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Phytosanitary Practices and Pesticide Levels in Fresh and Dried Mangoes Produced in Burkina Faso

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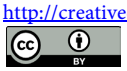


Abstract

Pesticides are used to control fruit flies and other potential crop pests, particularly mango in Burkina Faso. Pesticides are a potential health hazard for users and consumers and are a major constraint to the export and commercialization of mangoes. The objective of this study was to evaluate phytosanitary practices in orchards and pesticide residue levels in four varieties of fresh and dried mangoes (Amelie, Brooks, Kents and Lippens) produced in four localities in Burkina Faso in order to determine their health impact on consumers. Surveys on pesticide use and monitoring of phytosanitary practices were carried out among 16 orchard owners in the localities of Bobo-Dioulasso, Orodara, Toussiana and Banfora, a high mango production area. Also, a total of 120 samples, including 60 samples of fresh mangoes and dried 60 samples of dried mango were collected. A multi-residue method was developed to detect pesticide levels in the collected samples by gas chromatography with a micro-electron capture detector. The study revealed the use of unauthorized pesticides, often specifically for other crops, and a monitoring trapping network in the orchards against insects. 34 chemical pesticides were detected in 120 samples of all mango varieties collected. Pesticide residues were detected in 72% of the samples, and of the positive samples, 48.52% contained concentrations above the maximum residue limit permissibility. Organochlorine pesticide residues were present in fresh mangoes (60.5%) and a total of fifteen active compounds were detected in dried mangoes. The very poor management and use of pesticides found in these orchards could pose a threat to the productivity of natural ecosystems and the health of producers, processors

and consumers. Awareness raising and training of producers on the knowledge of the risks linked to the use of pesticides and good practices are necessary to preserve the health of all.

Keywords

Phytosanitary Problems, Orchards, Mangoes, Pesticides, Burkina Faso

1. Introduction

Fruits production in Burkina Faso in general and mango, in particular, contribute to our country's exports and national currency. In addition to feeding people, it has a key role in the country's agriculture and economy [1] [2]. Increasing quantities of fruits meeting specific quality criteria are required for dried mango production. Burkina's orchards, mainly located in the southern and western regions are enduring a decline in both the quantity and quality of their production due to several factors which include soil exhaustion, varietal problems, inadequate cultivation practices and phytosanitary problems [3] [4]. According to their corporation (the fruit and vegetable producers in Burkina Faso), pest problems are the most important factor in the decline in their production [5] [6] [7]. Orchard producers use pesticides of synthetic chemical pesticides and natural phytosanitary or attractants more often to combat fruit flies. Some studies highlighted poor phytosanitary practices in Burkina Faso [8] [9] [10]. The main hindrances of fruit exports are mainly their quality which pests and diseases are the origins. But very few studies focused on it particularly on fruit flies [11]. Mangoes are generally food products of high nutritional and commercial value. Also, mango is widely processed and consumed by the population in various forms, including dried, juice/nectar, jam and mango syrup [12]. Part of the mango produced in Burkina Faso is exported to foreign countries. Studies have revealed the presence of contaminants in fruits and vegetables, in particular pesticides. Pesticides are chemical or biological agents' chemical or biological agents capable of destroying pests or controlling their growth and reproduction their reproduction [13]. Pesticides have negative impacts on the health of operators and consumers of contaminated products [4]. Systemic intoxications, which can lead to death, but also allergic, dermatological and respiratory effects, are regularly reported among farmers using pesticides or working on treated crops [4]. A collective expertise of Inserm has synthesized the existing scientific data concerning certain cancers, neurological disorders (neurodegenerative diseases, such as Parkinson's disease and Alzheimer's disease, cognitive disorders, anxiety and depression), reproductive and developmental disorders and certain metabolic diseases [14]. The side effects of pesticides are the degradation of aquatic ecosystems, Alzheimer's disease, anxiety disorders, certain cancers affecting the bladder or kidney, asthma and wheezing, and thyroid pathologies [14]. Thus, knowledge of agricultural phytosanitary practices is an important aspect in the

search for alternative solutions against these pests. This study aims to contribute to the improvement of phytosanitary practices of mango producers in the context of food security by increasing the quantity and quality of mango produced in Burkina Faso and preserving the health of consumers.

2. Materials and Methods

2.1. Setting and Period of Study

The study was conducted from March to August 2022. Interviews with orchard owners focused on mango pests (diseases, insect pests, fruit flies), cultural characteristics of the orchards, varietal characteristics, control methods used, phytosanitary products used, packaging management and their knowledge of chemical risk. These data were collected from individual semi-structured surveys [15]. The data collected was manually processed and analyzed using the Epi-info software, Eureka 2003. The ecological conditions of these localities in the Houet, West and Comoé regions, which are areas of high fruit production in general and the most representative in terms of mango production in the region (according to the mango producers' organizations) in particular, guided our choice as the framework for the present study [16]. Eight orchard sites were selected according to the following criteria:

- the orchard must be located in an important mango production area;
- the orchard must have mango trees of production age;
- the orchard must be accessible in all seasons.

