Parasites of importance for human health on edible fruits and vegetables in Nigeria: a systematic review and meta-analysis of published data

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ABSTRACT

Contamination of edible fruits and vegetables is now a global public health issue despite their health benefits as non-pharmacological prophylaxis against chronic diseases. Studies that will harness the extent of parasitic contaminations will ensure public health protection. Here, the prevalence and distribution of parasites of importance for human health on fruits and vegetables in Nigeria were determined through a systematic review and meta-analysis of published data. The random-effects model was used to determine pooled prevalence estimate (PPE). Heterogeneity was evaluated by the Cochran's Q-test. Parasites overall PPE of 32.4% (95% CI: 0.73, 0.91) was observed from 19 eligible studies reported across 13 Nigerian states. Sub-groups PPEs ranged between 3.5% (95% CI: 0.45, 1.86) and 58.5% (95% CI: 1.40, 4.09). A high degree of heterogeneity 97.53% (95% CI: 0.30, 0.46, P : 0.000) was observed within studies and sub-groups. *Cryptosporidium* species were the most prevalent, while *Ancylostoma duodenale* and *Ascaris lumbricoides* had the widest geographical distribution. Pineapple (Prev: 41.3%, 95% CI: 0.40, 0.75) and lettuce (Prev: 51.5%, 95% CI: 0.37, 0.68) recorded the highest level of parasitic contamination. Parasites of importance for human health are prevalent on edible fruits and vegetables in Nigeria. Prevalence estimates were highest in the South-eastern region and during the most recent decade. Adequate washing of fruits and vegetables, on-farm irrigation of vegetables using good sources of water and adequate hygiene by food handlers will help the general public to maximize the health benefits associated with the intake of fruits and vegetables while minimizing the risk of acquiring parasitic infections.

KEYWORDS

Fruits; human health; Nigeria; parasites; vegetables

Introduction

Globally, the health benefits of fruit and vegetable intakes as non pharmacological prophylaxis against chronic diseases are increasingly being understood [1,2] and so, increased consumption is recommended in several dietary guidelines worldwide. For instance, a minimum of 400 g of daily intake of fruits and vegetables has been recommended by the World Health Organization and the Food and Agriculture Organization [3,4].

Substantive evidence has shown that a high intake of fruits and vegetables reduces the risk of chronic non-infectious diseases including hypertension [5–7], coronary heart disease [8–10], stroke [11,12], glaucoma [13], dementia [14], cancer [15–17] and type 2 diabetes mellitus [18] among many others.

Despite the aforementioned benefits, fruits and vegetables can serve as vehicles for the transmission of parasites of public health importance if not properly processed for human consumption. For instance, studies from Nigeria [19,20], Africa [21–23] and elsewhere in the world [24–26] have established the fact that fruits and vegetables can be contaminated by parasites and

pose health threats. This however, is more of a problem in resource limited countries like Nigeria where poor hygiene and sanitation, indiscriminate defecation by scavenging animals and humans as well as the use of unclean water for irrigation of fruits and vegetables are common. For instance, helminths including *Hymenolepis nana*, *Toxocara canis*, *Ascaris lumbricoides*, *Ancylostoma duodenale* and *Enterobius vermicularis* which are transmissible through the consumption of raw vegetables are well documented in humans in Nigeria [27–30].

This meta-analysis which is the first of its kind in Nigeria, has harnessed individual reports on parasitic contamination of fruits and vegetables processed for human consumption in Nigeria to provide vital epidemiological information including parasites of importance for human health (parasites that are naturally infective to man) that contaminated fruits and vegetables as well as their prevalence and distribution across Nigeria. It is envisaged that this information will help the general public to maximize the health benefits associated with the intake of fruits and vegetable while minimizing the risk of acquiring parasitic infections.

Materials and methods

The present study was guided by the recommendations published by Moher et al. [31] for Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA). The PRISMA checklist (Supplementary File 1) formed the basis for inclusion of information and the outcome of interest was the contamination of fruits and vegetables with parasites of public health importance.

