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Geohelminths contaminating edible raw vegetables sold in markets and irrigation sites in Katsina Northwest Nigeria

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Vegetables are major components of human diet but may act as vehicles for pathogens. The use of dung in producing vegetables is one factor that influences geohelminths contamination of vegetables. The study focused on geohelminths contamination of carrots (*Daurus carota*), lettuce (*Lactuva sativa*), spinach (*Spina ciaoleracea*), cabbage (*Brassi caoleracea*), and cucumber (*Cucumis sativus*) sourced from four markets (Central, Kofar Marusa, Yarkutungu and Chake) and four irrigation sites (Kofar Marusa, Kofar Durbi, Dan Lawal, and Kofar Sauri) in Katsina metropolis, Nigeria. The vegetables were examined for geohelminths using the sedimentation method and identified using colored Atlas of parasitology. Chi-square statistic tested associations between geohelminth contamination and sources and types of vegetables at 95% CI. From 540 vegetables examined, 387 were geohelminths contaminated, giving a prevalence of 71.7%. However, 206 (68.7%) of 300 market samples were contaminated as well as 181 (75.4%) of 240 samples from irrigated sites (P = 0.084). Furthermore, geohelminth contamination was highest in the Kofar Marusa irrigated site while the Kofar Marusa market had the least (66.7%), with no significant association (P = 0.677). The percentage prevalence of contaminated vegetables with eggs of *Ascaris lumbricoides*, hookworm, *Trichuris trichiura* and larvae of *Strongyloides stercoralis* was 37.4, 25.2, 6.3 and 2.8%, respectively, indicating potential risk for geohelminth parasites transmission through edible raw vegetables in Katsina where spinach had the highest geohelminths contamination rate (80%), followed by lettuce (75.7%), cabbage (70.0%), carrots (51.7% and cucumber with 56.7% (P=0.003). The study has added more knowledge on the geohelminth contamination of vegetables in Northwest Nigeria.

Key words: Geohelminths, vegetables, contamination, markets, irrigation sites.

INTRODUCTION

Geohelminths also known as Soil-Transmitted Helminths (STHs) are a group of parasitic worms that can infect people through contact with the parasite eggs or larvae present in the soil (WHO, 2023). The soil most often is contaminated through the deposition of eggs present in human faeces where sanitation is poor, especially in

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tropical and subtropical countries especially (WHO, 2023). Symptoms of STHs are known to affect children's physical and mental development (Bopda et al., 2016). Children and pregnant women are the most vulnerable to STHs due to low immunity (Tefera et al., 2017). Moreover, 1.5 billion individuals of the world's population are affected with STH, hence making it the most common infection (WHO, 2023). Geohelminth infections continue to be an important issue in many parts of the world (Tekalign et al., 2019), particularly in developing countries with low environmental sanitation and poor personal hygiene. STHs, e.g., *Ascaris*, hookworm, *Tricuris trichiura*, and *Strongyloides*, when found in individuals with light infection or asymptomatic, heavily infected individuals, may experience severe inflammatory colitis, which is associated with significant hemorrhage, diarrhea, bloody stool, intestinal blockage, weight loss and impair growth in children (Brian and Michael, 2004; CDC, 2020; Anisuzzaman et al., 2023). According to Dunn et al. (2016), the presence of STH parasites has even become a unique marker of poverty in areas with limited access to sanitation and clean water, as well as poor hygiene standards. Diseases caused by geohelminths or STHs categorized under Neglected Tropical Diseases (NTD) and efforts to control them were inadequate before the early 2000s (Stolk et al., 2016). Although STHs are endemic in South America, their spread is said to be very fast (Chammartin et al., 2013). The highest incidence of STHs is found in sub-Saharan Africa, America, China and East Asia (WHO, 2023). World Health Organization has six 2030 global targets for STHs, among which is to identify the sources of transmission (WHO, 2023). Vegetables have been identified as a vehicle for the transmission of human diseases since they can be contaminated directly or indirectly through polluted water, dirty hands, contaminated soil, insects, animals, or animal products (Nordberg and Carter, 1999). The ongoing use of untreated wastewater and manure as fertilizer for the production of fruits and vegetables in underdeveloped nations is a major contributor to contamination, resulting in a variety of diseases (Beuchat, 1998). The usage of organic fertilizer obtained from animal husbandry as a medium for fertilizing plants is one factor that influences the existence of soil-transmitted helminths in vegetables (Nazemi et al., 2012). There is a paucity of data on the transmission of geohelminthiasis in some parts of Northern Nigeria, especially Katsina metropolis, Katsina State, where a significant volume of human and animal waste is released into the soil daily. People in the Katsina metropolis have a habit of eating raw and unwashed vegetables, and it is also a common practice among farmers in the study area to fill the surfaces of the drainages (culverts), and septic tanks with earth materials, leave them overnight, then excavate and use as manure in the vegetable gardens. Therefore, this study assessed STHs that contaminate vegetables obtained from markets and irrigated farmlands in Katsina.

