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Original paper

Epidemiology and public health implications of parasitic contamination of fruits, vegetables, and water in Kwara Central, Nigeria

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ABSTRACT. Fruits and vegetables are sources of parasitic infections in humans. This study was designed to determine the epidemiology of parasitic contamination of fruits, vegetables, and water, as well as the perception of retailers, buyers, and consumers about its contamination in Kwara Central, Nigeria. A cross-sectional study design was employed for this study. A total of 160 fruits, 349 vegetables, and 51 water samples were randomly purchased/collected from thirty different markets. The samples were subjected to sedimentation and modified Ziehl-Neelsen staining techniques. All the types of fruits and vegetables sampled were contaminated with one or more parasites. Eleven different species of zoonotic parasites (6 protozoans and 5 helminths) were detected. *Entamoeba coli* (39.8%) and *Strongyloides stercoralis* (9.6%) were the most prevalent protozoan and helminth respectively. The prevalence of other protozoan parasites ranged between 21.3% (*Entamoeba histolytica*) and 2.3% (*Balantidium coli*), while that of helminths was between 5.7% (*Ascaris lumbricoides*) and 2.1% (*Trichuris trichiura*). Source of fruits and vegetables, source of manure for cultivation, the source of water for washing/wetting purpose, market type, washing of fruits and vegetables before display, the presence of children at home and in the market, and knowledge of parasitic contamination were the risk factors associated ($P<0.05$) with parasitic contamination of fruits and vegetables among sellers. There is a need to educate the general public on the possibilities of parasitic contamination of fruits and vegetables and its public health implications.

Keywords: fruits, parasitic contamination, public health implications, vegetables, zoonotic, Nigeria

Introduction

In the global context, fruits and vegetables are important part of a healthy human diet owing to their nutritional, antioxidative, and pharmacological values. Fruits and vegetables are low in calories and rich in complex carbohydrates, vitamins, minerals, dietary fiber, and even proteins. It could also have a positive effect on body-weight regulation, reduced risk of cardiovascular diseases, type 2 diabetes mellitus, hypertension, stroke, certain cancers, glaucoma, and dementia among many others [1–5]. Antioxidants in vegetables also help to protect the human body against oxidative stress, therefore improving immunity [6]. Due to its diverse importance and values, the World Health Organization (WHO) and the Food and Agriculture Organization (FAO) have recommended a daily intake of 400 g [7], which has led to an increase in its consumption in recent years.

In many countries of the world, fruits and vegetables are eaten raw or undercooked to retain the natural taste and preserve heat-labile nutrients. In some cases, fruits and vegetables are unwashed or unhygienically prepared before consumption. This play a major epidemiological role in the transmission of parasitic food-borne infections [4,5,8]. Contaminated fruits and vegetables act as vehicles for the transmission of parasitic infections as a result of various associated factors [1,3]. Contaminations can occur during the cultivation phase in fields due to the use of organic fertilizer from human and animal faeces, or contaminated irrigation or surface water. Contamination can also take place during harvesting, handling of the product by infected individuals, processing, packaging, storage, transportation, marketing, preparation for consumption as well as contact with infected vectors such as flies, rats, and domestic animals [2,9–12].

Parasites such as cestodes, nematodes, trematodes, and protozoa are known to contaminate fruits and vegetables [1]. These parasitic infections are of serious public health concerns, such as malnutrition and growth retardation of infected individuals (mostly the elderly, children, and immunocompromised individuals), which can lead to about 300 million severe illnesses with approximately 200,000 deaths occurring in developing countries [10,13,14].

In recent years, there has been an increase in the number of reported cases of food-borne parasitic illnesses linked to the consumption of contaminated fruits and vegetables [15].

This study was designed to determine the presence, prevalence, and risk factors associated with parasitic contamination of commonly consumed fruits and vegetables, and water used for washing/wetting, as well as the perception of retailers, buyers, and consumers about its contamination in line with its public health significance in Kwara Central, Nigeria.

Materials and Methods

Study design and setting

This was a descriptive cross-sectional study, with samples collected between March and July, 2019. The study was carried out in Kwara Central of Kwara State, Nigeria, which comprises four Local Government Areas (Asa, Ilorin East, Ilorin South, and Ilorin West). Kwara State is located between latitude 8°05N and 10°15N, longitude 2°73E and 6°13E. It is located in the middle belt within the Forest-Savanna region of Nigeria. The state has a total population of about 3 million persons and covers a total area of 36,825 km^2, which is approximately 8% of the total land area of Nigeria. The state records an average annual rainfall of between 112.8 cm and 146.9 cm and a mean annual temperature ranging from 22.1°C to 33.3°C. It has a mean relative humidity of 49.6% [16,17].

Sample size determination

The minimum sample size (N) was calculated using the qualitative variable formula for cross-sectional study as described by Charan and Biswas [18].

