

DETECTION OF PARASITES AND COLIFORM BACTERIA IN VEGETABLES FROM FRESH-FOOD MARKETS IN NAKHON NAYOK PROVINCE, THAILAND

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Abstract. Food-borne infectious diseases from parasites and bacteria are major global public health problems. A common source of food-borne infectious pathogens is fresh vegetable. In this study, sedimentation technique and the Most Probable Number (MPN) method was used to identify parasites and quantify coliform bacteria and *Escherichia coli* respectively in fresh vegetable (celery, coriander, leek, lettuce, and peppermint) samples ($n = 375$) from a fresh food market each located in four districts (Ban Na, Mueang, Ongkharak, and Pak Phli) of Nakhon Nayok Province, Thailand. Overall prevalence of parasite contaminated vegetables was 36%, celery with the highest (60%) and lettuce the lowest (13%) value; *Ascaris lumbricoides* was most predominant parasite; and Ongkharak District had the highest prevalence (78%). Nine percent of samples were contaminated with <3 MPN/g coliform bacteria and 65% with $>1,100$ to $\leq 2,400$ MPN/g (highest value of the technique); highest prevalence of coliform bacteria and *E. coli* were found in lettuce. Consumers should be made aware of the risk of contracting parasitic/bacterial infection from fresh vegetables if not properly prepared, and, at the same time, local health authorities should monitor fresh vegetables (and other food products) supply chain from farm to market to minimize risk of contracting food-borne diseases.

Keywords: coliform bacteria, contamination, fresh-food market, fresh vegetable, parasite

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INTRODUCTION

Infections caused by bacteria and parasites are still regarded as a serious global public health issue. In less developed nations where proper personal hygiene and sanitization procedures are lacking, bacteria and parasitic infections contribute to a high burden of disease (Punsawad *et al*, 2019). Climate, geography, soil type, and rainfall are environmental factors that significantly contribute to the rising prevalence of bacterial and parasitic infection. A wide variety of infectious organisms, from protozoa to helminths, are responsible for parasitic disorders, many of which have intricate life cycles that include vector transmission or intermediary hosts (Punsawad *et al*, 2019). Even if infection with the majority of these parasites is not fatal, several can produce persistent infections that frequently result in significant morbidity (Berger *et al*, 2010). As regards to bacterial infection, *Escherichia coli* is generally used as the principal indicator of contamination (Price and Wildeboer, 2017). Even most *E. coli* infections are mild, their existence indicates that other more pathogenic organisms that pose a threat to human health may also be present (Price and Wildeboer, 2017).

Vegetable is an essential source of vitamins and minerals for human health. In Thailand, many types of raw vegetables (*eg*, basil, cabbage, coriander, cucumber, lettuce,

peppermint, scallion, and tomato) are popular for consumption as salads and side dishes. However, the consumption of vegetables without boiling or other processes may cause parasitic and microbial infections (Sajjapala *et al*, 2014). Human parasitic infections or helminthiases, have a significant negative impact on low- and middle-income countries, including Thailand and its neighbors. An estimated 1.45 billion people are infected by helminths worldwide (Silver *et al*, 2018), with Southeast Asia accounting for one-third of cases (Gordon *et al*, 2017).

In Thailand many types of fresh vegetables have been found to have parasitic contamination, such as *Ascaris lumbricoides*, *Giardia intestinalis*, *Strongyloides stercoralis*, *Trichuris trichiura*, and *Blastocystis* spp (Boonjaraspinyo *et al*, 2013; Sajjapala *et al*, 2014; Punsawad *et al*, 2017; Punsawad *et al*, 2019), as well as bacterial contamination, in particular *E. coli* (Laksemi *et al*, 2019; Chongkonnee and Songthamwat, 2015). In Nakhon Nayok Province located in central Thailand, northeast of Bangkok, there have been no studies of parasitic or bacterial contamination of fresh vegetable. Here, we conducted a survey of the prevalence of intestinal parasites and coliform bacteria contaminating in fresh vegetables frequently consumed in Nakhon Nayok Province. The results should be of use to

the province health authorities in formulating policies and practices to minimize this health risk to consumers in the region.

