Health Security
Volume 20, Number 4, 2022 © Mary Ann Liebert, Inc.
DOI: 10.1089/hs.2022.0023

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Nutritional, Microbiological, and Toxicological Quality Assessment of Foods Sold in Urban and Suburban Markets in Burkina Faso

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Food safety risks are becoming a public health problem with important socioeconomic consequences for human well-being, especially for pregnant women and infants. In this article, we describe findings from microbiological, toxicological, and nutritional quality assessments of foods from 5 localities in Burkina Faso, with the aim to provide baseline data on the quality of food and the risks to mothers and children. Samples for assessment included food sold in markets, stores, and restaurants (eg, cereals, oilseeds, vegetables, edible oils, powdered milk, dried fish, packaged water, ready-to-eat meals). The research team selected the samples using the random route method and analyzed them at the National Public Health Laboratory in Ouagadougou between January and December 2020. A total of 443 food samples were collected, of which 101 were analyzed for microbial contamination, 360 were analyzed for the presence of toxins, and 59 were analyzed for their nutritional value. The microbiological quality of 11.88% of the food samples was unsatisfactory, and 41.50% were contaminated with aflatoxins. At least 1 pesticide residue and cyfluthrin were detected in 58.10% of samples. The most detected contaminant (cyfluthrin) was found in 79.10% of the analyzed samples. A peroxide index higher than the normal value (10 mEq/kg) was found in 3.38% of the oil samples and 76.27% of the oil samples had a

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vitamin A content lower than the recommended limit of 11 mg/kg. This study is the first in Burkina Faso that provides baseline data on the quality of food and potential health risks to mothers and children in Burkina Faso. Considering the level of contaminants reported in this article, it is imperative to enhance routine monitoring of foods in the country.

Keywords: Food safety, Toxicology, Bacteriology, Microbiology, Burkina Faso

Introduction

As a predominantly agrarian country located in the Sahel, Burkina Faso faces the challenge of ensuring food and nutritional security for its population.[1] This concern affects rural areas more than urban areas, and its extent varies by geographical location and social strata. Some regions, such as the Cascades, the Centre East, the Centre North, the East, the North, and the Southwest are affected above the World Health Organization (WHO) critical threshold.[2] Food security problems hinge on food safety problems; therefore, systems to provide data on food contamination and prevent foodborne illness must consider both microbiological and toxicological risk factors[3] and must consider both imported and locally produced foods. The evolution of agricultural practices for food production and conservation in Burkina Faso, and the diversification of supply sources, expose women and children in particular to a plethora of illnesses related to the presence of germs and chemical contaminants. Physicochemical and biological contaminants expose consumers to acute or chronic diseases such as cardiovascular diseases, obesity, cancers, degenerative neurological diseases, and immune system disorders.[4] Food safety risks are increasingly identified as a major public health concern worldwide, which has important and far-reaching socioeconomic consequences for human wellbeing.[5]

In Burkina Faso, several government studies have been conducted on the nutritional status of the population.[6-9] However, very little data are available about the quality of food, such as the level of biological and toxicological contamination. The interventions of various programs and projects to reduce mother and child mortality, in particular the free healthcare program for mothers and children under the age of 5 years, can only be consolidated by ensuring nutritional and safe food for households. The aim of this study was to evaluate the microbiological, toxicological, and nutritional quality of food, with the ultimate goal to improve maternal and child health.

Methods

Design, Time Period, and Setting

The study design was descriptive and cross-sectional. It was conducted from January to December 2020 in 5 localities of Burkina Faso: Bobo-Dioulasso, Cinkansé, Dakola, Niangoloko, and Ouagadougou. We selected these localities based on population size[10] and the intensity of commercial activity in the border areas. Of the localities included in the study, 2 were major cities with dense populations: Ouagadougou (2,453,496 inhabitants) and Bobo-Dioulasso (903,887 inhabitants). The remaining 3 were suburban localities: Niangoloko (20,377 inhabitants), bordering Côte d'Ivoire; Dakola (2,362 inhabitants), bordering Ghana; and Cinkansé (9,360 inhabitants), bordering Togo. This study was conducted by researchers from the National Public Health Laboratory, an arm of the Burkina Faso Ministry of Health, whose fundamental role is to control the quality of food, water, and drinks and their sources, especially those more likely to have an adverse effect on public health. The National Public Health Laboratory also has the role of evaluating the nutritional and functional properties of foods.