Sample collection

Only fresh fruits and vegetables, and water samples used for washing/wetting sold fruits and vegetables were used for this study. A total of 160 fruits, 349 vegetables, and 51 water samples were randomly purchased/collected from thirty different markets in Kwara Central of Nigeria. Five different fruits comprising of *Abelmoschus esculentus* (okro), *Cucumis sativus* (cucumber), *Lycoperisicon esculentum* (tomato), *Phaseolus vulgaris* (green beans), and *Solanum melongena* (garden egg); and 11 different vegetables including *Corchorus olitorius* (ewedu), *Amaranthus hybridus* (efo tete), *Celosia argentea* (efo soko), *Telfairia occidentalis* (ugwu), *Daucus carota* (carrot), *Brassica deracea* (cabbage), *Lactus sativa* (lettuce), *Ocimum gratissimum* (efiirin), *Vernonia amygdalina* (bitter leaf), *Sesamum radiatum* (eku), and *Talinum triangulare* (water leaf) were sampled. About 0.4 liters of the water used for washing/wetting the sold fruits and vegetables were also sampled from 51 fruits and vegetable sellers.

The fruits and vegetables were collected into sterile polythene bags labelled by sample type, date of collection, and name of the market. Water samples were also collected into well-labelled clean and sterile bottles. Samples were taken immediately to the Parasitology laboratory of the Faculty of Veterinary Medicine, University of Ilorin for immediate preparation and parasitological examinations.

Information on the perception of sellers, buyers, and consumers concerning the contamination of fruits and vegetables by parasites, and the handling of fruits and vegetables by sellers, buyers, and consumers was collected.

Sample preparation and parasitological analyses

Each sample was first carefully observed for the presence of gross parasites. About 200 g of each fruit and vegetable was weighed, soaked for about fifteen minutes, and vigorously and thoroughly rinsed in 500 ml of distilled water so as to detach the parasitic stages (cysts, oocysts, ova, and larvae) of protozoan and helminth parasites. Each water sample was transferred into a 500 ml sterile glass bottle. After overnight sedimentation of the wash solutions and water samples, the supernatant was carefully decanted and about 15 ml of the sediment was then filtered through a sieve into a centrifuge tube to remove large debris and undesirable materials. Filtrates were then centrifuged at 3000 rpm for 10 min.

Direct examination of the sediments and modified Ziehl-Neelsen staining technique were employed for the detection of protozoan and helminth parasites [19,20]. Briefly, the direct examination of sediments was done by resuspending the sediment, and a Pasteur pipette was used to take 1 or 2 drops of the suspension onto a clean grease-free slide. Few drops of Lugol's iodine solution were then added before a clean coverslip was placed. The smear was examined under a light microscope with a magnification of ×100 and ×400.

For the modified Ziehl-Neelsen technique, smears were made from the sediments of the centrifugation and stained accordingly for the detection of *Cryptosporidium* species and *Cyclospora* species.

Identification of protozoan (*cysts and oocysts*) *and helminth* (*ova and larvae*)

Cysts and oocysts of protozoans, and ova and larvae of helminths from the processing methods mentioned above were identified using parasitological keys as described by Soulsby [19], Taylor et al. [20], and Arora and Arora [21].

Samples that were positive following the parasitological techniques carried out were considered positive for the protozoan(s) and helminth(s) detected.

Questionnaire design and administration

Two well-structured questionnaires containing open-ended and closed-ended (dichotomous or multiple choices) questions were designed. One was designed to obtain epidemiological information from sellers of the different fruit and vegetable samples and water samples used for washing/ wetting the sold fruits and vegetables. The second questionnaire was used to obtain personal information from the sellers, buyers, and consumers.

Statistical evaluation

The data were initially statistically analyzed using the Microsoft Excel version 2016. Further analyses were carried out using the Statistical Package for Social Sciences (SPSS) version 22.0 (SPSS Inc., Chicago, Illinois). Descriptive statistics was conducted to estimate the prevalence using percentages, and presented as figure and tables. The Univariate analysis (Chi-square) was used to determine the level of parasitic contamination between the fruits and vegetables sampled. The Univariate analysis and odds ratios (ORs) with its 95% confidence interval (CI) were used to determine the association between each risk factor and the presence or absence of protozoan and helminth parasites contaminating fruits and vegetables. The ORs were calculated with respect to a reference category as indicated in the respective tables. The value of $P<0.05$ was considered statistically significant for all analyses.

Results

Two hundred and forty-eight of the sampled fruits and vegetables were contaminated with one or more parasites, this represented a 48.7% prevalence with a 95% confidence interval of 44.39–53.07. Twenty-seven of the 51 water samples collected were contaminated with one parasite or the other, representing a 52.9% prevalence. There was no significant statistical difference (P=0.065) in the prevalence rate of the different fruits sampled. The highest prevalence was recorded in *Solanum melongena* (garden egg) with a 100% parasite contamination rate, while *Phaseolus vulgaris* (green beans) had the least parasite contamination rate with a 36.7% prevalence. Among the vegetables, all of *Ocimum gratissimum* (efiirin), *Vernonia amygdalina* (bitter leaf), and *Talinum triangulare* (water leaf) were contaminated with a parasite or more (100%), while 40.0% of *Brassica deracea* (cabbage) was contaminated with parasites. There was a significant statistical difference (P=0.002) in the contamination rate of the different types of vegetables sampled. Furthermore, vegetables were more contaminated with parasites than fruits, although the difference was not statistically significant (P=0.346) (Tab. 1).