MATERIALS AND METHODS

Samples collection

Random samples ($n = 375$) of fresh vegetables (celery, coriander, leek, lettuce, and peppermint) were collected from four fresh markets, one market each from four districts of Nakhon Nayok Province, namely, Mueang Nakhon Nayok, Ban Na, Ongkharak, and Pak Phli Districts (latter three located 23, 47 and 45 km, respectively from the Mueang Nakhon Nayok District) (Fig 1) during September 2021- February 2022. Vegetables selected were those grown in soil, popular and could be consumed fresh. All parts of the vegetable except the root were used. The sample size was calculated from the following formula (Cochran, 1977):

$$n = Z^2 P(1-P)/D^2$$

where n = sample size; D = acceptable sampling error (set at 0.05); P = population proportion (set at 0.5); and Z = level of confidence according to the standard normal distribution (for a level of confidence of 95%, $Z = 1.96$)

Total number of fresh vegetable stalls from all four markets to be sampled was calculated using

a random sampling method according to the formula (Krejcie and Morgan, 1970):

$$n = \chi^2 NP(1-P)/e^2(N-1) + \chi^2 P(1-P)$$

where n = sample size; χ^2 = (Chi-square; when degree of freedom = 1 and reliability level 95% $\chi^2 = 3.841$); e = acceptable error of sample size (set at 0.05); N = Population size; and P = population proportions.

The sample size received from the calculation was 375. Due to the fact that the ratio of fresh vegetable stalls in Ban Na, Mueang, Ongkharak and Pak Phli is 29, 44, 12, 15 percent (Table 1), therefore, in order to maintain this ratio when sampling the vegetable stalls, number of vegetable stalls to be sampled in these 4 districts are 17, 26, 7 and 9, respectively. The same approach was applied to determine the number of vegetable samples. Of a total 375 samples, 110, 165, 45 and 55 vegetable samples will be collected from Ban Na, Mueang, Ongkharak and Pak Phli, respectively (Table 1).

Detection of intestinal parasites

Intestinal parasites were examined by sedimentation technique as preciously described (Punsawad *et al*, 2019). A fresh vegetable sample (200 g), not washed but roots removed, was placed in a solution of normal saline solution containing 0.9% (v/v) Lipon F detergent (Lion Corporation,

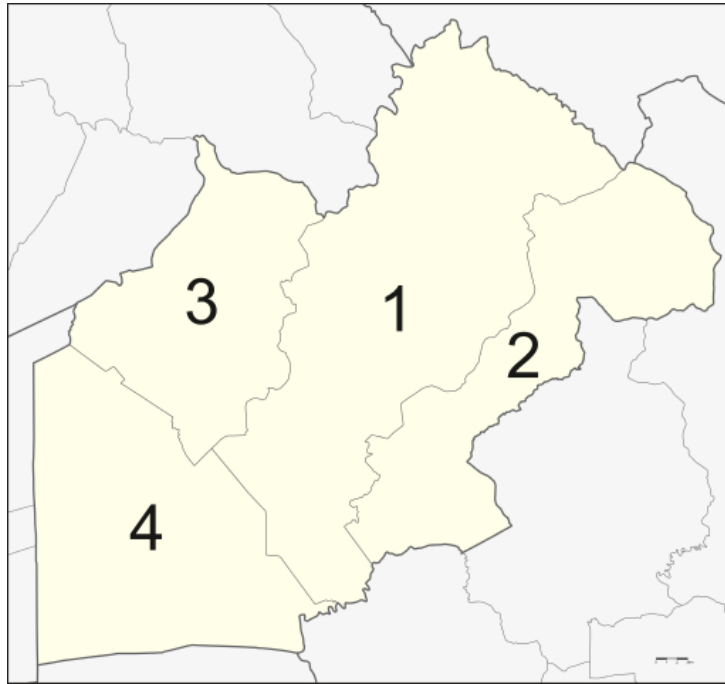


Fig 1 - Map of study districts, Nakhon Nayok Province, Thailand

1: Mueang District; 2: Pak Phli District; 3: Ban Na District; 4: Ongkharak District

(Source: https://en.wikipedia.org/wiki/Nakhon_Nayok_province)