2.2. Samples Collection

Fresh samples were collected from orchards and dried mango from production units. After sample collection, about 1 Kg of composite mango variety sample was separated and sealed in a polythene bag. A total of 120 samples (60 fresh mango samples and 60 dried mango samples) of four varieties commonly used in dried mango production were collected. The mango varieties involved Amelie, Lippens, Brooks and Kents. The sampling was carried out according to EU Directive 2002/63/EC [17]. They were coded with a unique identifier and placed in a refrigerator (4˚C) at the National Public Health Laboratory in Ouagadougou. Analyses were carried out within 24 hours as recommended by Islam and Shamsad [18].

2.3. Extraction and Cleaning of Pesticides Residues

The extraction of the samples was performed by adapting the QuECHERS method [19]. Micro-extraction of the finely ground sample with acetonitrile was performed in centrifuge tubes, purification was performed by centrifugation with salts (anhydrous sodium sulfate) and graphite carbon black (GCB) to mobilize the colored substances (chlorophyll and carotene) that are not active by precipitation [20]. The supernatant obtained from the frozen extract after centrifugation was collected in a vial using a Pasteur pipette. Analysis of the extracts

was performed using a gas chromatograph (Agilent Technologies) equipped with a micro-detector that captures electrons (GC-μECD/GC-FPD, Hewlett Packard). A capillary chromatographic column type dB-17 MS. It has a length of 30 cm, an internal diameter of 250 μm and a thickness of 0.25 μm. High-purity nitrogen was used as the carrier gas. The injection was performed using the Split/Splitless injection technique with an injection volume of 2 μl. The device temperatures were as follows: injector chamber programmed at 275˚C with a pressure of 20.72 psi; Column (75˚C for 0.5 min, 75˚C - 300˚C with 10˚C/min flow and 300˚C for 7 min) and detector at 325˚C.

2.4. Statistical Analysis

Microsoft Excel 2013 software and R software version 3.4.2 are used for data analyses. The chi-square test was used to compare the categorical variables among the groups. ANOVA help highlighted means, standard deviation and least significant difference ($p < 0.05$).

3. Results

3.1. Description of Studied Mangoes Varieties

Amelie variety is locally known as "Gouverneur" or "Greffée" is the earliest of the grafted cultivars, with rounded fruit, yellowish-green skin and soft, melting dark orange flesh. The Brooks variety is also referred to as "Late Mango". It's a late cultivar with elongated oval fruit with thick, tough dark green to yellowish green skin and firm, medium aromatic, slightly tart bright yellow flesh. Kents variety is a late season cultivar locally referred to as "Krouba-Krouba". It is also called "Laban" which means "fine" in the local language. Kents variety mango is a slightly oval fruit with a thick, fairly tough purplish-red skin and relatively firm orange to dark yellow flesh with a large number of fine, unobtrusive fibers. Lippens variety is locally known as "Timi-Timi". This variety produces slightly elongated fruits with yellowish-green or purplish skin and juicy flesh.

3.2. Field Treatments of Orchards with Insecticides

Thiacloprid and deltamethrin (Timaye) based product is used against mango fruit flies thirty (30) days before harvest to avoid residues on the fruits. **Figure 1** shows the trapping system at Timaye and the use of a sprayer in the orchards.

3.3. Pesticide Residues in Fresh and Dried Mangoes

A diversity of pesticides is used in agricultural production. These pesticides are chemically developed and produced for specific pests. Contamination of mangoes can result from treatment as well as inappropriate use and cross-contamination (orchards near cotton fields and/or market gardens). All samples were contaminated with pesticide residues. The different pesticides compound found are listed in **Table 1** and **Table 2**.

Figure 2 shows the chromatogram of the mango samples contaminated with

Figure 1. Timaye trapping system in orchards. Legend: (a) success bait; (b) GF-120 bait. (c) trap control; (d) sprayer for fly control.

pesticide residues.

The principal component analysis of the fresh mango samples was carried out using a biplot consisting of two axes (F1 and F2) which explained 57.79% of the variability of the study samples. The main axis F1 explained 33.10% of this variability and the second axis F2 was 24.69%. The two axes were used to determine the active pesticides compounds:

The first group consists of penconazol, beta endosulfan, bifenthrin, lindane, diflubenzamide, 24DDT, methoxychlor, quintozene, heptachlor, etc., which is related to the main axis F1;

A second group which includes pretilachlor, tetramethrin, simazine, chlorothalonil, pendimethalin, carbofuran, deltamethrin, propargite, methomyl, atrazine, heptenophos, beta HCB, ethoprophos, monocrotophos, mevinphos, chlordimrform and which is linked to the secondary axis F2.