The Ministry of Health's Research Ethics Committee approved the research protocol (No. 2020-8-151). We obtained administrative authorizations from the 5 health regions and obtained informed consent from stores, restaurants, and stall holders before their inclusion in the study. We also ensured the confidentiality of the data collected.

Sample Size

For the choice of sampling sites in each locality, markets were selected randomly by drawing lots from the list of markets in the city obtained from the town halls (Decree n°2020-078 CO/M/DAJC and n°2020 n°000060/CB/M/SG). Within the markets, stores were selected using the random route method.[11] This method consisted of following a specific itinerary in the chosen area, numbering the stores along the itinerary, and selecting the odd-numbered stores for sample collection. Foods were selected based on which were most consumed, as identified in a report from the Ministry of Agriculture.[6] We chose 9 food groups to include in the study: cereals and derived products (eg, corn, rice, flour), oilseeds (eg, peanuts), vegetables (eg, tomatoes), edible oils, prepackaged beverages, ready-to-eat meals (eg, rice sauce, pasta, beans, bread), dairy products (eg, milk powder), and fish (eg, dried fish). The following formula was used to obtain the number of samples to be taken for each type of food: $n = t^2 \times p \times (1-p) / m^2$, where n indicates the minimum sample size to be taken; t indicates the confidence level ($t = 1.96$ for a 5% risk); p indicates the desired proportion's expected value; and m indicates the error margin (5% level of significance).[12]

The application of this formula enabled us to determine sample sizes. For each type of food, the number of samples to be collected per locality was determined based on the number of inhabitants. Samples for toxicological, physicochemical, and nutritional analyses were packaged in plastic bags, placed in boxes, and transported to the laboratory at room temperature. Samples for microbiological analyses were collected aseptically (ie, packed in sterile bags, placed in a mobile refrigerator between 2 °C and 8 °C, and transported to the laboratory).

Sample Analysis Methods

We analyzed 3 types of parameters: microbiological (ie, total and thermotolerant coliforms, *Escherichia coli*, *Salmonella* spp.), toxicological (ie, metallic trace elements, aflatoxins, pesticide residues) and nutritional (ie, vitamin A, peroxide index). Microbiological parameters were determined using standardized (International Organization for Standardization [ISO]) methods according to Guiraud.[13] Table 1 gives the standard method used for each microorganism and the criteria for assessing the microbiological quality of food.

Microbiological Contamination Determination

Coliforms. Known to be an indicator of fecal contamination, coliforms were counted onto standard violet red bile lactose agar and incubated at 37 °C for 24 hours under ISO 4832:2006. Culture plates containing less than 150 colonies were considered. For culture plates with less than 15 colonies, averages were calculated to estimate the number of colony-forming units.

Thermotolerant coliforms. Also known to be an indicator of fecal contamination, thermotolerant coliforms were counted onto standard violet red bile lactose agar and incubated at 44.5 ± 0.5 °C for 24 hours under NF V60-2009. Culture plates containing less than 150 colonies were considered. For culture plates with less than 15 colonies, averages were calculated to estimate the number of colony-forming units.

***Escherichia coli*.** Identified through the test for indole production, methyl red reaction, Voges-Proskauer, and citrate utilization (IMViC) from thermotolerant coliforms. Suspected colonies from thermotolerant coliforms were selected and subcultured on nutrient agar at 37 °C for 24 hours. Pure cultures grown on nutrient agar were used for oxidase test and determination of IMViC pattern under standard procedures for food analysis. Positives colonies were transferred into Levine eosin methylene blue agar, which was incubated at 37 ± 1 °C for 24 hours. Colonies with green metallic sheen were considered to be *E coli*. *E coli* ATCC 8739 was used as positive control for all analyses.