Bangkok, Thailand), sufficiently cover the sample and shaken for 60 minutes to elute parasites from vegetable surface. The solution was filtered through two layers of gauze, left to stand overnight, and then centrifuged at 2,000g for 10 minutes. Slides were prepared from the sediment and examined under a light microscope (10x and 40x magnification) by two independent investigators, three slides for each

sample. For confirmation of parasite-positive sample, each slide was heat fixed, stained for 30 minutes with carbol-fuchsin (Sigma-Aldrich, St Louis, MO), de-stained for one minute with a 1% (v/v) HCl solution (Sigma-Aldrich, St Louis, MO), in 75% ethanol (Sigma-Aldrich, St Louis, MO). *Cyclospora cayentanensis* oocyst was identified by size (8-10 mm), round shape and red color (Sherchand and Cross, 2001).

Table 1

Number of stalls and fresh vegetables sampled at fresh food markets in four districts, Nakhon Nayok Province, Thailand (September 2021- February 2022)

District	Number of fresh vegetable stalls <i>n</i> (%)	Number of stalls sampled ^a	Total number of vegetable samples ^b	Number of samples collected per vegetable type ^c
Ban Na	20 (29)	17	110	22
Mueang	30 (44)	26	165	33
Ongkharak	8 (12)	7	45	9
Pak Phli	10 (15)	9	55	11

^aCalculation was based on the method of Krejcie and Morgan, 1970; ^bCalculation was based on the method of Cochran, 1977; ^cCalculation was based on number of vegetable samples divided by 5.

Detection of coliform bacteria and *Escherichia coli*

Coliform bacteria and *E. coli* were detected using a Most Probable Number (MPN) method (Ghimire *et al.*, 2020). Each fresh vegetable sample was added to a lactose culture medium (BD Difco BBL, Sparks, MD) and incubated at 37°C for 24 hours. MPN determination of total coliform (fecal and non-fecal) bacteria consisted of three tests: presumptive, confirmed and completed. In the presumptive test, a vegetable sample (50 g) was mixed with 450 ml of phosphate-buffered saline solution (PBS) and one ml aliquot of a 10-fold serial diluted (10^{-1} , 10^{-2} and 10^{-3}) solutions was mixed with nine ml of lauryl sulfate tryptose (LST) broth (Hi-media, Mumbai, India) in a Durham tube, incubated

at 35°C and gas formation inspected after 24±2 hours (continued for a maximum of 48±3 hours if no gas was observed). Water was used as a negative control. Confirmation test was performed by transferring one loopful of a suspected coliform bacteria-positive medium to 2% Brilliant Green Lactose Bile broth (BGLB) (Hi-media, Mumbai, India), incubated in a Durham tube at 35°C and gas formation observed after 24±2 hours (continued if no gas production was observed for a maximum of 48±3 hours). A completed test was performed by transferring one loopful of confirmed positive medium to *Escherichia coli* (EC) broth (Hi-media, Mumbai, India), incubated in a Durham tube at 44.5°C for 24±2 hours and gas formation observed (extended to 48±3 hours if necessary). Then, a loopful

of each positive EC broth sample was streaked on Eosin Methylene Blue agar (Hi-media, Mumbai, India), incubated for 24 hours at 37°C and the appearance of colonies with a greenish metallic sheen indicates the presence of *E. coli*.

Statistical analysis

Frequency of qualitative characteristics is reported as percentage. Rate of parasite contamination among various vegetable varieties and among various markets was compared using a chi-squared test and a *p*-value <0.05 is considered statistically significant. Calculations were carried out using a Statistical Package for the Social Sciences (SPSS) Statistics for Windows, version 23.0 (IBM Corp, Armonk, NY).

RESULTS

In Nakhon Nayok Province, Thailand, 375 fresh vegetable samples were tested for parasite and bacterial contamination in four different markets, each located in four districts during September 2021- February 2022. The average rate of parasite detection in all vegetable samples was 36% (135/375), with celery having the highest and lettuce had the lowest contamination rate (Table 2). Prevalence of parasite contamination varied among the four markets, with market in Ongkharak District having the highest and in Pak Phli District the lowest prevalence. When prevalence of pathogenic and non-pathogenic parasite contamination

Table 2

Parasite contamination of fresh vegetables in a fresh food market in four districts of Nakhon Nayok Province, Thailand (September 2021- February 2022)

