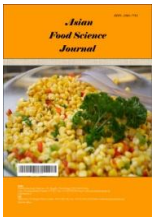

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Effect of Storage Temperature on the Microbial Quality of *Fura*

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Authors' contributions

This work was carried out in collaboration among all authors. Author JAA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors ESA and PA managed the analyses of the study and the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Fura, a semi-solid millet-based dumpling, is popularly consumed throughout West Africa. This work was aimed at evaluating the effect of storage temperature on the microbial and physicochemical properties of *fura*. Freshly prepared *fura* was stored at 30 and 4°C and sampled periodically to determine the changes in pH, titratable acidity, total soluble solids and total phenolic content. Additionally, the effect of storage temperature on the microbial (by enumerating aerobic mesophiles, lactic acid bacteria, *Enterobacteriaceae*, and yeast and moulds) quality was determined. Storage affected the acidity of *fura* with a decrease in pH and an increase in titratable acidity. The total soluble solids and total phenolic content were, however, not affected by storage temperature. Lactic acid bacteria were the predominant microbe present in *fura*. During storage at 30°C, faster growth of lactic acid bacteria and the other microbes was observed compared to storage at the lower temperature.

Keywords: Fura; microbial quality; pH; total soluble solids.

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1. INTRODUCTION

Fura is a popular traditional food in West Africa. It is a semi-solid dumpling produced by mixing millet flour with spices such as ginger, boiled for 30 min and pounded into doughs. Although *fura* is usually consumed in the afternoon, it is available throughout the day. Consumption involve homogenizing the dough into porridge using water, milk or *nono* (local yoghurt) [1-3]. When consumed with milk, the nutritional value of *fura* is enhanced and this can be used as an energy source and a nutrient deficiency intervention. Additionally, *fura* can be used as a weaning food for children [4-6].

Fura has limited storage life as it is usually prepared and stored under ambient temperatures. This is due to the fact that production is carried out on a small scale requiring little capital investment Also, preparative steps such as pounding and molding promote the proliferation of microbes which speeds up spoilage [7]. Recently, however, an increase consumption of *fura* has been observed due its unique taste [1]. To meet this demand, the storage ability of *fura* needs to be enhanced to ensure its continual availability.

The objective of this work was, therefore, to investigate the effect of storage on the microbial quality of *fura*. Freshly prepared *fura* was stored at ambient (30°C) and cold temperatures (4°C) and the effect of storage on aerobic mesophiles, lactic acid bacteria, *Enterobacteriaceae*, and yeast and molds determined. Additionally, the effect of storage temperature on pH, titratable acidity, brix and total phenolic content were determined.

2. MATERIALS AND METHODS

Freshly prepared *fura* was obtained from a producer in Cape Coast, Ghana. The *fura* was stored in incubators at 30 and 4°C. Sampling was carried out every 12 h for the *fura* stored at 30°C, while the *fura* stored at 4°C was sampled every 24 h. The microbial quality, pH, titratable acidity, and total soluble solids were determined immediately after sampling. Total phenolic content was determined on the samples after storage at -20°C. The proximate composition of the freshly prepared *fura* was also determined [8].

2.1 Determination of pH, Titratable Acidity, Total Soluble Solids and Total Phenolic Content

Fura (10 g) was homogenized in 100 mL distilled water and filtered. The filtrate was used to determine pH (B10P Benchtop) and total soluble solids (MA871, Milwaukee Instruments USA). Titratable acidity was determined by titrating 5 mL of the filtrate against NaOH (0.1 N) using phenolphthalein as indicator [9].

Total phenolic content was determined using the Folin-Ciocalteu reagent-based assay. Fura (10 g) was homogenized in 100 mL of 80% methanol solution. The homogenate was centrifuged and 750 µL Folin-Ciocalteu's reagent added to 100 µL of the supernatant. The mixture was incubated at 35°C for 3 h, the absorbance was measured at 725 nm and gallic acid used as the standard [10].

2.2 Microbial Analysis

Fura (10 g) was dissolved in 90 mL peptone water and used to perform serial decimal dilutions. Aerobic mesophiles were enumerated on plate count agar (Oxoid Ltd., UK) incubated at 30°C for 48 h while de Man-Rogosa-Sharpe agar (Oxoid Ltd., UK) was used to determine the load of lactic acid bacteria. Sabouraud Dextrose Agar (Oxoid Ltd., UK) was used to determine the load of yeast and moulds while *Enterobacteriaceae* were enumerated on Violet Red Bile Glucose agar (Oxoid Ltd., UK) [9].