MATERIALS AND METHODS

Study area

Katsina metropolis located at the extreme northern margin of Nigeria, covers a total land area of about 3,370 km² and lies between latitudes 11°08'N and 13°22'N; and longitudes 6°52'E and 9°20'E (Figure 1). For the most part of the year, the climate is hot and dry. Maximum day temperatures of over 38°C are frequent in March, April, and May, with lowest temperatures of around 22°C in December and January. Katsina's estimated population in 2007 was 459,022 (NPC, 2006 Census) with total annual rainfall ranging from 600 to 700 mm to the northern part of the state, that is, Kankia to Daura, while rainfall of about 1000 mm in Funtua and 800 mm in Dutsinma. The city is the center of an agricultural region that produces groundnuts, cotton, hides, millet, and guinea corn, as well as mills that produce peanut oil and steel (Bawa et al., 2014).

Study design and sample size

The sample size for this study was calculated using the sample size calculation according to Cochran (1963) and the resulted sample size is 540.The sample size was calculated using the assumption of prevalence rate of 50% (prevalence = 50.0% = 50.0/100 = 0.5). A standard epidemiological formula is used to calculate the sample size as follows (Cochran, 1963):

$$n_o = \frac{Z^2\ pq}{e^2}$$

where n = Sample size, z = standard normal distribution, 95% (1.96) confidence interval, p = prevalence rate 50.0% (0.50), q = 1-p, 1 = the maximum value of probability, e = allowable error taken as 5% (0.05).

$n = (1.96)^2 \times 0.50 \times (1\text{-}0.50) / (0.05)^2 = 385$

By adding attrition rate of 30%, therefore, 40/100 × 385 = 154
Actual sample size= 385 + 154 = 539 approximate to 540.

Sample collection

Five different types of vegetables, namely, carrots (*Daurus carota*), lettuce (*Lactuva sativa*), spinach (*Spina ciaoleracea*), cabbage (*Brassi caoleracea*) and cucumber (*Cucumis sativus*) were sampled from two sources comprising four major markets and four irrigation sites in Katsina metropolis. The markets are: Central market, Kofar Marusa market, Yarkutungu market and Chake market (Figure 1); while irrigation sites are: Kofar Marusa irrigation site, Kofar Durbi irrigation site, Dan Lawal irrigation site and Kofar Sauri irrigation site. These markets and irrigation sites were selected because the majority of the populace in Katsina metropolis depend on them for the supply of fruits and vegetables. A total of 540 different fresh vegetables were randomly sampled between 7:00 and 9:00 am (Tables 1 and 2). All samples collected were stored in individual sterile polythene bags, labelled and transported to the Biology Laboratory of Umaru Musa Yaradua University, Katsina State, Nigeria.

Parasitological analysis

Each sample was washed for the separation of any egg or larva of geohelminths according to Malann and Tim (2016). The concentration of eggs in the sediment was carried out by centrifugation as described by Amaechi et al. (2016). The sediment from each vegetable was put in different centrifuge tubes and