Table 1. Prevalence of parasites in the different fruits, vegetables, and water samples in Kwara Central, Nigeria

Sample types	N	Number positive (%)	χ^2 value	*P*-value
Fruits (160)				
Abelmoschus esculentus (okro)	49	23 (46.9)		
Cucumis sativus (cucumber)	31	12 (38.7)		
Lycoperisicon esculentum (tomato)	44	21 (47.7)	8.831	0.065
Phaseolus vulgaris (green beans)	30	11 (36.7)		
Solanum melongena (garden egg)	6	6 (100.0)		
Vegetables (349)				
Amaranthus hybridus (efo tete)	60	31 (51.7)		
Brassica deracea (cabbage)	30	12 (40.0)		
Celosia argentea (efo soko)	78	39 (50.0)		
Corchorus olitorius (ewedu)	54	28 (51.9)		
Daucus carota (carrot)	42	16 (38.1)		
Lactus sativa (lettuce)	19	10 (52.6)	22.77	0.002††
Ocimum gratissimum (efiirin)	6	6 (100.0)		
Sesamum radiatum (eku)	12	6 (50.0)		
Talinum triangulare (water leaf)	6	6 (100.0)		
Telfairia occidentalis (ugwu)	36	15 (41.7)		
Vernonia amygdalina (bitter leaf)	6	6 (100.0)		
Water sample	51	27 (52.9)	X	X
Total (fruits)	160	73 (45.6)	0.90	0.346
Total (vegetables)	349	175 (50.1)		

Explanations: N = number of each variable; †† = significant; χ^2 = Chi-square; X = not applicable

Eleven parasites comprising of 6 protozoan species and 5 helminth species were detected in the fruits, vegetables, and water sampled. Overall, *Entamoeba coli* (39.8%) was the most prevalent parasite, closely followed by *Entamoeba histolytica* (21.3%). *Balantidium coli* and *Trichuris trichiura* were the least prevalent parasites with a prevalence of 2.3% and 2.1% respectively. The prevalence of the other parasites ranged between 15.4% (*Cryptosporidium* species) and 2.5% (*Giardia lamblia*) (Fig. 1).

Five protozoan species and 2 helminth species were recorded in fruits, while 6 protozoan species and 4 helminth species were detected in vegetables. Three protozoans and 4 helminths were recorded in water samples used in washing/wetting the sold fruits and vegetables. Of the fruits sampled, *Entamoeba coli* (55/349; 34.4%; 95% CI=27.5 –42.0) was the most prevalent protozoan, while *Trichuris trichiura* (12/160; 7.5%; 95% CI=4.3 –12.7) was the most prevalent helminth. *Entamoeba coli* was the most prevalent protozoan detected in vegetables (151/349; 43.3%; 95% CI=38.2–48.5) and water (17/51; 33.3%; 95% CI=22.0–47.0), while, *Strongyloides stercoralis* was the most prevalent helminth detected in vegetables (12.6%) and water samples (43.3%) (Tab. 2).

The distribution and contamination patterns of parasites in the different fruits, vegetables, and water samples are shown in table 3. *Entamoeba coli* was detected in 4 of the 5 different types of fruit samples, 10 of the 11 different types of vegetable samples, and the water samples. *Balantidium coli*, *Ancylostoma duodenale*, *Ascaris lumbricoides*, and *Fasciola* species were not detected in the fruits sampled, while *Trichuris trichiura* was the only parasite absent as a contaminant of vegetables. *Cryptosporidium* species, *Entamoeba coli*, *Entamoeba histolytica*, *Ancylostoma duodenale*, *Ascaris lumbricoides*, *Fasciola* species, and *Strongyloides stercoralis* were the parasites found to contaminate water samples used for washing/wetting the sold fruits and vegetables.

