of ethnic artisan bread production processes.

Lactic acid bacteria were present in all samples, except a small amount in the Saaba ethnic artisan bread dough. The average lactic acid bacteria population was 5.70 10^7 CFU/g. This microbiota of artisan dough was higher than that of white maize flour (1.2×10^7 CFU/g) found by Coulibaly et al. [20]. These values were lower than those of liquid sourdough and crushed sourdough (1.6×10^9 and 1.7×10^9, respectively) reported by Taupier-Létage et al. [17]. From the same perspective, Ennadir et al. [21] showed that the enumeration of lactic acid bacteria from Moroccan wheat flour showed low values in most samples.

On the other hand, the absence of lactic acid bacteria can be considered fungal contamination. However, the ethnic artisan bread dough showed a lower bacterial microbiota than the yeast. This shows the dose of *Saccharomyces cerevisiae* yeast during this production period. These lactic acid bacteria were responsible for producing a specific aroma, while *Saccharomyces cerevisiae* was responsible for producing alcohol (fermentation) [19]. Artisan bread may have a low glycemic index, and its consumption would not increase blood sugar. Indeed, bacterial fermentation products also appear to contribute directly to lowering the glycemic index of sourdough bread [22].

Fungi were observed or isolated in some samples; for example, the Saaba production unit had a low lactic acid bacterial load, and all samples were abundant in yeast (2.5 10^8 CFU/g) and lactic acid bacteria (5.7 10^7 CFU/g). Indeed, the production process of this ethnic artisan bread requires sufficient time (at least 3 h).

Proximal composition and energy value of ethnic artisan bread

The ash, moisture, protein, fat, carbohydrate, and energy content of the five samples from each production unit are presented in Table 4.

The moisture of Ouagadougou artisan bread (PTO) was determined during this work. These bread had moisture ranging from 29.84% to 36.08% (Table 4). The moisture of the ethnic artisan bread was similar to those of the Benin ablo (32.77–39.90%) reported by Bokossa et al. [18]. They were close to those of ablo with fermented dough (39.73%) reported by Dossou et al. [30] and ablo in Togo (39.47%) reported by Bokossa et al. [18]. The dry matter content (DMC) of ethnic artisan bread was higher than that of fermented dough bread (24.55%) and Algerian semolina (20.68%) reported by Guendouze-Bouchefa

Fig. 3 Evolution of the dough during the ethnic artisan bread production. **A** Dough in first fermentation; **B** dough in second fermentation; **C** fermented dough in baking; and **D** ethnic artisan bread

Table 3 Microbiological characteristics of ethnic artisan bread dough

Microorganisms	UPY	UPB	UPS	UPW	UPZ	Assessment criteria
Yeasts (UFC/g)	$2.28.10^{8}$	$2.65.10^{8}$	$2.53.10^{8}$	$2.54.10^{8}$	$2.50.10^{8}$	10^{3};NF V08-59 [7]
LAB (UFC/g)	$7.27.10^{7}$	$5.36.10^{7}$	$1.00.10^{3}$	$5.27.10^{7}$	$4.91.10^{7}$	10^{3}; NF ISO 15,214 [8]

UPY: Yagma production unit; UPB: Bissigui production unit; UPS: Saaba production unit; UPW: Wamtenga production unit; UPZ: Zongo production unit; and LAB: Lactic acid bacteria

et al. [23]. It was also higher than that of lafu cassava bread (10.10) reported by Bessou et al. [24]. The variance analysis showed a significant difference between the moisture content of the ethnic artisan bread harvested. However, there was no significant difference between the moisture content of PTY, PTB, and PTW. In general, dry matter content, pH, and ash content decreased after fermentation and increased after baking [25].