Strategy for bibliography search

An extensive literature search was conducted between September 2016 and March 2017 on PubMed, Google Scholars, Medline, African Journals OnLine (AJOL) and cross checking of references of studies that resulted through the search of databases pertaining to the contamination of fruits and vegetables by parasites of public health importance. Several keywords and combinations were used to retrieve relevant information. Some of these combinations included, but were not limited to, prevalence or occurrence of parasites of importance for human health on fruits and/or vegetables or contamination of fruits or vegetable with parasites of importance for human health. Combinations for parasite specific searches included, but were not limited to, prevalence or occurrence or contamination of fruits or vegetables with *Hymenolepis* ± *nana*, *Cryptosporidium* ± species, *Ascaris* ± *lumbricoides* and *Ancylostoma* ± *duodenale*. Regional specific searches were narrowed to all 36 states and 6 regions of the Nigerian federation.

Inclusion and exclusion criteria

The selection of studies for eligibility was carried out in two steps. Step one was based on scanning through the titles while the second step was based on detailed review of abstract and full text. A study was considered eligible only if: (i) it was published in English, (ii) it was a cross sectional study, (iii) it was carried out in Nigeria, (iv) the Nigerian state where the study was carried out was stated, (v) the sample size and number of contaminated samples were clearly stated, (vi) it reported parasites of importance for human health, (vii) the method of detection was stated, and (viii) parasites were identified at least to the genus level.

Data extraction

From the eligible studies, surname of first author, year of study, year of publication, sample size, number of positive samples, state and region of the study, study design, type of sample (fruit or vegetable), and parasites of importance for human health identified at least to the genus level, were all extracted.

Data collation and analysis

Preliminary data analysis was carried out in Microsoft Excel. Further analyses were carried out using Graph-Pad Prism Version 4.0 and Comprehensive Meta-Analysis Version 3.0. Prevalence rates for individual studies were determined by multiplying the ratio of positive samples to sample sizes by 100%. The 95% confidence interval (95% CI) was determined using the binomial method with the formula $95\% \text{ CI} = p \pm z_{1-\alpha/2} \sqrt{p(1-p)/n}$ where p = proportion of interest, $z_{1-\alpha/2} = 1.96$ and n = sample size. The random-effects model was employed to determine the pooled prevalence estimates and their 95% CI with the assumption that the true effect sizes might differ due to variations in sample sizes, methodologies and design of the eligible studies [32]. Heterogeneity within studies was evaluated by the Cochran's Q-test. Percentage variation in prevalence estimate due to heterogeneity was quantified using the formula $I^2 = 100 \times (Q - df)/Q$, where Q is Chi square and df is degree of freedom which is determined by subtracting one from the number of studies. I-square values of 0, 25, 50 and 75% represented absence of, low, moderate and high heterogeneities respectively [33].

Results

Bibliography search and eligible studies

The flow chart for selection of eligible studies and list of excluded studies are presented in Figure 1 and Supplementary File 2 respectively. Of the 33 published studies retrieved, 23 were from databases and 10 from scanning through references. Five duplicate studies were removed after scanning through titles. Out of the 28 studies subjected to detailed abstract and full text review, 3 were excluded for lack of clearly stated data on sample size and/or positive samples and 6 others were excluded due to the inability of the studies to identify parasites at least to the genus level. Nineteen studies were finally included in the meta-analysis.

Study characteristics

The list and characteristics of eligible studies are presented in Table 1. Nineteen eligible studies consisting of a total of 2,365 positive samples from a total sample size of 7,308 were included in the meta-analysis. These studies were carried out between 2002 and 2015 and published between 2007 and 2016 respectively. Two studies each were reported from south-eastern and south-western regions while, 7, 1, 4 and 3 others were respectively reported from north-central, north-eastern, north-western and south-southern regions. Two studies considered fruits, 11 vegetables and 6 both fruits and vegetables. One study was published between 2002 and 2006 and 9 studies each between 2007 and 2011

Figure 1. Flow chart for the selection process of eligible studies.