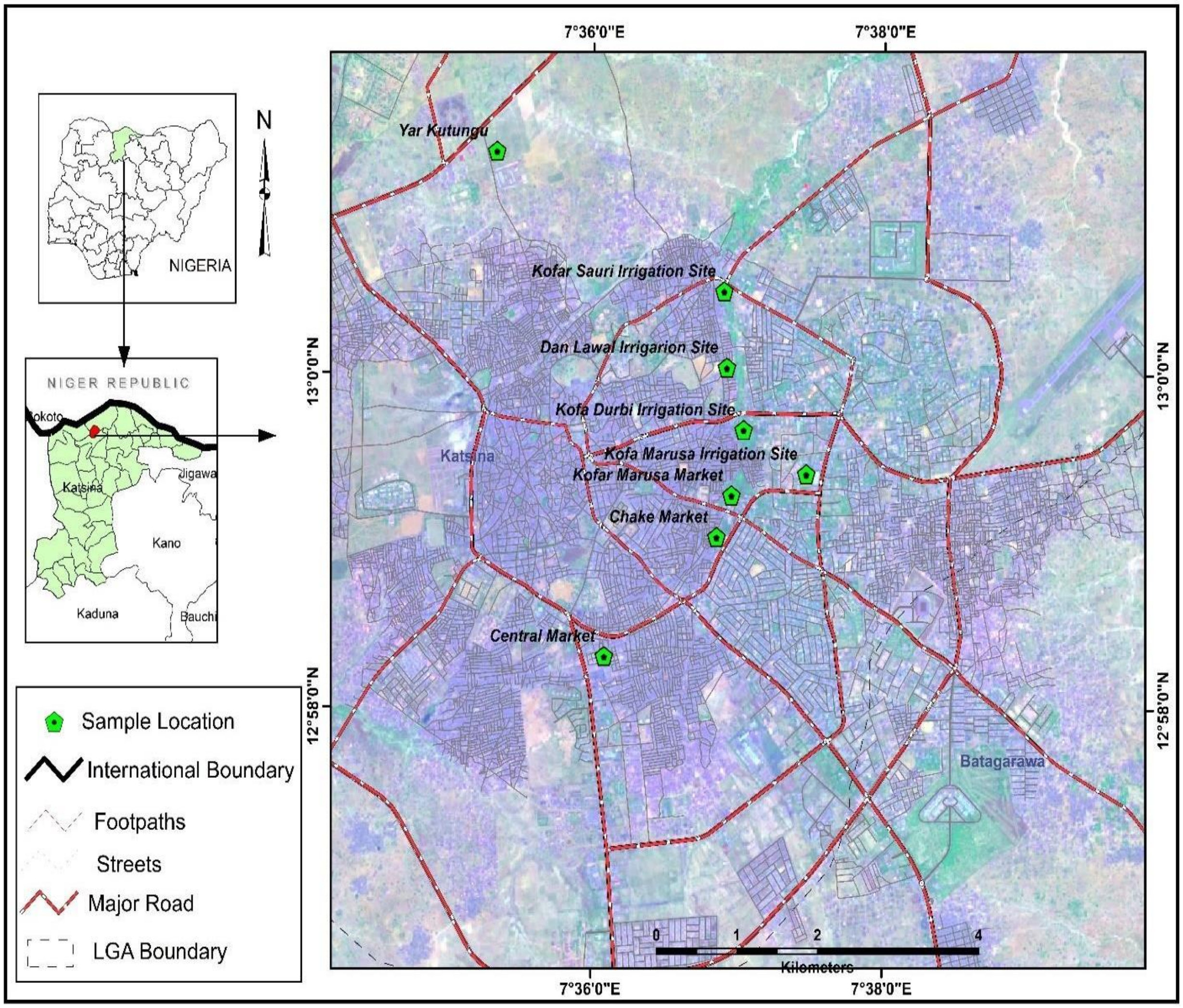

Figure 1. Map of Katsina metropolis showing selected markets and irrigation sites (Geography Department FUDMA).

Table 1. Prevalence of geohelminth-contaminated vegetables in relation to type of source and vegetable source.

Variable	Category	Vegetables examined (No.)	Vegetables positive for geohelminths (No.)	Prevalence (%)	P-value
Type of source	Markets	300	206	68.7	0.084
	Irrigation sites	240	181	75.4	
	Grand total	540	387	71.7	
Vegetable source	Yarkutungu market	75	51	68.0	0.677
	Kofar Marusa market	75	50	66.7	
	Chake market	75	52	69.3	
	Central market	75	53	70.7	
	Sub total	300	206	68.7	
	Kofar Marusa irrigation site	60	48	80.0	
	Kofar Durbi irrigation site	60	42	70.0	
	Kofar Sauri irrigation site	60	46	76.7	
	Dan Lawal irrigation site	60	45	75.0	
	Sub total	240	181	75.4	

Table 2. Prevalence of geohelminth-contaminated vegetables in relation to vegetable type.

