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Factors associated with parasitic contamination of fresh fruits retailed at major markets in Ibadan, Nigeria: A public health concern

*[1,2]Makanjuola, O. B., [1]Onifade, Y. M., and [1,2]Dada-Adegbola, H. O.

[1]Department of Medical Microbiology and Parasitology, University of Ibadan, Nigeria
[2]Department of Medical Microbiology and Parasitology, University College Hospital, Ibadan, Nigeria
*Correspondence to: funmimakanjuola@yahoo.com; +2348034731717; ORCID: 0000-0001-7785-0183

Abstract:

Background: Globally, cases of protozoan and helminths infections in humans have been linked to the consumption of unwashed fresh fruits and this has been prevalent especially in developing countries. The ingestion of parasite-contaminated fruits can lead to intestinal parasitosis that can result in childhood diarrhea, malnutrition and growth retardation. Hence, the aim of the study was to determine the prevalence of parasites contaminating fresh fruits sold in major markets in Ibadan, Nigeria, the sources and factors associated with contamination.
Methodology: This was a descriptive cross-sectional study of contamination rates of fresh fruits sold by vendors in 3 selected major markets from 3 local government areas in Ibadan, Nigeria. A total of 108 fresh fruits of 7 different types (orange, watermelon, mango, apple, banana, pineapple and carrot) were purchased from the vendors using proportional allocation method for the 3 markets, over a period of 4 weeks. The fruits were at each purchase, transported immediately to the parasitology laboratory of the University College Hospital Ibadan for analysis. Wet film microscopy of concentrated fruit samples through sedimentation technique was used to detect helminths eggs, cysts and larvae, and Kinyoun acid-fast stain was used to detect protozoan cysts and oocysts. Information on possible sources of fruit contamination and associated factors were collected from the fruit vendors and from environmental surveys, using a designed collection form. Data analysis was performed on SPSS version 28.0. Fisher's exact test was used to determine association between potential risk factors and parasitic contamination rates, and p-value ≤ 0.05 was considered statistically significant.
Results: Out of the 108 fruits examined, a total of 12 samples were positive for parasites (11.1%), with 2 (16.7%) of the 12 samples contaminated with multiple parasite species. *Strongyloides stercoralis* (n=6, 42.9%) was the most commonly identified parasite, followed by *Cryptosporidium* spp (n=5, 35.7%), *Trichomonas hominis* (n=2, 14.3%) and *Ascaris lumbricoides* (n=1, 7.2%). There was significant association (p<0.05) between parasitic contamination rates and factors such as method of fruit display, vendors' defecation practices, and presence of dirt around the vendors' premises. Although, parasitic contamination rates were higher with factors such as poor drainage systems, proximity of sellers to waste collection points, presence of animal droppings, and infrequently washed display containers, the differences were not statistically significant (p>0.05).
Conclusion: This high level of contamination of fresh fruits with intestinal parasites poses a health risk to the consumers, thus thorough washing of fruits before ingestion is highly recommended. Food safety should encompass the prevention of parasitic contamination at all stages from planting to ingestion.

Keywords: Intestinal Parasites, Protozoa, Helminths, WASH, Food safety, food-borne illnesses

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Facteurs associés à la contamination parasitaire des fruits frais vendus au détail sur les principaux marchés d'Ibadan, au Nigéria: un problème de santé publique

*[1,2]Makanjuola, O. B., [1]Onifade, Y. M., et [1,2]Dada-Adegbola, H. O.

[1]Département de Microbiologie Médicale et de Parasitologie, Université d'Ibadan, Nigéria
[2]Département de Microbiologie Médicale et de Parasitologie, Hôpital Universitaire, Ibadan, Nigéria
*Correspondance à: funmimakanjuola@yahoo.com; +2348034731717; ORCID: 0000-0001-7785-0183

Résumé:

