Frequency of parasitic infections in *Arachis hypogaea* L (groundnuts), *Citrullus lanatus* seeds (watermelon seeds), and *Ziziphus spinos-christi* (nabag) sold by street vendors in Khartoum State, Sudan: a cross-sectional study [version 1; peer review: 1 approved with reservations]

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**Abstract**

**Background:** Plant products, including seeds are an important source of vitamins, minerals, proteins, and energy. This study aimed to assess parasitic contaminations in roasted groundnuts, nabag, and tasali (watermelon seeds) sold by street vendors in Khartoum State, Sudan.

**Methods:** The frequency of parasitic contaminations among all crop products was detected by washing the plants with saline, and then conducting an examination using a formal ether concentration technique (FECT), followed by a saturated sugar floatation technique.

**Results:** The detected parasites belonged to two species: *Entamoeba histolytica* (33.3%) and *Giardia lamblia* (15.6%). No helminthic parasites were detected. Mixed contamination of the mentioned parasites was also observed (11.1%). The most contaminated crop was nabag, followed by groundnut, and finally tasali.

**Conclusion:** No relation was established between the positivity of samples for parasites and crop type, Khartoum State city, or seller sex. FECT was more sensitive than the saturated sugar floatation technique as a detection method.

**Keywords**

Arachis hypogaea L, Groundnuts, Citrullus lanatus, Nabag, Tasali
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Author roles: Suleiman Mohammed A: Formal Analysis, Investigation, Methodology; Abd Alla A: Formal Analysis, Supervision, Writing – Original Draft Preparation, Writing – Review & Editing; Galander A: Data Curation, Visualization; Elfaki T: Writing – Review & Editing; Ibrahim Hashim A: Writing – Original Draft Preparation; N. Altayb H: Resources, Software, Validation

Competing interests: No competing interests were disclosed.

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Introduction

Intestinal parasitic infections can be transmitted orally through the ingestion of infective agents from infected food, water, or contaminated hands. Food contamination and food borne parasitic diseases frequently occur globally. These are estimated to amount to 23.2 million cases and 45,927 deaths annually. A study in Ghana revealed *Ascaris lumbricoides* (roundworm), *Ancylostoma duodenale* (nematode), *Necator americanus* (hookworm), and *Strongyloides stercoralis* (threadworm) contaminations in tiger nuts. Another study on tiger nuts reported other contaminants such as animal droppings, fungi toxins and bacteria. Groundnuts, *Citrullus lanatus* seeds (watermelon seeds), and *Ziziphus spina-christi* (nabag) are widely consumed in Africa and the Middle East. Nabag and tasali are widely eaten in Sudan. These crops are natural sources of carbohydrates, proteins, fats, -iron, calcium, ascorbic acid, thiamine, riboflavin, and niacin. Groundnuts in Sudan are mainly used for oil extraction, but can be eaten as a snack: raw, or after roasting without its external cortex envelop. Nabag is eaten after the sweet pulp of the fruit is dried to produce fine flour. The flour is placed in small metal cups and steamed. Dried pulp flour and water are also mixed with sesame and shaped into small balls. Fruit pulp prepared in these two ways can be consumed either immediately or stored for future use. In addition to groundnuts, nabag, and tasali, many crop products represent an important and for some, the only source of income in Sudan.

Intestinal parasitic infections are very common worldwide. They are often not diagnosed and hence not treated, leading to harmful effects which can be lethal in some cases. Food contamination may occur when food is prepared, stored, or handled; this is a common phenomenon in public places like the streets. Identifying parasitic contamination will help fight these infections, because knowing contamination rates allows to take the necessary preventive measures. The objective of this study was to identify parasitic contamination rates in *Arachis hypogaea* L (groundnuts), *Citrullus lanatus* seeds (watermelon seeds), and *Ziziphus spina-christi* (nabag) sold by street vendors in Khartoum State, in Sudan.

Method

Study design

This descriptive cross-sectional study was conducted between July and October 2019 in Khartoum State, Sudan. The study included the Khartoum cities Khartoum, Bahri, and Omdurman.