Vegetable type	Vegetables examined (No.)	Vegetables positive for geohelminths (No.)	Prevalence (%)	P-value
Carrots	60	37	61.7	
Cabbage	140	98	70.0	
Lettuce	140	106	75.7	0.003
Spinach	140	112	80.0	
Cucumber	60	34	56.7	
Total	540	387	71.7	

centrifuged at 5000 rpm for 5 min. The supernatant was decanted and the sediment was stirred. A drop of each of the sediments was put on the center of a clean grease-free glass slide and stained with lugol's iodine after which a clean cover slip was placed gently to avoid air bubbles and over flooding. The preparation was examined under light microscopy using x10 and x40 objective lenses. Various eggs and larvae of geohelminths present were identified by comparing their morphological and morphometrical features with those in the colored Atlas of Parasitology (Ash and Orihel, 2007)

Data analysis

Data was analyzed using the Statistical Package for Social Science (SPSS) Version 22 where *Chi*-square (x^2) test was used to measure association between geohelminths contamination and the different types of vegetables, and locations of markets and irrigation sites. Statistical significance will be established for a value of P<0.005.

RESULTS

Prevalence of geohelminth-contaminated vegetables in relation to type of source and sources of vegetables

Out of a total of 540 vegetables examined in the study, 387 were positive for different geohelminth parasites, with an overall prevalence of 71.7% (Table 1). However, out of 300 market samples, 206 were positive with geohelminths, with a prevalence of 68.7%, while irrigation sites with 240 samples recorded 75.4%, making this difference statistically significant (P=0.084). Moreover, geohelminth contamination of vegetables was highest from the Kofar Marusa irrigation site, while Kofar Marusa market recorded the least (66.7%). There were no statistically significant differences between the prevalence of geohelminth-contaminated vegetables between markets and irrigation sites.

Prevalence of geohelminth-contaminated vegetables in relation to vegetable type

Prevalence of geohelminth-contaminated vegetables (Table 2) revealed that 80% of spinach was the most contaminated with geohelminth parasite stages, followed by 75.7% of lettuce. The least geohelminth-contaminated vegetable was the cucumber (56.7). Differences in the prevalence of geohelminth-contaminated vegetables between types of vegetables were statistically significant (P=0.003).

Prevalence of eggs and larvae of geohelminths contaminating vegetables in relation to vegetable source

The most prevalent geohelminth eggs detected in almost all sources of the vegetables were those of *Ascaris lumbricoides* 202 (37.4%), followed by Hookworm 136 (25.2%) and *Tricuris trichiura* (6.3%), while larvae of *Strongyloides stercoralis* recorded the least 15 (2.8%) (Table 3). There were no statistically significant differences between the prevalence of geohelminths with the sources of vegetables.

Prevalence of eggs and larvae of geohelminths contaminating vegetables in relation to vegetable type

A. lumbricoides eggs were identified from all vegetable types, with cabbage having the highest prevalence (42.1%), followed by spinach (39.3%) and carrot with the least prevalence (26.7%). Hookworm ova were also recovered from all vegetable types, with the highest prevalence of 27.9, 27.1 and 26.7% in lettuce, spinach, and carrot, respectively. Spinach had the highest rate of contamination (11.4%) with *T. trichiura* ova which differed significantly from other vegetables (P=0.037), while *S. stercoralis* larvae had the highest prevalence of 8.3% in carrots (Table 4).

Plate 1 shows the eggs and larvae results obtained from the study. The result of the examination showed the fertilized eggs of *A. lumbricoides*, rounded with a thick shell, bile stained and golden-brown colure (A). The larvae of hookworm with a white translucent colour, showing the long buccal canal with a pointed tail (B). The larvae of *S. stercoralis* with a notched tail and a shade of purple colour (C). The egg of *T. trichiura is* brown in

Table 3. Prevalence of eggs and larvae of geohelminths contaminating vegetables in relation to vegetable source.

Vegetable source	Vegetable examined (No.)	Number (%) of vegetables contaminated with species of geohelminths				
		Positive for geohelminths	*A. lumbricoides*	*T. trichiura*	Hookworm	*S. stercoralis* spp.
Market						
Yarkutungu	75	51 (68.0)	17 (22.7)	5 (6.7)	21 (28.0)	8 (10.7)
Kofar marusa	75	50 (66.7)	28 (37.3)	4 (5.3)	16 (21.3)	2 (2.7)
Chake	75	52 (69.3)	29 (38.7)	3 (4.0)	20 (26.7)	0 (0.0)
Central	75	53 (70.7)	24 (32.0)	1(1.3)	25 (33.3)	3 (4.0)
Irrigation site						
Kofar marusa	60	48 (80.0)	27 (45.0)	6 (10.0)	14 (23.3)	1 (1.7)
Kofar durbi	60	42 (70.0)	27 (45.0)	9 (15.0)	6 (10.0)	0 (0.0)
Kofar sauri	60	46 (76.7)	21 (35.0)	1 (1.7)	23 (38.3)	1 (1.7)
Dan lawal	60	45 (75.0)	29 (48.3)	5 (8.3)	11 (18.3)	0 (0.0)
Total	540	387 (71.7)	202 (37.4)	34 (6.3)	136 (25.2)	15 (2.8)
P-value			0.049	0.015	0.012	0.001

Table 4. Prevalence of eggs and larvae of geohelminths contaminating vegetables in relation to vegetable type.