Contexte: À l'échelle mondiale, des cas d'infections à protozoaires et à helminthes chez l'homme ont été associés à la consommation de fruits frais non lavés, et cette prévalence est particulièrement élevée dans les pays en développement. Français L'ingestion de fruits contaminés par des parasites peut entraîner une parasitose intestinale susceptible de provoquer des diarrhées infantiles, de la malnutrition et un retard de croissance. Par conséquent, l'objectif de l'étude était de déterminer la prévalence des parasites contaminant les fruits frais vendus sur les principaux marchés d'Ibadan, au Nigéria, ainsi que les sources et les facteurs associés à la contamination.
Méthodologie: Il s'agissait d'une étude transversale descriptive des taux de contamination des fruits frais vendus par des vendeurs sur 3 grands marchés sélectionnés dans 3 zones de gouvernement local d'Ibadan, au Nigéria. Un total de 108 fruits frais de 7 types différents (orange, pastèque, mangue, pomme, banane, ananas et carotte) ont été achetés auprès des vendeurs en utilisant la méthode d'allocation proportionnelle pour les 3 marchés, sur une période de 4 semaines. Les fruits ont été, à chaque achat, transportés immédiatement au laboratoire de parasitologie de l'Hôpital universitaire d'Ibadan pour analyse. Français La microscopie à film humide d'échantillons de fruits concentrés par technique de sédimentation a été utilisée pour détecter les œufs, les kystes et les larves d'helminthes, et la coloration acido-résistante de Kinyoun a été utilisée pour détecter les kystes et les oocystes de protozoaires. Des informations sur les sources possibles de contamination des fruits et les facteurs associés ont été recueillies auprès des vendeurs de fruits et à partir d'enquêtes environnementales, à l'aide d'un formulaire de collecte conçu. L'analyse des données a été réalisée sur SPSS version 28.0. Le test exact de Fisher a été utilisé pour déterminer l'association entre les facteurs de risque potentiels et les taux de contamination parasitaire, et la valeur $p \leq 0,05$ a été considérée comme statistiquement significative.
Résultats: Sur les 108 fruits examinés, un total de 12 échantillons étaient positifs pour les parasites (11,1%), avec 2 (16,7%) des 12 échantillons contaminés par plusieurs espèces de parasites. *Strongyloides stercoralis* (n=6, 42,9%) était le parasite le plus fréquemment identifié, suivi de *Cryptosporidium* spp (n=5, 35,7%), *Trichomonas hominis* (n=2, 14,3%) et *Ascaris lumbricoides* (n=1, 7,2%). Une association significative ($p<0,05$) a été observée entre les taux de contamination parasitaire et des facteurs tels que le mode de présentation des fruits, les pratiques de défécation des vendeurs et la présence de saleté autour des locaux. Bien que les taux de contamination parasitaire soient plus élevés en raison de facteurs tels que la mauvaise qualité des systèmes de drainage, la proximité des vendeurs avec les points de collecte des déchets, la présence d'excréments d'animaux et le lavage peu fréquent des contenants de présentation, les différences n'étaient pas statistiquement significatives ($p>0,05$).
Conclusion: Ce niveau élevé de contamination des fruits frais par des parasites intestinaux présente un risque pour la santé des consommateurs. Il est donc fortement recommandé de laver soigneusement les fruits avant leur ingestion. La sécurité alimentaire doit inclure la prévention de la contamination parasitaire à toutes les étapes, de la plantation à la consommation.

Mots-clés: Parasites intestinaux, Protozoaires, Helminthes, WASH, Sécurité alimentaire, maladies d'origine alimentaire

Introduction:

Fruits are one of the major sources of vitamins and minerals, high in fiber and help in promoting good health (1). A diet rich in fruits can lower blood pressure, reduce the risk of heart disease and stroke, lower the risk of eye and digestive problems, prevent some types of cancer and have a positive effect on blood sugar (2,3). In spite of these benefits, fruits could also constitute risk to human health when consumed unclean (4). A major risk from consumption of such unclean fruits is parasitic infections which are acquired through consumption of food or water contaminated with feces containing the infective stages of the parasite. Improperly cooked meat, vegetables and fresh fruits are the main sources of such contaminated food items (5).

Intestinal parasites feed off nutrients from their host, causing significant damage to human health including malnutrition, intestinal obstruction, amoebic liver abscess, skin rash, liver damage, malabsorption and are major contributors to childhood diarrhea and growth retardation (6,7). The consumption of fresh fruits plays a major role in the transmission of parasitic food borne diseases. Routes of contamination of fresh fruits vary as they can be contaminated throughout the process from planting to consumption. During the planting process, application of organic wastes to agricultural land as fertilizers, fecal matter contaminating irrigation water, poor personal hygiene, poor sanitation, and direct contamination by birds, wild animals and livestock can result in contamination (8).

In many developing countries the practice of irrigation of soil with untreated wastewater and use of manure and night soil as fertilizers in the cultivation of fruits often lead to parasitic infections when these fruits are eaten unwashed or uncooked (6). This practice which is growing prominence in Nigeria because of the high cost of mineral fertilizers and poor socio-economic conditions that is further worsened by poor environmental hygiene (9).

Inadequate hygiene practices during harvesting, packaging, transportation, and storage of fruits also contribute to the contamination of fruits. Globalization of food supply post-harvest has led to introduction of pathogens into new geographical areas through importation (10). Post harvesting contamination of fruits may occur when fresh fruits are rinsed, washed and sprinkled with contaminated and untreated water posing hazardous effects

on humans (11). The rate of contamination and species of parasites is affected by various factors including weather conditions such as temperature, rainfall, soil type, sociocultural status, season of sample collection and fruits examined (10).