The respondents (sellers, buyers, and

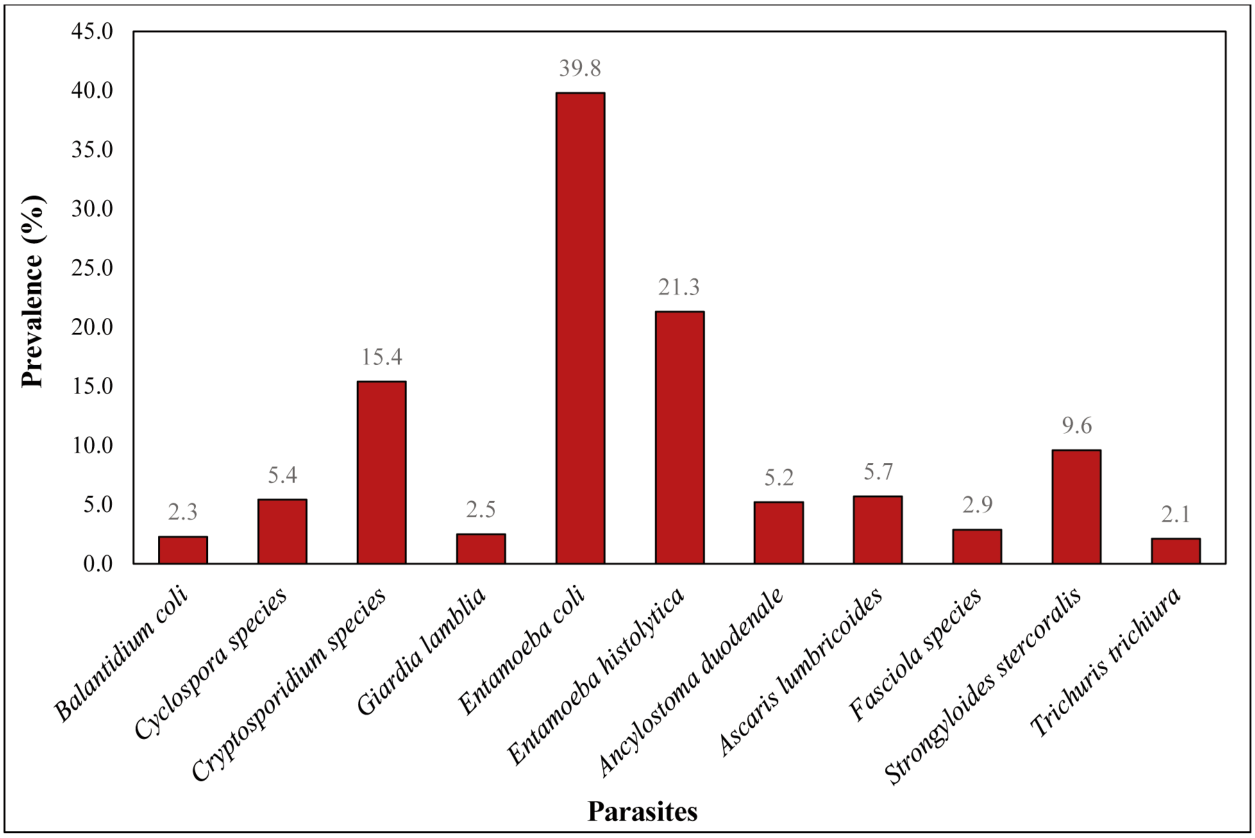

Figure 1. Overall prevalence (%) of helminth and protozoan parasites contaminating fruits, vegetables, and water samples in Kwara Central, Nigeria

consumers) were more of female (72.3%; 95% CI=66.3–77.7) than male (27.7%; 95% CI=22.3 –33.7). Most respondents were within the age group of 30–49 years, while those less than 20 years were the least. Over half of the respondents (123/235; 52.3%) were not sure of the possibility of parasites contaminating fruits and vegetables, while 47.7% (112/235; 95% CI=41.4–54.0) were aware of parasitic contamination in fruits and vegetables. Most of the respondents had secondary education (47.7%), 33.6%, and 14.9% had university education and primary education respectively, while 3.8% were not educated. All the respondents (235/235; 100%) wash fruits and vegetables before consumption. Most of the respondents (155/235; 66.0%; 95% CI=59.7–71.7) boil vegetables before consumption, 19.1% and 8.5% steam and blanch vegetables before consumption, while 6.4% eat vegetables raw (Tab. 4).

Source of fruits sold, market type, washing of fruits before display, and presence of children in the market were the risk factors associated ($P<0.05$) with parasitic contamination of fruits among fruit sellers (Tab. 5), while the source of vegetables sold, source of manure for cultivating vegetables, washing of vegetables before display, water sources for washing/wetting purpose, presence of children at home, presence of children in the market, and knowledge of parasitic contamination of vegetables were the risk factors associated ($P<0.05$) with parasitic contamination of vegetables among vegetable sellers (Tab. 6).

Discussion

The recovery of cyst and oocysts of protozoans and ova and larvae of helminths on fruits and vegetables is of great public health concern. This is because some of the fruits and vegetables may be eaten raw, not properly washed, or unhygienically prepared. In addition, people often pick up fallen fruits and eat after merely dusting off the visible dirt with their hands or clothing [22]. The 48.7% overall prevalence of parasitic contamination of fruits and vegetables we recorded is higher than the 11.6% documented by Adejayan and Olajumoke [23] and lower than the 73.5% reported by Fagbenro et al. [6] with both works carried out in Nigeria. Lower prevalence of 29.6%, 30.0%, 36.3%, and 40.3%, have been recorded in Egypt [8], Iran [24], Ethiopia

Table 2. Diversity and prevalence (%) of parasites contaminating fruits, vegetables, and water in Kwara Central, Nigeria

