



Parasitic Contamination of Commonly Consumed and Locally Cultivated Leafy Vegetables in Jos, North-Central Nigeria



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ARTICLE INFO

Article type:

Original article

Article history:

Received: 2 December 2021

Revised: 15 January 2022

Accepted: 9 February 2022

© The Author(s)

DOI: 10.52547/jhehp.8.1.1

Keywords:

Parasitic intestinal diseases

Vegetables

Nigeria

ABSTRACT

Background: Contamination of vegetables remains important for transmitting intestinal parasites in developing countries. This study aimed to investigate the types and levels of parasitic contamination of six commonly consumed vegetables in Jos, Nigeria.

Methods: Leafy vegetables (cabbage, African spinach, spring onion, lettuce, fluted pumpkin leaf, and sorrel leaf) were purchased from five central markets in Jos, from September 2020 to February 2021. Samples were rinsed in sterile water, 0.9% saline, 1.5% saline, and vinegar (containing 1.7% acetic acid) and then processed using sedimentation concentration technique. Sediments were examined using direct wet preparation.

Results: Overall prevalence of parasitic contamination was 75.9% (n = 270). African spinach recorded the highest contamination (91.1%), followed by lettuce (86.7%), while spring onion had the least contamination. Sixteen helminths and 4 protozoans were identified. *Taenia* species had the highest prevalence (33.9%), followed by *Entamoeba histolytica* (28.5%). *Schistosoma haematobium* had the least prevalence. Parasitic contamination was significantly different among markets and vegetable types ($P < 0.05$). Preliminary findings revealed that 1.5% saline rinse generally resulted in the highest parasite detection rates.

Conclusion: Findings revealed a high burden of parasitic contamination of leafy vegetables in Jos, Nigeria. Public enlightenment on proper handling and processing of vegetables, from farm to table, is recommended.

1. Introduction

Vegetables are the main sources of vitamins required by humans and animals. Leafy vegetables refer to the leafy part

of a plant consumed by humans and animals [1]. They are rich in vitamins, minerals, and fiber but low in calories. Following a diet rich in leafy greens offers numerous health benefits, including reduced risk of several health conditions



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such as hypertension, obesity, heart disease, and mental retardation [2]. In many parts of Nigeria, green leafy vegetables consumption has been widely accepted either as components of regular meals for preparing stews and soups or in the form of special cuisines [3]. Some vegetables may be eaten raw or slightly cooked, as vegetable salads. However, eggs or larvae of intestinal parasites on vegetable present a potentially significant source of gastroenteritis in humans [4]. Intestinal parasites contaminate vegetables through feces, sewages, and untreated irrigation water or surface water [5-8]. Contamination of vegetables can also occur during transportation (either to or from markets), storage in vegetable markets, and processing before consumption [9, 10].

In developing countries, gastroenteritis has been reported to cause the death of two to three million people and more than 0.5 million children annually [11-13]. High rates of diarrheal diseases due to intestinal parasites have been reported in communities where open defecation is common, and consumption of raw or slightly cooked vegetables is widely practiced. Such communities are common in many low- and middle-income countries (LMICs) such as Nigeria, emphasizing the need for effective strategies to prevent fecal-oral transmission of intestinal parasites in developing nations [4,5]. Assessing parasitic contamination level of vegetables is also needed for sensitizing the public on the need for proper handling and processing of vegetables before consumption. Therefore, this study was designed to investigate the types and levels of parasitic contamination of six commonly consumed leafy vegetables in Jos, Plateau State, North-Central Nigeria.

2. Materials and Methods

2.1. Study Area, Study Design, and Study Locations

The cross-sectional study was carried out between September 2020 and February 2021 in Jos North and Jos South Local Government Areas (LGAs), two most populated areas in Jos, the capital city of Plateau State, North-central Nigeria (Figure 1). Jos is located between Latitude 8° 24'N and Longitude 8° 32' and 10° 38'E. According to the last official national census figures in 2006, Jos North has an area of approximately 291 km² and a population of 429,300, while Jos south has an area of about 510 km² and a population of 306,716, [14]. Jos has a tropical climate and receives about 1,400 mm of rainfall annually, which comes from both conventional and orographic sources, owing to the city's

location on the Jos Plateau. Rainfall is abundant from May to September each year, with peaks in July and August [14]. Compared to other parts of Plateau State and Nigeria, the city has a temperate climate, with average monthly temperatures ranging from 21 °C and 25 °C. Jos and environs also contain a large area of agricultural land. These factors enable farmers to grow a wide variety of tropical and temperate fruits, vegetables, and crops that supply communities in neighboring states in North-Central Nigeria [15].

