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Influence of pH, Total Acidity and Technological Processes of Preparation of *babenda* "leafy vegetables and cereal sauce" on Pesticide Residues

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Abstract The uncontrolled use of pesticides on leafy vegetables has been frequently reported in recent years. The aim of this study was to evaluate the influence of pH, total acidity and various technological processes for the preparation of *babenda* on pesticide residues contained in leafy vegetable. The "*babenda*" is a Burkinabè dish consisting mainly of *Hibiscus sabdariffa, Amaranthus hybridus and Cleome gynandra* coarsely cut from steamed rice. The Quick, Easy Cheap Effective Rugged Safe Method (QuEChERS) and Gas Chromatography with Microelectron Capture Detector (GC-µECD) were used. Six pesticides were detected in 180 samples of leafy vegetables and cereal sauce (*babenda*) collected in 5 cities of Burkina Faso. Results showed that 56% of the samples contained residues among which 41.66% contained concentrations above the LMR and 25% contained multiple pesticides. There were found a correlation between pH and dieldrin content. Compared with the diuron with an average value of 0.0625-0.0969 $mg.kg^{-1}$, there is no correlation between this molecule and the pH (5.86) whose acidity varies between 0.04 - 0.10. The pH has an influence on the cypermethrin and the diuron. However acidity has an effect on the degradation of Lamda-cyhalothrines, 2, 4 DDT, dieldrin, heptachlor. For treatments of 150°C and 300°C, organochlorine pesticides are little or no degradation. There is a considerable reduction as the temperature increases. Only lindane, heptachlor, aldrin, alpa-endosulfan and 2, 4 DDT which have undergone total destruction from 250 and 300°C. Significant reductions were observed in all treatments applied. Future research needs to focus on the integration of food safety parameters into actual applied research at the level of *babenda* producers.

Keywords: *Pesticide, Babenda, technological processes, QuEChERS, LMR, Burkina Faso*

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1. Introduction

The *babenda* is a typical sauce of Burkina Faso, which was prepared and consumed during the lean season. It is prepare using leafy vegetables (*Hibiscus sabdariffa, Amaranthus hybridus and Cleome gynandra*) and cereals [1,2]. Leafy vegetables used for babenda preparation are mainly infected by pests such as aphids, nematodes, parasitoids, ladybugs, earworms and predatory mites etc. [3,4,5]. In order to increase vegetables yield, producers used many crop protection products such as synthetic pyrethroids, organophosphorus and organochlorines to stop insects attacks [4,5]. These active ingredients are used because of their high efficiencies and reduced decomposability. Several public health problems were associated with pesticide residues [6,7,8]. Market gardeners spray crops with plant protection products to fight pests. Many of these pesticides have a low rate of dissipation and therefore persist for a long time in leafy vegetables and then become part of our food chain [7,8,9,10]. Unfavorable practices of leafy vegetable farmers such as misuse of pesticides and failure to meet waiting times result in their uptake by vegetables. They enter the food chain and pose several health risks [11].

Pesticide residues in leafy vegetables and cooked dishes are a major concern for the consumer because of their negative health effects [7]. They are in fresh raw and processed products. Previous studies on ready meals have shown that processing techniques significantly reduce pesticide residues in vegetables and processed foods [11,12,13,14,15]. The techniques used for the commercial or home processing of leafy vegetables include washing, blanching, cooking, roasting, frying and boiling. Some authors like Kaushik *et al*. [16] reported that heat treatment on pesticide residues in leafy vegetables contribute to helps reduce the content of pesticide residues. These authors confirmed a reduction in pesticide residue levels through processing techniques in most foodstuffs, except for concentrated products such as fruit juice and pressing or extraction of vegetable seed oil. The technological processes and conditions used for cooking food are very varied [16,17]. Time / temperature, pH, total acidity, degree of water loss and whether the production system is opened or closed are important for the quantitative effects on pesticide residue levels [12,17,18]. Heat involved in cooking food increases the rate of degradation and volatilization of pesticide residues [19,20,21]. For example, in an earlier study of radio labeled chlorothalonil residues, open cooking resulted in 85-98% losses of pesticide residues through volatilization. Baking under closed conditions resulted in hydrolysis, with 50% of the chlorothalonil being recovered unchanged in the culture and the hydrolysis product in the liquor [22,23]. For compounds with low volatility and relatively stable hydrolysis such as dichlorodiphényltrichloroéthane (DDT) and synthetic pyrethroids, heat treatment losses may be low and concentrations may even increase due to moisture loss. However, deltamethrin would have a half-life of 9 minutes in boiling water and residues would have been reduced by 66% by cooking various vegetables [7-23]. Technological processing in its various forms combined with elements of washing, peeling, cooking and concentration etc. Previous studies of fruit vegetables treated with vinclozolin residues of 0.73 mg / kg yielded residues in canned juice, puree and ketchup at levels of 0.18, 0.73 and 0, respectively, 22 mg / kg^{-1} [24,25,26].

In this case, the relatively stable vinclozolin fungicide was transported in the process in significant amounts. Only 13% of parathion residues on tomatoes were found in canned juice or ketchup. The preparation of leafy vegetables has little or no influence on organochlorine pesticides, synthetic pyrethroids and organophosphorus compounds Tarnagda *et al*. [7]. There are a number of data available for the removal of organochlorine and organophosphorus pesticides during industrial and household vegetable and fruit processing [7,8,10-28]. Similar data on *babenda* are less numerous. Although the most logical approach to this problem of pesticide residues is to prevent contamination from the production site of leafy vegetables, a review of all methods that may decrease the level of pesticides in the *babenda* remains desirable. The objective of this study was to evaluate the influence of pH, total acidity and the technological processes of preparation of "*babenda*" sauce made from leafy vegetables and cereals" on pesticide contents.