Table 1. List and characteristics of studies included in the meta-analysis.

Study RN	Period of study	Study region	Sample Type	Sample size	Positives (%)	Prevalence (%)	(95% CI)
[19]	2010	North-east	V	1130	39	3.5	0.03, 0.05
[20]	2011	North-west	V	200	70	35.0	0.29, 0.42
[49]	2011–2012	North-central	V	300	60	20.0	0.16, 0.25
[50]	2012	North-central	V	150	61	41.0	0.33, 0.49
[51]	2010	South-west	F	96	34	35.4	0.27, 0.45
[52]	2002–2003	North-central	V	1200	450	36.0	0.35, 0.40
[53]	2008–2009	North-west	F/V	320	45	14.0	0.11, 0.18
[54]	2011	South-west	F/V	250	101	40.4	0.35, 0.47
[55]	2015	South-south	V	102	75	73.5	0.64, 0.81
[56]	2010	North-central	V	400	225	56.3	0.51, 0.61
[57]	2015	North-central	F	600	252	42.0	0.38, 0.46
[58]	2010	South-east	F/V	160	97	60.6	0.53, 0.68
[59]	2012–2013	South-south	F/V	250	106	42.4	0.36, 0.49
[60]	2014	North-central	V	160	88	55.0	0.47, 0.63
[61]	2012	North-central	V	150	96	64.0	0.56, 0.71
[62]	2013	South-south	F/V	600	98	16.3	0.14, 0.20
[63]	2014	South-east	F/V	100	55	55.0	0.45, 0.64
[64]	2009–2010	North-west	V	960	33	35.9	0.03, 0.05
[65]	2015	North-west	V	180	77	42.7	0.36, 0.50

Note: CI (Confidence interval), F (Fruit), RN (Reference number), V (Vegetable).

as well as 2012 and 2016. Thirteen studies had sample sizes of less than 400 and studies with sample sizes of 400–800 and >800 recorded 3 studies each. Microscopy was the diagnostic method employed by all the 19 eligible studies.

Regional and spatial distribution of eligible studies

Figure 2 presents the regional and spatial distribution of eligible studies. Seven studies representing 36.8% of the eligible studies were reported in North-central region. Studies were distributed across 3 of the 6 North-central

states namely Kwara and Nasarawa 1 (5.3%), Plateau 3 (15.8%) including the Federal Capital Territory, Abuja 2 (10.5%). One (5.3%) study each was reported in Borno state, North-eastern and Edo, South-south Nigeria. Four (21.1%) studies were published from North-western region in 2 states namely Kaduna 3 (15.8%) and Katsina 1 (5.3%). Three (15.8%) studies each were published from South-eastern (1 from Abia and 2 from Ebonyi) and South-western regions (1 study each from Ogun, Ondo and Oyo). Though the studies were reported across all the 6 regions in Nigeria, only 13 of the 36 states including Abuja were covered.

Figure 2. Distribution of eligible studies across Nigeria. Source: Solomon Ngutor Karshima

Pooled prevalence estimates and heterogeneity analysis

Results for pooled prevalence estimates and heterogeneity are presented in Table 2. A total of 2,365 of the 7,308 fruit and vegetable samples examined were contaminated with at least one parasite yielding an overall pooled prevalence estimate of 32.4% (95% CI: 0.73, 0.91). Pooled prevalence estimates in relation to regions

ranged from 3.5% (95% CI: 0.45, 1.86) in North-eastern to 58.5% (95% CI: 1.40, 4.09) in South-eastern regions. Prevalence estimates for sample types ranged between 29.9% (95% CI: 0.21, 0.53) for fruits/vegetables combined to 41.1% (95% CI: 0.35, 0.46) for fruits only. For the period of study, prevalence estimates ranged from 26.4% (95% CI: 0.97, 1.41) in studies carried out between 2007 and 2011, to 39.6% (95% CI: 0.77, 1.08) in those conducted

Table 2. Pooled prevalence estimates of parasites of public health importance stratified according to sub-groups.