Vegetable type	Number of samples with parasite contamination (%)				
	Ban Na District (N = 22)	Mueang District (N = 33)	Ongkharak District (N = 9)	Pak Phli District (N = 11)	Total (N = 75)
Coriander	1 (4)	7 (21)	5 (55)	1 (9)	14 (19)
Leek	6 (27)	21 (64)	8 (89)	0 (0)	35 (47)
Lettuce	1 (4)	2 (6)	7 (78)	0 (0)	10 (13)
Peppermint	2 (9)	18 (54)	9 (100)	2 (18)	31 (41)
Celery	14 (64)	22 (67)	6 (67)	3 (27)	45 (60)

Note: Distribution of the five fresh vegetable types in each sample was different.

in fresh vegetables were evaluated, among the pathogenic group *Ascaris lumbricoides* was the most prevalent (highest in celery) and hookworm the least prevalent (found only in celery), while among the non-pathogenic parasites free living larvae was the most prevalent (highest in peppermint) and *Endolimax nana* the least prevalent (found only in coriander and leek (Table 3).

The majority (65%) of fresh vegetable samples were contaminated with coliform bacteria at >3 MPN/g, reaching up to 2,400 MPN/g, with coliform bacteria counts highest in lettuce and lowest in peppermint (Table 4). Highest percent coliform bacteria contamination in vegetables was observed in Mueang District fresh food market and lowest in Ongkharak District. A lower percentage (39%) of all fresh vegetable samples were contaminated with *E. coli*, highest (51%) in Mueang District market and lowest (20%) in Pak Phli District (Table 4).

DISCUSSION

Vegetables can serve as passive vehicles for transmission of pathogenic parasites, protozoa and bacteria through a fecal-oral route (Beiromvand *et al*, 2013). This study found that the prevalence of parasite contamination in raw vegetable samples from Nakhon Nayok Province collected during September 2021- February 2022 was 36%, comparable to previous reports

in Nakhon Si Thammarat Province, Thailand (35.1%) (Punsawad *et al*, 2019), Zambia (35.8%) (Nyirenda *et al*, 2021), Poland (34.7%) (Klapec and Borecka, 2012), Shahrekord, Iran (32.6%) (Fallah *et al*, 2012), and Benha, Egypt (29.6%) (Eraky *et al*, 2014). Higher contamination rate (44.8%) was detected in Zahedan, Iran (Ebrahimzadeh *et al*, 2013) and lower rates in Yazd City, Iran (25.7%) (Yavari *et al*, 2019), Pakistan (19.7%) (Khan *et al*, 2021), and Sudan (13.5%) (Mohamed *et al*, 2016). The variations in parasite contamination rates can be attributed to differences in climatic condition, temperature, soil type, and water quality where the vegetables are grown, as well as hygiene conditions during vegetable transportation to and within the market.

We observed that the most contaminated vegetable sample was celery, followed by leek, peppermint, coriander, and lettuce, as reported in previous studies in Nakhon Si Thammarat Province, Thailand (Punsawad *et al*, 2019) and in Birjand city, South Khorasan (Rahimi *et al*, 2021). On the other hand, lettuce was reported having the highest rate in Khartoum State, Sudan (Mohamed *et al*, 2016), Tehran, Iran (Isazadeh *et al*, 2020), and Bahir Dar City, Northwest Ethiopia (Alemu *et al*, 2020). Again, these differences can be explained by variations in environmental factors.

The fact that celery has the highest contamination rate could be due to its

Table 3
 Pathogenic and non-pathogenic parasite contamination in fresh vegetables among the four markets in Nakhon Nayok Province, Thailand (September 2021- February 2022)

