

Hygienic Quality of *Macrotermes* (Isoptera, Termitidae) alates (consumed in Lomé Togo)

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ABSTRACT

Aim/Background: *Macrotermes* alates are a source of animal protein for many populations. However, their consumption is not without health risks related to their hygienic quality. This study aims to evaluate the hygienic quality of alates of the genus *Macrotermes* consumed in Lomé.

Materials and Methods: An analysis of some germs was then carried out on traditionally caught and roasted samples. These samples were compared to those obtained by capture with a swabbing net and oven dried at 45 °C for 72 hr. The impact of packaging with or without wrapping on the hygienic quality during storage was also assessed. **Results:** The data obtained showed that the alates samples captured and roasted in the traditional way were highly contaminated with the germs of interest after 7 days of storage. Unpackaged alates were more contaminated (25354333.00 ± 835.00 cfu/g FMAT, 6840.00 ± 92.00 cfu/g TC, 533.33 ± 62.00 cfu/g CF, 313.30 ± 12.99 cfu/g yeast and 46763.00 ± 418.00 cfu/g mould) than the packaged ones (570.00 ± 40.00 cfu/g FMAT, 16.00 ± 03.67 cfu/g TC, 10.00 ± 02.01 cfu/g CF, 07.01 ± 0.99 cfu/g yeast and 16.00 ± 02.00 cfu/g mould). In contrast, the oven dried and packaged alates sample showed only traces of FMAT (02.00 ± 00.10 cfu/g). **Conclusion:** It appears that the microbiological quality of consumed alates depends not only on the capture and cooking methods, but also on the packaging for preservation. It is therefore necessary to raise awareness of good hygiene practices in the interests of consumer health safety.

Keywords: *Macrotermes* alates, Food use, Hygienic quality, Togo.

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INTRODUCTION

Insect consumption is widespread in tropical and subtropical areas throughout the world.^[1] Insects are interesting sources of protein and lipids and are also rich in minerals.^[2] Promoting the consumption of edible insects (including the alates of termite) could therefore be a source of improvement in low protein diets.^[3] Termite alates are captured by hand or with the help of cages, at dusk and at night, in the presence of light

sources. Once caught, they are usually dried directly in the sun or lightly roasted.^[4] These poorly improved capture methods are one of the main reasons for the low value of these insects in the human diet. Indeed, the traditional methods of roasting, sun-drying, packaging and storage of *Macrotermes* alates seem insufficient to reduce water activity, and therefore contamination by pathogens. This situation does not guarantee the sanitary quality of this foodstuff. Post-harvest losses due to heavy rainfall, which prevents efficient and rapid drying, may also occur. In addition, hydrolysis and auto-oxidation of fats and proteolysis of proteins are often recorded during cooking of these alates.^[5] As a result, the final product is of poor quality with an unpleasant taste, thus contributing to the low acceptability of the product, making it not suitable for consumption.^[5] Yet

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the food use of *Macrotermes* alates could be of great interest in the fight against malnutrition. Improved methods of capture, drying and preservation would contribute effectively to the valorization of this food resource. In addition, these methods could contribute to the hygienic quality of the product, which is a vital issue in collective catering, since contamination can lead to food poisoning among consumers. In order to promote entomophagy on a large scale, it is then necessary to guarantee the health safety of consumers. Unfortunately, few studies have focused on this aspect in Togo. It is therefore important to evaluate the microbiological quality of traditionally treated alates and to propose better treatment methods in order to reduce their contamination by pathogenic germs.

MATERIALS AND METHODS

Framework of the Study

Sampling sites

Alates were sampled in 3 communes of the district Lomé including Agoè-Nyivé 1, Golfe 3 and Golfe 7 (Figure 1).

Scientific Framework

The experimental processing test and packaging were carried out at the Department of Biochemistry of the Faculty of Sciences (FDS) of the University of Lomé (Togo). The packaging used was designed at the Institut Togolais de Recherches Agronomiques (ITRA). The microbiological analysis was carried out at the Laboratoire de Microbiologie et de Contrôle de Qualité des Denrées Alimentaires (LAMICODA) of the Ecole Supérieure des Techniques Biologiques et Alimentaires (ESTBA) at the Université de Lomé (UL).