2.3 Statistical Analysis

Statistical analysis was carried out using the analysis of variance (ANOVA) and the student's t-test using SPSS (IBM, SPSS Statistics 20). The difference among means was identified at a significance level of 0.05. All reported values represent means from four independent replicates. The model of Baranyi and Roberts [11] was used to estimate the specific growth rate (μ_{max}, day^{-1}) and lag time (λ, days) of the microbial groups at the different storage conditions using SPSS 20.

3. RESULTS AND DISCUSSION

3.1 Effect of Storage Temperature on pH, Titratable Acidity, Total Soluble Solids and Total Phenolics

The effect of storage temperature on the pH and titratable acidity of *fura* is shown in Fig. 1. The

pH of the freshly prepared *fura* was 6.7. Different pH values of *fura* have been reported. A pH of 6.4 was observed by Durojaiye et al. [1] while Owusu-Kwarteng et al. [5] and Ogodo et al. [4] observed pH values in the range of 4.85-5.55 and 4.1-4.56, respectively. The differences between the observed pH and those reported by other researchers could be due the properties of the raw materials used in the preparation and the different techniques employed by different producers during *fura* preparation.

Storage temperature had an effect on both pH and titratable acidity. During storage at 30°C, the pH decreased from 6.7 to 5.1 after 2 d. Also, the pH decreased to 5.5 after 4 d of storage at 4°C. Accompanying the pH decrease was an increase in titratable acidity (Fig. 1). The titratable acidity increased from 0.11 (for the freshly prepared *fura*) to 0.17 and 0.15 mg /100 g after 2 d and 4 d of storage at 4 and 30°C, respectively.

A similar decrease in pH (from 6.4 to 4) was observed when *fura* was stored at 30°C for 72 h [1]. This observed decreases in pH with an increase in titratable acidity could be due to lactic fermentation which occurred on the surface of *fura* during storage [1]. Although the pH of *fura* stored at 4°C also decreased, the decreased was less when compared to *fura* stored at 30°C. The slow decrease in pH of *fura* stored at 4°C could be due to the inhibition of acidophilic microorganisms due to the low temperature of storage.

The proximate composition of *fura* is shown in Table 1. The *fura* had a moisture content of 49.65 g/100 g, crude protein content of 10.63 g/100 g and a crude fat content of 2.65 g/100 g. The fibre content was 8.65 g/100 g. Table 2 shows the changes in total soluble solids and total phenolic content of *fura* during storage. Both the total soluble solids and total phenolic content were not significantly affected by storage temperature.

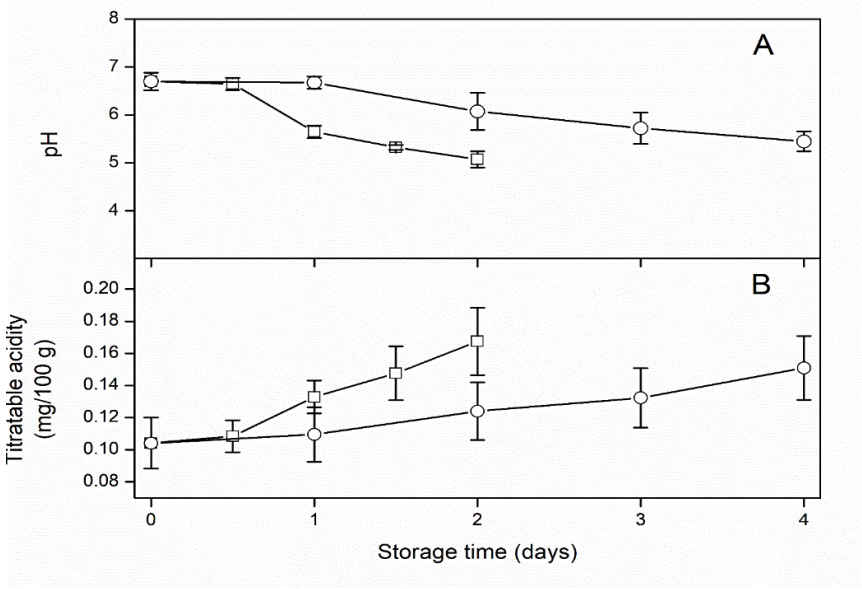

Fig. 1. pH (A) and titratable acidity (B) of *fura* stored at 30 (□) and 4°C (○)