Ethical considerations

Ethical approval for this study was received from the Sudan University of Science and Technology’s Committee of Medical Laboratory Science, with the ethical approval number (MLS–IEC–03–18). All participants in this study issued written informed consent for participation and data publication; for participants under 18 years old, consent was obtained from their guardians.

Sampling

The study was conducted on street vendors in Khartoum State, sampling groundnuts, nabag, and tasali. In total, 69.8 g of nabag, 50 g of tasali, and 69.9 g of groundnuts were purchased from 15 sellers in Sudan’s Khartoum state (five sellers from each city of interest, i.e. Bahri, Khartoum, and Omdurman), using a cluster random sampling technique, for a total of 45 samples (15 samples from each crop product type). The items were brought to the laboratory and tested under a microscope for parasitic agents. Sellers’ location, gender, and age group were observed.

Sample processing

Each product purchased from the same seller was put separately in clean, dry glass bottles after labelling, which were then filled up to the surface with distilled water. Bottles were left for one hour, and then the nabag, tasali, and groundnut were removed from the liquid using a plastic sieve; the washes were collected and then examined using a formal ether concentration technique (FECT) and saturated sugar floatation technique.

Formal ether concentration technique

Nabag and tasali washes were added to 4 ml of 10% volume per volume formal saline contained in a conical centrifuge tube. The contents were well-mixed by centrifuging for 20 seconds. After centrifugation four layers of ether, plant debris, formal saline, and deposit were discarded using a sterile plastic Pastier pipette. The deposits of sieved wash liquid were then examined under a microscope using 10× and 40× magnification, to detect parasitic agents such as cysts, trophozoite larva, helminth eggs, and species including *G lamblia*, *E histolytica*, *A lumbricoides*, *E. vermicuaris*, *T. trichiura*, *A. duodenale*, *N. americanus* and *S. stercoralis*.
Saturated sugar solution floatation technique
Approximately 1 ml of each previously prepared crop wash was put into a glass tube; then, the floatation solution (saturated sugar) was added gradually until a convex surface was formed on the top of the glass tube, which was then covered with a glass cover. The tube was left for 15–30 min, after which the glass cover was removed; the solution was put on a microscope slide, and examined under the microscope to detect parasitic agents.17

Statistical analysis
The statistical package for social science (SPSS, IBM) version 20 program, was used for data analysis. Statistical tests were performed at a 5% significance level (\(P < 0.05\)) and a confidence interval (CI) of 95%. The measured frequencies were computed. The statistical significance of relationships between variables was determined using Pearson’s Chi-squared test.

Results
The participants in this study were 15 street vendors selling groundnuts, nabag, and tasali. The population was divided into six age groups: 10–20, 21–30, 31–40, 41–50, 51–60, and over 61 years. The most common age group was 31–40 (46.7%), followed by 41–50 (20%), 21–30 (13.3%), 10–20 (6.7%), 51–60 (6.7%), and more than 61 (6.7%). Eight (53.3%) of the 15 subjects were women, while seven (46.7%) were men.

The total parasitic contamination rate was 60% (27 samples), divided as follows: 20% (\(n = 9\)) for groundnut, 22.2% (\(n = 10\)) for nabag, and 17.8% (\(n = 8\)) for tasali. A Chi-squared test was used to test the relationship between crop type and detection of parasites, revealing an insignificant relationship with \(P = 0.757\) (Table 1). The presence of both \(E.\ histolytica\) and \(G.\ lamblia\) accounted for 11.1% of the positive results.

The contamination rate assessed using FECT was 53.3% (24 samples), while the sugar floatation technique detected a contamination rate of 48.9% (21 samples); the correlation between detection and technique used was found to be highly significant at \(P = 0.000\) (Table 2). Using FECT, the detected prevalence of \(E.\ histolytica\), \(G.\ lamblia\), and mixed

Table 1. Frequency of study subjects according to age groups.