Parasite	Number of samples with parasite contamination categorized by vegetable type					Number of vegetable samples with parasite contamination*, n (%)
	Coriander (N = 75)	Leek (N = 75)	Lettuce (N = 75)	Peppermint (N = 75)	Celery (N = 75)	
Pathogenic parasite						
<i>Trichuris trichiura</i>	0	1	0	0	3	4 (1)
<i>Ascaris lumbricoides</i>	3	8	0	11	13	35 (9)
<i>Strongyloides stercoralis</i>	0	1	0	1	1	3 (1)
Hookworm	0	0	0	0	1	1 (<1)
<i>Enterobius vermicularis</i>	1	2	0	0	0	3 (1)
<i>Cyclospora cayentanensis</i>	1	6	1	6	11	25 (7)
<i>Giardia lamblia</i>	3	4	1	2	4	14 (4)
<i>Blastocystis</i> spp	2	3	1	0	6	12 (3)
<i>Entamoeba histolytica</i>	0	0	0	0	2	2 (<1)
Non-pathogenic parasite						
<i>Endolimax nana</i>	1	1	0	0	0	2 (<1)
<i>Entamoeba coli</i>	1	4	0	0	0	5 (1)
Free living larvae	2	5	7	11	4	29 (8)
Total	14 (19)	35 (47)	10 (13)	31 (41)	45 (60)	135 (36)

*Calculation was based on the maximum possible number of vegetable samples of 375.

Table 4
Coliform bacteria and *Escherichia coli* contamination in fresh vegetable samples from four markets in Nakhon Nayok Province, Thailand (September 2021- February 2022)

Vegetable type	Ban Na District (N = 110)			Mueang District (N = 165)			Ongkharak District (N = 45)			Pak Phli District (N = 55)						
	No. of vegetable samples with coliform bacteria at different levels (%)	No. of vegetable sample with <i>E. coli</i> positive (%)	No. of vegetable samples with coliform bacteria at different levels (%)	No. of vegetable sample with <i>E. coli</i> positive (%)	No. of vegetable samples with coliform bacteria at different levels (%)	No. of vegetable sample with <i>E. coli</i> positive (%)	No. of vegetable samples with coliform bacteria at different levels (%)	No. of vegetable sample with <i>E. coli</i> positive (%)	No. of vegetable samples with coliform bacteria at different levels (%)	No. of vegetable sample with <i>E. coli</i> positive (%)	No. of vegetable samples with coliform bacteria at different levels (%)	No. of vegetable sample with <i>E. coli</i> positive (%)				
													<3 MPN/g	3-1,100 MPN/g	>1,100 MPN/g	<3 MPN/g
Coriander	1 (1)	6 (6)	15 (14)	7 (6)	3 (2)	7 (4)	23 (14)	16 (10)	1 (2)	1 (2)	4 (9)	2 (4)	0 (0)	5 (9)	6 (11)	2 (4)
Leek	1 (1)	9 (8)	12 (11)	8 (7)	5 (3)	3 (2)	25 (15)	22 (13)	1 (2)	2 (4)	6 (13)	4 (9)	0 (0)	5 (9)	6 (11)	2 (4)
Lettuce	1 (1)	4 (4)	17 (15)	11 (10)	2 (1)	3 (2)	28 (17)	29 (18)	1 (2)	4 (9)	7 (15)	5 (11)	0 (0)	2 (4)	9 (16)	4 (7)
Peppermint	3 (3)	6 (6)	13 (12)	4 (4)	5 (3)	11 (7)	17 (10)	8 (5)	1 (2)	6 (13)	2 (4)	1 (2)	1 (2)	7 (13)	3 (5)	2 (4)
Celery	1 (1)	5 (4)	16 (14)	7 (6)	4 (2)	6 (4)	23 (14)	10 (6)	2 (4)	2 (4)	5 (11)	3 (7)	1 (2)	4 (7)	6 (11)	1 (2)
Total	7 (6)	30 (27)	73 (66)	37 (34)	19 (11)	30 (18)	116 (70)	85 (51)	6 (13)	15 (33)	24 (53)	15 (33)	2 (4)	23 (42)	30 (54)	11 (20)

MPN/g: most probable number/gram

small and numerous leaves allowing more retention of contaminants (eg, parasites) than vegetables with fewer leaves and smooth surface. In addition, celery contains several stalks connected at the base and with leaves near the top of the stalks. A celery stalk is roughly U-shape with slits, enabling parasites more frequently to attach to the surface and makes removal more difficult. Celery samples obtained from the four markets in were frequently in the form of stalks with roots, potentially increasing the risk of contamination with soil parasite. Raw celery is commonly used as a garnish in many Thai dishes. On the other hand, the low parasite contamination of lettuce could be attributed to the smooth surface of its stalks. Furthermore, lettuce samples from the four markets in Nakhon Nayok Province were frequently sold without stalks and roots.