Variables	Number of studies	Pooled prevalence estimates				Heterogeneity	
		Sample size	Positives	Prev. (%)	95% CI	I^2 (%)	Q-p
Region							
North-central	7	3,080	1,232	40.0	0.85, 1.22	0.0	0.832
North-east	1	1,130	39	3.5	0.45, 1.86	0.0	0.803
North-west	4	1,660	528	31.8	0.21, 0.41	94.8	0.000
South-east	2	260	152	58.5	1.40, 4.09	90.3	0.001
South-south	3	832	279	33.5	0.46, 0.89	71.1	0.009
South-west	2	346	135	39.0	0.32, 0.79	89.2	0.002
Specimen							
Fruits	2	696	286	41.1	0.35, 0.46	32.2	0.224
Vegetables	11	4,932	1,577	32.0	0.72, 0.97	0.0	0.016
Fruit/Vegetable	6	1,680	502	29.9	0.21, 0.53	97.6	0.000
Study period							
2002–2006	1	1,200	450	37.5	0.22, 0.39	98.7	0.000
2007–2011	9	3,816	1,007	26.4	0.97, 1.41	0.0	0.109
2012–2016	9	2,292	908	39.6	0.77, 1.08	0.0	0.284
Sample size							
<400	13	2,618	1,002	38.3	1.49, 2.09	72.7	0.000
400–800	3	1,400	538	38.4	0.62, 0.96	64.7	0.017
>800	3	3,290	825	25.1	0.42, 0.58	97.2	0.000
Overall	19	7,308	2,365	32.4	0.25, 0.45	98.2	0.000

Note: CI (Confidence interval), Prev. (Prevalence), I^2 (Inverse variance index), Q-p (Cochran's p-value).

between 2012 and 2016. The range for prevalence estimate based on sample sizes was 25.1% (95% CI: 0.42, 0.58) among studies with sample sizes >800 to 38.4% (95% CI: 0.62, 0.96) for studies with sample sizes ranging between 400 and 800.

The study showed a high degree of heterogeneity 98.2% (P: 0.000, 95% CI: 0.25, 0.45) which was observed even among sub-groups like Northern Nigeria 98.6% (P: 0.000, 95% CI: 0.18, 0.42) and Southern Nigeria 97.0% (P: 0.000, 95% CI: 0.30, 0.62) as shown in Supplementary Files 3–7. *Ancylostoma duodenale* and *Ascaris lumbricoides* which occurred in 17 (89.47%) of the 19 studies analysed recorded the widest geographical distribution. *Cryptosporidium* species had the highest prevalence-21.9% (95% CI: 0.15, 0.79) as shown in Table 3. The overall pooled prevalence estimates of parasites of public health importance on fruits and vegetables were 33.1% (95% CI: 0.27, 0.44) and 28.1% (95% CI: 0.02, 0.35) respectively. Pineapple (Prev: 41.3%, 95% CI: 0.40, 0.75) and lettuce (Prev: 51.5%, 95% CI: 0.37, 0.68) were respectively the fruit and vegetable with the highest level of parasitic contamination while, pawpaw (Prev: 12.0%, 95% CI: 0.04, 0.31) and cucumber (Prev: 3.7%, 95% CI: 0.01, 0.07) had the lowest level of contamination (Table 4).

Discussion

To the knowledge of the author, this meta-analysis is the first of its kind to consider the prevalence and distribution of parasites of importance for human health on fruits and vegetables across Nigeria. It was necessary to harness data from various individual studies published across the nation to provide useful epidemiological information including types, prevalence and distribution of parasites of importance for human health on fruits and vegetables in Nigeria. It is hoped that the results of this study will sensitize the general public of the risk associated with

poorly handled fruits and vegetables so as to maximize the benefits associated with their consumption while minimizing the risk of acquiring parasitic infections. The occurrence of parasites of importance for human health on fruits and vegetables in Nigeria may be attributable to contamination arising from parasites eggs, oocysts and larvae from the environment and water used for irrigation and washing of fruits and vegetables, poor hygienic practices by food handlers as well as indiscriminate defecation by domestic and wild animals.