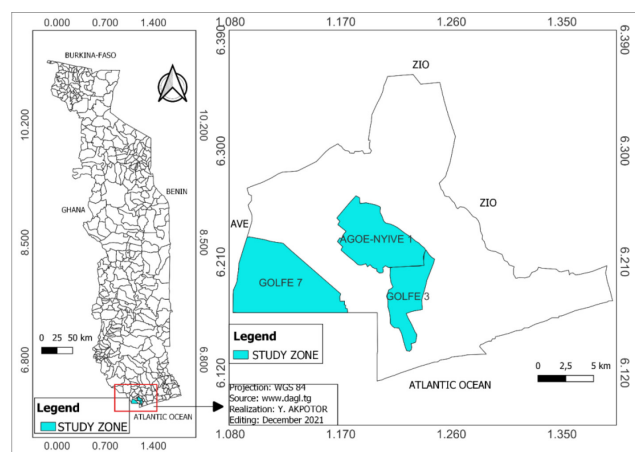


Figure 1: Map showing the sampling sites.

Sampling and Cooking

Alates were sampled during their swarming after heavy rains from the above mentioned three communes using basin of water (inside which they fall) and roasted in traditional way (Figure 2). These samples were provided by the consumers. Beside this traditional method of capture and processing, part of alates was also captured with sweep net from the campus of the University of Lomé (Togo). This sample was directly oven dried at 45°C for 72 hr without prior washing process (Figure 3).

Microbiological analyzes

Prior to microbiological analyses all the samples were labelled as follow AA/BB/CC where AA represents the site of collection, BB represents the way of conservation (packed or not) and CC represents the conservation time in days (Table 1).

The microbiological analyses were first carried out on the day of collection on the traditionally roasted samples (unpacked: «AN/NE/J0, GT/NE/J0 and GS/NE/J0» and packaged: «AN/EM/J0, GT/EM/J0 and GS/EM/J0») and on the oven-treated samples (UL/EM/J0a, UL/EM/J0b and UL/EM/J0c). The same analyses were then carried out on these different samples after three days and then after seven days.



Figure 2: Photo of *Macrotermes* alates captured (A) and roasted (B) traditionally.



Figure 3: Photos of *Macrotermes* alates sampled with sweep net (A) and oven dried (B).

Table 1: Identification of the samples analyzed.

Traditional processing (collection from the ground and roasting in a pot under low heat)				
Commune d'AgoeNyivé 1	Unpackaged samples		AN/NE/J0	
			AN/NE/J3	
			AN/NE/J7	
			AN/NE/J30	
	Packaged samples		AN/EM/J0	
			AN/EM/J3	
			AN/EM/J7	
			AN/EM/J30	
Commune du Golfe 3	Unpackaged samples		GT/NE/J0	
			GT/NE/J3	
			GT/NE/J7	
			GT/NE/J30	
	Packaged samples		GT/EM/J0	
			GT/EM/J3	
			GT/EM/J7	
			GT/EM/J30	
Commune du Golfe 7	Unpackaged samples		GT/EM/J90	
			GS/NE/J0	
			GS/NE/J3	
			GS/NE/J7	
	Packaged samples		GS/NE/J30	
			GS/EM/J0	
			GS/EM/J3	
			GS/EM/J7	
Experimental treatment (capture with swabbing net and oven cooking (45°C - 72 hr))	Université de Lomé	Packaged samples	UL/EM/J0	UL/EM/J0a
				UL/EM/J0b
				UL/EM/J0c
			UL/EM/J3	UL/EM/J3a
			UL/EM/J3b	
			UL/EM/J3c	
			UL/EM/J7a	
		UL/EM/J7	UL/EM/J7b	
	UL/EM/J7c			
	UL/EM/J30	UL/EM/J30		
	UL/EM/J90	UL/EM/J90		

AN: Agoe-Nyivé 1; GT: Golfe 3; GS: Golfe 7; UL: Université de Lomé; NE: Not packed; EM: Packed; Do: Sample analyzed on the day of collection; D3: Sample analyzed after three days of storage; D7: Sample analyzed after seven days of storage; D30: Sample observed after 30 days of storage; D90: Sample observed after three months of storage.

The results of these microbiological analyses were expressed as a mean followed by the standard error (SEM) of three values.

In addition, samples stored for a month (unpacked and packed) and after three months were visually observed.