Table 1. Proximate composition of *fura*

	Estimate		
Moisture (g/100 g)	49.65	±	3.56
Crude fat (g/100 g)	2.65	±	0.69
Crude protein (g/100 g)	10.63	±	2.65
Ash (g/100 g)	2.87	±	0.69
Fibre (g/100 g)	8.64	±	1.65
Carbohydrate	26.69		3.67

3.2 Effect of Storage Temperature on the Microbial Quality

The effect of storage temperature on the changes in aerobic mesophiles and lactic acid bacteria is shown in Fig. 2. The initial level of aerobic mesophiles and lactic acid bacteria were 4.36 and 3.95 log cfu/g. The levels of both aerobic mesophiles and lactic bacteria increased during storage, however, the increase was higher in *fura* stored at the higher temperature. At 30°C, the levels of aerobic mesophiles and lactic acid bacteria increased to 6.82 and 7.08 log cfu/g after 2 days of storage. This increase was characterized by lag periods of 0.35 and 0.39 days and specific growth rates of 1.78 and 2.82 day^{-1} for aerobic mesophiles and lactic acid bacteria, respectively (Table 3). At 4°C, however, microbial levels of 5.88 and 5.74 were observed for aerobic mesophiles and lactic acid bacteria (Fig. 2), respectively, after 4 days of storage. This reduced growth was also characterized by an increase lag phase and a reduced maximum specific growth rate (Table 3).

Table 2. Total soluble solids and total phenolic content of *fura* stored at different temperatures

Storage condition	Time (days)	Total soluble solids (°Brix)	Total phenolic content mg GAE/100 g
Fresh *fura*		0.56 ± 0.04	0.35 ± 0.05
30°C	0.5	0.51 ± 0.04	0.35 ± 0.03
	1	0.51 ± 0.09	0.31 ± 0.01
	1.5	0.51 ± 0.14	0.38 ± 0.01
	2	0.50 ± 0.05	0.43 ± 0.16
4°C	1	0.51 ± 0.04	0.34 ± 0.03
	2	0.51 ± 0.10	0.38 ± 0.03
	3	0.49 ± 0.10	0.34 ± 0.03
	4	0.45 ± 0.07	0.35 ± 0.03

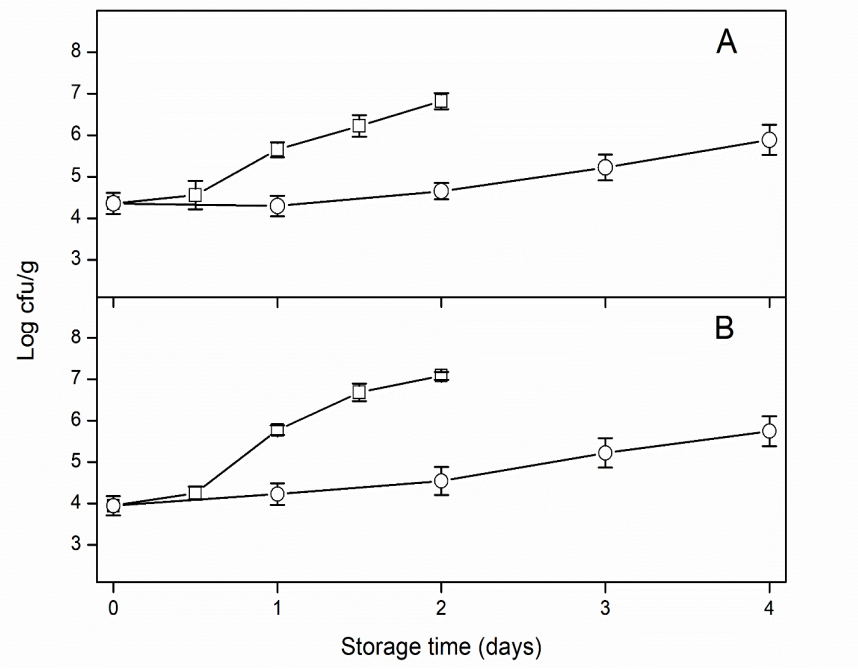

Fig. 2. Changes in the growth of aerobic mesophiles (A) and lactic acid bacteria (B) during storage of *fura* at 30 (□) and 4°C (○)

Table 3. Estimated lag duration (λ) and specific growth rate (μ_{max}) of the different groups of microbes present in *fura* during storage at 30 and 4°C