2. Materials and Methods

2.1. Sampling of the *babenda* Sauce

A total of one hundred and eighty (180) *babenda* samples sold in five cities in Burkina Faso (Ouagadougou, Bobo-Dioulasso, Ouahigouya, Koudougou, and Kaya) were collected between July and August 2019 for toxicological analyzes. The Figure 1 present the sampling sites

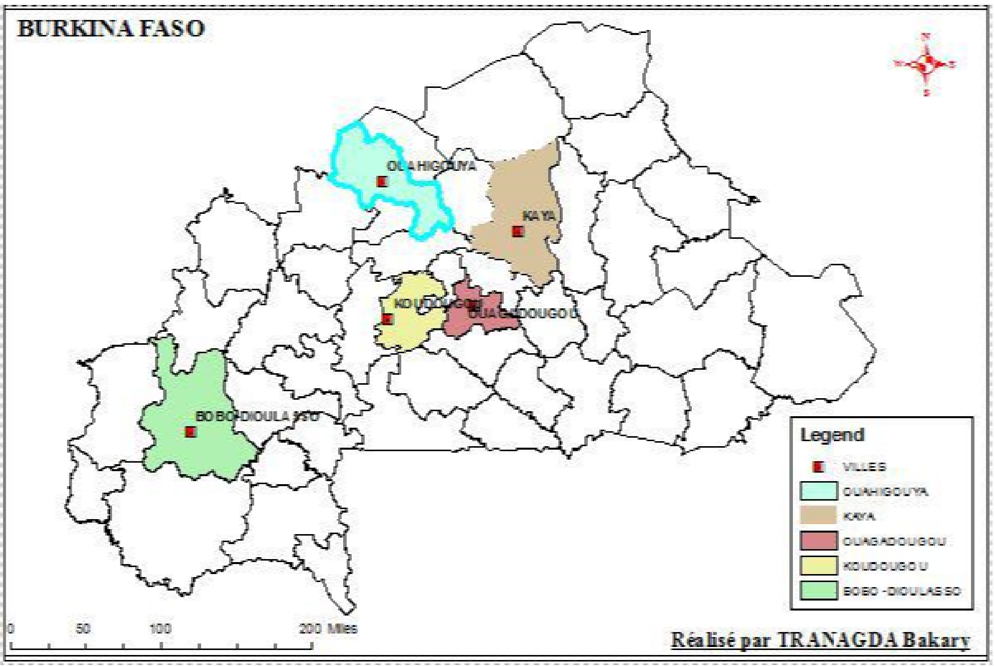

Figure 1. Geographical repair of the babenda production and marketing sites

Sampling was carried out in accordance with EU Directive 2002/63 / EC [29] on the determination of pesticide residue levels for compliance with maximum residue levels and the determination of pH, total acidity and the effect of heat treatment on active ingredients. All samples were purchased under normal conditions of immediate purchase for the consumer in order to take into account realistic consumer exposure conditions (public) and to reduce bias [30,31]. Sampling was conducted from a market system in five cities in Burkina (sellers, fixed and semi-mobile), to cover all types of markets used by *babenda* consumers in an African context [2]. At each sampling point, information such as the name of the sampling point (cities and market) as well as the dates on which the sampled batch was taken were recorded. Sampling was done using standardized random sampling methods [6,31,32,33,34]. Composite samples of 500g to 1kg of *babenda* were collected and sealed in sterile polyethylene bags. The samples were codified with a single identifier and placed in a refrigerator at 4°C until analysis Analyses were carried out within 24 h according to recommendation of Islam and Shamsad [35].

2.2. Determination of pH and Total Acidity

Ten grams (10 g) of each sample were dissolved in 50 ml of distilled water and mixed. The pH was directly measured with a digital pH-meter. For total acidity, 10 g of each sample are mixed with 50 ml of distilled water in rotating cones. The cones were then centrifuged for 15 minutes at 3900 rpm and the supernatant was collected. Titration was performed using 0.1 N KOH and phenolphthalein as indicator. All measurements including were repeated three times [36].

2.3. Determination of Pesticide Residues in *babenda* Sauce

The pesticide monitoring obtained from the surveys was used as a reference for the choice of active substances analyzed [5]. Given the different physico-chemical properties (rate of degradation, solubility in water) of pesticides and also their degree of toxicity, it was important to estimate the contamination by chemical class. Thus, the most used active ingredients in each chemical class (profenofos, Diazinon, Parathion-ethyl and Chlorpyrifos-methyl) for organophosphorus, lindane, aldrin, heptachlor, alachlor, and dieldrin for organochlorines and deltamethrin, cypermethrin, lambda-Cyhalothrin and tetramethrin have been targeted. Since these substances represent more than 65% of the pesticides used in the sites surveyed, their quantification makes it possible to measure, in a fairly representative way, the level of contamination of processed products (*babenda*).

Extraction and cleaning of the samples

The QuECHERS method was used with some modifications [37]. A micro-extraction of the sample finely crushed with acetonitrile was carried out in centrifuge tubes. While taking as a starting point of the literature [38], the purification of the extracts was carried out by centrifugation with salts (sulphate of anhydrous sodium) and carbon black graphitized (GCB) to mobilize the coloured substances (chlorophyl and carotene) that are non-active by precipitation. The supernatant obtained from the frozen extract after centrifugation was recovered in a vial using a Pasteur pipette. The analysis of the extracts was carried out using a chromatograph in gas phase (Agilent Technologies) that has a micro-detector that captures electron (GC-µECD/GC-FPD, Hewlett Packard). A capillary chromatographic column of type dB-17 MS. It had a length of 30 cm, an internal diameter of 250 µm and a thickness of 0.25 µm. Nitrogen of high purity was used as the carrier gas. The injection was carried out using Split/Splitless injection technique with an injection volume of 2 µl. The temperatures of the apparatus were as follows: - Room of injector programmed at 275°C with a pressure of 20.72 psi; - Column (75°C during 0.5 mn, 75-300°C with a flow of 10°C/mn and 300°C during 7mn); - Detector (325°C).

2.4. Influence of Heat Treatment On Pesticides

In most trials, we will use contaminated *babenda*, at a rate of 1ppm, with various pesticides (chlorinated mixes). The mixtures are prepared in such a way as to avoid interference due to possible conversion of an epoxide compound. For heat treatment, the sealed tubes were placed in an automatic muffle oven at different temperatures: 150°C, 200°C, 250°C and 300°C, for varying times: 1h, 2h, 3h and 4h.