The ash content of the ethnic artisan bread was determined during the analyses (Table 4). The bread showed ash contents ranging from 0.36 to 0.52%. These contents were lower than the FAO [1] and AOAC [26]

Table 4 Proximal composition and energy value of ethnic artisan bread

Samples	Ash (%)	Moisture (%)	Protein (%)	Lipid (%)	Sugars (%)	Energy value
UPY	0.55 ± 0.04[b]	29.84 ± 2.38[a]	10.60 ± 0.10[c]	0.64 ± 0.04[c]	88.20 ± 0.02[a]	401.04 ± 0.04[c]
UPW	0.45 ± 0.02[ab]	32.94 ± 0.05[ab]	10.36 ± 0.05 [bc]	0.54 ± 0.01[b]	88.59 ± 0.07[b]	400.87 ± 0.15[c]
UPZ	0.48 ± 0.04[ab]	35.53 ± 1.03[b]	9.80 ± 0.30[a]	0.66 ± 0.01[c]	89.05 ± 0.32[c]	401.43 ± 0.23[d]
UPS	0.36 ± 0.00[a]	33.33 ± 3.00[ab]	10.20 ± 0.10[b]	0.38 ± 0.01[a]	88.98 ± 0.08[bc]	400.35 ± 0.06[b]
UPB	0.44 ± 0.00[a]	33.17 ± 0.83[ab]	10.32 ± 0.00[b]	0.31 ± 0.01[a]	88.90 ± 0.00[c]	399.36 ± 0.07[a]
P-value	0.112	0.280	0.001	0.000	0.000	0.000

Columns with the same letter mean that there is no significant difference according to the Fisher test at the 5% threshold

UPY: Yagma production unit; UPB: Bissigui production unit; UPS: Saaba production unit; UPW: Wamtenga production unit; UPZ: Zongo production unit; P: probability threshold

foodstuff contents, as well as those of the Benin ablo (2.09–2.15%) reported by Bokossa et al. [18]. In contrast, 40% of the samples (PTY, PTB) were similar to standard bread and artisan French bread (0.5–0.6%) reported by Choudar et al. [27]. They were also similar to organic bread (0.58%) reported by Taupier-Létage et al. [17]. The ash contents of ethnic artisan bread from Yagma and Bissigui were close to that of fermented bread (0.69%) but lower than that of the doughnut (0.96%) reported by Soro et al. [25]. The variance analysis showed a significant difference between the ash content of different loaves of bread. According to Koffi et al. [28], the ash content of ethnic artisan bread decreases after fermentation and increases after baking. Ethnic artisan bread could be used in the dietary program to meet the body's micronutrient requirements, especially in children and pregnant women [29].

The protein content of ethnic artisan bread ranged from 9.8% to 10.6% (Table 4). It was lower than that of wheat bread (12.6%) reported by Petrova and Petrov [30] and similar to that of ablo fermented bread (10.24) reported by Dossou et al. [31]. The protein contents of ethnic artisan bread were also higher than those of ablo bread (7%) and lafu bread (5.4) reported by Dossou et al. [31] and Bokossa et al. [18], respectively. These contents were lower than that of wheat flour type 55 (13.3%) reported by Mofakkir [32]. However, they were similar to unfermented bread (9.2%) reported by Guendouze-Bouchefa et al. [23]. The protein and sugar composition of the flour was an important effect on bread production (Table 2). Proteins have crucial biological roles because they influence the activity of dough microbiota and, therefore, the quality of bread. Therefore, ethnic artisan bread can be offered to vulnerable people. Regarding the protein content of all cereal products, it is beneficial to the population to consume ethnic artisan bread with protein-rich foods to avoid protein deficiency diseases such as marasmus and kwashiorkor.

Ethnic artisan bread could be consumed with lipid-rich foods (grubs, locusts, butter, skewers, etc.) to enhance its energy value. The lipid content of ethnic artisan bread was between 0.28 and 0.67% (Table 4). This lipid content was lower than that of flour (2.1%) reported by Mofakkir [32], that of rice ablo (1.5%) in Benin reported by Bokossa et al. [18], and that of wheat bread (1.5%) reported by Petrova and Petrov [30]. It was similar to that of maize ablo (0.79%) in Benin, reported by Bokossa et al. [18], and that of iron-fortified bread (0.35%) from Algeria, reported by Guendouze-Bouchefa et al. [23]. According to the analysis of variance, there was no significant difference between the lipid levels of ethnic artisan bread. On the other hand, there was no significant difference between the lipid content of PTY and PTZ.