The parasites identified in this study were reported in other parts of Africa [21,23,34,35] and other parts of the world [25,26,36]. The pooled prevalence estimate of 32.4% revealed by this study is higher than the 13.5 [23] and 15.5% [25] reported by individual surveillance studies from Sudan and Iran respectively. The present finding is however similar to the prevalence rates of 30.0 [36] and 31.7% [34] reported by other sets of individual surveillance studies from Bangladesh and Egypt respectively. This finding is also in line with the only published meta-analysis on parasitic contamination of vegetables in Iran [37] which also reported similar parasites as those identified by the present study. These variations may be attributable to differences in levels of environmental contamination, hygiene and sanitation, qualities of irrigation water, and factors that influence parasite survival in the environment such as temperature, humidity, rainfall and soil moisture. Methods of detection employed by the different studies and skill levels of researchers may also be contributing factors.

The higher prevalence of these parasites in south-eastern Nigeria may be attributable to factors including lower temperatures, higher rainfall and soil moisture [38] in the region. These factors might have increased the survivability of eggs, oocysts and larvae of parasites in the environment resulting in the contamination of fruits and vegetables in the region. Other factors may include

Table 3. Pooled prevalence estimates and distribution of parasites of public health importance on fruits and vegetables.

Parasites	Number of studies	Pooled prevalence estimates				Heterogeneity	
		Sample size	Positives	Prev. (%)	95% CI)	I^2 (%)	Q-p
Cestodes							
<i>Hymenolepis nana</i>	6	3,730	31	0.83	0.46, 2.48	0.0	0.883
<i>Taenia</i> species	4	1,280	39	3.05	0.21, 1.37	42.8	0.186
Nematodes							
<i>Ancylostoma duodenale</i>	17	6,818	518	7.60	0.87, 1.36	0.0	0.457
<i>Ascaris lumbricoides</i>	17	6,978	612	8.77	0.93, 1.38	0.0	0.201
<i>Enterobius vermicularis</i>	3	1,000	32	3.20	0.18, 1.49	0.0	0.305
<i>Strongyloides stercoralis</i>	15	6,228	473	7.60	0.47, 0.79	9.2	0.000
<i>Toxocara</i> species	1	150	6	4.00	0.33, 9.99	0.0	0.835
<i>Trichuris trichura</i>	13	5,672	84	1.48	0.22, 0.87	0.0	0.016
Trematodes							
<i>Fasciola gigantica</i>	2	352	20	5.68	0.19, 2.20	0.0	0.663
<i>Schistosoma</i> species	2	250	34	13.60	0.32, 1.89	0.0	0.584
Protozoa							
<i>Balantidium coli</i>	4	1,220	17	1.39	0.54, 4.33	0.0	0.426
<i>Cryptosporidium</i> oocysts	2	320	70	21.88	0.15, 0.79	85.7	0.008
<i>Entamoeba coli</i>	8	1,730	105	6.07	0.60, 1.55	0.0	0.891
<i>Entamoeba histolytica</i>	9	3,652	176	4.82	1.56, 2.92	66.1	0.000
<i>Giardia lamblia</i>	6	2,220	34	1.53	3.35, 13.7	89.4	0.000
<i>Trichomonas hominis</i>	2	1,400	114	8.14	0.13, 0.56	93.1	0.000

Note: Prev. (Prevalence), CI (Confidence interval), I^2 (Inverse variance index), Q-p (Cochran's p-value).

Table 4. Pooled prevalence estimates of parasites of public health importance based on fruit and vegetable types.