Locally cultivated green leafy vegetables were purchased once weekly from five different central markets in Jos, using a stratified random sampling technique. The five markets in this study comprised Building Materials Market and Bukuru-Kugiya Market in Jos South Local Government Area (LGA), Jos Main Market (Terminus), Farin Gada Market, and Gada Biyu Market in Jos North LGA. These markets were selected because they typically received a large supply of vegetables directly from producers (farmers) and served as supply points to smaller markets in Jos and other parts of Plateau State. The markets were visited regularly in the order listed between September 2020 and February 2021.

2.2. Specimen Collection

Six commonly consumed leafy vegetables in Jos and environs, including some frequently consumed without cooking, were selected for this study. The vegetables included cabbage (*Brassica oleracea*), African spinach (*Amaranthus cruentus*), spring onion (*Allium sp.*), lettuce (*Lactuca sativa*), fluted pumpkin leaf (*Telfairia occidentalis*), and sorrel leaf (*Rumex acetosa*) (Figure 2). A total of 270 vegetable samples, comprising 45 of each vegetable type (nine samples from each five markets), were selected through stratified random and analyzed. Field samples were transported in labeled sterile plastic bags to the Multi-Purpose Laboratory of the College of Medicine and Health Sciences, Bingham University (Jos Campus), Nigeria, for analysis. Key informant interviews were also conducted during the study to identify factors that may have contributed to the levels of parasitic contamination of leafy vegetables in the study area and to provide preliminary findings on which future risk factor studies could be based. Key informants included vegetable farmers, large-scale vendors, and retailers. Informed consent was obtained before each interview section. Interview questions included sources of vegetables sold in the market, availability of pipe-borne water, presence of water bodies and animals within the market, and type of platform used for the sale of vegetables.