2.5. Statistic Analysis

The dendogramme and Analyses of variance (ANOVA) were realized using XLSTAT-Pro 7.5. Means, standard deviation and the least significant difference between the means were determined ($p<0.05$). Newman-Keuls correlations among nutritional and physicochemical values were estimated for all the investigated factors. Sofware R 3.1.2 was used for the principal component analysis.

3. Results and Discussion

3.1. Physicochemical Characteristics of the *babenda*

Babenda are slightly acidic and have a pH between 4.87 ± 0.04 and 5.33 ± 0.06 with an average value of 5.12 ± 0.04. Their acidity ranges from 0.060 ± 0.02 to 0.077 ± 0.04 g / 100 g with an average of 0.07 ± 0.02 g.

3.2. Various types of Chemical Pesticides Found in the *babenda* Sold in the Five cities of Burkina

Analysis of pesticide content in *babenda* collected in Burkina Faso's five cities indicated that pesticide residues were detected in 56% of the samples and among the positive samples, 25% contained concentrations above the Limit of Residues Maximum (LMR), 10% samples contained multiple pesticides. A total of six active ingredients were detected in the *babenda* and its pesticides are from the family of pyrethroids (cypermethrin and lamda-cyhalothrin) organochlorine compounds (diuron, 2,4 DDT, heptachlor, dieldrin)

In general, there was a decrease in the level of pesticide residues in the samples analyzed. Cypermethrin was detected in samples (OH9) ranging from 0.0006 to 0.001 $mg.kg^{-1}$ with an average of 0.0008 $mg.kg^{-1}$. The concentrations of lamda-cyhalothrins ranged from 0.00025 to 0.0021 $mg.kg^{-1}$ in the samples (OH8) with an average value of 0.0012 $mg.kg^{-1}$, in contrast to the 2.4 DDT samples (O4) recorded pesticide residue levels of 0.00095 to 0.0035 $mg.kg^{-1}$. The same O4 sample recorded levels of dieldrin at levels ranging from 0.06475 to 0.0901 $mg.kg^{-1}$. A 13% contamination of the *babenda* samples by the diuron from 0.09695 to 0.09732 $mg.kg^{-1}$ in the samples (KG7) with an average value of 0.0971 $mg.kg^{-1}$, while as the values recorded by heptachlor from 0.0278 to 0.0345 $mg.kg^{-1}$ in the *babenda* sample (KG5). 1.66% of 2,4 DDT, 3,33% of lamda-cyhalothrin, 5% of dieldrin, 13,33% of diuron, 3,33% of cypermethrin were the percentages of synthetic pyrethroids and organochlorines detected after cooking.

Compared to organochlorine herbicides, the diuron was the most detected with 13.33%. The levels of pesticides detected in the samples taken in the five cities of Burkina Faso are shown in Table 1.

3.3. Effect of Pretreatments on Pesticide Residues in the *babenda*

3.3.1. Principal Component Analysis of Metal Trace Elements

Principal component analysis of leafy vegetable samples was performed using a two-axis biplot (F1 and F2) that explained 41.24% of the variability of the study samples. The main axis F1 explained 22.16% of this variability and the secondary axis F2 19.08%. The two axes made it possible to determine six active ingredients namely:

- A first group consisting of durion and cypermethrin which is linked to the main axis F1;
- A second group that includes 2,4 DDT, dieldrin, heptachlor and Lamda-cyhalothrin which is linked to the secondary axis F2.

Observations made on the main axis showed that the samples (KG8, KA6, KG10, O18, OHG8, OHG9) are contaminated with the diuron and cypermethrin. While that performed on the secondary axis has distinguished a contamination of organochlorine pesticides and synthetic pyrethroids in samples of *babenda* collected (2, 4 DDT, dieldrin, heptachlor and lamda-cyhalothrines). Figure 2 shows the analysis of the main components of the effect of pH, acidity and pesticides in the studied *babenda* samples.

The pH is a factor used to control the effectiveness of the treatments, the acidity on the other hand makes it possible to determine the good progress of the thermal treatments. There is a correlation between pH and dieldrin content. A large part (percentaga) of *babenda* has a pH of 4.48 - 5.47 and an acidity of between 0.07-0.09, the dieldrin content varies from 0.00172 to 0.00336 $mg.kg^{-1}$. Compared to the diuron with an average value of 0.0625 - 0.0969 $mg.kg^{-1}$) there is no correlation between this molecule and the pH (4.48 -5.86), the acidity of which varies between 0, 04 - 0,10. The pH and the influence of the cyperméthrine and diuron (O18, OH9, B7, OHG8, KG7, O12, KG10, K9, K10, KG4, KG7) are continually influenced by the influence of the Lamda-cyhalothrines, 2,4 DDT, dieldrin, heptachlor (OH4, B5, 04, 018, OHG3, KG8, K4, KG5, B7, 07). Pesticide levels detected in samples taken in the five cities of Burkina Faso are recorded in Table 1.