In recent times, there has been a global increase in the cases of food borne illnesses and outbreaks linked to consuming fresh fruits (12). Previous studies have shown that many fresh fruits purchased from markets in different regions from developing countries were contaminated with helminths eggs and larvae including *Ascaris lumbricoides, Trichuris trichiura, Ancylostoma duodenale,* and *Necator americanus* (hookworms)*,* as well as protozoan cysts such as *Giardia intestinalis, Entamoeba histolytica, and Cryptosporidium* spp (5,6,13-15).

In Ibadan, Nigeria, a city highly endemic for Soil Transmitted Helminths (STHs), contamination is particularly concerning due to inadequate sanitation and open defecation practices, which exacerbate the risk of soil-transmitted helminth infections (16). However, there has been little information available about the burden of parasitic contamination in recent times. Furthermore, previous studies did not investigate factors determining such contaminations. It is crucial to identify contaminating parasites as well as their sources with the goal of providing suitable, effective, and feasible intervention methods for monitoring and controlling them before these food items reach the final consumers. Hence, this study evaluated the current prevalence of parasites on fresh fruits sold in major markets in Ibadan, Oyo state, Nigeria and the likely sources of contamination.

Materials and method:

Study design and setting:

This was a descriptive cross-sectional study of fresh fruits retailed by vendors in three selected markets in Ibadan, the capital of Oyo state, south-western Nigeria and a major center of commerce in the state. Bodija, Oje, and Ayeye markets in three local government areas of Ibadan were purposively selected for this study to reflect the major sources of fruit in the city. These are major markets where farmers bring in their fruit harvests to be sold.

Bodija is situated in Ibadan North local government is the largest food market in Ibadan with a large fruit section, Oje market is situated in Ibadan North-East local government and is the most popular fruit market, while Ayeye Market situated in Ibadan North-West local government is also a popular fruit market. Sample collection and analysis was conducted within a 4-week duration from April to May 2023.

Ethical considerations:

This research was ethically approved by the local institutional review board with code number UI/EC/23/0186. Informed consent was obtained from all participating fruit vendors.

Study population, sample size and sampling:

The study population comprised of fresh fruits sold in the selected markets by fruit vendors. The fruits include orange (*Citrus sinensis*), watermelon (*Citrullus lanatus*), mango (*Mangifera indica*), apple (*Malus domestica*), banana (*Musa acuminate*), pineapple (*Ananas comosus*), and carrot (*Daucus carota*). The sample size was estimated using the formular for cross-sectional studies and the prevalence determined from a previous study in Nigeria (17). A minimum sample size of 98 fresh fruits was obtained and a 10% non-response rate was included to obtain adjusted sample size of 108.

Approximately 17 to 18 fruit vendors were randomly sampled weekly at the selected markets, with proportionate allocation of number of fruit samples for the markets (1.5: 1.5: 1 for Oje: Bodija: Ayeye) based on the estimated size of each market. Sampling was done over a period of 4 weeks to obtain the sample size of 108.

Data and sample collection:

Structured questionnaire were designned and used to collect information on the socio-demographic characteristics of the fruit vendors such as age, sex, and level of education. Information such as market place, source of fruits, means of transportation, method of fruit display, method of storage, and the fingernail status of the vendors were collected. Observations of the market environment for the presence of waste bins, dumping site, wastes and toilet facilities were documented.

Each set of fruit sampled was packaged into sterile polythene bags, labelled with a unique laboratory identification, name of market, date of purchase, and transported to the parasitology laboratory for analysis.

Macroscopic/microscopic examination of samples:

Each fruit sample was examined macroscopically for presence of segments or adult forms of helminths. The fruit samples were then concentrated by the sedimentation technique before microscopic examination for the presence of ova or cyst of helminths using saline and iodine mounts, and for oocysts using modified Ziehl Neelsen (ZN) staining.

Concentration of parasites using the sedimentation method:

Each fruit sample was thoroughly washed in 100ml of physiological saline (0.85% NaCl) for 2 minutes. The suspension was strained using a sterile sieve to remove undesirable materials. The filtrate was left to stand for about 12 hours. The supernatant was discarded and the sediment was transferred to a 15ml centrifuge tube. For concentrating the parasite, the tube was centrifuged at 3000 rpm for 5 minutes and the supernatant was carefully decanted without shaking. The sediment was agitated by gently shaking the tube to redistribute the parasites (18). The resultant suspension was used for wet smear and modified ZN acid-fast staining.

Wet smear preparation for microscopy:

A drop each of the suspension was placed on both ends of a clean grease-free microscopic slide, one for saline and the other for iodine mounts (a drop of Lugol's iodine was added to one of the suspensions). A thin smear was made, and the suspension drops were carefully covered with cover slip each and observed under light microscope using 10x and 40x objective for the presence of parasites.

Modified Ziehl Neelsen staining procedure:

Fixed slides of fruit suspension were stained with cold carbol fuchsin for 15 mins, rinsed, decolorized with 1% hydrochloric acid alcohol and counterstained with 0.5% malachite green. These were allowed to air dry and examined microscopically under immersion oil for oocysts of parasites (19).