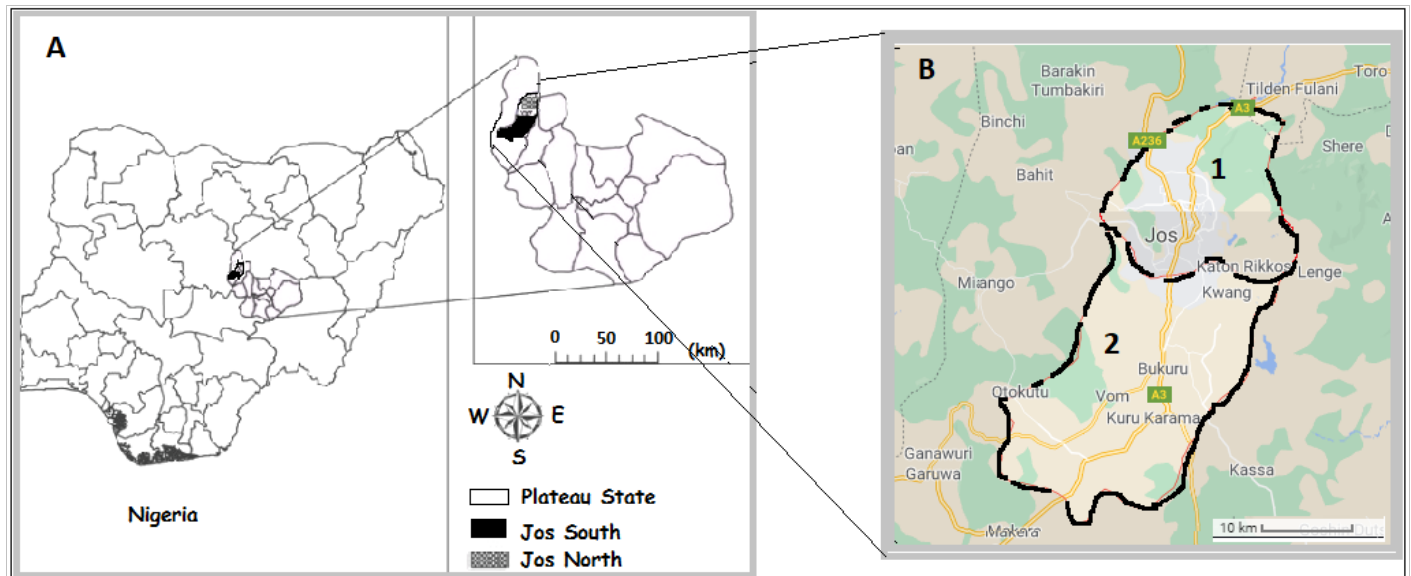


Figure 1: Study area map in Plateau State, Nigeria.

A: Nigeria map with inset showing Plateau State, Jos North and Jos South Local Government Areas (LGAs). B: Inset showing geographical areas of Jos North (1) and Jos South (2) LGAs (Adapted from Google Maps, 2021)

2.3. Specimen Preparation and Laboratory Analyses

In the laboratory, edible parts of the vegetables were separated from non-edible parts and chopped. Equal samples (200g each), labeled 1, 2, 3, and 4, were taken and rinsed in 150 ml of sterile water, 0.9% saline, 1.5% saline, and vinegar (containing 1.7% acetic acid), respectively. These washing methods have been previously used to detect parasites on vegetables, with varying levels of efficacy [16-20]. Combined use of these methods in this study (to rinse equal samples of each vegetable specimen) provided a more reliable estimate, as the total parasitic contamination of each vegetable was obtained as the aggregate of parasitic contaminations detected using the four washing methods. Moreover, this approach inherently provided an opportunity for an initial assessment of the relative efficacy of the four above-mentioned methods. After using sterile gauze to remove visible particles, the rinsed vegetables were left for 12 h or overnight in the washing solutions for sedimentation. The top water was discarded and the remaining water was centrifuged at 1500 rpm for five min. After centrifugation, the supernatant was discarded and the sediment examined under a light microscope using low-power (10X) and high-power (40X) objectives for parasite stages (cysts, eggs, or larvae) after adding a drop of Lugol's iodine solution. The analysis process followed standard guidelines as previously described [21]. Parasite identification was carried out by skilled medical laboratory personnel, and positive samples were recorded. Personal safety precautions were taken during every procedure.

2.4. Data Analysis

Data were entered into Excel Spreadsheet (Microsoft Office, 2010) and analyzed with GraphPad Prism 9.2.0 (GraphPad Software, San Diego, CA, USA). Qualitative variables were described by frequency (percentage). Chi-square test was used to compare the levels of parasitic contamination among vegetable types and markets. A *P*-value less than 0.05 was considered statistically significant.

3. Results and Discussion

During this study, a total of 20 parasites, comprising 16 helminths and 4 protozoans, were detected as parasitic contaminants of fresh leafy vegetables in Jos, Nigeria. Their names and levels in each vegetable type are shown in Table 1. Multiple parasitic contamination of leafy vegetables was frequently observed (Figure 3). *Taenia* species were found to be the most prevalent parasites (33.9%), followed by *Entamoeba histolytica* (28.5%) and *Ascaris lumbricoides* (28.1%) while *Schistosoma haematobium* had the least prevalence of 0.4%. As shown in Table 2, among the four washing solutions used during the study, 1.5% saline generally had the highest parasite detection rates, accounting for (46.3%) of parasites. The parasitic contamination levels based on the vegetable type and markets are shown in Table 3. Bukuru-Kugiya market in Jos South LGA recorded the highest parasite count (175; 33.7%), while Farin-Gada market in Jos North LGA recorded the least contamination (62; 12.0%).