Search for Micro-organisms

The microbiological analyses were carried out by AFNOR standardised methods. Thus, 25 g were taken from each of the batches and placed in a bottle

containing 225 ml of peptone water and then ground in the stomacher for 2 min. The initial solution obtained after revivification constitutes the stock solution. To carry out the 10^{-1} dilution, 1 ml of the stock suspension was taken and put into 9 ml of peptone water. To make the 10^{-2} ml dilution of the solution, 1 ml of the 10^{-1} solution was added to 9 ml of peptone water and so on for 10^{-3} , 10^{-4} dilutions. The diluent used to prepare the stock solutions was the same as that used to make the decimal dilutions. This diluent therefore did not introduce quantitative or qualitative variations in the microbial flora.

The germs tested were Total Aerobic Mesophilic Flora (TAMF), total coliforms, thermotolerant or faecal coliforms, sulphite-reducing anaerobes (SRA), yeasts and moulds. The results of these analyses were interpreted according to Commission Regulation (EC) No 2073/2005 of 15 November 2005 on microbiological criteria for foodstuffs.^[6] This regulation sets out the microbiological criteria for defining the acceptability of foodstuffs. All results were expressed in colony size units per gram of sample (cfu/g).

Enumeration of FMAT

These are micro-organisms capable of multiplying between + 25 and + 40°C with an optimum of + 30°C in aerobiosis. Their enumeration is carried out according to the NF V 08-051 standard.^[7] The method used is plating by incorporation into PCA agar, which consists of enumerating the viable microorganisms present in the sample. The inoculations are carried out with dilutions of 10^{-4} and 10^{-7} . A one ml volume of each dilution is taken and placed in a sterile Petri dish. Ten to fifteen ml of PCA, previously prepared and heated to 45°C, is then poured into the dish. The inoculum and PCA were then homogenised by rotating the dish and dried. After solidification, a second layer (protective layer) was poured on to prevent the development of any surface contamination flora. The plates were then incubated in an oven at +30°C for 48 hr. The whitish colonies that had grown deep into the soil were counted. The exact number N of germs per gram of *alates* was obtained by applying the following formula:

$$N = (\sum c * d) / V;$$

$\sum c$ = sum of colonies on counted plates.

V = volume of inoculum applied to each box.

d = Dilution at which the first counts are obtained.

This formula is also valid for the enumeration of the other germs studied. The results are expressed in cfu/g.

Enumeration of Total Coliforms

Total coliforms are rod-shaped bacteria with a rounded end. They are Gram-negative and are present in soil, water, etc. They normally live in the intestine of humans and animals but can become pathogenic. These germs possess the enzyme β -galactosidase which hydrolyses lactose at 37°C to produce red colonies on VRBL (crystal violet and neutral red lactose medium).

The method used is culture on deoxycholate lactose agar medium and incubation at 37°C for 24 hr as described in standard NF V08-050, April 2009.^[8] To do this, 0.1 ml of the sample was inoculated onto a Petri dish previously poured with deoxycholate lactose agar and dried. The plate was then spread and incubated at $37 \pm 1^\circ\text{C}$ for 24 hr. The appearance of visible colonies indicates the probable presence of total coliforms.

Enumeration of faecal coliforms

This research was carried out according to the standardised method NF 08-060 March 1996.^[9] The method is enumeration by incorporation into DL agar. Two dilutions (10^{-2} and 10^{-3}) were used. Inoculation and enumeration were done in the same way as above. Incubation was done in an oven at +44°C and only bright red to pinkish colonies were counted.

Enumeration of Sulphite Reducing Anaerobes (SRAS)

RSAs are commensal bacteria of the intestine and saprophytes of the soil, and are therefore an indication of past faecal contamination. The enumeration of RSA was carried out by plating 0.1 ml of the sample to be analysed in 20 ml of Sulfite Polymyxin (SPS) medium. The medium was solidified and incubated at 37°C for 24 hr as described in NF EN ISO 15213.^[10] The characteristic colonies of RSA are black on the selective agar medium (SPS).