The primary axis showed that samples from Brooks, Lippens, Amélie and Kents are contaminated with organochlorine, organophosphate, carbamate and synthetic pyrethroid pesticides. For dried mangoes, the principal component analysis of the samples was carried out using a biplot consisting of two axes (F1 and F2) that explained 72.38% of the variability of the study samples. The main axis F1 explained 42.63% of this variability and the secondary axis F2 explained 29.74%. The two axes identified the following active ingredients: A first group consisting of deltamethrin, lindane, dieldrin, atrazine, beta HCB and which is related to the main axis F1; A second group consisting of heptachlor, permethrin, 24DDT, alachlor, beta endosulfan and linked to the secondary axis F2.

These samples are contaminated with organochlorine pesticides and synthetic

Table 1. Different types of active ingredients detected in fresh mangoes.

Mango varieties	Name of pesticides detected	Range of pesticide/ Résidus (mg/kg)	Numbers contaminated sample	A number of samples containing of multiple residues of pesticides for each product	Number of sample exceeding MRL	MRL (mg/kg)
Lippens (15 samples)	Methomyl	0.0097 - 0.010	1	1	2	0.05
	Carbofuran	0.0060 - 0.080	2			0.5
	Mevinphos	0.0020 - 0.050	1	1	1	-
	Heptenophos	0.0014 - 0.00110	1			-
	Ethoprophos	0.0152 - 0.0180	1			0.01
	Chlordimrform	0.0016 - 0.0130	2	1		-
	Monocrotophos	0.0294 - 0.0340	1		1	0.01
	Dimethoate	0.0023 - 0.05	1			0.02
	Beta HCB	0.0046 - 0.06	2	1	1	0.01
	Quintozene	0.00102 - 0.012	1	1		0.02
	Chlorothalonil	0.0058 - 0.0775	1		1	-
	Simazine	0.006 - 0.0198	2	1		-
	Atrazine	0.0037 - 0.05	1			-
	Alachlore	0.001 - 0.092	3	1		0.01
	Heptachlore	0.006 - 0.054	1	1	1	0.01
	Triadimefon	0.001 - 0.025	2			-
	Pendimethalin	0.00108 - 0.0142	2			-
	Metazochlor	0.007 - 0.092	1			-
	Penconazol	0.0035 - 0.08	2		1	-
	Beta endosulfan	0.007 - 0.009	3	1		0.05
	Imazalil	0.004 - 0.055	1			0.05
	Pretilachlor	0.007 - 0.087	2		2	
	Dieldrine	0.006 - 0.0103	1			0.01
	op'DDT	0.003 - 0.045	3	1		0.05
	Benalaxyl	0.002 - 0.060	2			-
	Propiconazol	0.005 - 0.015	1		1	-
	Propargite	0.008 - 0.09	1	1		-
	Tetramethrine	0.0013 - 0.0135	2	1		0.05
	Bifenthrin	0.0030 - 0.075	1			-
	Azinphos-Ethyl	0.007 - 0.095	1	1	1	0.05
	Permethrin	0.004 - 0.087	2			0.05
	Cyfluthrin	0.005 - 0.082	1	1		0.02
	Deltamethrin	0.004 - 0.0019	2	1		0.02
	Azoxytrbin	0.006 - 0.086	1	1		-

Continued

Amélies (15 samples)	Methomyl	0.00368 - 0.065	2	1	2	0.05
	Chlorothalonil	0.00107 - 0.011	1	1		-
	Benalaxyl	0.001 - 0.016	1	1	1	-
	Carbofuran	0.006 - 0.076	3			0.05
	Tetramethrine	0.0011 - 0.014	1	1		0.05
	Beta HCB	0.008 - 0.016	2	1		0.01
	Lindane	0.0003 - 0.037	1	1	1	0.01
	Simazine	0.008 - 0.0085	2			-
	Atrazine	0.007 - 0.078	3	1	2	-
	Triadimefon	0.001 - 0.03	2	1		-
	Penconazol	0.008 - 0.094	1	1	1	-
	Pretilachlor	0.006 - 0.0065	1	1		-
	Propiconazol	0.005 - 0.052	2			-
Kents (15 samples)	Methomyl	0.0096 - 0.0102	2	1	1	0.05
	Ethoprophos	0.00107 - 0.018	1			0.01
	Heptenophos	0.0011 - 0.012	1			-
	Monocrotophos	0.0045 - 0.057	2	1	1	-
	Chlorothalonil	0.00016 - 0.028	2			-
	Penconazol	0.008 - 0.0196	1	1	1	-
	Propiconazol	0.009 - 0. 0107	2			-
	Permethrin	0.005 - 0. 088	1	1	1	0.05
	Cyfluthrin	0.0010 - 0.0023	1	1	2	0.02
	Deltamethrin	0.005 - 0.023	2	1		0.02
	Quintozene	0.00028 - 0.0523	1		1	0.02
	Lindane	0.0003 - 0.048	2			0.01
	Beta endosulfan	0.009 - 0.0602	1	1		0.05
	Imazalil	0.005 - 0.0102	2		2	0.05
	Pretilachlor	0.007 - 0.094	2	1		-
	24DDT	0.005 - 0.023	2	1	1	-
	Propargite	0.007 - 0.082	1	1	1	-
	Bifenthrin	0.003 - 0.013	2	1		-
	Tetramethrin	0.002 - 0.032	1			0.05
Brooks (15 samples)	Methomyl	0.005 - 0.097	2	1		0.05
	Carbofuran	0.0007 - 0.0097	1			0.5
	Diflubenzamide	0.0004 - 0.0102	1			-
	Mevinphos	0.005 - 0.0824	2	1		-
	Heptenophos	0.0012 - 0.0177	1			-