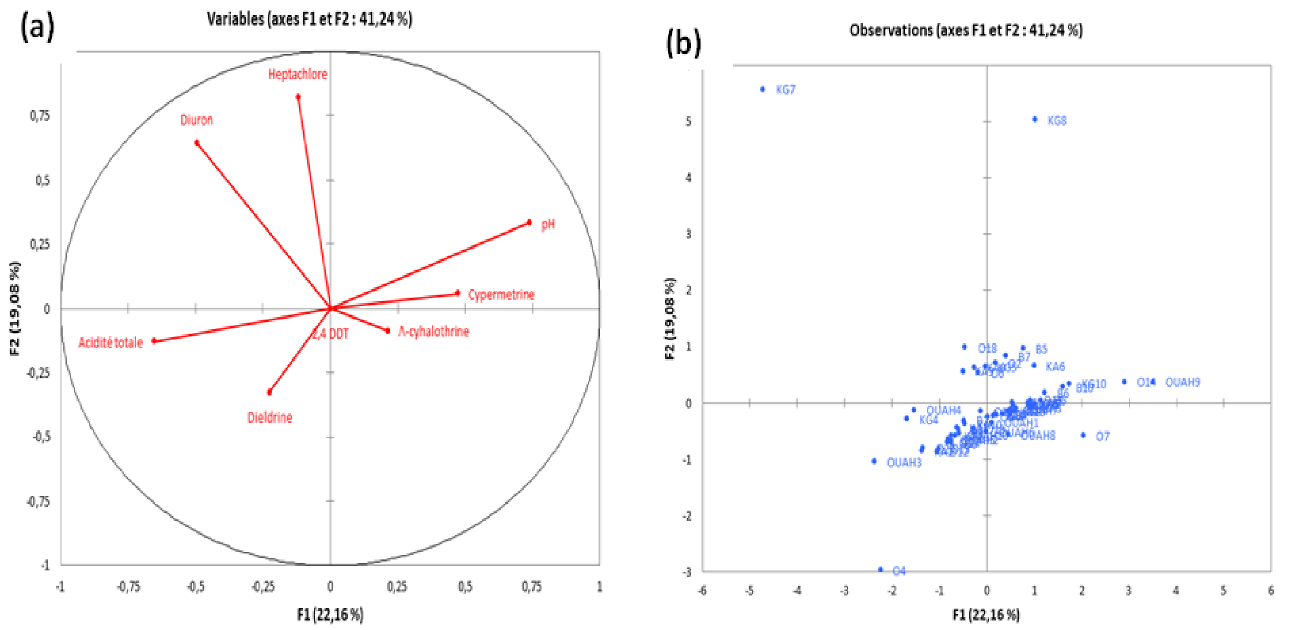

Figure 2. ACP of the influence of pH and total acidity on pesticide degradation. (a) variables of pH and total acidity on pesticide degradation and variable cites (b)

Table 1. Pesticide levels detected in samples taken in the five cities of Burkina Faso

Samples	pH	Total Acidity	Method of extracting pesticides	Number of samples exceeding the LMR	Concentration of pesticide residues (mg/kg)	Pesticid Group	active molecules	samples with multiple	Average (mg/kg)	LMR (mg/kg)	LD (mg/kg)
	4,56	0,07	QuEChERS				nd				
	5,33	0,05	QuEChERS	1	0.061288	Organochlorés	Duiron		0.0613 - 0.0862	0.05	0.01
	4,46	0,06	QuEChERS				nd				
	4,40	0,06	QuEChERS	2	0.000948	Organochlorés	2,4 DDT	2	0.00095 - 0.0032	0.05	0.002
			QuEChERS		0.064746	Organochlorés	Dieldrine		0.06475 - 0.0901	0.02 - 0.05	0.004-0.01
	5,40	0,03	QuEChERS				nd				
	5,22	0,06	QuEChERS	1	0.057557	Organochlorés	Diuron	1	0.05756 - 0.05886	0.05	0.01
	5,30	0,04	QuEChERS	1	0.00047	pyréthrinoïdes	Λ-cyhalothrine		0.00047 - 0.007	0.05 - 0.02	
	5,22	0,07	QuEChERS				nd				
	5,17	0,07	QuEChERS	1	0.006947	Organochlorés	Diuron		0.00694 - 0.0356	0.05	0.01
*Babenda*_36(a)	5,21	0,05	QuEChERS				nd				
	4,58	0,07	QuEChERS				nd				
	4,25	0,06	QuEChERS	1	0.000426	Organochlorés	Diuron		0.000426 - 0.0026	0.05	0.01
	4,37	0,07	QuEChERS				nd				
	5,58	0,03	QuEChERS	1	0.00034	pyréthrinoïdes	Cypermethrine		0.00034 - 0.0224	0.05	0.0001-0.05
	5,52	0,05	QuEChERS				nd				
	5,59	0,11	QuEChERS				nd				
	5,34	0,04	QuEChERS				nd				
	4,90	0,07	QuEChERS	2	0.005628	Organochlorés	Heptachlore	2	0.00563 - 0.0467	0.05 - 0.01	0.002
			QuEChERS		0.001705	Organochlorés	Diuron		0.0017 - 0.0038	0.05	0.01
	4,88	0,07	QuEChERS				nd				
	4,58	0,10	QuEChERS				nd				
	5,27	0,07	QuEChERS				nd				
	5,35	0,11	QuEChERS				nd				
*Babenda*_36(b)	5,00	0,09	QuEChERS				nd				
	5,21	0,06	QuEChERS				nd				
	5,24	0,03	QuEChERS	1	0.004075	Organochlorés	Heptachlore		0.0041 - 0.0078	0.05 - 0.01	0.002
	5,67	0,05	QuEChERS				nd				
	5,71	0,09	QuEChERS	1	0.003246	Organochlorés	Heptachlore		0.00312 - 0.0487	0.05 - 0.01	0.002
	5,30	0,03	QuEChERS				nd				
	4,84	0,08	QuEChERS				nd				
	5,73	0,03	QuEChERS				nd				
*Babenda*_36(c)	4,83	0,09	QuEChERS				nd				
	5,31	0,05	QuEChERS				nd				
	5,22	0,05	QuEChERS				nd				
	5,28	0,16	QuEChERS	1	0.06526	Organochlorés	Diuron		0.0653 - 0.0680	0.05	0.01
	5,21	0,07	QuEChERS	1	0.00359	Organochlorés	Heptachlore		0.0036 - 0.00473	0.05 - 0.01	0.002
	5,47	0,07	QuEChERS				nd				
	4,48	0,10	QuEChERS	1	0.969458	Organochlorés	Diuron	1	0.09695 - 0.09732	0.05	0.01
	5,86	0,04	QuEChERS	1	0.027820	Organochlorés	Heptachlore		0.0278 - 0.0345	0.05 - 0.01	0.002
	5,62	0,08	QuEChERS				nd				
	5,82	0,03	QuEChERS				nd				
	4,83	0,09	QuEChERS	1	0.000843	Organochlorés	Dieldrine		0.00084 - 0.0026	0.02 - 0.05	0.004-0.01
	5,31	0,05	QuEChERS				nd				
	5,22	0,05	QuEChERS				nd				
	5,28	0,16	QuEChERS	1	0.00120	Organochlorés	Heptachlore		0.0012 - 0.0028	0.01- 0.05	0.002
	5,21	0,07	QuEChERS				nd				
*Babenda*_36(d)	5,47	0,07	QuEChERS	2	0.002125	Organochlorés	Dieldrine	1	0.00212 - 0.0046	0.02 - 0.05	0.004-0.01
			QuEChERS		0.003097	Organochlorés	Heptachlore		0.0031- 0.0425	0.05 - 0.01	0.002
	4,48	0,10	QuEChERS				nd				
	5,86	0,04	QuEChERS	1	0.061661	Organochlorés	Diuron	1	0.0617- 0.0633	0.05	0.002
	5,62	0,08	QuEChERS	1	0.074813	Organochlorés	Diuron	1	0.0748 - 0.0804	0.05	0.002
	5,82	0,03	QuEChERS				nd				
*Babenda*_36 (e)	4,95	0,05	QuEChERS				nd				
	4,62	0,07	QuEChERS				nd				
	4,51	0,15	QuEChERS				nd				
	4,52	0,10	QuEChERS	1	0.002855	Organochlorés	Heptachlore		0.0028-0.0039	0.05 - 0.01	0.002
	4,68	0,08	QuEChERS				nd				
	4,60	0,03	QuEChERS				nd				
	5,33	0,06	QuEChERS				nd				
	5,24	0,09	QuEChERS	1	0.00025	pyréthrinoïdes	Λ-cyhalothrine	1	0.00025-0.0021	0.05 - 0.02	0.0006 -1.9
	5,46	0,05	QuEChERS	1	0.00063	pyréthrinoïdes	Cypermethrine		0.0006-0.001	0.05 - 0.25	0.0001 - 0.05
	4,79	0,08	QuEChERS				nd				
Total : 180				**41.66%**			**6**	**25%**	**56%**		