The carbohydrate content of the ethnic artisan bread varied between 88.20 and 89.05% (Table 4). This content was higher than that of wheat bread (71.20%) reported by Petrova and Petrov [30], that of the 15% composite bread (79.34%), and the 20% composite bread (74.14%) reported by Meite et al. [34]. On the other hand, this content was similar to that of regular bread (86.66%) and 5% composite bread (84.91%) measured by Adrian [35]. The analysis of variance showed that there was no significant difference between the carbohydrate content of the samples.

Artisan bread has a high carbohydrate content, a low protein content, and a very low lipids content. Our results were similar to those reported for regular bread by Meite et al. [34]. The high carbohydrate content of artisan bread confirms the priority energy function of bread [35].

The energy value of the ethnic artisan bread varied from 399.36 to 401.43 kcal/100 g dry matter (Table 4). This value was lower than the value of the ordinary bread and the composite bread of Abidjan, whose energy values were, respectively, 405.92 kcal/100 g and 404.17 kcal/100 g reported by Meite et al. [34] but

Table 5 Mineral composition of ethnic artisan bread

Samples	Calcium (mg/kg)	Zinc (mg/kg)	Iron (mg/kg)
UPY	290.03 ± 2.58 [c]	89.27 ± 0.38[c]	76.06 ± 26.06[a]
UPW	178.98 ± 0.52[b]	58.26 ± 1.97[b]	389.10 ± 32.89[b]
UPZ	90.96 ± 1.06[ab]	54.60 ± 0.76[b]	117.92 ± 3.25[a]
UPS	0.00 ± 0.00 [a]	15.36 ± 0.41[a]	76.32 ± 16.04[a]
UPB	100.84 ± 2.06 [ab]	11.56 ± 5.54[a]	69.18 ± 36,74[a]
P	0.004	0.000	0.000

Columns with the same letter mean that there is no significant difference according to the Fisher test at the 5% threshold

UPY: Yagma Production Unit; UPB: Bissigui Production Unit; UPS: Saaba Production Unit; UPW: Wamtenga Production Unit; UPZ: Zongo Production Unit; P: probability threshold

higher than those of wheat bread with dairy products [36]. The variance analysis showed no significant difference between the energy values of the ethnic artisan bread samples. Because of their high energy value, the ethnic artisan bread of Ouagadougou and Saaba is desired for the Diet of pregnant women and children.

Mineral composition of ethnic artisan bread

The mineral composition of ethnic artisan bread from the five production units is presented in Table 5.

The calcium content of ethnic artisan bread was between 89.90 and 292.61 mg/kg, with an average of 172.74 mg/kg (Table 5). The calcium content of ethnic artisan bread was lower than those of organic bread (254.4 mg/kg) found by Taupier-Létage et al. [17]. However, this content was superior to bread from organic flour T55 (150 mg/kg) and lower than those of T80 cylinder bread. However, only the calcium content of the sample of artisan Yagma bread (PTY) was similar to that of millstone flour (288.7) and artisan pre-fermented wheat bread (289.8). The analysis of variance showed that there was a significant difference between the levels of calcium. Calcium is an essential element in the multiplication and growth of yeasts. The deficiency in mineral salts (calcium, potassium, sodium) or trace elements (zinc, iron) reduces the fermentation power. Mineral salts stimulate yeast growth and are essential constituents of enzyme systems [4]. Ethnic artisan bread could be recommended and served to vulnerable people. The consumption of foods rich in minerals, such as magnesium and zinc with vitamins C, D, and E, can contribute to a better lifestyle, boost immunity, and help fight infection [33].