Data analysis:

Data analysis was performed on SPSS version 28.0. The data were summarized and presented using descriptive statistics. Fisher Exact test was used to compare the rate of parasitic contaminations among different fruit types sold in different markets and to determine the association between the risk factors and parasitic contamination. A p-value ≤ 0.05 was considered statistically significant.

Results:

A total of 108 samples of fruits were purchased, consisting of 42 (38.9%) in Oje market, 40 (37.0%) in Bodija market and 26 (24.1%) in Ayeye market based on proportional ratio of 1.5: 1.5: 1. (Table 1). A total of 12 (11.1%) of the 108 fruit samples were positive for parasites during the study. The distribution of parasitic contamination according to the different markets showed highest contamination rate in Ayeye (19.2%, 5/26) market, followed by Oje (14.3 %, 6/42) market and lowest in Bodija (2.5%, 1/40) market. However, statistical analysis did not indicate a significant association between contamination rates and the type of markets (p=0.057) (Table 1).

Table 1: Prevalence of parasitic contamination of fresh fruits in major markets in Ibadan, Nigeria

Markets	**No of fruits examined**	**No of fruits contaminated (%)**	**Fisher**	***p* value**
Bodija	40	1 (2.5)	5.569	0.057
Oje	42	6 (14.3)		
Ayeye	26	5 (19.2)		
Total	**108**	**12 (11.1)**		

Table 2: Frequency of parasites contaminating fresh fruits in major markets in Ibadan, Nigeria

Parasite	**Frequency**	**Percentage (%)**
Ascaris lumbricoides	1	7.1
Trichomonas hominis	2	14.3
Cryptosporidium spp.	5	35.7
Strongyloides stercoralis	6	42.9
Total	**14**	**100.0**

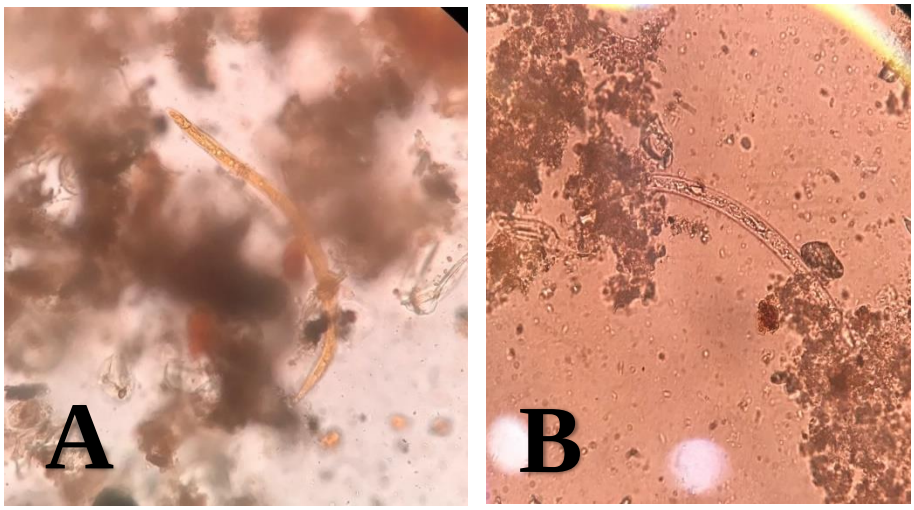
Table 3: Parasite contamination rates for different fresh fruit types in major markets in Ibadan, Nigeria