<table>
<thead>
<tr>
<th>Age groups (years)</th>
<th>Males</th>
<th>Females</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>10–20</td>
<td>1</td>
<td>0</td>
<td>1 (6.7%)</td>
</tr>
<tr>
<td>20–30</td>
<td>1</td>
<td>1</td>
<td>2 (13.3%)</td>
</tr>
<tr>
<td>30–40</td>
<td>3</td>
<td>4</td>
<td>7 (46.7%)</td>
</tr>
<tr>
<td>40–50</td>
<td>2</td>
<td>1</td>
<td>3 (20%)</td>
</tr>
<tr>
<td>50–60</td>
<td>0</td>
<td>1</td>
<td>1 (6.7%)</td>
</tr>
<tr>
<td>More than 61</td>
<td>0</td>
<td>1</td>
<td>1 (6.7%)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>7 (46.7%)</td>
<td>8 (53.3%)</td>
<td>15 (100%)</td>
</tr>
</tbody>
</table>

Table 2. Comparison between parasite species detected and technique used.

<table>
<thead>
<tr>
<th>Parasite spp.</th>
<th>Technique, % (n)</th>
<th>FECT</th>
<th>Sugar</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Positive</td>
<td>Negative</td>
<td>Positive</td>
</tr>
<tr>
<td>(E.\ histolytica)</td>
<td>33.3 (15)</td>
<td>0 (0)</td>
<td>37.8 (17)</td>
</tr>
<tr>
<td>(G.\ lamblia)</td>
<td>11.1 (5)</td>
<td>0 (0)</td>
<td>8.9 (4)</td>
</tr>
<tr>
<td>(E.\ histolytica) and (G.\ lamblia)</td>
<td>8.9 (4)</td>
<td>0 (0)</td>
<td>2.2 (1)</td>
</tr>
<tr>
<td>None</td>
<td>0 (0)</td>
<td>46.7 (21)</td>
<td>0 (0)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>53.3 (24)</td>
<td>46.7 (21)</td>
<td>48.9 (22)</td>
</tr>
<tr>
<td><strong>100 (45)</strong></td>
<td>100 (45)</td>
<td>100 (45)</td>
<td>100 (45)</td>
</tr>
</tbody>
</table>
contamination of *E. histolytica* and *G. lamblia* were 33.3% (15), 11.1% (5), and 8.9% (4), respectively; when using the sugar floatation technique, the detected prevalence of *E. histolytica*, *G. lamblia*, and mixed contamination of *E. histolytica* and *G. lamblia* were 37.8% (17), 8.9% (4), and 2.2% (1), respectively (Table 2). The prevalence rates of *E. histolytica* in groundnuts, nabag, and tasali were 15.6% (7), 8.9% (4), and 8.9% (5), respectively, and for *G. lamblia* were 2.2% (1), 6.7% (3), and 6.7% (3) (Table 3). Mixed contamination was found in groundnuts, nabag, and tasali in the following proportions: 2.2% (1), 6.7% (3), and 2.2% (1), respectively. Contamination rates for groundnut, nabag, and tasali detected by FECT were 20% (9), 20% (9), and 13.3% (6), respectively, while those detected using the sugar floatation technique were 20% (9), 13.3 % (6), and 15.5% (7).

The relationship between crop type positivity to contamination and technique used was negligible for both FECT ($P = 0.655$) and sugar floatation technique ($P = 0.591$) (Table 4). The 31-40 age group had the highest contamination rate (33.3%), followed by 41–50 (13.3%), more than 61+ (6.7%), 51–60 (4.4%), 21–30 (2.2%), and 10–20 (0%) groups. There was a significant association between seller age group and outcome positivity ($P = 0.028$). Contamination rates were 24.4%, 20%, and 15.6% in Khartoum state cities, i.e. Khartoum, Bahri, and Omdurman, respectively. There was no relation between city and contamination rate ($P = 0.329$). The results revealed that *E. histolytica* was the dominant parasite across all city, with prevalence rates of 17.8%, 17.8%, and 8.9 % in Khartoum, Bahri, and Omdurman, respectively; while *G. lamblia* had lower prevalence rates in Khartoum, Bahri, and Omdurman, at 13.4%, 4.4%, and 8.9%, respectively. Relationship testing between city and species detected yielded insignificant results ($P = 0.460$).