a. Ouagadougou, b. Bobo-Dioulasso, c. Koudougou, c. Kaya, e. Ouahigouya, LMR: Maximum Residue Limit, LOD: Detection limit, nd: Non detect.

3.3.2. Effect of Different Heat Treatments

For sample (a) after treatments at 150°C and 300°C, organochlorine pesticides are little or no degradation. Figure 3 shows the residual percentages at different temperatures. There is a considerable reduction as the temperature increases. Only pesticides (Lindane, Heptachlor, Aldrin, Alpa-Endosulfan and 2,4 DDT) have undergone total destruction from 250-300°C. Pesticide content before and after thermal destruction of chlorinated derivatives are recorded in Table 2.

Table 2. Pesticide content before and after thermal destruction of chlorinated derivatives

Samples_City	Pesticides	**To**	150°C	200°C	250°C	300°C
i	Lindane	0.02875	0.02438	0.02438	nd	nd
	Heptachlore	0.03978	0.03453	0.03453	nd	nd
	Aldrine	0.01548	0.01397	0.01397	nd	nd
	Chlorpyrifos-Ethyl	1.09794	2.1474	2.1474	nd	nd
	Alpa-Endosulfan	0.01540	0.01437	0.01437	nd	nd
	Dieldrine	0.01775	0.01648	0.01648	nd	nd
	Bêta-Endosulfan	0.01591	0.01513	0.01513	nd	nd
	2,4 DDT	0.01392	0.01204	0.01204	nd	nd
a	Lindane	0.02875	0.01679	0.000135	nd	nd
	Heptachlore	0.03978	0.02302	nd	nd	nd
	Aldrine	0.01548	0.009778	0.0008812	nd	nd
	Chlorpyrifos-Ethyl	1.09794	0.55467	0.522291	0.51757	0.501588
	Alpa-Endosulfan	0.01540	0.010412	0.001742	nd	nd
	Dieldrine	0.01775	0.013117	0.004597	0.00343059	0.00064244
	Bêta-Endosulfan	0.01591	0.0119515	0.0033744	0.006462	0.00036997
	2,4 DDT	0.01392	0.00894122	0.00326	0.0006344	
b	Lindane	0.02438	0.0105332	0.000061576	nd	nd
	Heptachlore	0.03453	0.0150384	nd	nd	nd
	Aldrine	0.01397	0.0068801	0.000752708	nd	nd
	Chlorpyrifos-Ethyl	2.1474	0.557242	0.519974	0.507391	0.502535
	Alpa-Endosulfan	0.01437	0.00679948	0.00070754	0.0126379	nd
	Dieldrine	0.01648	0.00939854	0.00172491		
	Bêta-Endosulfan	0.01513	0.00775899	0.0029709	0.00151677	0.00025395
	2,4 DDT	0.01204	0.00590360	0.00020363		
c	Lindane	0.02438	0.00730475	nd	nd	nd
	Heptachlore	0.03453	0.0106584	nd	nd	nd
	Aldrine	0.01397	0.525912	0.0007394	nd	nd
	Chlorpyrifos-Ethyl	2.1474	0.538145	0.0052571	0.005014	nd
	Alpa-Endosulfan	0.01437	0.00533982	0.000936965	nd	nd
	Dieldrine	0.01648	0.00601662	0.0030317	nd	nd
	Bêta-Endosulfan	0.01513	0.00585159	0.00170709	0.0013267	nd
	2,4 DDT	0.01204	0.00418872	0.00022507		nd
d	Pesticides	T0	150°C c	200°C c	250°C c	300°Cc
	Lindane	0.02438	0.00995817	nd	nd	nd
	Heptachlore	0.03453	0.0141520	nd	nd	nd
	Aldrine	0.01397	0.00563942	0.00135659	nd	nd
	Chlorpyrifos-Ethyl	2.1474	0.557730	0.523017	0.501108	nd
	Alpa-Endosulfan	0.01437	0.00515024	0.001331226	nd	nd
	Dieldrine	0.01648	0.00749959	0.00385710	nd	nd
	Bêta-Endosulfan	0.01513	0.00640440	0.00212566	0.002004	nd
	2,4 DDT	0.01204	0.00622448		nd	nd
e	Pesticides	T0	150°C	200°C	250°C	300°C
	Lindane	0.02438	0.0126900	0.00064664	nd	nd
	Heptachlore	0.03453	0.0185328	0.00245923	nd	nd
	Aldrine	0.01397	0.0078172	0.00222361	nd	nd
	Chlorpyrifos-Ethyl	2.1474	0.578507	0.00538873	nd	nd
	Alpa-Endosulfan	0.01437	0.00710191	0.00309476	nd	nd
	Dieldrine	0.01648	0.008349001	0.00470184	nd	nd
	Bêta-Endosulfan	0.01513	0.00830964	0.0042019	nd	nd
	2,4 DDT	0.01204	0.00699775	0.000602918	nd	nd