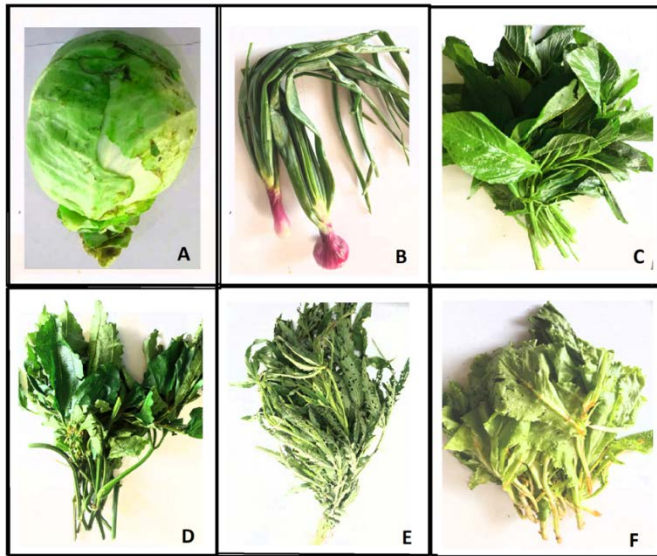


Figure 2: Six leafy vegetables used during this study
 A. Cabbage (*Brassica oleracea*), B. Spring onions (*Allium sp.*), C. African spinach (*Amaranthus cruentus*), D. Fluted pumpkin leaf (*Telfairia occidentalis*), E. Sorrel leaf (*Rumex acetosa*), and F. Lettuce (*Lactuca sativa*)

As shown in Table 3, African spinach had a parasite count of 127 (24.5%), and lettuce with a parasite count of 116 (22.4%), while spring onion had the least count of 42 (8.1%). These results are similar to the positivity rates of the samples for parasites, shown in Figure 4. African spinach and spring onion had the highest and lowest positivity rates of 91.1% and 53.3%, respectively. In all, 205 (75.9%) out of 270 fresh leafy vegetable samples were positive for at least one parasite. Table 4 summarizes the preliminary findings obtained from the key informant interviews conducted. It revealed that Farin Gada, Gada Biyu, and Bukuru-Kugiya markets had water bodies within their premises. It also revealed that cattle, sheep, and pigs were regularly present within Bukuru-Kugiya market.

A total of 205 out of 270 (75.9%) samples examined during this study were found to harbor intestinal parasites, indicating high levels of parasitic contamination that is similar to findings from a previous study in Akure, Southwestern Nigeria, which reported an overall prevalence of 88.8% [22]. Many of the vegetable samples included in the present study such as lettuce and cabbage are routinely consumed raw or slightly cooked in the form of vegetable salads. Parasitic contamination of leafy vegetables may therefore contribute significantly to the burden of diarrheal diseases in Jos, Nigeria, since previous studies have reported high incidences of parasitic gastrointestinal diseases in populations where raw vegetables are frequently consumed [23 - 25].

African spinach had the highest parasite count (24.5%), followed by lettuce (22.4%), sorrel leaf (16.8%), and cabbage (14.5%). This is similar to a previous study in Jos, in which

cabbage and lettuce were among the three most-contaminated vegetables [26]. Cabbage and lettuce were also among the top-four most contaminated vegetable species from two other studies in Ethiopia [27, 28]. However, it is different from a study in Saudi Arabia, which reported the absence of parasites in 17 cabbage samples collected from local markets [24]. Since these two vegetables (i.e., lettuce and cabbage) are typically consumed raw or partially cooked in Jos and other parts of Nigeria, proper handling and washing are essential before consumption to prevent disease transmission. The present study was conducted from September 2020 to February 2021, which falls within the late-wet to early/peak dry seasons in Nigeria, when many vegetable farmers switch to irrigation farming. The water quality used for irrigation of vegetable farms in the study area may consequently contribute to the levels of parasitic contamination observed in this study. This is also related to a previous study which suggested that significant seasonal variation existed in the levels of parasitic contamination of fresh leafy vegetables in Benha, Egypt, with the highest prevalence in summer and the lowest in winter [17]. The Highest levels of parasitic contamination of vegetables were also obtained during summer in another study in Kermanshah, western part of Iran [29]. Identifying risk factors associated with parasitic contamination of commonly consumed leafy vegetables in Jos, Nigeria, and environs is therefore much needed for proper understanding of strategies for reducing the parasite burden of green vegetables and preventing associated diseases.