Parasites	N	Prevalence (%)	95% Confidence interval
Fruits (160)			
Protozoans			
Cyclospora species	9	5.6	3.0–10.3
Cryptosporidium species	20	12.5	8.2–18.5
Giardia lamblia	7	4.4	2.1–8.8
Entamoeba coli	55	34.4	27.5–42.0
Entamoeba histolytica	19	11.9	7.7–17.8
Helminths			
Strongyloides stercoralis	3	1.9	0.6–5.4
Trichuris trichiura	12	7.5	4.3–12.7
Vegetables (349)			
Protozoans			
Balantidium coli	13	3.7	2.2–6.3
Cyclospora species	21	6.0	4.0–9.0
Cryptosporidium species	64	18.3	14.6–22.7
Giardia lamblia	7	2.0	1.0–4.1
Entamoeba coli	151	43.3	38.2–48.5
Entamoeba histolytica	89	25.5	21.2–30.3
Helminths			
Ancylostoma duodenale	25	7.2	4.9–10.4
Ascaris lumbricoides	28	8.0	5.6–11.4
Fasciola species	13	3.7	2.2–6.3
Strongyloides stercoralis	44	12.6	9.5–16.5
Water sample (51)			
Protozoans			
Cryptosporidium species	2	3.9	1.1–13.2
Entamoeba coli	17	33.3	22.0–47.0
Entamoeba histolytica	11	21.6	12.5–34.6
Helminths			
Ancylostoma duodenale	4	7.8	3.1–18.5
Ascaris lumbricoides	4	7.8	3.1–18.5
Fasciola species	3	5.9	2.0–15.9
Strongyloides stercoralis	7	13.7	6.8–25.7

Explanations: N = number of vegetables, fruits or water samples parasite(s) was detected

[25], and Philippines [26] respectively. Although higher prevalence (50.9%) was reported in Brazil [10], which is similar the result of this present study. Parasitic contamination of fruits and vegetables encountered in our study may be from the water samples used for washing/wetting (since over half of the water sampled were contaminated with parasites), or from organic manures (animal or human faeces) used in their cultivation, or due to the indiscriminate defecation by man and animals in

Table 3. Distribution and patterns of parasites contaminations on fruits, vegetables, and water samples in Kwara Central, Nigeria

		Parasites and its numbers, prevalence (%)											
Samples	N	*B. coli*	*Cyclospora* species	*Cryptosporidium* species	*G. lamblia*	*E. coli*	*E. histolytica*	*A. duodenale*	*A. lumbricoides*	*Fasciola* species	*S. stercoralis*	*T. trichiura*	n
Fruits													
1	49	0 (0.0)	7 (14.3)	13 (26.5)	0 (0.0)	18 (36.7)	6 (12.2)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	4
2	31	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	12 (38.7)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	3 (9.7)	0 (0.0)	2
3	44	0 (0.0)	2 (4.5)	6 (13.6)	7 (15.9)	13 (29.5)	7 (15.9)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	6 (13.6)	6
4	30	0 (0.0)	0 (0.0)	1 (3.3)	0 (0.0)	12 (40.0)	6 (20.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	3
5	6	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	6 (100.0)	1
Total	160	0 (0.0)	9 (5.6)	20 (12.5)	7 (4.4)	55 (34.4)	19 (11.9)	0 (0.0)	0 (0.0)	0 (0.0)	3 (1.9)	12 (7.5)	
X		0	2	3	1	4	3	0	0	0	1	2	
Vegetables													
6	54	7 (13.0)	6 (11.1)	24 (44.4)	0 (0.0)	36 (66.7)	13 (24.1)	0 (0.0)	6 (11.1)	6 (11.1)	12 (22.2)	0 (0.0)	8
7	60	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	18 (30.0)	18 (30.0)	0 (0.0)	3 (5.0)	6 (10.0)	0 (0.0)	0 (0.0)	4
8	78	0 (0.0)	9 (11.5)	12 (15.4)	6 (7.7)	37 (47.4)	15 (19.2)	18 (23.1)	0 (0.0)	0 (0.0)	12 (15.4)	0 (0.0)	7
9	36	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	12 (33.3)	6 (16.7)	0 (0.0)	12 (33.3)	0 (0.0)	6 (16.7)	0 (0.0)	4
10	42	0 (0.0)	0 (0.0)	7 (16.7)	1 (2.4)	12 (28.6)	6 (14.3)	0 (0.0)	1 (2.4)	0 (0.0)	0 (0.0)	0 (0.0)	5
11	30	6 (20.0)	6 (20.0)	9 (30.0)	0 (0.0)	12 (40.0)	6 (20.0)	1 (3.3)	0 (0.0)	1 (3.3)	1 (3.3)	0 (0.0)	8
12	19	0 (0.0)	0 (0.0)	6 (31.6)	0 (0.0)	6 (31.6)	19 (100.0)	6 (31.6)	6 (31.6)	0 (0.0)	13 (68.4)	0 (0.0)	6
13	6	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	6 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1
14	6	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	6 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1
15	12	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	6 (50.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1
16	6	0 (0.0)	0 (0.0)	6 (100.0)	0 (0.0)	6 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	2
Total	349	13 (3.7)	21 (6.0)	64 (18.3)	7 (2.0)	151 (43.3)	89 (25.0)	25 (7.2)	28 (8.0)	13 (3.7)	44 (12.6)	0 (0.0)	
Y		2	3	6	2	10	8	3	5	3	5	0	
Water samples	51	0 (0.0)	0 (0.0)	2 (3.9)	0 (0.0)	17 (33.3)	11 (21.6)	4 (7.8)	4 (7.8)	3 (5.9)	7 (13.7)	0 (0.0)	7