To : Initial temperature nd: Non detect

After 4 hours of heating, chlorpyrifos-ethyl, dieldrin and bêta-endosulfan were maintained at levels of 0.501588, 0.00064244 and 0.00036997 mg / kg^{-1}, respectively, which underwent a significant reduction from 300 ° C.

Figure 3 shows the similarity dendogram and class profile of *babenda* samples as a function of the influence of pH, acidity and detected pesticides.

Figure 4, Figure 5, Figure 6, Figure 7, Figure 8 and Figure 9 shows the results obtained after the heat treatments from 150 ° C to 300 ° C for 1, 2, 3 and 4h. It is seen that Chlorpyrifos-Ethyl and Beta-Endosulfan being the most resistant are reduced in 4 hours at concentrations of 0.502535 and 0.00025395 mg / kg-1, respectively. The destruction of other organochlorine pesticides is slower, lindane, heptachlor, aldrin dieldrin and 2,4 DDT being the most sensitive are completely destroyed in 4 hours. The same observation made in sample (c) shows that chlorpyrifos-ethyl and bêta-Endosulfan being the most resistant are reduced in 3h at concentrations of 0.005014 and 0.0013267 mg / kg^{-1}, respectively. And the sample (d) shows a considerable reduction of chlorpyrifos-ethyl and Beta-Endosulfan at levels of 0.501108 and 0.002004 mg / kg^{-1}, respectively.

At the level of the sample (d) we see a total reduction of all the molecules after 3 hours of heating at 250 ° C.

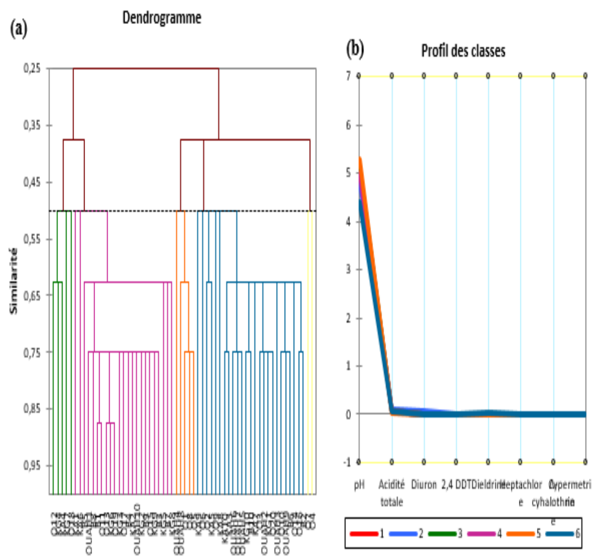

Figure 3. Dendogram of similarity and class profile of *babenda* samples according to the influence of pH, acidity and pesticides detected. (a) Similarity diendogram of *babenda* samples (b) Class Profile.

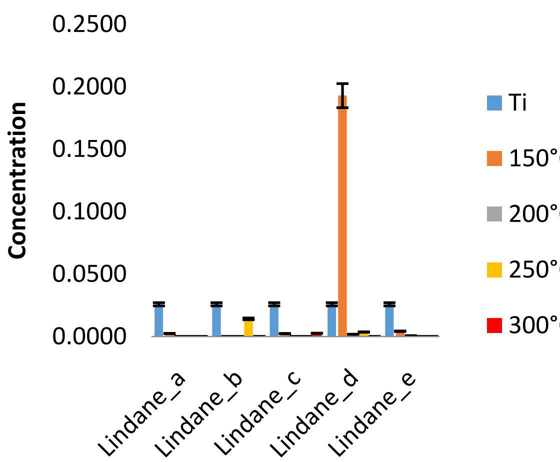

Figure 4. Influence of heat treatment on the degradation of lindane in the *babenda* collected in the five cities of Burkina Faso

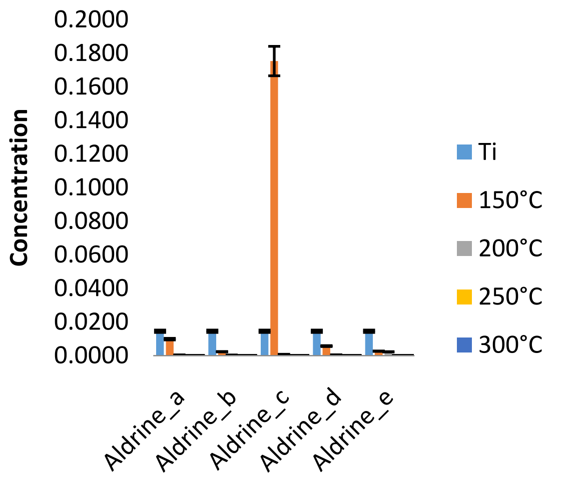

Figure 5. Influence of heat treatment on the degradation of aldrine in the *babenda* collected in the five cities of Burkina Faso