***Salmonella* spp.** *Salmonella* species were investigated according to the standard horizontal method for

Table 1. Criteria for Assessing the Microbiological Quality of Foods

		Criteria	
	Microorganisms	*m CFU per g*	*M (3m) CFU per g*
Ready-to-eat meals	*Salmonella*	Absence/25g	—
	Staphylococci	10^2	3×10^2
	Total aerobic mesophilic flora	3×10^3	9×10^3
	Coliforms	10^3	3×10^3
	Thermotolerants coliforms	10	3 x 10
	Escherichia coli	10	3 x 10
	Yeast and mold	10^4	3×10^4
	ASR	30	90
Conditioned milk powder	*Salmonella*	Absence/25g	—
	Staphylococcus aureus	10	30
	Total aerobic mesophilic flora	5×10^4	1.5×10^5
	Coliforms	1	3
	Thermotolerants coliforms	Absence	—
	Escherichia coli	Absence	—
	Yeast and mold	Absence	—
	ASR	10	30
	Clostridium perfringens	1	3
	Bacillus cereus	Absence	—

Data derived from Guiraud J.[13] CFU ≤ m = satisfactory; m < CFU ≤ M = acceptable; CFU > M = not satisfactory. Abbreviations: ASR, anaerobic sulfite-reducing bacteria; CFU, colony-forming unit; m, lower limits of appreciation; M, upper limits of appreciation.

detection of *Salmonella* spp ISO 6579-1:2017. The nonselective enrichment was accomplished by adding 25 g of each sample into 225 mL buffered peptone water and homogenized in a BagMixer 400 (Interscience, Saint Nom, France). Incubation was done at 37 °C for 18 to 20 hours. The selective enrichment step was performed onto both Müller-Kauffman tetrathionate and Rappaport Vassiliadis soy broths incubated at 37 ± 1 °C and 42 ± 1 °C, respectively, for 18 to 20 hours. A brilliant green at 0.95% was added to the selective media tetrathionate broth to inhibit the growth of gram-positive bacteria. Selective isolations were performed onto xylose lysine deoxycholate and *Salmonella-Shigella* agars. Five suspected colonies of each sample were streaked onto nutrient agar and were performed using API 20E test for biochemical confirmation. *S typhimurium* (ATCC 14028) and *S enteritidis* (ATCC 13076) were used as positive controls. The key biochemical tests included the fermentation of dulcitol, fermentation of glucose, H_2S production, lysine decarboxylase, negative indole test, and negative urease reaction.

Dose of Aflatoxins Determination

The samples collected in the form of grains were finely ground with an M20 Universal Mill (IKA Works, Wilmington, NC). To reduce the risk of contamination, the grinder was cleaned before the first use and after each grinding. The powdered samples resulting from this process were packed in plastic bags.

Aflatoxins Extraction

To extract the aflatoxins, 5 g of the sample was weighed and poured into an Erlenmeyer flask containing 25 mL of an extraction solution composed of 70% methanol and 30% distilled water. The resulting mixture was stirred on a rotary shaker for 2 minutes to enable the toxins to dissolve. After this step, the mixture was filtered through Whatman paper. Finally, 15 mL of the filtrate was removed and added to 45 mL of phosphate-buffered saline. The resulting solution was used for the purification of aflatoxins.

Aflatoxins Purification

The purification of aflatoxins was performed using Afla-Star immunoaffinity columns obtained from Romer Labs. In brief, this procedure consists of passing the filtrate diluted with phosphate-buffered saline through the column at a flow rate of approximately 3 mL/min. The column was then washed with 20 mL of distilled water in small portions of about 10 mL at a maximum flow rate of 5 mL/min and dried by applying a vacuum for 5 to 10 seconds. The aflatoxins were eluted with 1.5 mL of methanol, and then 1.5 mL of double-distilled water was added to the collected volume. A volume of 2.8 mL was collected in a 4 mL recovery vial.