In the current study the most predominant pathogenic parasite was *Ascaris lumbricoides* (35±9%), consistent with studies conducted in Asmara, Eritrea (12.5%) (Ahmed *et al*, 2018), Ilorin, north central Nigeria (28%) (Amaechi *et al*, 2016), Jordan (21%) (Ismail, 2016), Pakistan (12.3%) (Khan *et al*, 2021), and southern Ethiopia (20.8%) (Bekele *et al*, 2017). However, lower rates of *A. lumbricoides* infestation were reported in Nakhon Si Thammarat, Thailand (2.6%) (Punsawad *et al*,

2019) and northwest Ethiopia (1.3%) (Alemu *et al*, 2020). Differences in environmental conditions and sanitary practices could, again, account for the phenomena. Furthermore, *A. lumbricoides* eggs are especially hardy, able to endure harsh chemicals and desiccation, allowing the eggs to remain in soil or months or even years (Roberts *et al*, 2019).

The second most prevalent parasite contamination found in the current study was *Cyclospora cayetanensis* (25±7%), at variance with studies in Nakhon Si Thammarat, Thailand (10.6%) (Punsawad *et al*, 2019), Accra, Ghana (43%) (Duedu *et al*, 2014), Ghana (36.4%) (Kudah *et al*, 2018), Jimma Town, Ethiopia (21.9%) (Tefera *et al*, 2014), and northwestern Ethiopia (13.5%) (Alemu *et al*, 2020), which reported *Strongyloides stercoralis* as the second most prevalent contamination. In addition, low contamination of *Blastocystis* spp, *Entamoeba histolytica*, *Enterobius vermicularis*, and *Giardia lamblia* were detected in the vegetable samples collected from Nakhon Nayok Province, in line with reports from Accra, Ghana (Duedu *et al*, 2014), Iran (Ezatpour *et al*, 2013) and northwestern Ethiopia (Alemu *et al*, 2020).

As regards to nonpathogenic parasites, namely, such as *Endolimax nana*, *Entamoeba coli*, and free-living larvae, our findings were consistent with a previous report from Iran (Ezatpour *et al*, 2013). Although such

protozoa species can infect people with no harmful effects, their presence in stool is a critical sign of fecal-oral infection.

Coliform bacteria were present in all 375 samples analyzed. Sixty-five percent of samples had an MPN exceeded the detection limit (2,400 MPN/g) of the method used. Lettuce was the most contaminated vegetable, followed by coriander, celery, leek, and peppermint. As expected, the highest *E. coli*-positive samples were those with the highest coliform bacteria counts. Similar findings were reported in Nepal (Ghimire *et al*, 2020). Coliform bacteria are commonly found in soil and are generally harmless. They are frequently associated with foods grown close to the ground or foods that have been handled by humans during harvesting and processing. *E. coli* are found in gastrointestinal tract of warm-blooded animals and its presence in humans is an indicator of fecal contamination in the food supply chain (Oliver *et al*, 2014).

The study contains several limitations. Firstly, the impact of seasonal fluctuation on parasite contamination was not investigated. Secondly, the hygienic processes employed at each market prior to displaying the products were not looked into. Thirdly, the sedimentation method employed for the detection of intestinal parasites has low sensitivity and specificity for protozoa with low

specific gravity. Future studies will have to take these limitations into account.

In conclusion, the findings of this study reveal that fresh vegetables sampled in four markets in four districts of Nakhon Nayok Province, Thailand contained a significant amount of contamination by parasites and bacteria, both pathogenic and non-pathogenic. If not properly processed, consumption of the five types of fresh vegetables sampled could pose a health risk to consumers. Contamination by pathogenic organisms of vegetables obtained from fresh food markets must be considered a food safety issue and appropriate steps should be taken by local health authorities to minimize the risk of foodborne disease. At the same time, those involved in growing, transporting and delivery of fresh food products to markets should be provided with health education and instructions on proper hygienic practices.

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CONFLICT OF INTEREST DISCLOSURE

The authors declare no conflict of interest.