Enumeration of Yeasts and Moulds

Moulds are eukaryotic micro-organisms that grow by means of several cell filaments called hyphae. Yeast is a microscopic form of fungi with a single round or oval cell. The enumeration of yeasts and moulds was carried out in culture on sabouraud agar medium + chloramphenicol and incubation at 37°C for 24 hr according to the ISO 021527-2: 2008 standard.^[11]

Statistical Analysis

The data from the microbiological analyses were discussed according to Commission Regulation (EC) No 2073/2005 of 15 November 2005 on microbiological criteria for foodstuffs. This regulation sets out the

microbiological criteria for defining the acceptability of foodstuffs.

All results were expressed in colony size units per gram of sample (cfu/g).

In order to estimate the duration of food use of roasted and packaged alates and those ovens dried and packaged, the samples were stored for up to three months and observed with the naked eye.

Data processing was carried out using GraphPad Prism software 8.0.1 and presented as mean followed by Standard Error Mean (SEM) ($n = 3$). Differences were considered significant at the 5% level ($p < 0.05$).

Evolution of biological germs according to the treatments and conservation time

Evolution of the Total Aerobic Mesophilic Flora (TAFM)

The results in Table 2 showed that the number of total germs present in the unpackaged roasted alates samples was above the maximum recommended value and increased over time. In the packaged roasted alates samples and in the oven-treated samples, the number of total germs was medium and low respectively on the first day and then decreased considerably over time (Table 2).

Evolution of Total Coliforms

The results showed that the number of Total Coliforms present in the unpackaged roasted alates samples was above the maximum recommended value on day three and increased with time. In contrast, the number of Total Coliforms was low in the roasted and packed alates samples and non-existent in the oven-treated alates samples (Table 3).

Table 2: Evolution of total germs (TAFM) as a function of treatment and time.

	Number of germs in cfu per g of sample		
	Unpackaged roasted	Packaged roasted	Oven treated at 45°C for 72 hr
J ₀	201693,00 ± 158,00	3900,00 ± 126,00	11,70 ± 3,83
J ₃	468900,00 ± 552,00	155,00 ± 25,00	05,33 ± 01,33
J ₇	25354333,00 ± 835,00	570,00 ± 40,00	02,00 ± 00,10
Indicator values (EC NO 2073/2005)	< 100	< 100	< 100

Results are expressed as mean ± MSE ($n = 3$). Do: Samples analysed on the first day after roasting; D3: Samples analysed on the third day after roasting; D7: samples analysed on the seventh day after roasting

Table 3: Evolution of total coliforms as a function of treatment and time.

	Number of germs in cfu per g of sample		
	Unpackaged roasted	Packaged roasted	Oven treated at 45°C for 72 hr
J ₀	73,33 ± 14,57	46,67 ± 07,36	00,00 ± 00,00
J ₃	190,00 ± 25,60	08,00 ± 01,87	00,00 ± 00,00
J ₇	6840,00 ± 92,00	16,00 ± 03,67	00,00 ± 00,00
Indicator values (EC NO 2073/2005)	< 100	< 100	< 100

Results are expressed as mean ± MSE (n = 3). Do: Samples analysed on the first day after roasting; D3: Samples analysed on the third day after roasting; D7: samples analysed on the seventh day after roasting

Table 4: Evolution of thermotolerant coliforms according to treatment and time.

	Number of germs in cfu per g of sample		
	Unpackaged roasted	Packaged roasted	Oven treated at 45°C for 72 hr
J ₀	03,33,33 ± 1,57	03,33 ± 01,57	00,00 ± 00,00
J ₃	20,00 ± 15,60	06,67 ± 01,90	00,00 ± 00,00
J ₇	533,33 ± 62,00	10,00 ± 02,01	00,00 ± 00,00
Indicator values (EC NO 2073/2005)	< 100	< 100	< 100

Results are expressed as mean ± MSE (n = 3). Do: Samples analysed on the first day after roasting; D3: Samples analysed on the third day after roasting; D7: samples analysed on the seventh day after roasting

Evolution of Thermotolerant or Faecal Coliforms

Table 4 showed that the number of faecal coliforms present in the unpackaged roasted alates samples was above the maximum recommended value on day 7 and increased with time. In contrast, the number of faecal coliforms was low in the roasted and packed alates samples and non-existent in the oven-treated termite samples (Table 4).

Evolution of Sulphite Reducing Anaerobes (SRA)

Table 5 shows the evolution of SRA by treatment, conditioning and the conservation duration of alates. Sulphite-reducing anaerobes were not detected in all samples analysed (Table 5).