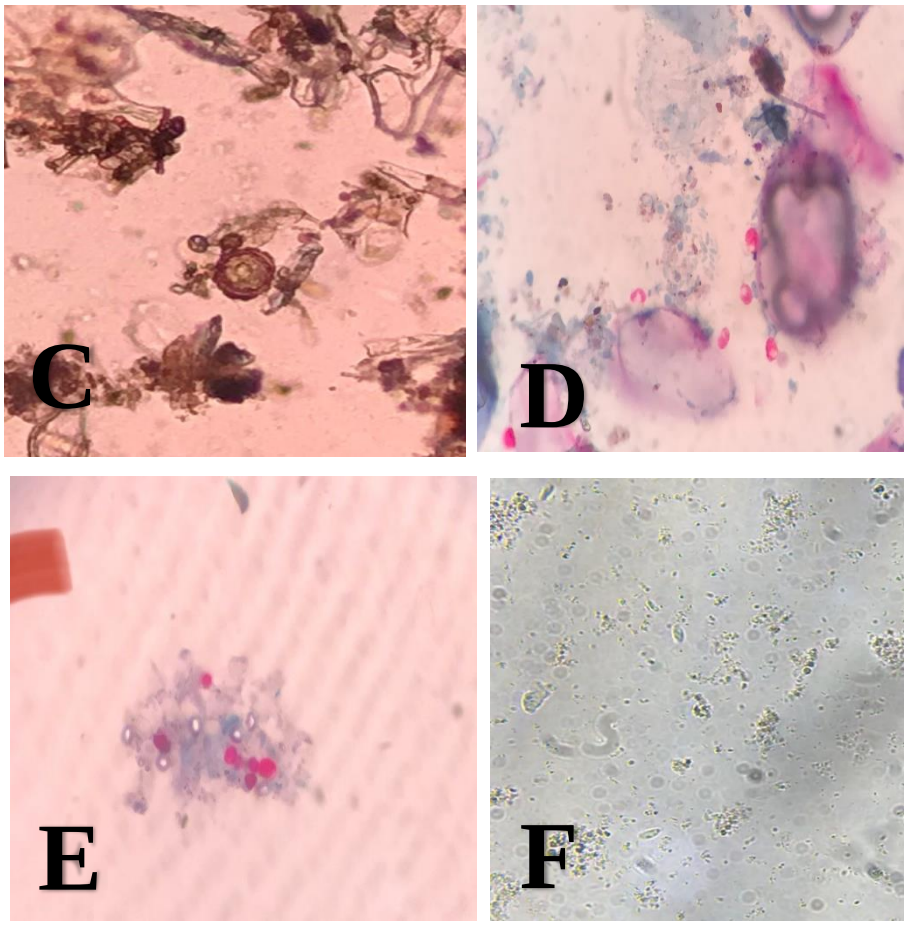
Fruits/markets	Bodija		Oje		Ayeye		Total examined	Total contaminated
	Examined	Contaminated	Examined	Contaminated	Examined	Contaminated		
Apple	3	0	2	0	3	0	8	0
Banana	2	0	6	0	5	0	13	0
Carrot	4	1	3	0	3	1	10	2 (20.0)
Mango	8	0	6	0	6	1	20	1 (5.0)
Orange	7	0	14	2	2	0	23	2 (8.7)
Pineapple	8	0	6	3	4	2	18	5 (27.8)
Watermelon	8	0	5	1	3	1	16	2 (12.5)
Total	**40**	**1 (2.5)**	**42**	**6 (14.3)**	**26**	**5 (19.2)**	**108**	**12 (11.1)**

Fisher Exact test 7.574, p=0.189

Parasites identified include *Ascaris lumbricoides, Cryptosporidium* spp*, Strongyloides stercoralis,* and *Trichomonas hominis* (Fig 1). The most frequent parasitic contaminant of the fruits is *S. stercoralis* (n=6, 42.9%), followed by *Cryptosporidium* spp (n=5, 35.7%), *T. hominis* (n=2, 14.3%), and *A. lumbricoides* (n=1, 7.1%) (Table 2).

Parasitic contamination rate was highest for pineapple fruits (27.8%, 5/18), followed by carrots (20.0%, 2/10), watermelon (12.5%, 2/16), orange (8.7%, 2/23), and mango, with the least (5.0%, 1/20) (Table 3). However, statistical analysis did not indicate a significant association between parasitic contamination rates and type of fruits (p=0.189) (Table 3). Contamination with more than one parasite specie was observed in some of the fruits examined, with 2 (16.7%) of the 12 contaminated samples showing contamination with two different parasites species.





A – Larva of *Strongyloides stercoralis* in iodine wet mount; B - Larva of *Strongyloides stercoralis* in normal saline wet mount; C – Ova of *Ascaris lumbricoides;* D – Oocyst of *Cryptosporidium* spp in modified Ziehl Neelsen stain; E – Oocyst of *Cryptosporidium* spp in modified Ziehl Neelsen stain; F – Trophozoite of *Trichomonas hominis* in normal saline wet mount

Fig 1: Microscopic pictures of parasitic types contaminating fresh fruits at major markets in Ibadan, Nigeria

With respect to potential vendor factors associated with parasitic contamination, most of the vendors (67.0%) reported defecation during market hours, however only 42.9% regularly washed hands after bowel movement (Table 4). Furthermore, an assessment of the nails of the vendors revealed that majority of the vendors (64.3%) had short but dirty finger nails. The analysis indicated a significant association between the vendors defecation practice and parasitic contamination rate (p=0.01).

Although the highest contamination rate was seen with fruits transported by public buses or taxi (12% vs 0% for other means), there was no statistically significant association between the means of transportation and parasitic contamination rate (p=1.000). However, there was a significant difference between contamination rates of fruits displayed on the floor (20.0%) compared to those displayed by other means (p=0.026). Fruits sold by vendors who do not regularly wash their fruits before displaying, had three times more contamination rate (13.1%) compared to those who regularly wash hands before displaying fruits (4.2%) (p=0.22). Also, fruits sold by vendors who kept their left-over fruits by covering outside with clothes were the most contaminated (Table 4).