REFERENCES

- Alemu G, Nega M, Alemu M. Parasitic contamination of fruits and vegetables collected from local markets of Bahir Dar City, Northwest Ethiopia. *Res Rep Trop Med* 2020; 11: 17-25.
- Ahmed K, Nur D, Desale A, Zemat M. Parasitic contamination of freshly consumed vegetables sold in the markets and farm fields within and around Asmara. *Pharmacol Online* 2018; 3: 19-30.
- Amaechi EC, Ohaeri CC, Ukpai OM, Adegbite RA. Prevalence of parasitic contamination of salad vegetables in Ilorin, North Central, Nigeria. *Momona Ethiop J Science* 2016; 8: 136-45.
- Beiromvand M, Akhlaghi L, Fattahi Massom SH, *et al.* Prevalence of zoonotic intestinal parasites in domestic and stray dogs in a rural area of Iran. *Prev Vet Med* 2013; 109: 162-7.
- Bekele F, Tefera T, Biresaw G, Yohannes T. Parasitic contamination of raw vegetables and fruits collected from selected local markets in Arba Minch town, Southern Ethiopia. *Infect Dis Poverty* 2017; 6:19.
- Berger CN, Sodha SV, Shaw RK, *et al.* Fresh fruit and vegetables as vehicles for the transmission of human pathogens. *Environ Microbiol* 2010; 12: 2385-97.
- Boonjaraspinyo S, Boonmars T, Kaewsamut B, *et al.* A cross-sectional study on intestinal parasitic infections in rural communities, northeast Thailand. *Korean J Parasitol* 2013; 51: 727-34.
- Chongkonnee N, Songthamwat D. Detection of parasite contamination in fresh vegetables from Phra Nakhon Sri Ayutthaya District, Phra Nakhon Si Ayutthaya Province, 2015 [cited 2022 Jun 26] Available from: URL: https://www.researchgate.net/publication/303330196_Detection_of_Parasitic_Contamination_in_Vegetables_from_Phra_Nakhon_Si_Ayutthaya_District_Phra_Nakhon_Si_Ayutthaya_Province#fullTextFileContent [in Thai]
- Cochran WG. Sampling techniques. 3rd ed. New York: John Wiley & Sons; 1977.
- Duedu KO, Yarnie EA, Tetteh-Quarcoop PB, Attah SK, Donkor ES, Ayeh-Kumi PF. A comparative survey of the prevalence of human parasites found in fresh vegetables sold in supermarkets and open-aired markets in Accra, Ghana. *BMC Res Notes* 2014; 7: 836.
- Ebrahimzadeh A, Jamshidi A, Mohammadi S. The parasitic contamination of raw vegetables consumed in Zahedan, Iran. *Health Scope* 2013; 1: 203-7.
- Eraky MA, Rashed SM, Nasr Mel-S, El-Hamshary AM, Salah El-Ghannam A. Parasitic contamination of commonly consumed fresh leafy vegetables in Benha, Egypt. *J Parasitol Res* 2014; 2014: 613960.
- Ezatpour B, Chegeni AS, Abdollahpour F, Aazami M, Alirezaei M. Prevalence of parasitic contamination of raw vegetables in Khorramabad, Iran. *Food Control* 2013; 34: 92-5.