**Discussion**

Groundnut and watermelon seeds are important cash crops. They respectively represented 43,532 USD (59,620 tons) and 49,355 USD (74,149 tons) of Sudanese exports in 2018. To the best of our knowledge, this study was the first to look into the parasitic contamination of groundnuts, nabag, and tasali sold by Sudanese street vendors. Two studies in Ghana and Nigeria estimated parasitic infections in the root plant *Cyperus esculentus L.* (tiger nuts); those studies were similar to some degree, and found contamination to be significant. The overall contamination rate in the previous study was 60%, which is considered significant. This rate was expected, because vendors sold their products unprotected and handled them with their bare hands. Contamination does not necessarily happen at the selling stage; it can happen during crop farming, harvesting, storage and transport, and even at home, according to Idaho, 2011 and Porter et al., 1990. Contamination may occur during the planting phase as a result of polluted irrigation water, as mentioned by Keraita et al., 2002, which is contaminated as a result of inadequate or insufficient sanitation infrastructures to cope with the rate of urbanization. In our study, the most contaminated crop was nabag (22.2%), followed by groundnut (20%), and finally tasali. This may be due nabag being sold raw, which also exposes it to the previously mentioned contamination factors, particularly during the growing and harvesting phases; When nuts fall to the ground, they may come into contact with potentially polluted soil, as well as other external contaminants carried by wind, humans, or animals.

**Table 3.** Correlation between crop type and detected parasite species.

<table>
<thead>
<tr>
<th>Crop type</th>
<th>Parasite spp., % (n)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><em>E. histolytica</em></td>
<td><em>G. lamblia</em></td>
</tr>
<tr>
<td>Groundnuts</td>
<td>15.6 (7)</td>
<td>2.2 (1)</td>
</tr>
<tr>
<td>Nabag</td>
<td>8.9 (4)</td>
<td>6.7 (3)</td>
</tr>
<tr>
<td>Tasali</td>
<td>8.9 (4)</td>
<td>6.7 (3)</td>
</tr>
<tr>
<td>Total</td>
<td>33.4 (15)</td>
<td>15.6 (7)</td>
</tr>
</tbody>
</table>

**Table 4.** Comparison between contaminated crop type and technique used.

<table>
<thead>
<tr>
<th>Crop type</th>
<th>Positive results, % (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FECT</td>
</tr>
<tr>
<td>Groundnut</td>
<td>20 (9)</td>
</tr>
<tr>
<td>Nabag</td>
<td>20 (9)</td>
</tr>
<tr>
<td>Tasali</td>
<td>13.3 (6)</td>
</tr>
<tr>
<td>Total</td>
<td>53.3 (24)</td>
</tr>
</tbody>
</table>
However, because groundnuts grow beneath the soil surface, they might be damaged if the nuts comes into contact with soil that has been contaminated, or with polluted irrigational water.

Despite this, salting and roasting may help to reduce contamination. Tasali had the lowest contamination rate in comparison to others. This could be explained by it being protected by the fruit (watermelon) during growing and harvesting, as well as the washing, salting, and roasting processes that occur before it is eaten. In our study, the parasites detected belonged to two species: *E. histolytica* (44.4%) and *G. lamblia* (26.7%). *E. histolytica* was the most common of both in all sampled crops (groundnut: 17.8% vs 4.4%, nabag: 15.6% vs 15.6%, and tasali: 11.1% vs 8.9%). Groundnuts had the highest rate of *E. histolytica* contamination (44.4%). This finding is consistent with a Nigerian study on tiger nuts, which are similar to groundnuts in their cultivation process, and in which *E. histolytica* was identified as the only protozoan parasite (25% contamination rate). The precise prevalence rates of the occurrence of contamination, positivity of crop samples to contamination (P-value: 0.807 and 0.329 respectively), while the age group played a role in it.