The zinc content of ethnic artisan bread varied from 11.56 to 89.27 mg/kg, with an average of 61.81 mg/kg (Table 5). This content was similar to that reported by Taupier-Létage et al. (2007) [17]. The zinc content of ethnic artisan bread was also similar to that of sourdough bread (64 mg/kg) found by Taupier-Létage et al. [17]. The analysis of variance showed that there was a significant difference between the zinc contents. Fertilization, production system, and method of milling of wheat could be responsible for the variation in the mineral content of the flour used in bread making [37], and therefore that of bread.

Ethnic artisan bread could be used as a food ration to meet the body's demand for mineral salts. At the end of the analysis, the iron content of ethnic artisan bread ranged from 69.18 ± 36.74 to 389.10 ± 32.89 mg/kg with an average of 145.71 mg/kg. These contents were lower than the contents of Ablo (320.5) and fermented dough bread (290.3) reported by Bokossa et al. [18] (Table 5). These values were lower than that found by Bokossa et al. [18]. However, the iron contents of ethnic artisan bread were higher than those of type 55 flour (12 mg/kg) reported by Taupier-Létage et al. [17]. The analysis of variance showed that there was a significant difference between the iron contents. Iron is the essential constituent of hemoglobin in red blood cells, myoglobin in muscles, and certain enzymes such as cytochromes [35, 37]. Consumption of ethnic artisan bread constitutes a significant gain for pregnant women and infants. A study reported that minerals such as Fe, Cu, and Zn are essential in the health of pregnant women and the development of the fetus, in the health of the newborn, and the consumption of Tabnen-naow can provide a proper concentration of these elements in the body of women during pregnancy reducing the risk of complications [38].

Ethnic artisan bread can be considered a functional food because it is generated according to traditional manufacturing [39].

Conclusion

The results of this work showed a nutritional contribution to ethnic artisan bread. Indeed, ethnic artisan bread contains carbohydrates, proteins, and minerals such as iron, calcium, and zinc that could significantly contribute to food security in developing countries.

As originality, the ethnic artisan bread is baked in a traditional artisan oven built from local earth. The baking conditions are assessed thanks to the experience of the artisan baker.

In addition, this fermented food is highly appreciated for its flavor and consistency by the population from other cities due to its nutritional quality reported in this study.

Ethnic artisan bread is a very simple food because of its process and classical production technique.

The ethnic artisan bread production diagram developed with the help of artisan bakers could be used for bread production in areas of high food insecurity. For further work, it would be essential to evaluate the effect of ethnic artisan bread consumption on the glycemic index and develop local flour bread. It is also necessary to analyze industrial bread to compare it to artisan bread.

Acknowledgements
The authors would like to acknowledge the Laboratoire National de Santé Publique (LNSP)-Burkina Faso, the University Joseph KI-ZERBO, and the artisan bakers in Burkina Faso.

Author contributions
The first author designed the study and contributed to data collection, analysis, interpretation, and manuscript preparation. The second to sixth authors contributed to data collection, analysis, interpretation, and manuscript preparation. The seventh had the role of supervision. All authors read and approved the final manuccript.

Funding
There is no funding resource for this publication.

Availability of data and materials
All data and materials are presented in this manuscript.

Declarations

Competing interests
There are no competing interests regarding this publication.

Author details
[1]Laboratoire de Biochimie et Immunologie Appliquées (LaBIA), Université Joseph KI-ZERBO, 03 BP 7131 Ouagadougou, Burkina Faso. [2]Centre National de Recherche et de Formation sur le Paludisme (CNRFP), 01 BP 2208 Ouagadougou, Burkina Faso. [3]Centre Universitaire Polytechnique de Kaya, Université Joseph KI-ZERBO, 03 BP 7131 Ouagadougou 03, Burkina Faso. [4]Université Thomas Sankara, 12 BP 417 Ouagadougou, Burkina Faso. [5]Laboratoire National de Santé Publique (LNSP), 09 BP 24 Ouagadougou 09, Burkina Faso.