Vegetable type	Vegetable examined (No.)	Number (%) of vegetables contaminated with species of geohelminths				
		Positive for geohelminths	*A. lumbricoides*	*T. trichiura*	Hookworm	*S. stercoralis*
Carrots	60	37 (61.7)	16 (26.7)	0 (0.0)	16 (26.7)	5 (8.3)
Cabbage	140	98 (70.0)	59 (42.1)	8 (5.7)	30 (21.4)	1 (0.7)
Lettuce	140	106 (75.7)	54 (38.6)	9 (6.4)	39 (27.9)	4 (2.9)
Spinach	140	112 (80.0)	55 (39.3)	16 (11.4)	38 (27.1)	3 (2.1)
Cucumber	60	34 (56.7)	18 (30.0)	1 (1.7)	13 (21.7)	2 (3.3)
Total	540	387 (71.7)	202 (37.4)	34 (6.3)	136 (25.2)	15 (2.8)
P-value			0.200	0.037	0.676	0.053

colour with a thick wall showing the barrel-shaped and transparent plug at both ends (D).

DISCUSSION

Geohelminth-contaminated vegetables are being reported in this study from major markets and irrigated sites in Katsina metropolis, North West Nigeria. Several studies in different countries have also reported the presence of geohelminth-contaminated vegetables. Similar studies conducted in north of Iran (Taghipour et al., 2019), Ghana (Duedu et al., 2014), and in Nigeria at Ilorin (Amaechi et al., 2016), Ebonyi State (Iyabo and Oluchi, 2015), Kaduna (Dada et al., 2015) Bauchi (Istifanus and Panda, 2018; Abubakar et al., 2020) and Kaduna (Faith et al., 2022) all reported the prevalence of geohelminths in vegetables at varying percentages. The presence of these parasites in food, particularly in vegetables, is still considered one of the most critical public health issues mostly affecting communities with a lifestyle of eating raw or slightly-cocked vegetables. It has been established that the consumption of contaminated raw vegetables significantly increases the chances of infections with those microorganisms that can remain viable in harsh conditions (Bezanson et al., 2011).

In this study, a relatively higher percentage of parasitic contamination was obtained from vegetables sampled from the irrigation sites than those from the markets (Table 1). This could be attributed to several factors. Firstly, irrigation sites often have moist soil conditions which provide a suitable environment for the survival and development of geohelminth eggs and larvae which can contaminate the soil through fecal matter from infected individuals. Secondly, irrigation sites are more commonly used for other agricultural activities, including the application of contaminated manure on crops (Javier et al., 2017). Faith et al. (2022) also reported a 50.6% prevalence of fruit and vegetables in the market. So, if proper hygiene and sanitation practices are not followed,

Plate 1. The different types of Soil Transmitted Helminths: (A) Egg of *A. lumbricoides*; (B) Larvae of hookworm; (C) Larvae of *S. stercoralis;* (D) Egg of *T. trichiura*.

contaminated water used for irrigation can lead to the deposition of geohelminth eggs on vegetables. Thirdly, the presence of animals, such as livestock, in and around irrigation sites can increase the likelihood of geohelminth transmission. Animals can be hosts for geohelminths and their waste can contaminate the soil contributing to the higher prevalence in these areas (Amouei et al., 2018). The combination of favorable environmental conditions, agricultural activities and animal presence make irrigation sites more exposed to geohelminth contamination of vegetables when compared with what happens in markets. In contrast to irrigation sites, once the vegetables are taken from irrigated farms to markets, they are usually placed on paved surfaces and become less exposed to further contamination with geohelminth eggs and larvae unlike on contaminated moist soil conditions observed at irrigation sites. Furthermore, in markets, the careful handling, cleaning and washing of raw fruits and vegetables to make the attractive to would-be buyers can probably help to reduce the risk of further geohelminth contamination. The high prevalence of geohelminth-contaminated vegetables also observed in the markets cannot be far from the fact that the markets have no standard selling kiosks, and retailers do not wash the vegetables properly with clean water. In addition, all the vegetables were usually displayed for sale on tattered wet mats and sacks along market pathways. Some of the vegetables, especially spinach, had evidence of farm mud on them so the possibility of passers-by stepping on some vegetable leaflets may help to further spread contamination of the vegetables with STHs.