Continued

Ethoprophos	0.0017 - 0.0103	2	1	1	0.01
Chlordimrform	0.0015 - 0.0365	1	1		-
Monocrotophos	0.0038 - 0.0692	1	1		-
Dimethoate	0.0004 - 0.0056	2	1		0.02
beta HCB	0.06 - 0.00863	2	1	2	-
Quintozene	0.0011 - 0.00102	1			0.02
Lindane	0.0003 - 0.0035	2	1		0.01
Chlorothalonil	0.0026 - 0.0094	1	1	1	-
Simazine	0.006 - 0.0615	1	1		-
Atrazine	0.005 - 0.0158	1		1	-
Alachlore	0.001 - 0.028	2	1	1	0.01
Heptachlore	0.004 - 0.0198	1			0.01
Triadimefon	0.001 - 0.038	2	1		0.01
Metazochlor	0.002 - 0.026	3	1		-
Penconazol	0.008 - 0.084	2	1		-
Imazalil	0.005 - 0.054	1	1	2	0.05
Pretilachlor	0.006 - 0.0652	3			-
Dieldrine	0.004 - 0.0646	1			0.01
Propiconazol	0.006 - 0.0625	1	1		-
Propargite	0.0014 - 0.0148	1		1	-
Tetramethrine	0.009 - 0.0156	1	1		0.05
Methoxychlor	0.006 - 0.074	2			0.01
Azinphos-Ethyl	0.003 - 0.038	1		1	0.05
Permethrin	0.04 - 0.055	1	1	1	0.05

pyrethroids. Figure 3 shows the principal component analysis of pesticide residues in the mango samples.

4. Discussion

4.1. Assessment of the Importance of Fruit Fly Attacks on Mango

The majorities of producers recognize at least fruit flies and are able to recognize their attacks. The present study shows that fruit fly attacks on mango that are well-perceived by mango producers. In fact, Ouédraogo [1], during surveys on mango phytosanitary problems conducted among producers in Kénédougou, showed that 62.76% of the producers interviewed complained about fruit fly damage and 78.9% of them considered it to be very important. More than the majorities of the mango producers surveyed consider that fruit fly attacks on mangoes occur when the fruit is ripening. This could be explained by the abundance of fruit at the time of mango ripening, which would make fly attacks

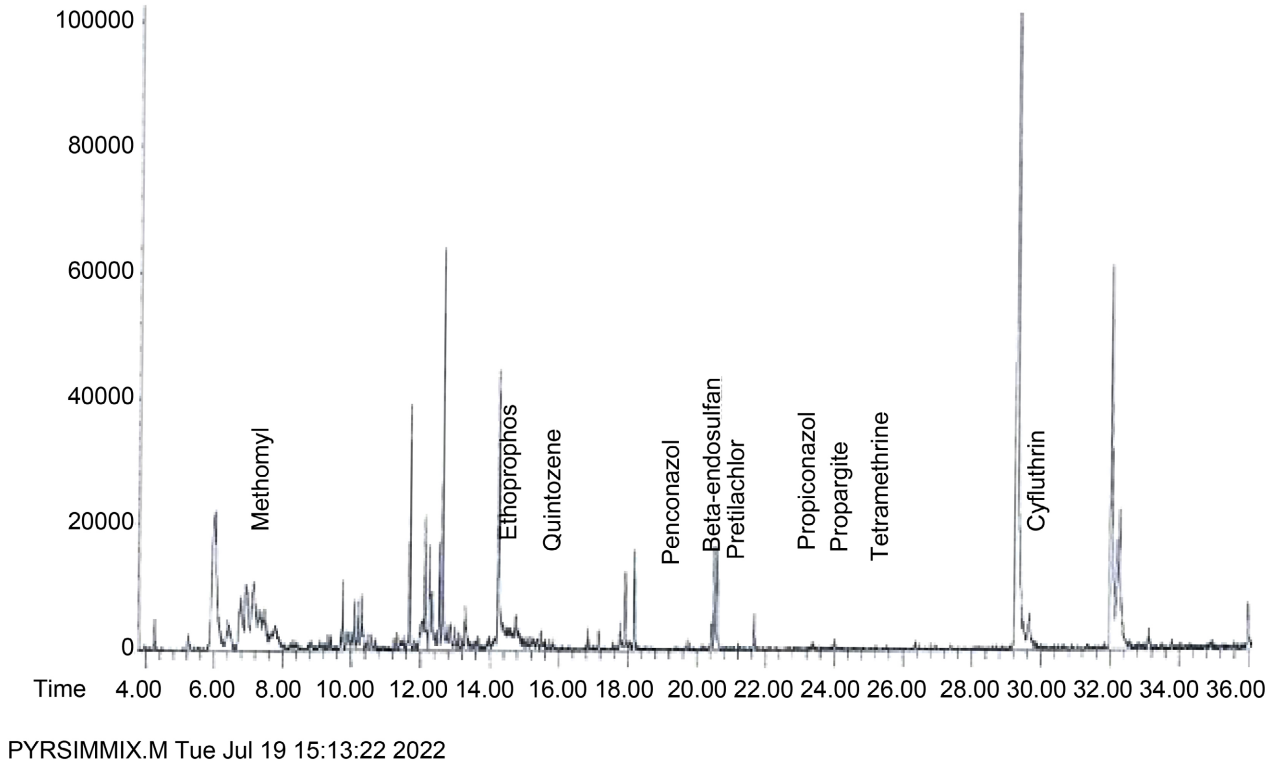
Table 2. Different types of active ingredients detected in dried mangoes.