The assessment of the overall general condition of the vendors' environment, whether clean or dirty is presented in Table 5. The highest contamination rate was seen in vendors with dirty environment (13.3% vs 4%). However, statistical analysis did not indicate any significant association between the general condition of the environment and parasitic contamination rate (p=0.288). All the fruit samples with parasitic contamination were from vendors who were not aware of a market refuse dump site.

There was a statistically significant association between the presence of dirt around the vendors and parasitic contamination rate (p=0.032). The fruits sold by vendors with dirt around them were 5 times more likely to be contaminated when compared to those sold by vendors with no dirt around them. Notably vendors with waste bin within one meter from their selling point had twice parasitic contamination rate compared to those with waste bins farther away that one meter (17.9% vs 8.8%).

Table 4: Post-harvest factors associated with the parasitic contamination of fresh fruits sold in major markets in Ibadan, Nigeria

Post-harvest factors		**Contamination**		**Fisher**	**P value**
		No (%)	**Yes (%)**		
Source of fruits	Directly from farm	52 (89.7)	6 (10.3)	0.074	1.000
	Middlemen	44 (88.0)	6 (12.0)		
Mean of transportation	Personal vehicle	2 (100.0)	0	0.499	1.000
	Bus or Taxi	88 (88.0)	12 (12.0)		
	Truck	6 (100.0)	0		
Packaging during transportation	Arranged on the floor of vehicle	34 (85.0)	6 (15.0)	1.750	0.610
	Basket	26 (86.7)	4 (13.3)		
	Carton	5 (100.0)	0		
	Sacks	31 (93.9)	2 (6.1)		
Means of display of fruits	On the floor	36 (80.0)	9 (20.0)	6.112	0.026*
	Bucket	1 (100.0)	0		
	Cart	6 (100.0)	0		
	In a tray	9 (100.0)	0		
	On a table	43 (93.5)	3 (6.5)		
Frequency of washing of the display materials	Daily	17 (100.0)	0	4.851	0.144
	Weekly	23 (95.8)	1 (4.2)		
	Monthly	6 (5.6)	1 (14.2)		
	Never	50 (83.3)	10 (16.7)		
Washing of fruits with water before displaying	No	73 (86.9)	11 (13.1)	1.590	0.219
	Yes	23 (95.8)	1 (4.2)		
Source of water for washing fruits	Not applicable	73 (86.9)	11 (13.1)	2.905	0.366
	Pipe – borne	13 (100.0)	0		
	Well	10 (90.9)	1 (9.1)		

* = statistically significant

Table 5: Environmental factors associated with the parasitic contamination of fruits sold in major markets in Ibadan, Nigeria

Environmental factors		**Contamination**		**Fisher**	***p* value**
		No (%)	**Yes (%)**		
Presence of drainage system	No	52 (92.9)	4 (7.1)	1.854	0.226
	Yes	44 (74.6)	8 (15.4)		
Condition of drainage system	Good	2 (100.0)	0	3.515	0.325
	Fair	17 (89.5)	2 (10.5)		
	Poor	24 (80.0)	6 (20.0)		
Presence of waste bin 1 m from selling point	No	73 (91.3)	7 (8.8)	1.742	0.292
	Yes	23 (82.1)	5 (17.9)		
Presence of dumping site	No	92 (88.5)	12 (11.5)	0.519	1.000
	Yes	4 (100.0)	0		
Presence of dirt around the seller.	No	49 (96.1)	2 (3.9)	5.057	0.032*
	Yes	47 (82.5)	10 (17.5)		
Presence of insects, animals or pest in the surroundings	No	49 (90.7)	5 (9.3)	0.375	0.761
	Yes	47 (87.0)	7 (13.0)		
Presence of animal excreta around selling point	No	92 (89.3)	11 (10.7)	0.419	0.452
	Yes	4 (75.0)	1 (25.0)		
General condition of environment	Clean	24 (96.0)	1 (4.0)	1.666	0.288
	Dirty	72 (86.7)	11 (13.3)		
Condition of storage area.	Clean	18 (100.0)	0	2.700	0.211
	Dirty	78 (86.7)	12 (13.3)		
Condition of storage and display materials	Clean	14 (100.0)	0	2.011	0.358
	Dirty	82 (87.2)	12 (12.8)		

Presence of toilet close to selling point, presence of water source(s) close to selling point and presence of hand wash area close to selling point were all constant (No), thus excluded from the table; * = statistically significant

Discussion:

In accordance with the prevailing circumstances seen in many developing nations, Nigeria exhibits a widespread distribution of intestinal parasites, and this is largely attributed to the favorable climatic conditions and unsanitary environments that facilitate the contamination of water, food items, and soil by fecal matter (20,21). This study assessed the level of parasitic contamination, the prevalence of different intestinal parasites and the possible source of contamination of fruits sold in major fruit markets in Ibadan, Nigeria. The overall parasitic contamination rate was 11.1% which agrees with similar findings from Bauchi, northern Nigeria with reported parasitic contamination rate of 14.3% (22). However, the rate from this study is lower than the rates from other parts of Nigeria such as Onitsha markets in Anambra State, and in Katsina State, with prevalence of 43.8% and 41.7% respectively. Outside Nigeria, similar higher rates of 39.0%, and 42.6% respectively were reported from Egypt and Southwest Ethiopia (6,10,23,24).