Evolution of Yeast

Table 6 shows the evolution of the yeasts by treatment, conditioning and conservation duration of alates. The number of yeasts present in the unpackaged roasted alates samples was above the maximum recommended value and these yeasts increased in number over time

Table 5: Evolution of SRA germs according to treatment and time.

	Number of germs in cfu per g of sample		
	Unpackaged roasted	Packaged roasted	Oven treated at 45°C for 72 hr
J ₀	00,00 ± 00,00	00,00 ± 00,00	00,00 ± 00,00
J ₃	00,00 ± 00,00	00,00 ± 00,00	00,00 ± 00,00
J ₇	00,00 ± 00,00	00,00 ± 00,00	00,00 ± 00,00
Indicator values (EC NO 2073/2005)	< 100	< 100	< 100

Results are expressed as mean ± MSE (n = 3). Do: Samples analysed on the first day after roasting; D3: Samples analysed on the third day after roasting; D7: samples analysed on the seventh day after roasting

Table 6: Evolution of yeast as a function of treatment and time.

	Number of germs in cfu per g of sample		
	Unpackaged roasted	Packaged roasted	Oven treated at 45°C for 72 hr
J ₀	00,00 ± 00,00	00,00 ± 00,00	00,00 ± 00,00
J ₃	00,00 ± 00,00	00,00 ± 00,00	00,00 ± 00,00
J ₇	313,30 ± 12,99	07,01 ± 00,99	00,00 ± 00,00
Indicator values (EC NO 2073/2005)	< 100	< 100	< 100

Results are expressed as mean ± MSE (n = 3). Do: Samples analysed on the first day after roasting; D3: Samples analysed on the third day after roasting; D7: samples analysed on the seventh day after roasting.

(Table 6). In contrast, they were low in the packaged roasted alates samples and non-existent in the oven treated alates samples (Table 6).

Mould Evolution

Table 7 shows the evolution of moulds by treatment, conditioning and conservation duration of alates. The number of moulds present in the unpackaged roasted samples was above the maximum recommended value and these moulds increased in number over time (Table 7). In contrast, they were low in the packaged roasted alates samples and non-existent in the oven treated alates samples (Table 7).

It can then be assumed that oven-treated and then packaged alates could present almost no health risk and could therefore be stored for a longer period of time compared to traditionally roasted and packaged or unpackaged alates.

Observation of alates packed and stored at room temperature for up to three months

The roasted and packaged alates samples show mould visible to the naked eye after one month of storage

Table 7: Mould growth as a function of treatment and time.

	Number of germs in cfu per g of sample		
	Unpackaged roasted	Packaged roasted	Oven treated at 45°C for 72 hr
J ₀	06,67 ± 01,67	07,50 ± 01,50	00,00 ± 00,00
J ₃	1907,00 ± 147,00	02,50 ± 00,36	00,00 ± 00,00
J ₇	46763,00 ± 418,00	16,00 ± 02,00	00,00 ± 00,00
Indicator values (EC NO 2073/2005)	< 100	< 100	< 100

Results are expressed as mean ± MSE (n = 3). Do: Samples analysed on the first day after roasting; D3: Samples analysed on the third day after roasting; D7: samples analysed on the seventh day after roasting.



Figure 4: Photos of roasted *Macrotermes alates* wrapped in polyethylene plastic and then kept for one month.

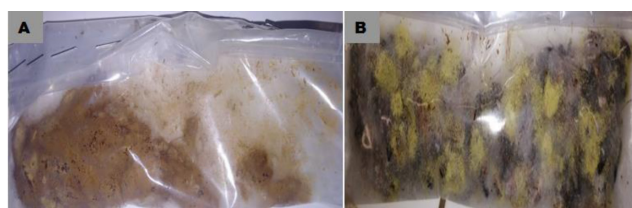


Figure 5: Photographs of roasted, packaged and stored *Macrotermes alates* for three months A: completely rotten and B: completely covered with mould.

(Figure 4) and look completely rotten and unsuitable for human consumption after three months of storage (Figure 5).

On the other hand, the oven dried and packaged sample showed satisfactory hygienic quality and good organoleptic quality, as they retained the same aroma, colour, flavour and texture as they had three months ago (Figure 6). This is due to the thorough drying in the oven and indicates that this treatment allows for a longer period of food use of the product.