Mango varieties	Name of pesticides detected	Range of pesticide/ Résidus (mg/kg)	Numbers contaminated sample	A number of samples containing of multiple residues of pesticides for each product	Numbers of Sample exceeding MRL	MRL (mg/kg)
Lippens (15 samples)	Heptachlore	0.004 - 0.054	12	1	1	0.01
	Beta endosulfan	0.007 - 0.09	8	1		0.05
	Dieldrine	0.006 - 0.010	4			0.01
	Op'Ddt	0.003 - 0.045	1	1		0.01
	Deltamethrin	0.004 - 0.0191	5	1		0.05
	Lindane	0.002 - 0.037	2	1	1	0.01
Kents (15 samples)	Permethrin	0.005 - 0.088	6	1	1	0.05
	beta endosulfan	0.009 - 0.0602	2	1		0.05
	24DDT	0.005 - 0.0023	7	1	1	-
Amélies (15 samples)	Deltamethrin	0.004 - 0.190	2	1		0.05
	Lindane	0.003 - 0.036	9	1		0.01
Brooks (15 samples)	Beta HCB	0.008 - 0.0863	2	1	2	0.01
	Atrazine	0.005 - 0.0158	1		1	-
	Alachlore	0.001 - 0.028	3	1	1	0.01
	Dieldrine	0.006 - 0.065	1			0.01
Total = 60	**15**		**65**	**12**	**8**	

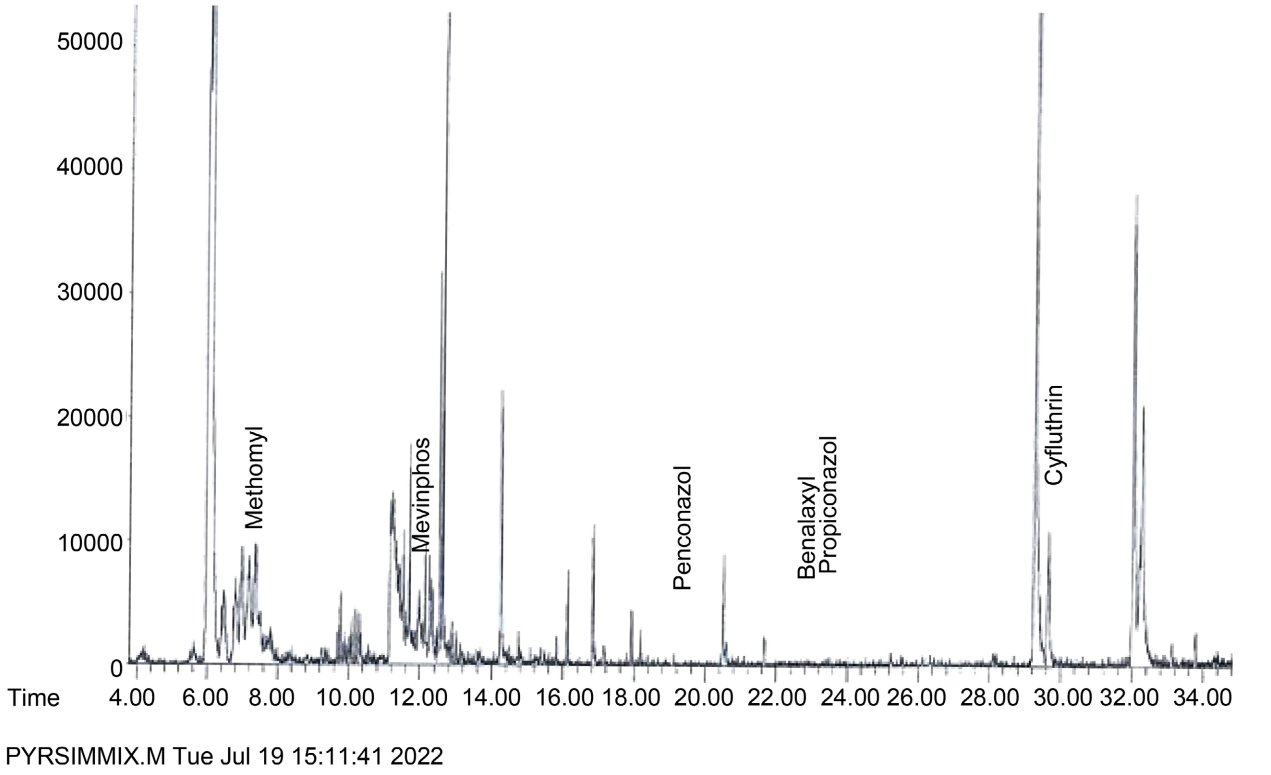
more noticeable than during other periods. This explanation is in line with the work of Fletcher [21], according to which the abundance of hosts favors the development of fruit flies. It should be noted, however, that with regard to the period of attack on mango by fruit flies, Laroussilhe [22] emphasizes that they occur from the time the fruit swells until ripening.