1 = *Abelmoschus esculentus* (okro); 2 = *Cucumis sativus* (cucumber); 3 = *Lycoperisicon esculentum* (tomato); 4 = *Phaseolus vulgaris* (green beans); 5 = *Solanum melongena* (garden egg); 6 = *Corchorus olitorius* (ewedu); 7 = *Amaranthus hybridus* (efo tete); 8 = *Celosia argentea* (efo soko); 9 = *Telfairia occidentalis* (ugwu); 10 = *Daucus carota* (carrot); 11 = *Brassica deracea* (cabbage); 12 = *Lactus sativa* (lettuce); 13 = *Ocimum gratissimum* (efiirin); 14 = *Vernonia amygdalina* (bitter leaf); 15 = *Sesamum radiatum* (eku); 16 = *Talinum triangulare* (water leaf); N = number of vegetables/ fruits/ water samples collected; n = number of species of parasite(s) in each vegetable/fruit/water sample; X = number of fruit types contaminated by parasite(s); Y = number of vegetable types contaminated by parasite(s)

Table 4. Socio-demographic characteristics of respondents (sellers, buyers, and consumers) and their perception concerning parasites contamination of fruits and vegetables in Kwara Central, Nigeria (n=235)

Variable	Proportion (%)	95% Confidence interval
Gender of respondent		
Female	170 (72.3)	66.3–77.7
Male	65 (27.7)	22.3–33.7
Age of respondent (years)		
<20	6 (2.6)	1.2–5.5
20–29	95 (40.4)	34.4–46.8
30–49	122 (51.9)	45.6–58.2
>50	12 (5.1)	2.9–8.7
Do you know parasites can contaminate fruits and vegetables?		
Yes	112 (47.7)	41.4–54.0
Not sure	123 (52.3)	46.0–58.6
Educational status		
Not educated	9 (3.8)	2.0–7.1
Primary education	35 (14.9)	10.9–20.0
Secondary education	112 (47.7)	41.4–54.0
University education	79 (33.6)	27.9–39.9
Do you wash fruits and vegetables before consumption?		
Yes	235 (100.0)	98.7–100.0
No	0 (0.0)	0.0–1.3
How do you prepare vegetables before consumption?		
Blanching	20 (8.5)	5.6–12.8
Boiling	155 (66.0)	59.7–71.7
Steaming	45 (19.1)	14.6–24.7
Eaten raw	3 (6.4)	3.9–10.3

farmlands, or from the handling by the farmers and sellers. This level of parasitic contamination is of great public health concern. Despite the level of parasitic contamination, our findings that all the buyers and consumers wash fruits and vegetables before consumption, and two-thirds of the buyers and consumers boil vegetables before consumption, could have reduced the level of human cases of infections.

All the fruit and vegetable types sampled were contaminated with one or more parasites, in like manner, there had been reports of parasitic contamination in all fruits and vegetables studied in Nigeria [6,27] and other parts of the world [2,8,10,15,25,26]. This implies that parasitic contamination of fruits and vegetables is a global threat, and so calls for immediate efforts to control it and to curb its adverse effects.

We observed that vegetables were more contaminated with parasites compared to fruits. Auta et al. [28] and Nasiru et al. [29] also reported a similar finding in their studies. The higher prevalence of parasitic contamination in vegetables may be due to the rough surfaces and leaf folds of vegetables which may retain dirt that cannot be easily washed off [22].

The high level of water contamination with parasites may be attributed to water pollution with both human and animal faeces. Parasitic contamination of water has been reported in different water sources (stream, well, rain and borehole) in Nigeria with an alarming prevalence of

Table 5. Risk factors associated with parasites contaminations of fruits among fruit sellers in Kwara Central, Nigeria (n=66)