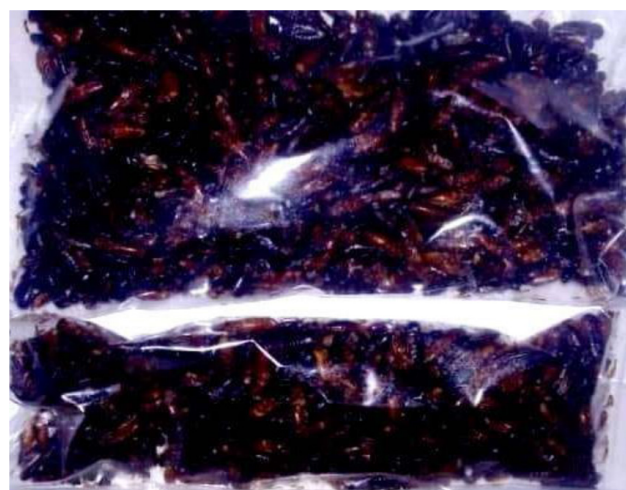


Figure 6: Photos of *Macrotermes alates* oven-treated at 45°C for 72 hr, packed and then kept for three months.

DISCUSSION

The data from these analyses were discussed according to Commission Regulation (EC) No 2073/2005 of 15 November 2005 on microbiological criteria for foodstuffs. This regulation sets out the microbiological criteria for defining the acceptability of foodstuffs.

Evolution of biological germs as a function of treatment and time

Evolution of the Total Aerobic Mesophilic Flora (TAFM)

The unpackaged roasted alates showed an unsatisfactory hygienic quality compared to the total sprouts as these sprouts were present in numbers far above the indicator value already on the first day according to Regulation (EC) No 2073/2005. These germs continued to proliferate in the following days in these samples. These results are in line with those obtained on the Migratory Locust (*Locusta migratoria*) and the House Cricket (*Tenebrio molitor*).^[13] This non-conformity would be due to hygiene and sanitation before, during and after roasting, but also to the inadequate storage temperature which would have led to increasing of germs. It may also be due to the inappropriate heat treatment.^[12]

The roasted and packaged alates showed a satisfactory hygienic quality with respect to total sprouts. On the first day after roasting, these germs averaged 3900 ± 1626 cfu/g and decreased in number over time. This decrease would be due to the packaging (Table 2). Indeed, the packaging would have prevented oxygen from entering the product. This would have slowed down the multiplication of germs and led to a reduction of bacteria within the packaging.

For the oven dried alates, the average total germ count was only 11.70 ± 3.83 cfu/g on day 1. These results

therefore showed a very satisfactory hygienic quality. This method of treating alates can therefore be used to preserve them for a longer period of time without altering the sanitary quality, since the average number of germs was only 02.00 ± 00.10 cfu/g after 7 days of preservation.

Evolution of Total Coliforms

The results indicated a change in total coliforms as a function of the treatment, packaging and shelf life of the alates analysed.

On the first day, the unpackaged roasted alates were of satisfactory hygienic quality with respect to total coliforms, but were not from the third day onwards.

Indeed, total coliforms multiplied on the remaining days to reach an average value of 6840 ± 92.00 cfu/g already on day 7. These unpackaged roasted alates therefore have a low optimal conservation duration (less than 3 days). This presence of total coliforms indicates a possible faecal contamination.^[12] It may also indicate ineffective heat treatment or subsequent contamination. They may also indicate poor cleaning and sanitation of the equipment. This absence of germs would be due to the fact that these insect samples were freeze-dried and therefore the activity of the water would be negligible to cause the multiplication of these germs.

As for the roasted and packaged alates, the results of the analyses showed a satisfactory hygienic quality with respect to total coliforms. The number of total coliforms was reduced over time. Plastic packaging could have a positive impact on the reduction of total coliforms. These total and coliforms were not found in the oven dried alates even on the seventh day. Their duration of conservation could therefore exceed 7 days when packaged, with a satisfactory sanitary quality for food use.

Evolution of Thermotolerant or Faecal Coliforms

The results indicated the evolution of faecal coliforms according to the treatment, packaging and shelf life of the analysed alates.