Fruits/Vegetables	Scientific name	NS	Pooled prevalence estimates				Heterogeneity	
			SS	NP	Prev. (%)	95% CI	<i>I</i> ₂ (%)	Q- <i>p</i>
Fruits								
Avocado pear	<i>Persea Americana</i>	2	36	11	30.6	0.13, 0.58	56.0	0.113
Banana	<i>Musa acuminata</i>	3	161	29	18.0	0.20, 0.34	0.0	0.734
Garden egg fruit	<i>Solanum macrocapon</i>	4	120	32	26.7	0.19, 0.67	83.2	0.000
Guava	<i>Psidium guajava</i>	2	70	18	25.7	0.11, 0.89	91.9	0.000
Mango	<i>Mangifera indica</i>	3	176	43	24.4	0.09, 0.56	83.4	0.002
Sweet orange	<i>Citrus sinensis</i>	6	251	33	13.1	0.24, 0.35	0.0	0.716
Pawpaw	<i>Carica papaya</i>	1	25	3	12.0	0.04, 0.31	0.0	1.000
Pineapple	<i>Ananas comosus</i>	5	201	83	41.3	0.40, 0.75	76.6	0.002
Watermelon	<i>Citrillus lanatus var lanatus</i>	3	161	30	18.6	0.08, 0.53	81.2	0.005
Overall (Fruit)	-	-	1,201	282	23.5	0.17, 0.30	85.6	0.000
Vegetables								
Berry/Roots								
Carrot	<i>Daucus carota sativus</i>	10	1,102	233	21.1	0.17, 0.34	87.3	0.000
Cucumber	<i>Cucumis sativus</i>	5	630	23	3.7	0.01, 0.07	48.3	0.102
Tomato	<i>Lycopersicon esculentum</i>	10	950	187	19.7	0.18, 0.36	86.0	0.000
Sub-total	-	-	2,682	443	16.5	0.07, 0.22	97.4	0.000
Leafy Greens								
Bitter leaf	<i>Vernonia amygdalina</i>	4	141	38	27.0	0.18, 0.50	66.6	0.030
Cabbage	<i>Brassica oleracea var capitata</i>	11	1,237	350	28.3	0.18, 0.52	96.0	0.000
Fluted pumpkin	<i>Telfairia occidentalis</i>	8	290	125	43.1	0.31, 0.67	87.0	0.000
Garden egg leaf	<i>Solanium macrocapon</i>	8	813	135	16.6	0.15, 0.43	90.5	0.000
Jute mallow	<i>Corchorus olitorius</i>	4	171	57	33.3	0.13, 0.71	92.5	0.000
Lettuce	<i>Lactuca sativa</i>	10	802	413	51.5	0.37, 0.68	93.4	0.000
Spinach	<i>Spinacia oleracea</i>	16	1,150	401	34.9	0.37, 0.57	88.3	0.000
Waterleaf	<i>Talinum triangulare</i>	9	296	121	40.9	0.34, 0.70	87.0	0.000
Sub-total	-	-	4,900	1,640	33.5	0.26, 0.43	97.1	0.000
Overall (Vegetable)	-	-	7,582	2,083	27.5	0.20–0.35	98.0	0.000

Notes: CI (Confidence interval), I^2 (Inverse variance index), NP (Number positive), NS (Number of studies), Prev. (Prevalence), Q-p (Cochran's p-value), SS (Sample size).

indiscriminate defecation by animals and humans infected with these parasites and the use of unclean water to wash fruits and irrigate vegetables on farms.

Contaminated water has been reported as the major medium for the transmission of sporulated oocysts of *Cryptosporidium* species [39]. Thus, the high prevalence of *Cryptosporidium* oocysts observed in this study may be due to possible irrigation of vegetables and washing of both fruits and vegetables with contaminated water. *Ancylostoma duodenale*, *Ascaris lumbricoides*, *Strongyloides stercoralis* and *Trichuris trichiura*, all classified as geo-helminths, were reported in the majority of studies published on fruits and vegetables in Nigeria. The utilization of soil as a vehicle for their transmission may be a possible explanation for their abundance. The presence of soil transmitted helminths on fruits and vegetables in the food chain in Nigeria may be a major potential public health problem in the country.