Variables	Parasite + ve (%)	Parasite - ve (%)	OR (95% Cl)	*P*- value
Source of fruits sold				
Farmers	40 (95.2)	2 (4.8)	13.6 (2.9–101.0)	<0.01[††]
Middle men [a]	14 (58.3)	10 (41.7)	1.0	
Manure application				
Yes	37 (84.1)	7 (15.9)	5.0 (0.1–21.1)	0.35
Not sure	16 (80.0)	4 (20.0)	3.7 (0.1–16.5)	0.69
No [a]	1 (50.0)	1 (50.0)	1.0	
*Manure source				
Organic	26 (83.9)	5 (16.1)	1.5 (0.3–8.0)	0.60
Inorganic [a]	10 (76.9)	3 (23.1)	1.0	
Market type				
Open market	53 (88.3)	7 (11.7)	34.3 (14.1–91.3)	<0.01[††]
Grocery store [a]	1 (16.7)	5 (83.3)	1.0	
Washed before display				
Yes	51 (87.9)	7 (12.1)	11.4 (2.2–69.6)	<0.01[††]
No [a]	3 (37.5)	5 (62.5)	1.0	
Water sources for washing/wetting purpose				
Well	34 (85.0)	6 (15.0)	5.4 (0.5–60.0)	0.16
Stream	10 (100.0)	0 (0.0)	X	
Pipe borne	8 (66.7)	4 (33.3)	1.9 (0.2–24.6)	0.61
Rain [a]	2 (50.0)	2 (50.0)	1.0	
Means of display				
Table	34 (81.0)	8 (19.0)	1.1 (0.1–5.8)	0.91
Wheel barrow	8 (100.0)	0 (0.0)	X	
Shelf	4 (66.7)	2 (33.3)	0.5 (<0.1–6.6)	0.61
Floor [a]	8 (80.0)	2 (20.0)	1.0	
Presence of children at home				
Yes	29 (90.6)	3 (9.4)	3.4 (0.9–17.2)	0.08
No [a]	25 (73.5)	9 (26.5)	1.0	
Presence of children in the market				
Yes [a]	40 (90.9)	4 (9.1)	5.5 (1.4–24.1)	0.01[††]
No	14 (63.6)	8 (36.4)	1.0	
Gender of seller				
Female	42 (84.0)	8 (16.0)	1.8 (0.4–6.8)	0.47
Male [a]	12 (75.0)	4 (25.0)	1.0	
Age of seller				
<20	10 (100.0)	0 (0.0)	X	
20 to 30	34 (77.3)	10 (22.7)	0.9 (0.1–4.5)	0.90
30 to 50 [a]	8 (80.0)	2 (20.0)	1.0	
>50	2 (100.0)	0 (0.0)	X	
Knowledge of parasites contaminations of fruits				
No	28 (87.5)	4 (12.5)	2.13 (0.6–9.0)	0.27
Yes [a]	26 (76.5)	8 (23.5)	1.0	

Explanations: * = (n=44); X = not applicable; OR = odds ratio; CI = confidence interval; [a] = reference category; [††] = significant

Table 6. Risk factors associated with parasites contaminations of vegetables among vegetable sellers in Kwara Central, Nigeria (n=124)

Variables	Parasite + ve (%)	Parasite - ve (%)	OR (95% Cl)	*P*-value
Source of vegetables sold				
Farmers	70 (85.7)	7 (14.3)	5.1 (1.9–14.5)	<0.01[††]
Middle men [a]	31 (74.5)	16 (25.5)	1.0	
Manure application				
Yes	68 (84.0)	13 (16.0)	5.1 (0.5–52.5)	0.16
Not sure	31 (79.5)	8 (20.5)	3.7 (0.3–40.5)	0.26
No [a]	2 (50.0)	2 (50.0)	1.0	
*Manure source				
Organic	55 (91.7)	5 (8.3)	6.6 (1.8–25.5)	<0.03[††]
Inorganic [a]	13 (61.9)	8 (38.1)	1.0	
Market type				
Open market	94 (83.2)	19 (16.8)	2.8 (0.7–10.7)	0.15
Grocery store [a]	7 (63.6)	4 (36.4)	1.0	
Washed before display				
Yes	93 (85.3)	16 (14.7)	5.0 (1.5–16.2)	0.01[††]
No [a]	8 (53.3)	7 (46.7)	1.0	
Water sources for washing/wetting purpose				
Well	66 (86.8)	10 (13.2)	8.4 (1.5–51.3)	0.02[††]
Stream	17 (94.4)	1 (5.6)	18.7 (1.8–58.7)	0.01[††]
Pipe borne	15 (65.2)	8 (34.8)	2.4 (0.4–16.0)	0.33
Rain [a]	3 (42.9)	4 (57.1)	1.0	
Means of display				
Table	64 (81.0)	15 (19.0)	1.2 (0.3–4.1)	0.74
Wheel barrow	16 (100.0)	0 (0.0)	X	
Shelf	7 (63.6)	4 (36.4)	0.5 (0.1–2.9)	0.44
Floor [a]	14 (77.8)	4 (22.2)	1.0	
Presence of children at home				
Yes	54 (90.0)	6 (10.0)	3.2 (1.2–9.6)	0.02[††]
No [a]	47 (73.4)	17 (26.6)	1.0	
Presence of children in the market				
Yes	75 (91.5)	7 (8.5)	6.5 (2.4–18.6)	<0.01[††]
No [a]	26 (61.9)	16 (38.1)	1.0	
Gender of seller				
Female	80 (84.2)	15 (15.8)	2.0 (0.7–5.4)	0.17
Male [a]	21 (72.4)	8 (27.6)	1.0	
Age of seller				
<20	18 (100.0)	0 (0.0)	X	
20–30	64 (77.1)	19 (22.9)	0.8 (0.2–2.7)	0.81
30–50 [a]	16 (80.0)	4 (20.0)	1.0	
>50	3 (100.0)	0 (0.0)	X	
Knowledge of parasites contaminations of vegetables				
No	55 (91.7)	5 (8.3)	4.3 (1.5–13.7)	<0.01[††]
Yes [a]	46 (71.9)	18 (28.1)	1.00	

Explanations: * = (n=44); X = not applicable; OR = odds ratio; CI = confidence interval; [a] = reference category; [††] = significant between 10 to 45% [30].