The antiprotozoal and anthelmintic activities of *Allium* species have been previously reported [30-32]. During this study, spring onion (*Allium sp.*) had the least parasite counts and parasite positivity rates among leafy vegetables samples collected from the five markets. Spring onion is rich in volatile sulfur-containing compounds and can prevent or treat several parasitic protozoal and helminth diseases [32, 33]. Therefore, further studies on the health benefits of spring onion, especially against intestinal parasites, are recommended. However, this is contrary to some previous studies on parasitic contamination of vegetables, where spring onions had the highest parasite prevalence [34, 35]. The differences could be related to the prevailing human and environmental factors associated with its production, transport, and processing in the different study areas. As previously stated, this further emphasizes the need for analysis of the factors related with parasitic contamination of vegetables in Jos, Nigeria.

Contrary to some previous studies which reported zero or low prevalence for *Taenia* spp [20, 36-38], our results revealed that *Taenia* species were the most prevalent parasites (33.9%). However, the high prevalence obtained for *Taenia* species in the present study is similar to that obtained in a recent study in Nasarawa State, Nigeria, where the prevalence rate of *Taenia* spp (18.8%) was only close to *Strongyloides stercoralis* (28.9%) [39].

Table 1: Parasitic contamination levels of commonly consumed leafy vegetables in Jos, North-central Nigeria

Parasites	Vegetable Types						
	Cabbage (%) (n=45)	Spring onion (%) (n=45)	African spinach (%) (n=45)	Fluted pumpkin leaf (%) (n=45)	Sorrel leaf (%) (n=45)	Lettuce (%) (n=45)	Total (%)
Protozoa							
<i>Entamoeba histolytica</i>	10 (22.2)	5 (11.1)	9 (20.0)	12 (26.7)	14 (31.1)	27 (60.0)	77 (28.5)
<i>Entamoeba coli</i>	3 (6.7)	2 (4.4)	4 (8.9)	6 (13.3)	9 (20.0)	13 (28.9)	37 (13.7)
<i>Balantidium coli</i>	4 (8.9)	2 (4.4)	2 (4.4)	5 (11.1)	6 (13.3)	4 (8.9)	23 (8.5)
<i>Giardia lamblia</i>	1 (2.2)	5 (11.1)	9 (20.0)	3 (6.7)	9 (20.0)	4 (8.9)	31 (11.5)
Helminthes							
<i>Taenia</i> spp.	13 (28.9)	5 (11.1)	31 (68.9)	13 (28.9)	18 (40.0)	25 (55.6)	105 (38.9)
<i>Ascaris lumbricoides</i>	19 (42.2)	6 (13.3)	19 (42.2)	6 (13.3)	12 (26.7)	14 (31.1)	76 (28.1)
<i>Diphyllobothrium latum</i>	12 (26.7)	4 (8.9)	12 (26.7)	7 (15.6)	7 (15.6)	14 (31.1)	56 (20.7)
<i>Enterobius vermicularis</i>	1 (2.2)	0	5 (11.1)	1 (2.2)	4 (8.9)	3 (6.7)	14 (5.2)
<i>Hymenolepis nana</i>	4 (8.9)	0	7 (15.6)	1 (2.2)	1 (2.2)	1 (2.2)	14 (5.2)
<i>Strongyloides stercoralis</i>	0	3 (6.7)	1 (2.2)	8 (17.8)	1 (2.2)	1 (2.2)	14 (5.2)
<i>Schistosoma japonicum</i>	2 (4.4)	2 (4.4)	4 (8.9)	2 (4.4)	0	2 (4.4)	12 (4.4)
<i>Fasciola hepatica</i>	1 (2.2)	1 (2.2)	3 (6.7)	0	0	5 (11.1)	10 (3.7)
<i>Hookworm</i>	0	4 (8.9)	3 (6.7)	1 (2.2)	2 (4.4)	1 (2.2)	11 (4.1)
<i>Ophiocordyceps sinensis</i>	2 (4.4)	2 (4.4)	3 (6.7)	3 (6.7)	1 (2.2)	0	11 (4.1)
<i>Hymenolepis diminuta</i>	1 (2.2)	1 (2.2)	8 (17.8)	1 (2.2)	0	1 (2.2)	12 (4.4)
<i>Trichuris trichuria</i>	2 (4.4)	0	4 (8.9)	1 (2.2)	1 (2.2)	0	8 (3.0)
<i>Fasciolopsis buski</i>	0	0	1 (2.2)	0	0	1 (2.2)	2 (0.7)
<i>Paragonimus westermani</i>	0	0	0	1 (2.2)	2 (4.4)	0	3 (1.1)
<i>Schistosoma mansoni</i>	1 (2.2)	0	1 (2.2)	0	0	0	2 (0.7)