Aflatoxins Analysis

For each sample, a volume of 20 µL of purified extract was taken from the vial and injected into the UltiMate 3000 UHPLC (Thermo Fischer Scientific, Waltham, MA) equipped with a fluorescence detector type RF-10AXL (Shimadzu Scientific Instruments, Columbia, MD). The operating conditions and the performance data of the aflatoxin analysis method are summarized in Table 2.

Dose of Pesticide Residue Determination

Pesticide residues were extracted from the samples using the QuEChERS (quick, easy, cheap, effective, rugged, and safe) method and then determined using an Agilent 7890A gas chromatograph (GC)/mass spectrometer (MS) (Agilent, Santa Clara, CA). The samples used underwent all the different stages of pesticide residue analysis as follows.

Instruments and Chromatographic Condition

Pesticide residues were then determined by analysis of samples using gas chromatography (Agilent 7890A) coupled to mass spectrometry (Agilent 5975C inert). The GC system was equipped with an Agilent fused silica capillary column HP-5ms (30 m × 0.25 mm × 0.25 µm). The chromatographic instrumental settings were as follows: the carrier gas was nitrogen, injector set at 250 °C in splitless mode; the GC oven temperature program was initiated at 50 °C, raised to 100 °C (at a rate of 25 °C/min) and raised from 100 °C to 300 °C (at a rate of 7.5 °C/min) before being held for 3 minutes; the injection volume was 1 µL, and the flow rates of makeup gas were 20 mL/min. The MS

Table 2. Chromatographic Operating Conditions and Validation Data of Aflatoxins Analysis Performance

Criteria	*Value*
Chromatographic operating conditions	
Column	Shim-pack CLCG-ODS C18, 4 µm, 150 mm x 4.6 mm
Mobile phase	Methanol/acetonitrile (50:50; v/v)
Pump flow rate	1 mL/min
Temperature	40 °C
Injected volume	20 µl
Detector	Fluorescence: λ Excitation: 360 nm; λ Emission: 440 nm
Analysis time	15 minutes
Validation data of aflatoxins analysis performance	
Repeatability, %	96.7
Reproducibility, %	96.1
Recovery rate, %	94.2
Limit of detection, µg/kg	0.3
Limit of quantitation, µg/kg	1.0

detector was run in selected ion monitoring mode with the following settings: S quad 180 °C; MS source 230 °C; ion source: EI, 70 eV. Three ions were selected for each pesticide. The highest relative abundant ion was used as the quantifier ion while the other ions were taken for confirmation as qualifier ions.

Pesticide Residue Extraction

In a 50 mL centrifuge tube with a screw cap, we weighed 5 g of previously homogenized sample. We added 10 mL of acetonitrile and 100 µL of the internal standard solution of PCB 28 (0.1 mg/L). For 1 minute, the vortex vigorously stirred the entire mixture. Four grams of magnesium sulfate, 1 g of sodium chloride, 1 g of trisodium citrate dihydrate, and 0.5 g of disodium citrate sesquihydrate were added. The mixture was vigorously stirred with the vortex for 1 minute before being centrifuged for 5 minutes at 3500 rpm.

Pesticide Residue Purification

We transferred 6 mL of the supernatant to a centrifuge tube containing 150 mg of magnesium sulfate and 25 mg of ammonium persulfate; the mix was vigorously shaken with the vortex for 1 minute; the whole was centrifuged for 5 minutes at 3500 rpm; 1 mL of the extract was transferred to a screw-top bottle with 10 µL of the 5% formic acid solution to stabilize the extract; the reagent blank followed the same extraction process but free of sample; and purified and acidified extracts were transferred to vials for analysis by GC/MS. The analysis of the samples by chromatography was carried out under the conditions of use established in the procedure for the use of GC/MS.