Eleven different parasites (protozoans and helminths) were detected in our study. These parasites have been documented to be zoonotic, as they infect both humans and animals [20]. This number is higher than the 4, 5, 6, 7, 8, 9, and 10 different parasite species detected by Alhabbal [15], Balarak et al. [31], Simon-Oke et al. [22], Vizon et al. [26], Alemu et al. [9], Bakri et al. [32], and Luz et al. [10] respectively in their various studies. In line with our results, Auta et al. [28] and Alemu et al. [33] reported 11 species of parasites on fruits and vegetables in their studies carried out in Nigeria and Ethiopia respectively. The reason for the high diversity of parasites detected in our study may be attributed to the fact that we sampled 16 types of fruits and vegetables.

Entamoeba coli and *Strongyloides stercoralis* were the most prevalent protozoan and helminth detected respectively in our study. Balarak et al. [34] and Al-Megrin [35] had reported *Entamoeba coli* to be the most prevalent parasite contaminating vegetables in Iran and Saudi Arabia respectively. *Strongyloides stercoralis* has been documented to be the most common parasite contaminating vegetables in Nigeria [36] and Ghana [2]. *Strongyloides stercoralis* has been noted to be widely distributed in areas of poor hygiene and sanitation. Infection may have occurred due to soil and water being contaminated by animals (dog, cat, etc.) and human faeces [2,20].

Most of the respondents were not aware that parasites can contaminate fruits and vegetables. This may have a negative effect on public health as their ignorance of parasitic contamination may not make them to thoroughly wash fruits and vegetables before consumption. The low number of respondents with University education could have resulted in the low level of knowledge of possible contamination of fruits and vegetables by parasites. There is need to educate sellers, buyers, and consumers on the possibilities of parasitic contamination on fruits and vegetables.

A significantly higher level of parasite contamination was observed on fruits and vegetables bought from farmers. The low level of parasitic contamination observed on fruits and vegetables bought from middlemen may be linked to the fact that they would have washed the fruits and vegetables before selling them to the retailers. Washing fruits and vegetables with clean water can reduce the level of parasitic contamination on them [3], this may be the reason we observed a significantly lower level of parasitic contamination on fruits and vegetables that were washed before they were displayed for sale.

We observed a higher level of parasitic contamination in fruits and vegetables sold in the open markets compared to those sold in grocery stores. In a similar manner, Alemu et al. [33] reported a higher prevalence of parasite contamination of fruits and vegetables sold in the open markets compared to grocery stores. The dirty nature of open markets and roaming of animals in open markets may have resulted in the higher level of parasitic contamination on fruits and vegetables.

All the parasites (protozoans and helminths) observed in our study are known to infect humans. The detection of these parasites may be attributed to the presence of children in the marketplaces and homes of most of the fruit and vegetable sellers. Intestinal parasitic infections are the most common infections among children in developing countries of the world [37]. The handling of fruits and vegetables by sellers following improper washing of hands after clearing the faeces of children, or after washing faeces off the children may lead to contamination of the fruits and vegetables with parasites.

The use of faecal materials (organic manure) from infected humans and animals as manure on farmlands can contaminate vegetables before harvest [4,6,8,10]. In a similar manner, we reported a significantly higher prevalence of parasitic contamination in fruits and vegetables grown with organic manure compared to those grown with inorganic manure.

Water sources been a significant risk factor in the contamination of fruits and vegetables by parasites is not out of place. Parasitic contamination of different water sources have been reported by Ani and Itiba [38] and Iyaji et al. [39]. The highest prevalence of parasitic contamination on fruits and vegetables washed/wetted with water from streams, may be attributed to the high contamination of stream water as reported by Simon-Oke et al. [30]. Streams get contaminated with parasites as a result of human activities such as indiscriminate dumping of waste and defecation into the water bodies and the erosion of faecal materials of both animals and human origins into streams following rainfalls.

The fact that a large number of sellers were ignorant of the possibility of fruits and vegetables been contaminated with parasites could have led to the improper handling of fruits and vegetables by sellers, resulting in an increased level of parasitic contamination of fruits and vegetables we observed in this study.

In conclusion, parasitic contamination on fruits and vegetables is of great public health concern in Kwara Central, Nigeria. Eleven different parasites species (6 protozoans and 5 helminths) were detected to contaminate fruits and vegetables and these parasites are zoonotic. All the sampled types of fruits and vegetables were contaminated with one or more species of parasites. A high prevalence of parasitic contamination was observed in water samples used for washing/wetting sold fruits and vegetables, which was a factor responsible for the high prevalence of parasitic contamination of fruits and vegetables recorded in this study. Most buyers, consumers, and sellers of fruits and vegetables are ignorant of parasitic contamination of fruits and vegetables. There is need to educate the general public on the possibilities of parasitic contamination of fruits and vegetables and its public health implications.

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