Infection of cattle (by *Taenia saginata*) and pigs (by *T. solium* and *T. asiatica*) may occur through ingestion of contaminated vegetables with eggs or gravid proglottids. After transmission to humans (the only definitive hosts), *T. saginata* (beef tapeworm), *T. solium* (pork tapeworm), and *T. asiatica* (Asian tapeworm) cause taeniasis in humans [40]. *Taenia solium* also causes cysticercosis, a severe condition in which ingested eggs develop larvae (termed cysticerci) in various human organs [40, 41]. In this present study, gastroenteritis-causing protozoan parasites, such as *Entamoeba histolytica*, *Entamoeba coli*, and *Giardia lamblia*, were among the most occurring parasites. This is similar to results of a study conducted at two central markets in Khartoum, Sudan, in which the most detected parasites in vegetable samples in both markets were *E. histolytica/dispar* (42.9%), *G. lamblia* (22.9%), and *E. coli* (14.3%) [38]. Indeed, the incidence of diarrheal diseases caused by protozoan parasites, such as amoebiasis, giardiasis, and cryptosporidiosis, has increased in the last decade, especially in developing countries [42-46]. The presence of *E. histolytica*, *Ascaris lumbricoides*, and *Entamoeba coli* among the highest occurring parasites is similar to previous findings [47, 48]. For instance, in a similar study conducted in Tabuk, Saudi Arabia, *Entamoeba spp.* and *A. lumbricoides* were the most common detected parasites [37].

Different washing solutions were used to detect and reduce parasitic contamination of vegetables, with varying efficacy levels. These include water (pure, distilled, sterile,

and tap water), saline (including 0.45%, 0.9%, 1.5% and saline), 10% formal saline, germicide, and vinegar (including 1%, 3%, 5%, and 10%) [17-19, 20, 37-39]. Assessing the relative efficacy of the four washing methods revealed that 1.5% saline rinse generally resulted in the highest parasite detection rates, indicating its efficiency in reducing parasitic contamination of vegetables before consumption. This is similar to previous findings which reported that higher saline concentrations were more effective for detecting parasitic contaminants of vegetables compared to water or physiological saline [49, 50]. However, it is different from results of another study that revealed that washing vegetables twice with saline (including 1.5% saline) was not effective for parasite removal [20].

Table 2: Parasite detection rate in different washing solutions during the study

Vegetable Type	Parasite Detection Rate (%)			
	Sterile Water (n=45)	0.9% Saline (n=45)	1.5% Saline (n=45)	Vinegar (1.7% acetic acid) (n=45)
African spinach	62.2	55.5	60.0	25.8
Cabbage	44.4	35.5	53.3	44.4
Lettuce	44.4	51.1	53.3	40.0
Spring onion	11.1	24.4	31.1	11.1
Fluted Pumpkin	40.0	31.1	40.0	8.8
Sorrel leaves	37.7	31.5	40.0	28.8
Total (n=270)	40.0	38.1	46.3	30.7

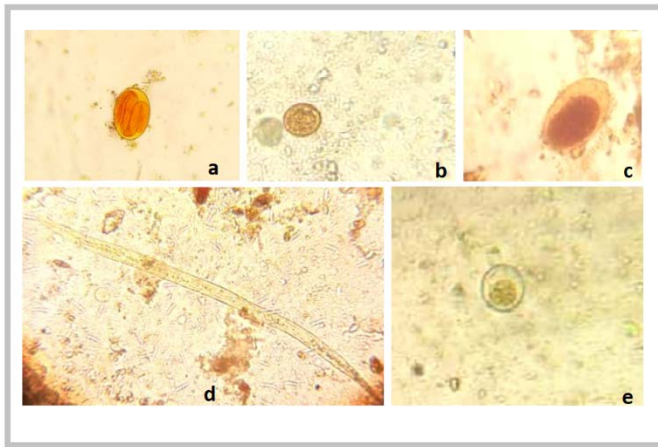


Figure 3: Some parasites detected during the study *Enterobius vermicularis* egg (a), *Taenia saginata* egg (b), *Hookworm* egg (c), *Strongyloides stercoralis* larva (d), *Hymenolepis nana* egg (e). Original magnification: 40X