Determination of Peroxide Index and Vitamin A in Food Oils

The peroxide index was determined by iodometric titration (ISO 3960-1977 [F]). The method is based on the treatment of a test sample, dissolved in acetic acid and chloroform, with a solution of potassium iodide. The released iodine was titrated using a 0.1 N sodium thiosulfate solution. Briefly, about 2 g of oil were dissolved in 10 mL of chloroform. After the addition of 15 mL of acetic acid and 1 mL of saturated potassium iodide, the solution was stirred for 1 minute and placed for 5 minutes in the dark. After the addition of 75 mL of distilled water and a few drops of starch indicator (1%), the solution was titrated with 0.1 N sodium thiosulfate until the blue color disappeared. A blank, consisting of the reaction medium without the analyte, was prepared using the same procedure as the samples and then titrated.

The method used was adapted from HPLC for the determination of vitamin A in edible oil (Thermo Fisher Scientific UltiMate 3000 UHPLC coupled to a UV detector) according to the French Standard NF T 90-210. Two grams of oil were dissolved in 20 mL of acetone, homogenized with a vortex, and injected into a vial with a syringe fitted with a filter. The mobile phase was methanol, and the reversed-phase column was an Agilent ZORBAX C18. The detection wavelength was 325 nm. The standard used was retinol palmitate (type IV, 1,800,000 USP units/g).

Dose of Trace Metallic Elements

To determine the metallic trace elements, the food matrices underwent dry digestion. The acid digestion of samples described by Demirel et al[14] in 2008 was applied. To a test portion of 0.5 g of finely ground samples in a test tube, 10 ml of nitric and hydrochloric acid solution were added in the proportion of 3 parts to 1. The mixture was heated at 150 °C for 2 hours. After cooling, the digestate obtained was filtered with Whatman paper, and the final volume was reduced to 20 mL with deionized water. A Varian (now Agilent) AA240FS Atomic Absorption Spectrometer with single and phased array hollow cathode lamps was used for trace element analysis.

Statistical Analysis and Data Processing

Data from the field and laboratory were entered into Microsoft Excel and analyzed using IBM SPSS Statistics for Windows version 23.0 (IBM Corp, Armonk, NY) and GraphPad Prism version 8 (Dotmatics, Boston, MA). Limit values for microbiology, toxicology, and other factors were calculated.

Results

Microbiological Quality of Food

A total of 443 food samples were collected in the 5 localities of the 5 regions covered by the study. Of these samples, prepackaged water (n = 58) and ready-to-eat meals (beans, rice sauce, pasta, bread) and milk powder (n = 101) were used for microbiological analysis. If the 58 water samples, a total of 1.72% (n = 1) were poor quality. Of the samples of ready-to-eat meals and milk powder, the microbiological quality of 73.27% (n = 74) were satisfactory, 14.85% (n = 15) were acceptable, and 11.88% (n = 12) were unsatisfactory according to the criteria for appraising the microbiological quality of food (Table 1).

Dose of Aflatoxins in Foodstuffs

Table 3 shows various foods, including maize, rice, cereal meal, and peanuts, and the levels of aflatoxins they contain. Results revealed that 41.50% of the samples were contaminated with aflatoxins. Of these contaminated samples, 50.00% had aflatoxin content above the maximum upper limit and 16.03% had aflatoxin levels above the maximum tolerated limit of total aflatoxins in food (5 µg/kg, European

standard). The maximum aflatoxin limit is the value of the aflatoxin concentration below which a food is considered fit for human consumption. Of the different classes of aflatoxins assayed, aflatoxin B_1 was the most detected (6.26%).

Determination of Peroxide Index and Vitamin A in Food Oils

A peroxide index higher than the normal value (10 mEq/kg) was detected in 3.38% of the oil samples, and 76.27% of the oils had vitamin A levels below the recommended standard (ie, vitamin A content <11 mg/kg). Of these oil samples with vitamin content below the standard, 93.33% did not contain vitamin A. Considering both parameters, a total of 77.97% of the food oil samples were noncompliant.