Storage temperature	Microbial group	λ (days)	μ_{max} (day^{-1})
30°C	Aerobic mesophiles	0.35 ± 0.26	1.76 ± 0.44
	Lactic acid bacteria	0.39 ± 0.16	2.82 ± 0.58
	Yeast and moulds	0.83 ± 0.08	0.66 ± 0.09
	Enterobacteriaceae	0.11 ± 0.10	0.38 ± 0.02
4°C	Aerobic mesophiles	1.60 ± 0.10	0.64 ± 0.03
	Lactic acid bacteria	0.83 ± 0.28	0.56 ± 0.05
	Yeast and moulds	1.46 ± 0.18	0.23 ± 0.02
	Enterobacteriaceae	1.17 ± 0.02	0.24 ± 0.01

Fig. 3 shows the changes in yeast and molds, as well as *Enterobacteriaceae* during storage of *fura*. The initial level of yeast and molds, and *Enterobacteriaceae* were 1.89 and 1.50 log cfu/g. During storage, the levels of yeast and molds increased to 2.55 and 2.49 after 2 and 4 days of storage at 30 and 4°C, respectively, with lag periods of 0.83 and 0.66 days. Similarly, the levels of *Enterobacteriaceae* increased to 2.23 and 2.10 after 2 and 4 days of storage at 30 and 4°C, respectively.

The microbial load of *fura* observed in this study was similar to that observed by other researchers [4,5]. Generally, lactic acid bacteria are the predominant microbes present and responsible for the spoilage of *fura* during storage. The growth of lactic acid bacteria could have been responsible for the lowering of pH during storage. Indeed, different strains of lactic acid bacteria have been isolated from *fura* prepared under different conditions [4,5,12]. Storage temperature affected the growth of microbes in *fura*. At the low temperature of storage, slow growth of microbes was observed, showing that the storage of *fura* can be enhanced when the temperature of the external environment is reduced.

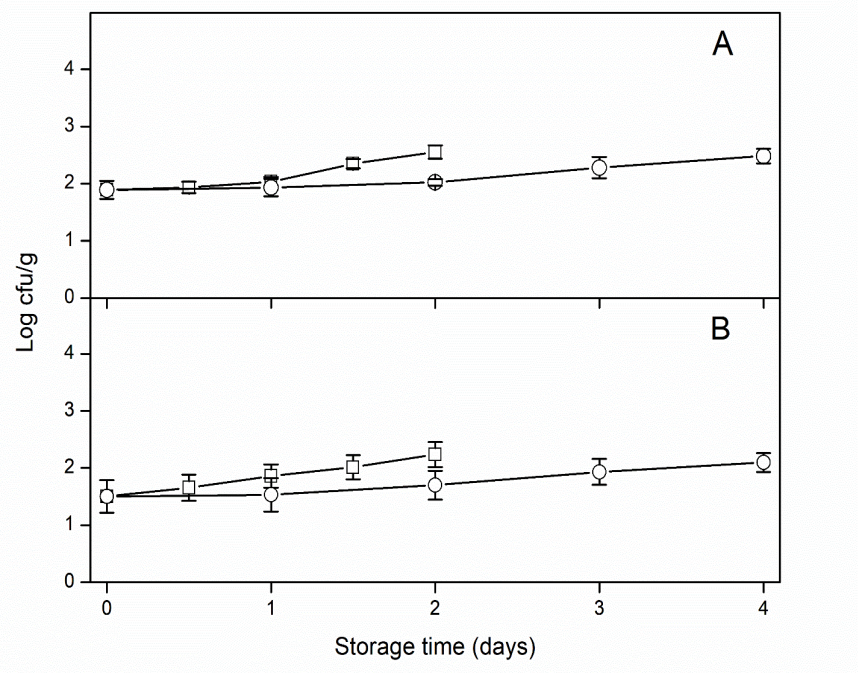

Fig. 3. Changes in the growth of yeast and moulds (A), and *Enterobacteriaceae* (B) during storage of *fura* at 30 (□) and 4°C (○)

4. CONCLUSION

Storage temperature affected the acidity of *fura* with a decrease in pH and an increase in titratable acidity, however, storage at the higher temperature was characterized by a faster acidification. The total soluble solids and total phenolic content were not affected by storage temperature. Lactic acid bacteria were the predominant microorganism present in *fura*. During storage at 30°C, faster growth of lactic acid bacteria and the other microbes was observed compared to storage at the lower temperature.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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