The present study also indicated that vinegar (containing 1.7% acetic acid) was the least effective for detecting parasitic contamination of vegetables. In the light of a previous study, which reported that 1.0% acetic acid was ineffective for reducing the viability of parasite eggs on vegetables [18], vinegar containing higher concentrations of acetic acid may be necessary to accurately detect and reduce parasitic contamination. Therefore, more studies, in which the experiments are replicated, with larger sample sizes, which incorporate contact time effect are recommended to conclusively evaluate the relative efficacy of the four washing solutions. Since only a single rinse was done in the present study, future studies can also assess the effect of double or triple rinse.

During this study, vegetable samples obtained from Bukuru-Kugiya market in Jos South LGA had the highest levels of parasitic contamination. In contrast, those from Farin-Gada market in Jos North LGA had the least. Preliminary findings from the key informant interviews revealed that Bukuru-Kugiya market, the only study location with the regular presence of animals, was also locally

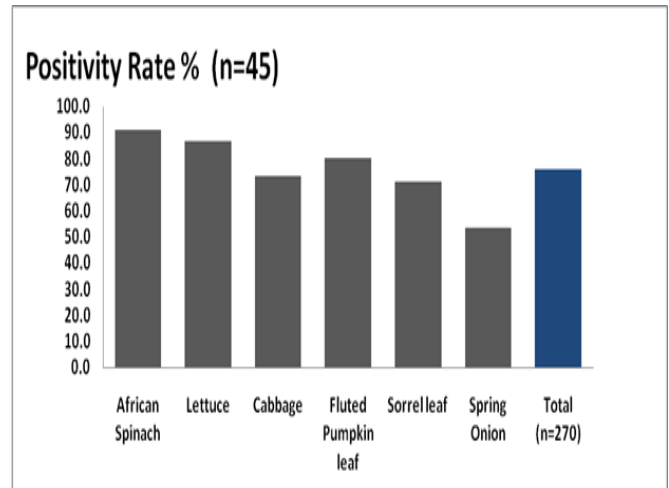


Figure 4: Parasite burden of commonly consumed leafy vegetables in Jos, Nigeria

referred as "cattle market" because it served as an essential point for sale of cattle, sheep, and goats. An artificial pond in the market, which served as the drinking water source for the ruminants, was also used by vegetable vendors to wash and sprinkle vegetables.

These factors may have contributed to the high levels of parasitic contamination of vegetables from this market. The finding is in line with a similar study in Sudan which revealed that water samples used to spray vegetables in two central markets had high levels of parasitic contamination [38]. Presence of animals in vegetable markets in Jos and environs should therefore be discouraged. Although this is not immediately feasible, water sources for animal use should be separated from those for washing vegetables. Another factor that may have contributed to the burden of parasitic contamination of vegetables from this market was the platform used to display and sell vegetables. Unlike the other four markets, where vegetables were mostly displayed on floor mats or wooden tables, Bukuru-Kugiya market was the only study location where vegetables were generally displayed directly on the uncemented floor.

Table 3: Parasite count based on location and vegetable type

Location		*Parasite count of leafy vegetables						Total parasite count per location
#LGA	Market	Cabbage	Spring onion	African spinach	Fluted pumpkin	Sorrel leaf	Lettuce	
Jos South	Building Materials	7	11	25	10	10	19	82 (15.8%)
	Bukuru-Kugiya	27	20	38	21	29	40	175 (33.7%)
Jos North	Farin Gada	7	0	15	10	11	19	62 (12.0%)
	Gada Biyu	10	9	24	9	16	6	74 (14.3%)
	Terminus	25	2	25	21	21	32	126 (24.3%)
Total parasite count per vegetable type		76 (14.6%)	42 (8.1%)	127 (24.5%)	71 (13.7%)	87 (16.8%)	116 (22.4%)	519 (100.0%)