Determination of Pesticide Residue Content of Samples

Regardless of the matrix analyzed and the sampling location, at least 1 pesticide was detected and quantified. As shown in Table 4, about 58.10% of the samples had at least 1 pesticide residue. Cyfluthrin was found in 79.10% of the samples, making this active substance the most common residue found in the different types of foods.

Trace Metallic Elements are Contained in Foods

A total of 222 samples were analyzed for trace metals. Nine trace metals—iron, zinc, manganese, cobalt, cadmium, lead, copper, nickel, and chromium—were assayed in rice, corn, peanuts, tomatoes, and dried fish using atomic absorption spectrometry. Iron and zinc were found to be the most common trace metals in the foodstuffs studied. The highest median iron value of the food group (68.80 mg/kg) was observed in dried fish, followed by corn (43.09 mg/kg) and peanuts (28.92 mg/kg). About 77.95% of tomato samples had lead levels above the maximum limit set by Codex Alimentarius, while 71.16% of tomato samples showed cadmium concentrations above the maximum limit.

Table 3. Determination of Aflatoxins in Foodstuffs

Food Type	*Collection Location*	*Total Samples n*	*Samples Contaminated With Aflatoxins n*	*Samples With Aflatoxins Concentration Above Maximum Limit*[a] *n*
Maize	Bobo-Dioulasso	6	1	0
	Cinkansé	3	0	0
	Dakola	3	1	1
	Niangoloko	3	1	0
	Ouagadougou	4	4	3
	Total	19	8 (42.10%)	4 (50.00%)
Rice	Bobo-Dioulasso	8	3	2
	Cinkansé	6	0	0
	Dakola	6	3	0
	Niangoloko	6	0	0
	Ouagadougou	14	3	0
	Total	40	9 (22.50%)	2 (22.22%)
Cereal flours	Bobo-Dioulasso	14	12	3
	Cinkansé	10	5	5
	Dakola	10	6	2
	Niangoloko	10	7	2
	Ouagadougou	50	24	4
	Total	94	54 (57.44%)	16 (29.62%)
Peanuts	Bobo-Dioulasso	12	12	10
	Cinkansé	10	0	0
	Dakola	09	0	0
	Niangoloko	10	5	2
	Ouagadougou	18	1	0
	Total	59	18 (30.50%)	12 (66.66%)
Total		212	88 (41.50%)	34 (16.03%)

[a]The maximum aflatoxin content limit (5 μg/kg) is the value of the aflatoxin concentration below which a food is considered fit for human consumption.

Table 4. Distribution of Pesticide Residue in Food Types and Locations From Which They Were Obtained

Food Type	*Collection Location*	*Total Samples n*	*Samples That Contained Cyfluthrin n*	*Samples That Had More Than 1 Pesticide n (%)*
Maize	Bobo-Dioulasso	6	2	1 (16.7)
	Cinkansé	3	1	1 (33.3)
	Dakola	3	1	1 (33.3)
	Niangoloko	3	0	1 (33.3)
	Ouagadougou	4	3	3 (75.0)
	Total	19	7 (10.29%)	7 (100.0)
Dried fish	Bobo-Dioulasso	9	9	9 (100.0)
	Dakola	7	6	7 (100.0)
	Niangoloko	7	5	7 (100.0)
	Ouagadougou	15	14	2 (13.3)
	Cinkansé	-	0	0
	Total	38	34 (50.00%)	25 (73.53)
Rice	Bobo-Dioulasso	6	5	5 (83.3)
	Cinkansé	6	4	5 (83.3)
	Dakola	6	6	2 (33.3)
	Niangoloko	4	1	3 (75.0)
	Ouagadougou	14	10	11 (78.6)
	Total	36	26 (38.24%)	26 (100.0)
Tomato	Bobo-Dioulasso	11	1	5 (45.5)
	Cinkansé	10	0	3 (30.0)
	Dakola	9	0	5 (55.5)
	Niangoloko	9	0	7 (77.8)
	Ouagadougou	16	0	8 (50.0)
	Total	55	1 (1.47%)	28 (50.91)
Total		148	68 (79.10%)	86 (58.10)