The difference in rates between our study and others might be due to the variations in geographical location, climatic and environmental conditions, poor post-harvest handling method and socioeconomic status. Other procedural factors including variation in sample size and techniques used for identification of parasites may also account for the observed differences (6). For example, a previous study in Ibadan, Oyo state, Nigeria compared the extent of parasitic contamination using two conventional techniques, sedimentation and floatation techniques for isolation of parasites. It was observed that the sedimentation method had a much higher recovery rate of 86.9% while the floatation method had just 13.1% (25). The overall contamination rate in the present study though lower than the previously cited studies, is however higher than the findings from a study in Kogi, Nigeria, which reported a low prevalence of 6.8% (17). The factors mentioned above could also have contributed to the lower reported prevalence. For example, unlike this present study, the study done in Kogi did not include Modified Ziehl-Neelsen staining technique for detection of protozoan oocysts.

In this study, pineapple was the most frequently contaminated fruit (27.8%) while mango was the least contaminated (5%). This result is similar to the findings from studies carried out much earlier in by Alli in 2011 and by Okunlola in 2021 where pineapple was also reported as the most frequently contaminated with 62.5 % and 46.7% contamination respectively (25,26). This may be due to the rough surface of pineapple fruit which makes the adhesion of parasitic eggs, larvae or cyst to the surface easier either on the farm or during handling (27). Carrot, watermelon and orange also recorded a high level of contamination rate with 20.0%, 12.5% and 8.7% contamination rates respectively. The high contamination rate recorded in carrots may be because carrots grow in the ground, leading to higher risk of contamination particularly if night soil is used as fertilizer (28). We did not identify any contamination in bananas and apples, in agreement with a study done in South India which reported no contamination for banana and 1 (6.6%) contamination for apple (29). This might be attributed to the smooth surface of these fruits which impede the adherence of parasitic eggs, larvae, or cysts to their surfaces (29).

Although there was no significant association between parasitic contamination and market types, the rate of contamination in Oje and Ayeye markets were over 5 times higher than that of Bodija market (OR=7.526, 95% CI =1.0-60.7, p=0.0303). This finding could be attributed to differences in drainage, personal hygiene, source of water and other environmental factors in these markets (25). The isolated parasites are mainly of faecal origin implying the fecal contamination of the samples from humans or animals (22). This contamination may arise from the use of manure for cultivation and sewage water for irrigation of these fruits as studies have shown the soil and rivers in Nigeria and other developing countries to be contaminated with fecal parasites (25,30-32). The level of sanitation in the market premises apparently plays a major role in the occurrence of parasitic contamination. In this present study, there was a significant association between the presence of dirt around the vendors, waste disposal practices, where the vendors defecate and the rate of parasitic contamination. Although majority of the vendors used the public toilets in the markets to defecate, their poor maintenance and hygiene could contribute to the contamination of fruits. There is also a high probability of the vendors in these markets were handling the fruits with faecally contaminated hands.

Additionally, the means of fruit transportation from farms to markets may also contribute to contamination. Most of the vendors used public vehicles, with their fruits arranged on the floor inside the vehicle, to convey fruits to the markets. They also moved these fruits in vehicles used for transporting other items thus encouraging cross contamination. Although, it was not statistically significant, in this study, fruits sold by vendors that use public transport were more prone to contamination compared to those who use personal vehicles which had no contamination.

The means of display of fruits could also play a major role in the variation in para-

sitic contamination among the markets. Most vendors display fruits on the floor and by the roadside, exposed to dust, flies and other insects making them prone to contamination. Flies such as housefly could easily carry parasite eggs and cyst from the dirty market premises, the refuse, uncovered drainages, and surroundings and transfer them mechanically to the displayed fruits (24). We observed that fruits displayed on the floor had a higher contamination rate of 20.0% when compared to those displayed on the table which was about one third of the floor rate. The detection of intestinal parasites on fruits sold in these selected markets has a significant health implication, particularly given the consumption of unwashed fruits potentially leading to infections and diseases. Our results emphasize the importance of adequate water, sanitation and hygiene (WASH) practices in reducing the spread of infectious agents (33).