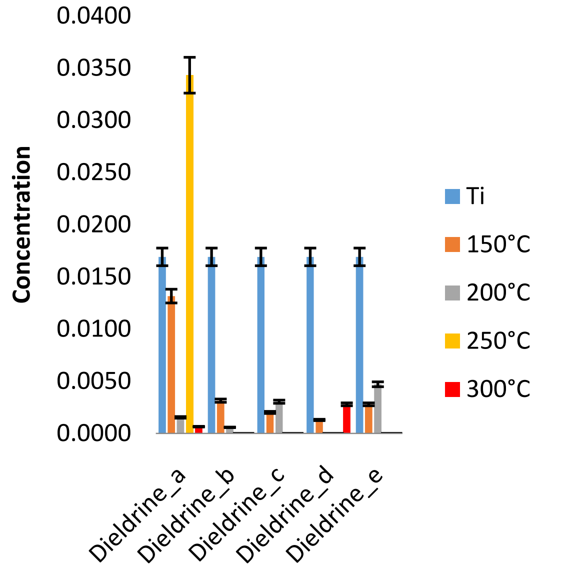

Figure 6. Influence of heat treatment on the degradation of dieldrine in the *babenda* collected in the five cities of Burkina Faso

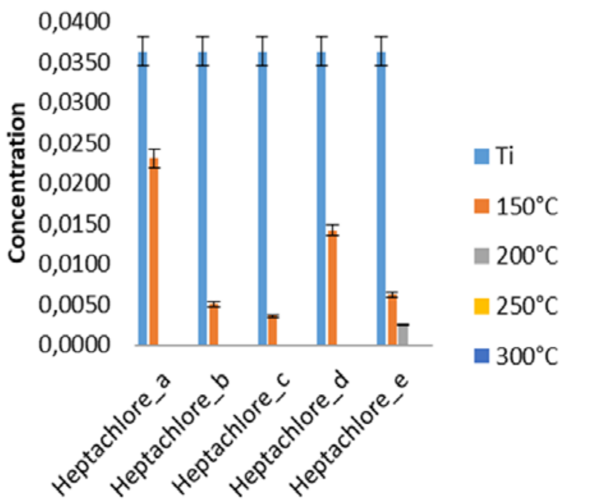

Figure 7. Influence of heat treatment on the degradation of heptachlore in the *babenda* collected in the five cities of Burkina Faso

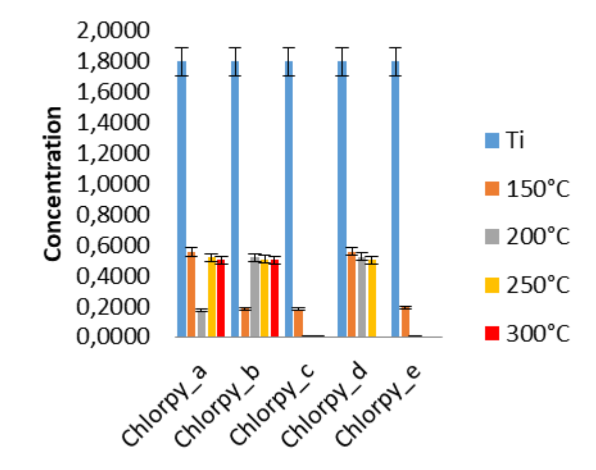

Figure 8. Influence of heat treatment on the degradation of Chlorpyrifos-Ethyl in the *babenda* collected in the five cities of Burkina Faso

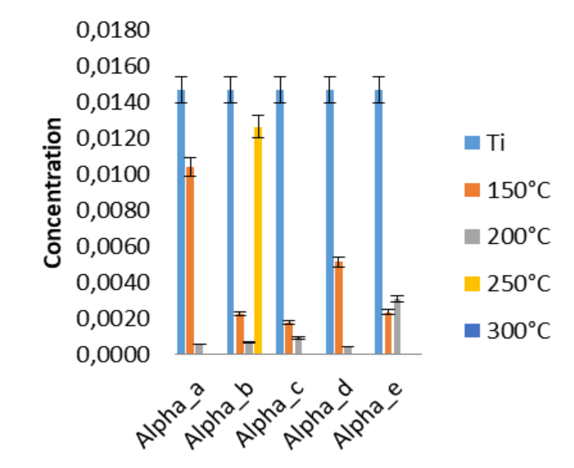

Figure 9. Influence of heat treatment on the degradation of Alpa-Endosulfan in the *babenda* collected in the five cities of Burkina Faso

The pesticide contents before and after the thermal destruction of the chlorinated derivatives are recorded in Table 2. The Ascending Hierarchical Classification indicates, on the basis of the detected pesticides, that the *Babenda* samples taken in the five cities are divided into six groups according to their origin (Figure 3), Figure 4, Figure 5, Figure 6, Figure 7, Figure 8, Figure 9 shows the results obtained after the heat treatments from 150°C to 300°C for 1, 2, 3 and 4h.

Classes 1 and 5 consist of samples of cities whose pH, acidity and active ingredient content differs from that of all samples (Figure 3). Classes 3 and 5 are samples containing at least one pesticide. Chromatograms of *babenda* samples containing pesticide residues - a: Chromatogram of a sample from Ouagadougou - b: Chromatogram of a Bobo sample; c: Chromatogram of a sample at 150 ° C.

Fruits and vegetables are usually perishable by nature. This can result in substantial losses for farmers and consumers. The main objective of processing fruit and vegetables is to provide consumers with safe, nutritious and acceptable food throughout the year [39].

Food processing refers to methods and techniques applied to raw ingredients to turn them into a consumable form [2]. Food processing also includes the preparation of basic raw materials, such as washing, removing contaminants and foreign matter, and peeling and dressing (eliminating non-consumable parts of the raw agricultural product).

Two composed pyrethrinoids (λ-cyalothrine et cyperméthrine), four organocyclo compounds (2,4 DDT, diuron, heptachlore, dieldrine) (Figure 2). 41.66% of the samples exceeded the LMR, 10% samples contained multiple pesticides. These results are similar to those obtained by Holland *et al*. [40] who showed a reduction of pesticides in plant products ranging from 0-90%. In general, residual pesticide levels in the five surveyed cities were identical, lower or higher than the critical lines of the LMR (Table 1) authorized [41,42,43,44].