Discussion

During a 12-month period, 443 food samples were collected and studied. Of these, 101 were analyzed for microbial contamination, 360 were analyzed for the presence of toxins, and 59 were analyzed for their nutritional value. The microbiological quality of 11.88% of food samples was unsatisfactory, and 41.50% were contaminated with aflatoxins. At least 1 pesticide residue and cyfluthrin were detected in 58.10%. The most detected contaminant was found in 79.10% of the analyzed samples; 3.38% of the oil samples had a peroxide index higher than the normal value (10 mEq/kg) and 76.27% of the oil samples had a vitamin A content lower than the recommended limit of 11 mg/kg.

According to WHO,[15] the contamination of food by microbiological agents is a public health problem throughout the world. The possible contamination of food by microorganisms, and especially their proliferation during the manufacturing, transport, and conservation processes, raises legitimate concerns.[16] The presence of microorganisms in raw materials is explained by the fact that they are often contaminated in the field, during transport, during storage at wholesalers and manufacturers, or during processing. This being the case, it is possible that the 11.88% of foods that are of unsatisfactory microbiological quality in this study are related to contamination by microorganisms in the field or during transport, storage, or processing. According to WHO,[15] a majority of countries recently demonstrated a substantial increase in the presence of microorganisms in food, including pathogens such as *Salmonella* and enterohemorrhagic *E coli*. This is in line with our findings, which show that *Staphylococcus aureus, E coli, and Bacillus cereus* had contaminated the food samples. Similar microbiological results were reported by a team in Madagascar.[16] Infants and babies are more susceptible to infection by foodborne pathogens because of their less-developed immune systems and lack of competing organisms in their gut flora.[17] *Enterobacter sakazakii* is an opportunistic pathogen associated with severe foodborne illnesses in infants and neonates, such as fatal neonatal meningitis, sepsis, death, and necrotizing enterocolitis.[18,19] These pathogens, isolated during our study, could cause certain diseases such as diarrhea and meningitis in children. Certainly, the low contamination rates of food such as ready-to-eat meals (11.88%) and prepackaged water (1.72%) obtained

during the study could be justified by habits such as regular handwashing and food hygiene practice inculcated during the COVID-19 pandemic. Indeed, cooking food (eg, rice, sauce, beans, pasta) for a relatively long time (about 2 hours), often at high temperatures, can destroy microorganisms, but it does not necessarily affect some chemicals, including mycotoxins or pesticide residues.

Mycotoxins are a group of toxic secondary metabolites produced by fungi belonging primarily to the genera *Aspergillus*, *Penicillium*, *Fusarium*, and *Alternaria*.[20] Aflatoxin B_1 is among the most potent known carcinogen.[4] The results of this work showed that 41.50% of the analyzed food samples were contaminated with aflatoxins and that aflatoxin B_1 was the most encountered mycotoxin, with levels above the normal tolerated limit (5 μg/kg). As there are no regulations on mycotoxins in Burkina Faso,[21] the permitted limits are those of the European Union. In a study conducted in Burkina Faso and Mozambique, researchers found that 33% of the samples were contaminated with aflatoxins and that half (50%) of the maize samples were contaminated with aflatoxin B_1 at concentrations up to 636 μg/kg.[21] The presence of mycotoxins is related to climatic conditions, cross-contaminants, or storage time,[22] and could justify the results of this study. Another study conducted by Adaku Chilaka et al[23] found the presence of aflatoxins in foodstuffs at high levels, especially aflatoxin B_1 in maize in Burkina Faso (22.5-1343 μg/kg) and in Cameroon (37-24225 μg/kg). Exposure to mycotoxins can be through ingestion, inhalation, or dermal absorption. They stated that the "degree of toxic effect is dependent on the toxin type; exposure dose and duration; age, sex, and health status of the host; exposure route; and possible synergistic effects of other chemicals to which the individual is exposed." In the case of children, mycotoxins have been associated with developmental defects such as neurodevelopmental disorders as shown in epidemiological studies from 2017 and 2019.[24,25] Mycotoxins contamination in maize has been linked to a high incidence of neural tube defects in areas of the world where maize is a major staple food, such as African communities.[26,27] In addition, exposure to toxigenic fungi and their metabolites has been linked to child growth and weight impairment.[28-36] This scenario of stunting and wasting is often seen in lower-income countries,[37] especially those in sub-Saharan Africa.