Received: 16 July 2022 Accepted: 28 November 2022
Published online: 09 December 2022

References

1. Barrett F. Role of bread in international nutrition. Cereal-food world; 1975.
2. BAMIO ZF. Marché du pain au Burkina Faso. Investir au Burkina. 2016. https://urlz.fr/j1LY
3. FAO. Forest Resources assessment. FAO Rome. 1995. p. 76.
4. Castan C, Rapior S, Fons F. Levure de bière: un champignon aux multiples bienfaits pour la santé et la beauté. Sciences pharmaceutiques et biologiques. Thèse, Université de Montpellier ; 2016. p. 89.
5. Acourene S, Ammouche K. Valorisation des rebuts de dattes par la production de la levure boulangère, de l'alcool et du vinaigre. Algérie: Sciences et Technologie à Université Mentouri Constantine; 2008. p. 38–45.
6. Makhoul S, Romano A, Capozzi V, Spano G, Aprea E, Cappellin L, Benozzi E, Scampicchio M, Märk TD, Gasperi Flavia El-Nakat H, Guzzo J, Biasio F. Volatile compound production during the bread-making process: Effect of flour, yeast and their interaction. Food Bioprocess Technol. 2015;8(9):1925–37.
7. Fessard A. Recherche de bactéries lactiques autochtones capables de mener la fermentation de fruits tropicaux avec une augmentation de l'activité antioxydante. Doctoral dissertation, Université de la Réunion. 2017. p. 174.
8. NF (Norme française) V08-59. Microbiologie des aliments - Dénombrement des levures et moisissure. Normes nationales et documents normatifs nationaux. 2003. p. 8.
9. ISO 15,214. Microbiology of food and animal feeding stuffs-horizontal method for the enumeration of mesophilic lactic acid bacteria-colony-count technique at 30 degrees C. 1998; 1:7.
10. NF EN ISO 712, V03-707. Céréales et produitscéréaliers - Détermination de la teneuren eau - Méthode de reference. 2010. p. 23.
11. ISO 2171. Cereals, pulses, and by-Products-Determination of ash yield by incineration. 2007; 4:11.
12. NF EN 15 948. Céréales-Détermination de la teneur en eau et en protéine-Méthode utilisant la spectroscopie dans le proche infrarouge. 2020. p. 47.
13. ISO 659. Graines oléagineuses-Détermination de la teneur en huile (Méthode de référence). 2009; 3:14.
14. Al-Hooti S, Sidhu JS, Qabazard H. Chemical composition of seeds of date fruit cultivars of United Arab Emirates. J Food Sci Technol Mysore. 1998;35:44–6.
15. Merrill AL, Watt BK. Food energy value: basis and derivation (No. 74). Human Nutrition Research Branch, Agricultural Research Service, US Department of Agriculture. 1955.
16. ISO 13,312. Iron Ores-Determination of Potassium-Flame atomic absorption spectrometric method. 2017. p. 13.
17. Taupier-Létage B, Abécassis J, Viaux P, Fontaine L. Qualités des blés biologiques et qualités nutritionnelle et organoleptique des pains biologiques. Partie A: Présentation Du Programme et Synthèse Générale. France: Institut Technique de l'Agriculture Biologique; 2007.
18. Bokossa YI, Banon SJ, Tchekessi CK, Dossou YP, Adeoti K, Assogba E. Caractérisation physico-chimique et microbiologique d'Ablo: Une Pâte fermentée du Bénin. J Rech Sci Université de Lomé. 2013;15(2):389–97.
19. Mananjara P, Tsirinirindravo HL, Raherimandimby M, Randrianierenana A. Etude des levures endogènes de *Evodiabilahe* (*Rutaceae*) endémique de Madagascar. Int J Biol Chem. 2016;10(4):1694–701. https://doi.org/10.4314/ijbcs.v10i4.20.
20. Coulibaly EN, Assidjo C, Gattan N. Qualité microbiologique des farines de maïs aux marchés d'Abidjan. Revue Maroquine des Sciences Agronomiques et Vétérinaires. 2018;6(5):476–82.