This can result from inappropriate or abusive pesticide use and farmers' lack of environmental education [5]. Our results are lower than those obtained by Radwan *et al.* [23], which reported levels of Chlorpyrifos of 20 and 38mg/kg^{-1} respectively following the blanching of the tomato. These results resonate with 66.5% of total detections and 35% of multiple pesticide detections observed in apples in Poland [45] and are also consistent with recent findings in Ghana [35,36,37,38], Zambia [34] and Kuwait [46].

Fifty percent of total pesticide detections were above legally authorized Codex LMR and were dominated by organophosphates; classified as very dangerous (class 1B) [47]. But these results are lower than those obtained in Côte d'Ivoire by Touré *et al.* [48] who reported that Chlorpyriphos-methyl content was 0.338 mg.kg-1 in *Amaranthus hybridus* in the residue analysis. Results similar to those of Byrne *et al.* [49] studied the effects of cooking on chlorpyrifos and 3, 5, 6-trichloro-2-pyridinol on apples, cherries, sweet potatoes, peppers and winter squash. Chlorpyrifos was reduced in apples (39%), peppers (30%), sweet potatoes (76%) and winter squash (98%). However, other samples in the same studies showed increases: winter squash (70%), pepper (17%). For the chlorpyrifos metabolite, 3, 5, 6-trichloro-2-pyridinol, the increase was observed in apples (60%), cherries (10%) and sweet potatoes (90%). The contamination of *babenda* samples with a pyrethroid compound is also comparable to that of other active ingredients. The pyrethroid results obtained in this study are much higher than those obtained from those recommended by the Codex Alimentaruis [50] and the EU [45] in plant products (0.01 and 0.67 mg.kg^{-1}). Similar results to the work done in Burkina Faso by Tarnagda *et al.* [7] which found that 58.40% of samples contained residues exceeding the maximum residue limits (LMRs) proposed by FAO / WHO, while 41.6% contained residues within acceptable limits.

50% of the *babenda* samples contained pesticides. This research work is also in agreement with that of Tariq *et al.* [51] that found pesticide residues in 35% of fresh product samples and 10% of processed vegetables. Our results corroborate previous studies that show that technology treatments reduce the amount of pesticide residues in vegetables [52,53,54]. In-process unit operations typically involve washing the raw product (leafy vegetables) with large amounts of water, often using high-pressure sprayers and often incorporating surfactants or other auxiliaries [55]. Reduced washing results in the elimination of pesticide residues in various crops [52,53].

In the production process of *babenda*, leafy vegetables are bleached, which promotes the elimination of 50% of pesticides [2-7]. Lopez-Perez *et al.* [53] reported that bleaching eliminated 82% of cauliflower methidathion residues. However, for African consumers, the "lack of knowledge" about pesticide residues in foods, the "lack of awareness" about the link between consumption and pesticide intoxication, as well as other social ills mask the visibility of the chronic effects of exposure to pesticide residues [56].

The (significant) decrease in lindane content in *babenda* samples can be explained by assuming that this relatively volatile component actually disappears. Destruction of organochlorine pesticides is unlikely at the temperatures used. Our tests confirm the resistance of organochlorine pesticides to heat treatments and our results are consistent with those reported by Kroger *et al*. [57] who worked with a range of different substances; however, this resistance is not uniform; cyclohexane derivatives are the most sensitive to heating. This is different with U.V. ray treatment; in this case the derivatives of methanoindene and dimethanonaphthalene are the most rapidly destroyed. For the percentages of destruction, our results agree with those of Heckmati and Bradley [58] who reported a percentage of destruction ranging from 15% for cyclohexanes to 45% for dieldrin. Thermal treatments of 150°C to 300°C, applied to organochlorine pesticides for periods ranging from 1 to 4 hours, mainly degrade cyclohexane derivatives. The heat involved in cooking is reported to increase the rate of degradation and volatilization of pesticide residues. Similar findings were made by Rasmusssen *et al*. [22]; Radwan *et al*. [23]; Walia *et al*. [24]. In a previous study of radiolabelled chlorothalonil residues in 2010, open-air cooking resulted in 85-98% loss of pesticide residues through volatilization.

The greater reduction of highly water-soluble pesticides during cooking may be due to the fact that they have been degraded and transferred to the cooking water more easily than those which are poorly soluble in water. Angioni *et al*. [25] reported that leafy vegetables had a higher surface area / mass ratio than other crops. Pesticides that have penetrated deeper into the core of samples may be less affected during treatment. During the washing process, pesticide residues remained more on leafy vegetables. This could be due to the fact that the pesticides on leafy vegetables have entered the waxy cuticle and could not be further affected by washing. Washing has proven to be the least effective treatment method for reducing pesticides. Keikotlhaile *et al*. [59] found that washing had less impact than frying, peeling, boiling and muffling of the meta-analysis. In addition, during frying, the oil interacts more with the outer layers than with the core of the sample. Other physico-chemical parameters such as thermal degradation may play an important role in heating treatment processes.

4. Conclusion

It is unlikely that the temperatures used will have any destructive influence on organochlorine compounds. The elimination of these compounds by the methods examined is not significant. Heat treatment and homogenization during the preparation of the *babenda* increase to a small extent the extractibility of the incorporated organochlorine pesticides. The influences of the physico-chemical properties were significant ($p < 0.05$) during the cooking processes of our study. There was a significant difference between pH, acidity, but not heat treatment. The *babenda* analyzed shows a contamination by pesticide residues that is alarming. The majority of samples showed that pesticide levels are relatively higher; probably because of excessive use of chemical pesticides by market gardeners. The risks of contamination of the food chain by the consumption of *babenda* sold on the markets of the five cities of Burkina Faso are not negligible.

Monitoring of the pesticide content of *babenda* for consumption should be continued; because this sauce is highly consumed during major ceremonies in Burkina Faso.

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