Pesticides help control insect pests, weeds, and several types of fungi, and thus contribute to the economical production of food in large quantities. On the other hand, when misused, they can be dangerous to human health. Their residues in food are contaminants of public health concern, which have triggered apprehension.[4] In our study, more than half (58.1%) of the samples contained at least 1 pesticide. This result could be explained by the abusive use of pesticides in Burkina Faso, where there are no regulations governing the use of pesticides. Exposure to these pesticides could increase the chances of miscarriage, babies born with birth defects, or other problems. Some pesticides may also be able to pass into breast milk and cause problems for babies and mothers. This situation constitutes a health risk for the population, and measures should be taken to reduce the use of pesticides in Burkina Faso. About 77.95% of the 222 tomato samples analyzed had lead levels above the maximum limit set by the Codex Alimentarius. The average lead level (3.63 mg/kg) in tomatoes reported by Gebeyehu et al[38] in Ethiopia was higher than the median level found in the tomato samples reported in our study. In addition to the problems of physicochemical contaminants in foods highlighted in this study, there are nutritional problems that could cause danger to human health.

The high values of the peroxide index detected in 3.39% of the food samples in this study could be due to a long storage time with the traders and exposure to air during sales. These results are similar to those of Tarnagda et al[39] in Burkina Faso, who reported 2 vegetable oil samples with a higher-than-normal peroxide index (10.59 and 19.73 mEq/kg). In relation to the vitamin A content of food oils, our results showed that 71.19% of the 59 samples did not contain vitamin A, despite the WHO guidelines and the regulations in place in Burkina Faso. These results contrast with that of Siby et al[40] in Mali, who found that out of 270 samples of vegetable oil analyzed in Bamako, nearly 48.5% were deficient in vitamin A. The difference in the higher percentage reported in Mali could be related to the number of samples, the locality, and the setting of the study.

These results show that programs for enriching food oils with vitamin A are inadequate in Burkina Faso. It is therefore important that the government, through the Ministry of Health, revisit the question of enriching food oil. This is why the National Public Health Laboratory, an important arm of the Ministry of Health, must play its role of food quality control.

Although several baseline datasets have been generated in this study, some limitations are acknowledged. These include unassayed parameters such as veterinary drug residues, arsenic, mercury, para-anisidine, and polycyclic aromatic hydrocarbons, which limit further assessment of the toxicological quality of foods, and the inaccessibility of certain areas of the country due to repeated terrorist attacks, which prevented food samples from being taken in these areas.

Conclusion

Results from this study reveal that most foods consumed in Burkina Faso are poor in nutrients and susceptible to contamination. The levels of microbes, toxins, and pesticides detected are of public health concern. It behooves the regulatory authorities to enforce regulations and put new ones in place where they may be lacking. This study provides baseline data on the quality of food and the health risks to mothers and children, which could be leveraged upon to inform policy and conduct further studies.

Acknowledgments

This work was initiated by the Productions et analyses des données pour améliorer la santé de la mère et de l'enfant au Burkina Faso project in collaboration with the National Institute of Public Health, financed by the European Union (FED/2019/407-596). The authors warmly thank the National Institute of Public Health of Burkina Faso for the scientific collaboration; the European Union for the financing of this project; the regional health directorates of the Centre, Hauts-Bassins, Cascades, and Centre-East regions of Burkina Faso for authorizing the conduct of this study; and the populations of the Centre, Hauts-Bassins, Cascades, Centre-East, and Centre-South regions of Burkina Faso for their collaboration.

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Manuscript received February 8, 2022;
revision returned April 8, 2022;
accepted for publication April 18, 2022.

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