#LGA- Local Government Area

*Parasite counts are significantly different ($P < 0.05$)

Table 4: Summary of findings from key informant interview

Market	Location type	Presence of pipe-borne water	Presence of water body near market	Platform for sale of vegetables	Regular presence of animals within market	Sources of Vegetables	Supplier
Building materials	Jos metropolis	Present	None	Vegetables sold on mats laid on uncemented floor	No	Jos South, Jos North and Jos East LGA	Farmers
Bukuru-Kugiya	Rural	None	Present (Artificial pond)	Vegetables sold on uncemented floor	Yes (cattle, sheep, pig)	Jos South, Riyom and Barkin-Ladi	Farmers
Farin Gada	Rural	None	Present (Farin Gada river)	Vegetables sold on mats laid on uncemented floor	No	Jengre, Miango and Rukuba in Bassa LGA	Farmers
Gada Biyu	Jos metropolis	None	Present (Gada Biyu river)	Vegetables sold on wooden tables	No	Agingi in Bassa LGA, Farin-Gada market and Chobe	Large scale vendors
Terminus	Jos metropolis	Present	None	Vegetables sold on wooden tables	No	Chobe, Farin-Gada and Building materials market	Large scale vendors

Terminus market in Jos North, with the second-highest levels of parasitic contamination, is the largest studied market and is centrally located within the city. Though the market had the infrastructure for pipe-borne water, water flow was very epileptic, causing sellers to store water and reuse it for washing vegetables. Storage process and containers quality may have contributed to the high parasitic contamination in the area.

4. Conclusion

A 75.9% prevalence of intestinal parasites in commonly consumed leafy vegetable samples collected at various markets in Jos, Nigeria, indicates a high rate of parasitic contamination. Findings of the present study are even more significant, considering the role of Jos as the hub of vegetable production, from where many other urban and suburban communities in North-Central Nigeria (including Abuja, the nation's capital) receive lots of their vegetable supplies. Based on preliminary obtained results, 1.5% saline rinse was most effective for detecting and reducing parasitic contamination, and may be useful for reducing the parasite load of vegetables before consumption. However, further studies are needed to conclusively evaluate the effectiveness of this saline concentration and identify factors associated with parasitic contamination of vegetables in Jos and environs. Considering that the vegetables selected for this study are usually consumed raw or in slightly cooked forms, regular enlightenment of the public (including key stakeholders such as farmers, large-scale distributors, vegetable vendors, and operators of restaurants) on proper handling and processing of vegetables, is recommended for reducing the incidence of parasitic diseases in Jos, Nigeria, and environs.

Authors' Contributions

Catherine Nadabo: Field investigation; Laboratory investigation; Data analysis; Writing-original draft. **Seljul Crown Ramyil:** Field investigation; Laboratory investigation. **Cornelius Sunday Bello:** Conceptualization; Study design; Supervision. **Oluwagbenga Adebayo Adeola:** Study design; Supervision; Data analysis; Writing-original draft; Writing-review and Editing. **Racheal Ike:** Laboratory investigation. **Timothy Oluwbenga Ogundeko:** Field investigation; Laboratory investigation. **Aminat Yusuf Omope:** Laboratory investigation. **Philemon Adu:** Laboratory investigation.

Conflicts of Interest

The Authors declare that there is no conflict of interest.

Acknowledgements

This article is from an extensive research on parasites in Jos, Nigeria. Ethical approval for the parasite study was obtained from the Health Research Ethics Committee of Bingham University Teaching Hospital, Jos, Nigeria [PLS/SHQ.113/Vol .IX/267, NHREC/21/05/2005/00673]. The research protocol was also reviewed and approved by the Research Committee of the Faculty of Basic Clinical Sciences, Bingham University, Nigeria.

The authors would like to express their appreciation to Mr. Jones Ihimekpen of the Department of Chemical Pathology and Mrs. M. E. Kinkini of the Department of Hematology, College of Medicine and Health Sciences, Bingham University for their assistance during the laboratory investigation phase of this study.

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