These results showed a satisfactory hygienic quality with respect to faecal coliforms for all samples analysed up to the third day after roasting. In contrast, the unpackaged roasted alates showed unsatisfactory sanitary quality with respect to faecal coliforms on day seven. This presence of faecal coliforms indicates definite faecal contamination.^[12] It could also be due to a lack of hand washing or inadequate hand washing during the processing of the alates. No faecal coliform germs were detected in the oven dried alates. This could be explained by the low water activity of these alates.

Evolution of Sulphite Reducing Anaerobes (SRA)

The data also indicated the evolution of RSAs as a function of the treatment, conditioning and shelf life of the alates analysed.

No SRA was detected in all samples which were therefore of satisfactory quality with respect to RSA. These alates could therefore be stored for at least 7 days compared to SRA.

Evolution of Yeast

The data show the evolution of yeasts as a function of treatment, packaging and shelf life of the analysed alates. Yeasts were present to a very high degree in the unpackaged alates batch from day three onwards (Table 6). When yeasts proliferate in food and their population reaches excessive levels, they can cause deterioration of products in terms of taste, texture and appearance.^[12] Their presence in the samples analysed indicates that this batch of alates was not storable for more than 3 days under conventional conditions. The roasted and packaged alates presented a satisfactory quality with respect to yeasts as their number in this batch of samples was below the recommended limit (EC Regulation N°2073, 2005). No yeast was detected in the oven dried alates.

Mould Evolution

The data in Table 7 showed a fairly high presence of moulds in the batch of unpacked alates from day three onwards. Indeed, when moulds and yeasts proliferate in food and their population reaches an excessive level, they can cause spoilage of food products in terms of taste, texture and appearance. Their presence then indicates that this batch of termites was not storable for more than 3 days. The roasted and packaged alates presented a satisfactory quality with respect to moulds as their number in this sample was below the threshold value according to Regulation (EC) No 2073/2005. No moulds were detected in the oven dried alates.

It can then be assumed that oven-treated and then packaged alates could present almost no health risk and could therefore be stored for a longer period of time compared to traditionally roasted and packaged or unpackaged alates.

Observation of alates packed and stored at room temperature for up to three months

From the physical observations of the samples, it can be seen that the roasted and packaged alates samples show mould visible to the naked eye after one month of storage and look completely rotten and therefore unfit for human consumption after three months of storage.

On the other hand, the oven dried and packaged sample showed satisfactory hygienic quality and good organoleptic quality, as they retained the same aroma, colour, flavour and texture as they had three months ago (Figure 6). This is due to the thorough drying in the oven and indicates that this treatment allows a longer period of food use of the Product.

These results are in line with those obtained on the Migratory Locust (*Locusta migratoria*) and the House Cricket (*Tenebrio molitor*).^[13] This non-conformity would be due to hygiene and sanitation before, during and after roasting, but also to the inadequate storage temperature which would have led to increasing of germs. It may also be due to the inappropriate heat treatment.^[12]

CONCLUSION

This study is a contribution to food safety through the evaluation of the sanitary quality of the alates of *Macrotermes*. Microbiological analysis of samples of these alates showed the presence of total coliforms, faecal coliforms, moulds, yeasts and total aerobic mesophilic flora. These traditionally processed alates are therefore of unsatisfactory hygienic quality, due to non-compliance with good processing and hygiene practices. They cannot therefore be preserved for a long time under traditional processing conditions. In contrast, the treatment of these termites under the experimental conditions improved their sanitary quality for a nutritional benefit over a long period.

An evaluation of the nutritional value and sanitary quality of oven dried alates in sterile plastic packaging and stored for three months is then necessary to corroborate the conclusions of this study.

ACKNOWLEDGEMENT

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

Ethical consideration

The authors state that they have respected all ethical considerations in this study.

Author Contributions

Conceived and designed the experiments: Kadanga Mawabena, Kasseney Dodji Boris, Dossou Bayi Reine, Mélila Mamatchi and Paka Essodolom; Analyzed the data: Kadanga Mawabena, Mélila Mamatchi and Awilli Tètouwala; Wrote the paper: Kadanga Mawabena, Kasseney Dodji Boris, Dossou Bayi Reine, Mélila Mamatchi and Awilli Tètouwala; Supervised the activities: Tchacondo Tchadjobo and Glitho Adolé Isabelle

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