The practice of open defecation by some Nigerians who lack toilet facilities in rural settlements where most of Nigerian fruits and vegetables are cultivated, may explain the higher prevalence of *Taenia* species which are usually transmitted through environmental contamination with faeces of infected persons. *Ascaris lumbricoides* was the most prevalent of all the nematodes reported on fruits and vegetables in Nigeria during the period under review, concurring with reports that this parasite is the commonest helminth of humans worldwide [40,41]. This high prevalence of *Ascaris lumbricoides* on fruits and vegetables was probably influenced by the large number of infected people (25% of the world's population) who

are capable of contaminating the environment [40], the durability of eggs under varying environmental conditions [42], the high fecundity [43] as well as the sticky nature of the egg shell of *Ascaris* [44] which might have influenced their attachment on fruits and vegetables.

Cryptosporidium species, a common water contaminant, had the highest prevalence of all the protozoan parasites reported on edible fruits and vegetables. This may be due to pre-washing of fruits and vegetables with unclean water before marketing. *Fasciola gigantica*, which was the most prevalent trematode reported on fruits and vegetables, is endemic in Nigerian livestock [45–48] and might have resulted from environmental contamination by grazing ruminants.

The prevalence estimate of the parasites was higher on vegetables than fruits, probably due to the large contact surface areas of leafy vegetables which might have increased the chances of parasite contamination. Pineapples were the most contaminated fruit probably due to their rough surfaces that might have influenced the attachment of eggs, oocysts and larvae of parasites. Another possible reason is because this fruit is not normally prewashed, as other fruits like oranges, guava and mango. Lettuce was the most contaminated of all the vegetables analysed corroborating results from Egypt [34,35], Sudan [23] and Bangladesh [36].

The implication of this finding on public health is the risk of acquiring these parasitic infections through the consumption of contaminated fruits and vegetables. This is particularly of concern due to the habits of eating unwashed fruits and vegetables like garden eggs, lettuce

and cabbage. To maximize the health benefits of fruits and vegetables intake while minimizing the risk of parasitic infections, consumers must ensure proper washing of fruits and adequate cooking of vegetables whenever possible. Other potential public health risks that may be associated with the acquisition of these parasitic infections are anaemia, stunted growth, as well as intellectual and cognitive retardation. Other common symptoms may include nausea, anorexia, diarrhoea, obstruction of intestinal lumen and distended abdomen.

The limitations of the present study were the high degree of heterogeneity among studies which was also observed within sub-groups. This high degree of variability may be due to the influence of study location, study population, sample sizes, study designs and methods of diagnosis of the individual studies. Despite the important information provided by this meta-analysis, this finding might not be absolutely applicable to the entirety of Nigeria especially with the fact that studies were published from only thirteen of the thirty-six states of the Nigerian federation. The majority of the studies were in North-central region, on vegetables and had sample sizes of less than 400 resulting in an un-even distribution of studies. This will also limit the absolute application of this finding in the entirety of Nigeria. Again, prewashing of fruits and vegetables before marketing as was the case for majority of the eligible studies would have affected the parasitic loads identified by the various studies meta-analyzed. The variations in quantities of sample sizes analyzed by the individual studies included in this meta-analysis which ranged between 50 and 250 g might have also influenced the detection of parasites.

Conclusion

Data from studies published in Nigeria revealed high prevalence estimates of parasites of importance for human health on edible fruits and vegetables. Highest pooled prevalence were observed in South-southern region, studies published between 2012 and 2016, studies with sample sizes of less than four hundred and on vegetables. *Cryptosporidium* species had the highest prevalence while *Ancylostoma duodenale* and *Ascaris lumbricoides* recorded the widest geographical distribution. The study revealed a high degree of heterogeneity among studies and sub-groups. Irrigation of vegetables using clean sources of water, adequate washing of fruits, proper cooking of vegetables, adequate hygienic practices by food handlers and control of environmental contamination by straying animals will reduce the public health risk associated with the consumption of fruits and vegetables in Nigeria.

Disclosure statement

The author declares no conflict of interest.

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