4.2. Pesticides Levels in Fresh Mangoes

Thirty-four (34) chemical compounds were detected in fresh mangoes including pyrethroid compounds (tetramethrin, permethrin, deltamethrin, etc), organochlorine compounds (lindane, heptachlor, alachlor and dieldrin) and carbamates (quintozene, carbofuran) (**Figure 2** and **Figure 3**). These results are more than those obtained by Farag *et al.* [23] who detected 16 pesticide residues (chlorpyrifos, diazinon, malathion, profenofos, sulfur, chlorpyriphos-methyl, carbendazim, cypermethrin, ethion, propargite, permethrin, λ-cyhalothrin, methomyl, phenpropathrin, quinalphos and pirimiphos-methyl) in fruits and vegetables sold in the Egyptian market. Variations in pesticide compounds between different mango varieties are mainly due to inappropriate or abusive use of pesticides and ignorance of environmental issues farmers [24]. The pesticide residual levels of the 120 samples studied were more than or equal to the Maximum Residue Limits



(a)



(b)

Figure 2. Chromatogram of mango samples contaminated by pesticide residues. Legend. (a) Chromatogram of fresh mango samples. (b) Chromatogram of dried mango samples.

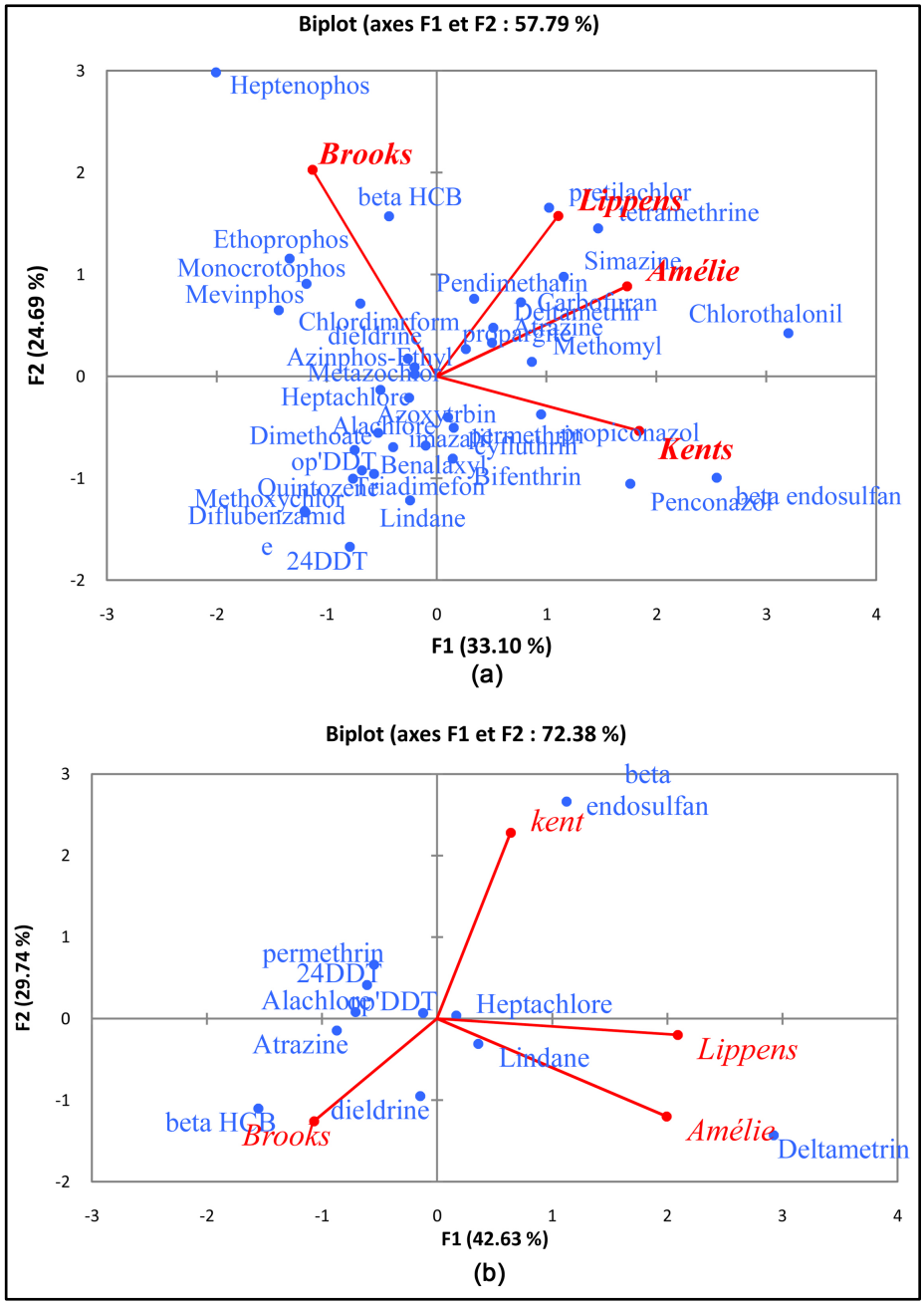


Figure 3. Principal component analysis of pesticide residues in fresh and dried mangoes. Legend. (a) Fresh mangoes. (b) Dried mangoes.

(**Table 1** and **Table 2**) allowed by FAO/WHO [25] and the EU [26]. These results are similar to those reported by Bempah *et al.* [27] who showed that permethrin levels in all vegetable fruits ranged from 0.006 mg/kg in pear to 0.090 mg/kg in lettuce with a range of 0.004 - 0.008 mg/kg and 0.011 - 0.051 mg/kg, respectively. For cyfluthrin, our values found in fresh mango (0.025 mg/kg) are higher than those of Bempah *et al.* [27] who reported cyfluthrin levels ranging from 0.008 mg/kg in watermelon and 0.020 mg/kg in a pineapple with a range of 0.004 - 0.010 mg/kg and 0.018 - 0.021 mg/kg, respectively. The levels of delta-

methrin ranged from 0.04 mg/kg - 0.087 mg/kg and corroborated with those found by Mensah *et al.* [28] which were 0.008 mg/kg in pear and 0.044 mg/kg in a pineapple with a range of 0.007 to 0.010 mg/kg and 0.026 to 0.062 mg/kg, respectively. The results of the present survey further support the findings of the study conducted in India by Kumar *et al.* [29] with residues of cypermethrin and fenvalerate ranging from 0.045 to 0.064 mg/kg, 0.046 to 0.067 mg/kg in grapes respectively. A similar study was also conducted in the Danish market which indicated pyrethroid insecticide residues in 54% of leafy vegetable samples [30].