Strongyloides stercoralis, *Cryptosporidium* spp*, T. hominis,* and *A. lumbricoides,* were the four types of parasites we identified from the fruit samples collected from these markets. However, these findings from our study differ from those from other parts of Nigeria and such variation in the parasites identified may be due to the geographical differences based on location of the study. For instance, a study in River State identified *Entamoeba coli, Entamoeba histolytica, Giardia lamblia, Balantidium coli, A. lumbricoides, Ancylostoma* and *Fasciola* spp (14). Larvae of *S. stercoralis* (42.9%) was the most frequently detected parasite in our study. This might be due to the free-living state of the parasite making it abundant in the environment, hence easily contaminating fruits. In contrast to this study, a previous study in Ibadan, Oyo state, Nigeria over a decade earlier reported a lower prevalence of *S*. *stercoralis* in fruits (25). In agreement with our findings, a study in Benue State, Nigeria reported *S*. *stercoralis* as the second most common parasite identified in fruits with a similar observation reported by some researchers in South India (29,34).

It has been reported that flies can act as vectors for various pathogenic parasites including *Cryptosporidium* spp (35). Oocyst of *Cryptosporidium* spp (35.7%) was the second most detected parasite in the present study. A study conducted in markets of Northwest Mexico, reported *Cryptosporidium* spp as the most prevalent parasitic pathogen (11.7%) (4). The high contamination of fruits in this study with *Cryptosporidium* spp also agrees with a study done in Ghana which reported a high prevalence of 11.1% for *Cryptosporidium* spp (36). Another study in Southern Ethiopia also reported a high prevalence of *Cryptosp oridium* spp (4.7%). The third most prevalent parasite detected in this present study was *T. hominis* (14.3%). This finding is similar to that of a study in Jos, Nigeria which reported *T. hominis* as the parasite with the highest contamination rate of 24.9% (9). It is remarkable that among the four parasites identified in this study, *T. hominis,* a flagellate that does not have a cystic form to withstand adverse environmental conditions recorded a high prevalence. This contamination is thus likely to be recent and might be from the water used in washing the fruits (9).

Ova of *A. lumbricoides* were the least detected parasites (7.1%). Although this finding is similar to a study done in Southern Thailand, which reported a low prevalence of 2.6%, it is in contrast to reports from other parts of Nigeria (37). A study in Owerri, Imo State, Nigeria, reported *A. lumbricoides* as the most prevalent parasite detected in fruit with rate of 37% (38). Another study in rural villages of Ebonyi State, Nigeria, also reported *A. lumbricoides* (54.5%) to be the most prevalent parasite detected in fruits (27). Other studies done outside Nigeria including Southwest Ethiopia, have also reported high prevalence of *A. lumbricoides* (10). The variation in the prevalence could be attributed to several factors such as difference in geographic locations, local hygiene and sanitation practices, samples sizes, methods of detection and even seasonal variation. For example, in the study done in Ebonyi State, Nigeria, the fruits were analyzed with both sedimentation and floatation techniques and this could have contributed to a higher prevalence (27). Contamination with multiple species was observed in some of the fruits in this study. This might indicate the possibility of a high-level contamination of fruits, which may result in multiple parasitic infections in humans. Additionally, such findings suggest the persistence of intestinal parasitic infections within the region (17).

Although not reported, other microbial organisms apart from parasites were identified during the study, including bacteria, fungi and rotifers. This is similar to a study done in Osogbo, southwest Nigeria which identified six bacteria and one fungal isolate (39). Rotifers also identified in this present study are microscopic, multicellular aquatic invertebrate organisms. Because of their size, shape and habitat, they can be confused with protozoans but have little significance to humans. They have some economic significance but do not cause diseases in humans (40). Our study is limited by the relatively small sample size which affected the statistical conclusions we could have made from the data collected. A study with larger sample size is thus needed.

Conclusion:

Our study showed that parasitic contamination rate in fruits sold in markets in Iba-

dan, Oyo State, Nigeria, is considerably high, indicating the potential risk of contracting helminths and protozoan infection through ingestion of unwashed or uncooked fruits bought from these markets. Although, the prevalence rate has reduced when compared to previous studies done in the same region, it still poses a serious public health challenge.

The findings of this present study also revealed poor socio-economic conditions, poor sanitation practices, and inadequate public health enlightenment. It is essential to educate market vendors on proper fruit washing and maintaining good hand hygiene while selling to ensure food safety. Public health departments should promote awareness campaigns focusing on proper fruit handling and emphasizing food sanitation and personal hygiene. Governments should reinforce environmental policies and sanitation laws and prioritize the provision and maintenance of modern amenities like toilets, running water, and effective drainage systems within market areas to ensure good sanitary infrastructure.

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Contributions of authors:

DHO designed the study; MOB and OYM conducted the literature search; OYM and DHO conducted the experimental work; OYM and MOB analyzed the data and wrote the manuscript. MOB revised the manuscript, and all authors approved the final manuscript.

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Authors declare no conflict of interest.

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