21. Ennadir J, Hassikou R, Bouazza F, Amallah L. Caractérisation phénotypique et génotypique des bactéries lactiques isolées des farines de blé d'origine marocaine (Phenotypic and Genotypic Characterization of Lactic Acid Bacteria Isolated from Wheat Flour from Morocco). J Mater Environ Sci. 2014;5:1125–32. https://doi.org/10.1139/w11-139.
22. Remesy C, Leenhardt F, Fardet A. To give a new future to bread within the framework of a sustainable and preventive diet. Cah de Nutr et de Diet. 2015;50(1):39–46.
23. Guendouze-Bouchefa N, Belkacem Y, Adjlane D. Fortification en Fer de la Farine panifiable et de la Semoule. République algérienne démocratique et populaire. Université A Mira-Bejaia. Mémoire de Master. 2017. p. 87.
24. Bessou F, Bokossa YI, Metohoue R. Substitution de la farine de blé par la farine fermentée de manioc (lafu), dans la préparation du pain de boulangerie. J Rech Sci Université de Lomé. 2012;14(1):1–9.
25. Soro G, Adja GM, Tohouri P. Qualité physicochimique en saison pluvieuse des eaux de surface de la région de Bonoua. Int J Res Sci Innov Appl Sci. 2017;20(1):117.
26. AOAC (Association of Official Analytical Chemists). Analyse physico-chimique des denrées alimentaires. 1999.
27. Choudar Y, Cojocam A, Holly P, Jiscra P. Elément de différenciation entre le pain standard et le pain tradition française. Projet agroalimentaire sur le pain. Thèse. 2011. p. 71.
28. Koffi KE, Fofana I, Soro D, Yeo MA. Influence de la fermentation sur les caractéristiques physicochimique et sensorielle de la farine composite à base de banane plantain et d'amande de cajou. Eur Sci J. 2017;13(30):395–416.
29. Fardet A, Leenhardt F, Rémésy C. Donner un nouvel avenir au pain dans le cadre d'une alimentation durable et préventive. Cah de Nutr et de Diet. 2015;50(1):39–46.
30. Petrova P, Petrov K. Lactic acid fermentation of cereals and pseudocereals: Ancient nutritional biotechnologies with modern applications. Nutrients. 2020;12(4):1118.
31. Dossou J, Osseyi GE, Ahokpe FKK, Odjo SDP. Évaluation des procédés traditionnels de production du ablo, un pain humide cuit à la vapeur, au Bénin. Int J Biol Chem. 2011. https://doi.org/10.4314/ijbcs.v5i3.72185.
32. Mofakkir H. Contrôle de qualité du blé et de la farine. Université sidi Mohamed Ben Abdellah. Mémoire de Master. 2016. p. 38.
33. Galanakis CM, Aldawoud TM, Rizou M, Rowan NJ, Ibrahim SA. Food ingredients and active compounds against the coronavirus disease (COVID-19) pandemic: a comprehensive review. Foods. 2020;9(11):1701.

34. Meite A, Kouamé KG, Coulibaly S. Etude de la valeur nutritionnelle du pain normal et du pain composites contenant de la farine en graine délipidées de *Citrullus lanatus*. Bull Soc R Sci Liege. 2008;77:80–103.
35. Adrian J. Considérations sur le rôle du pain en alimentation. Médecine et Nutrition. 2002;38(5):169–76.
36. Graça C, Raymundo A, Sousa I. Wheat bread with dairy products—technology, nutritional, and sensory properties. Appl Sci. 2019;9(19):4101.
37. Taupier-Létage, B. Maîtrise de la Production de Blé en Agriculture Biologique et des Procédés de Mouture Adaptés à la Fabrication de Farine de Haute Densité Nutritionnelle. *Rapport final Contrat AQS n*. 2001.
38. Chandra RK. Micronutrient and Immune Functions: An Overview. Thèse de doctorat. 1990. p. 87.
39. Galanakis CM. Functionality of food components and emerging technologies. Foods. 2021;10(1):128.

Publisher's Note