The concentration of organochlorine and synthetic pyrethroid pesticide residues in the various fresh and dried mango samples was compared to the maximum residue limits set by the European Commission [31] and the Burkina national standard [32] (**Table 1** and **Table 2**). The results of the study indicate that despite the majority of mango producers using agrochemicals responsibly, residue levels in fruits and vegetables are higher than the Maximum Residue Limit (MRL) and could pose health problems as these mangoes are regularly consumed by the population. Overall, the results revealed that organochlorine pesticide residues were present in 60.5% and 39.5% of synthetic pyrethroids were present in fresh mangoes. The high presence of pyrethroid insecticide residues in fresh mangoes is also an indicator of a public health problem and a change in the pattern of insecticide use in Burkina Faso from organochlorines to pyrethroids (easily degradable groups of these insecticides). The concentration of methoxychlor in the mango samples was somewhat high (0.006 and 0.074 mg/kg). This active ingredient could have an impact on human health. Our results are higher than those reported by Bempah and Donkor [33] who found a mean value of 0.004 and 0.041 mg/kg was obtained in mango and onion samples, with a range of 0.004 - 0.006 and 0.025 - 0.066 mg/kg, respectively. The mean value of the sum was 0.016 mg/kg obtained for all commodities tested. The mean values of 0.03 and 0.045 mg/kg for p,p'-DDE were recorded in all tested mango samples. DDT is generally used against a wide variety of agricultural and forestry pests and insect pests, including vectors such as mosquitoes and tsetse flies. Aldrin is an alicyclic chlorinated hydrocarbon and is rapidly converted to the epoxide form. The presence of dieldrin in mangoes is higher than those found by Bempah *et al.* [27] with an average of 0.006 mg/kg in pineapples and 0.040 mg/kg in tomatoes with values of 0.004 - 0.008 and 0.080 - 0.015 mg/kg, respectively. Thus, the concentration levels of dieldrin varied from 0.010 mg/kg in cucumber and 0.090 mg/kg in banana with a range of 0.005 - 0.013 and 0.013 - 0.203 mg/kg, respectively. A mean value of 0.016 mg/kg and 0.037 mg/kg was recorded for aldrin and dieldrin, respectively. The results further revealed that the concentration of cypermethrin and methamidophos in the fresh mango sample was comparatively higher compared to the dried mango samples. The variation in pesticide residues between different mango varieties is mainly due to the use of different pesticides at different concentrations in different localities depending on the pest attack.