In this study, spinach was the most contaminated vegetable followed by lettuce (Tables 2 and 4) perhaps due to the larger surface area of the leaves, providing more space for geohelminth attachment (Ogbolu et al., 2011). This finding is also similar to the result of the study in Jos, Nigeria where Agbalaka et al. (2019) reported higher contamination in spinach and lettuce. In the present study, cucumbers had the least contamination in line with previous reports from Dutsinma town Katsina State Nigeria (Auta et al., 2017) and from an urban area in India (Sonia et al., 2018). This might be due to the smooth leathery surface of cucumber which tends to reduce the rate of parasitic attachment, and may also be attributed to the fact that cucumbers are typically grown above ground, which probably reduces their exposure to geohelminth parasites. In a study conducted in major markets in Ibadan, Adejayan and Morenikeji (2015) recorded absence of geohelminth parasite in cucumber, maybe for the same reason.

The recovery of geohelminths eggs and larvae from vegetables is of great public health importance.

The presence of *A. lumbricoides,* hookworm, *S. stercoralis* and *T. trichiura* reported in the present study points to the fact that when hygienic standards are compromised during the planting and harvesting of vegetables, there is a great potential for acquiring geohelminth infections by consuming such raw vegetables (Amahmid et al., 1999; Barnabas et al., 2023). *A. lumbricoides* eggs are known to withstand a wide variety of adverse environmental conditions (Damen et al., 2007) so large numbers of eggs voided in feces could be viable in exposed soil or manure used for vegetable production in the study area. This may account for the high prevalence of vegetables contaminated with *A. lumbricoides* eggs. The result from this study is in agreement with Nasiru et al. (2015) who reported a high prevalence of *A. lumbricoides* in geohelminth-contaminated fruits and vegetables in Gusau, Zamfara State, and Abe et al. (2016) in Lafia, who also reported high prevalence of *A. lumbricoides* in contaminated fruits and vegetables. On the other hand, Barnabas et al. (2023) reported a high contamination of 50.0% of *S. stercoralis,* followed by hookworm at 37.0% and *A. lumbricoides* at 7.2% while Abubakar et al. (2020) reported that hookworm has the highest contamination

Disease caused by STH can lead to declining health conditions, lowering the nutritional status of the population, productivity, and loss of carbohydrates and protein (Shumbej et al., 2015). Outbreaks of human infections have been reported in the past (Blackburn and McClure, 2009) due to the consumption of food-borne pathogens, especially contaminated raw vegetables. Several studies have reported negative health consequences associated with the consumption of geohelminth-contaminated vegetables. For instance, Mascarini-Serra et al. (2010) observed that ingestion of geohelminths through contaminated vegetables led to an increased risk of gastrointestinal infections, and further demonstrated that geohelminth eggs on vegetables consumed by humans, caused abdominal pain, diarrhea and vomiting. Fauziah et al. (2022) investigated the effects of consuming vegetables contaminated with geohelminths on nutritional status and growth in children and associated it with poor nutrient absorption leading to deficiencies in essential vitamins and minerals, that prolonged and hindered the normal growth and development of children.

Conclusion

Geohelminths were found in some of the vegetables sampled in this study, which highlights the possibility of edible raw vegetables, especially the leafy ones, serving important roles in geohelminthiasis. Vegetables collected from irrigation sites were more contaminated than those collected from markets. Spinach had a higher level of contamination while cucumbers were least contaminated. *A. lumbricoides* eggs were identified as the most prevalent geohelminth contaminating raw vegetables in Katsina. Consumption of geohelminth-contaminated fresh vegetables from the study sites could constitute a potential risk to public health.

Recommendations

(1) It is essential to implement proper hygiene and sanitation practices in vegetable markets and gardens to minimize the risk of geohelminth infections.
(2) A good hygiene culture should be imbibed to avoid the continued spread of geohelminth infections that arise through eating contaminated vegetables.
(3) Vegetables should be carefully washed to prevent being infected with intestinal helminth diseases.
(4) Constant monitoring of parasitic contamination of foods, particularly vegetables, can provide a clear view of the potential risk of foodborne parasites in a region like North West Nigeria.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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