- Fallah AA, Pirali-Kheirabadi K, Shirvani F, Saei-Dehkordi SS. Prevalence of parasitic contamination in vegetables used for raw consumption in Shahrekord, Iran: influence of season and washing procedure. *Food Control* 2012; 25: 617-20.
- Ghimire A, Upadhyaya J, Nayaju T, *et al.* Microbial and parasitic contamination of fresh raw vegetable samples and detection of the *Bla_{TEM}* and *Bla_{CTX-M}* genes from *E. coli* isolates. *Agriculture* 2020; 10: 341.
- Gordon CA, Kurscheid J, Jones MK, Gray DJ, McManus DP. Soil-transmitted helminths in tropical Australia and Asia. *Trop Med Infect Dis* 2017; 2: 56.
- Isazadeh M, Mirzaii-Dizgah I, Shaddel M, Homayouni MM. The prevalence of parasitic contamination of fresh vegetables in Tehran, Iran. *Turkiye Parazitol Derg* 2020; 44: 143-8.
- Ismail Y. Prevalence of parasitic contamination in salad vegetables collected from supermarkets and street vendors in Amman and Baqa'a - Jordan. *Pol J Microbiol* 2016; 65: 201-7.
- Khan W, Rafiq N, Nawaz MA, *et al.* Parasitic contamination of fresh vegetables sold in open markets: a public health threat. *Braz J Biol* 2021; 82: e242614.
- Klapec T, Borecka A. Contamination of vegetables, fruits and soil with geohelminths eggs on organic farms in Poland. *Ann Agric Environ Med* 2012; 19: 421-5.
- Krejcie RV, Morgan DW. Determining sample size for research activities. *Educ Psychol Meas* 1970; 30: 607-10.
- Kudah C, Sovoe S, Baiden F. Parasitic contamination of commonly consumed vegetables in two markets in Ghana. *Ghana Med J* 2018; 52: 88-93.
- Laksemi DA, Suwanti LT, Mufasirin M, Suastika K, Sudarmaja M. Opportunistic parasitic infections in patients with human immunodeficiency virus/acquired immunodeficiency syndrome: a review. *Vet World* 2019; 13: 716-25.
- Mohamed MA, Siddig EE, Elaagip AH, Edris AM, Nasr AA. Parasitic contamination of fresh vegetables sold at central markets in Khartoum state, Sudan. *Ann Clin Microbiol Antimicrob* 2016; 15: 17.
- Nyirenda SS, Bukowa KM, Banda WR, *et al.* Parasitic contamination of common vegetables sold in Lusaka, Zambia. *J Food Qual Hazards Control* 2021; 8: 112-8.
- Oliver DM, van Niekerk M, Kay D, *et al.* Opportunities and limitations of molecular methods for quantifying microbial compliance parameters in EU bathing waters. *Environ Int* 2014; 64: 124-8.
- Price RG, Wildeboer D. *E. coli* as an indicator of contamination and health risk in environmental waters, 2017 [cited 2022 Jun 26] Available from: URL: <https://www.intechopen.com/chapters/53957?fbclid=IwAR04SwhGN0aCapOu1oqyIEhTU2TijZrkUgW-mzvbQLb6MG2u5Oi8H9tk1D4>

- Punsawad C, Phasuk N, Bunratsami S, Thongtup K, Siripakonuaong N, Nongnaul S. Prevalence of intestinal parasitic infection and associated risk factors among village health volunteers in rural communities of southern Thailand. *BMC Public Health* 2017; 17: 564.
- Punsawad C, Phasuk N, Thongtup K, Nagavirochana S, Viriyavejakul P. Prevalence of parasitic contamination of raw vegetables in Nakhon Si Thammarat province, southern Thailand. *BMC Public Health* 2019; 19: 34.
- Rahimi SM, Behravan M, Ramazani AA, Pourmohammad A, Solgi R. Prevalence of parasitic contamination of raw vegetables consumed in Birjand city, South Khorasan province. *Gene Rep* 2021; 24: 101268
- Roberts LS, Janovy J Jr. Foundations of parasitology. 8th ed. New York: McGraw-Hill, 2009.
- Sajjapala T, Tansakul K, Phetnok K. Contamination and reducing of parasite in fresh vegetables by washing, 2014 [cited 2022 Jun 26]. Available from: URL: <https://he02.tci-thaijo.org/index.php/dmsc/article/view/243256/165394> [in Thai]
- Sherchand JB, Cross JH. Emerging pathogen *Cyclospora cayentanensis* infection in Nepal. *Southeast Asian J Trop Med Public Health* 2001; 32 (Suppl 2): 143-50.
- Silver ZA, Kaliappan SP, Samuel P, et al. Geographical distribution of soil transmitted helminths and the effects of community type in South Asia and South East Asia - a systematic review. *PLoS Negl Trop Dis* 2018; 12: e0006153.
- Tefera T, Biruksew A, Mekonnen Z, Eshetu T. Parasitic contamination of fruits and vegetables collected from selected local markets of Jimma Town, Southwest Ethiopia. *Int Sch Res Notices* 2014; 2014: 382715.
- Yavari MR, Mirzaei F, Shahcheraghi SH, Bafghi AF. Parasitic contamination on fresh raw vegetables consumed in Yazd City, Iran, during 2017-2018. *Chinese J Med Res* 2019; 2: 70-3.