4.3. Pesticides Levels in Dried Mangoes

Analysis of pesticide content in dried mangoes indicated that pesticide compounds were detected in 57% of the samples. Among positive samples, 30% contained concentrations above the MRL, and 12% of the samples contained multiple pesticides. A total of fifteen active compounds were detected in dried mangoes and these pesticides are synthetic pyrethroids (permethrin and deltamethrin) and organochlorine compounds (lindane, alachlor, heptachlor, dieldrin). Cypermethrin was detected in Lippens, Kents and Amélie with a content ranging from 0.005 to 0.009 mg/kg with an average of 0.0008 mg/kg. Deltamethrin concentrations ranged from 0.0005 to 0.0090 mg/kg in the (Lippens) samples, while permethrin in the (Kent) samples recorded pesticide levels from 0.0004 to 0.0082 mg/kg. Amelia recorded levels of deltamethrin ranging from 0.0002 to 0.0007 mg/kg and lindane recorded levels of 0.003 - 0.0035 mg/kg. The values recorded for heptachlor ranged from 0.0006 to 0.0054 mg/kg in the Lippens sample compared to the Brooks variety, the values recorded by alachlor ranged from 0.001 to 0.0028 mg/kg. Two pyrethroid compounds (deltamethrin, permethrin), eight organochlorine compounds (2, DDT, duiron, heptachlor, dieldrinlindane, beta HCB, atrazine, alachlor, dieldrin, op'DDT, heptachlor, beta endosulfan) were identified. These results are similar to those obtained by Holland *et al.* [34] who showed a reduction of pesticides in plant products ranging from 0 - 90%. This may result from inappropriate or abusive use of pesticides [4]. Our results are lower than those performed by Radwan [35] who reported chlorpyrifos levels of 20% and 38% respectively following tomato blanching. 50% of total pesticide detections were above the *Codex Alimentarius* MRLs allowed by law and were dominated by organophosphates; classified as very hazardous (class 1B) [36]. Pesticides are responsible for certain cancers, neurological disorders, reproductive and developmental disorders and certain metabolic diseases [14]. The main objective of fruit and vegetable processing is to provide consumers with safe, healthy, nutritious and acceptable food throughout the year [37]. The processing of dried mangoes also includes the preparation of fresh mangoes, such as washing, removal of contaminants and foreign matter, and peeling and cutting (removal of non-edible parts).

5. Conclusion

The majorities of fresh and dried mangoes show relatively high pesticide contamination, probably due to excessive use of chemical pesticides and industrial processing. Pesticide residues were detected in 72% of the samples, and of the positive samples, 48.52% contained concentrations above the maximum residue limit permissibility. Organochlorine pesticide residues were present in fresh mangoes (60.5%) and a total of fifteen active compounds were detected in dried mangoes. The risks of contamination of the food chain through the consumption of mangoes sold in Burkina Faso are not negligible. This contamination could be the cause of many illnesses for consumers but also cause a lot of dam-

age to agricultural production and operators. This is a significant result in that it shows that human health is directly affected by the consumption of fresh and/or dried mangoes. Monitoring of pesticides in fresh mangoes for dried mango production should be continued, as this product is widely exported and used domestically for mango juice production. Therefore, measures must be taken by the government to preserve the health of producers and consumers. This involves strengthening controls on unauthorized pesticides at the borders and in the markets. Also, the emphasis must be placed on training and sensitization of producers in the domain of pesticides, particularly in respect of the regulations on the use of pesticides and encouraging the use of biopesticides.

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Conflicts of Interest

The authors declare no conflict of interest.

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Abbreviations

QuECHERS: Quick, Easy, Cheap, Effective, Rugged and Safe

GCB: Graphite Carbon Black

GC: Gas Chromatograph

MRL: Maximum Residue Limit

DD: Dichloro-Diphenyl-trichloroethane

FAO: Food and Agriculture Organization of the United Nations

WHO: World Health Organization