Between the saturated sugar floatation technique (prevalence rate: 48.9%) and FECT (prevalence rate: 53.3%), the FECT detecting 44.2% of *E. histolytica* and *G. lamblia* was found to be the most efficient technique for crop examination (P = 0.000). FECT outperformed the saturated sugar floatation technique in detecting both parasites, with FECT detecting 44.2% of *E. histolytica* and *G. lamblia* while the sugar floatation technique detected 40% of *E. histolytica* and 11.1% of *G. lamblia*. According to our study, seller sex and location (stationed vehicle or no vehicle) did not affect the positivity of crop samples to contamination (P-value: 0.807 and 0.329 respectively), while the age group played a role in the occurrence of contamination. These results suggest that contaminated crop products could be a major source of infection.

**Conclusions**

Roasted groundnut, nabag, and tasali that were sold by street vendors in Khartoum State, Sudan were highly contaminated with protozoan parasites. *E. histolytica* was the dominant parasite in all seeds tested. No connection was found between the crop type and the detected parasite species. Although the rate of contamination for female sellers was higher, the relationship between seller sex and positivity to contamination was not significant. There was no found correlation between the seller’s location and positivity to contamination.

**Data availability**

**Underlying data**


Data are available under the terms of the Creative Commons Attribution 4.0 International license (CC-BY 4.0).

**Acknowledgements**

This work was based on a Master’s dissertation; we thank all members of the Parasitology and Medical Entomology Department, College of Medical Laboratory Science, Sudan University of Science and Technology, whose help was deeply appreciated. Many thanks to Miss. Alaa Mohammed Ahmed Mohammed for her assistance in collecting samples.

**References**

6. Ogban EI, Ukpong IG: Intestinal parasites associated with tiger nuts, *Cyperus esculentus* L. Calabar Nigeria: Implications for...
Open Peer Review

Samar Al Nahhas

Department of Animal Biology, Faculty of Science, Damascus University, Damascus, Syria

This scientific article addresses the frequency of parasitic infections in some vegetative crops. It addresses an important topic concerning both human and animal nutrition. Raw vegetables and fruits are one of the most essential sources of nourishment. They often contribute to an epidemiological role in the transmission of parasitic food-borne diseases. Usually, fruits and vegetables become contaminated with different parasitic phases (cyst, oocyst, ova, and larvae) during irrigation by waste water or by direct contamination from animals and humans during harvesting, packing, transport processing, distribution, and marketing.

In Sudan as in many countries revealed the presence of different parasites species like soil worms, protozoa, fungus...etc.

Identifying parasitic contamination will help fight these infections, because knowing contamination rates allows applying strict control of fruit and vegetable cultivation areas, such as keeping animals far from direct contact with agricultural crops, periodic inspection of water sources used in irrigation, as well taking the necessary preventive measures.

I have some points that need to be clarified:

- The authors record the Sellers ‘gender and age group, what is the benefit? Page 5: last paragraph before discussion, they mentioned “The 31-40 age group had the highest contamination rate...... outcome positivity”. Have the authors tested stool samples isolated from vendors?

- It is not possible to distinguish and differentiate E. histolytica from the morphologically identical nonpathogenic species E. dispar and E. moshkovskii using light microscopy. How did the authors confirm the presence of Entamoeba histolytica?

- The authors applied two techniques: FECT and sugar floatation. What is the benefit?

Is the work clearly and accurately presented and does it cite the current literature?
Yes

Is the study design appropriate and is the work technically sound?
Yes

Are sufficient details of methods and analysis provided to allow replication by others?
Yes

If applicable, is the statistical analysis and its interpretation appropriate?
Yes

Are all the source data underlying the results available to ensure full reproducibility?
Yes

Are the conclusions drawn adequately supported by the results?
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: parasitology, infectious diseases, molecular diagnosis, immuno diagnosis, microbiology, enteric parasites, leishmaniasis, malaria, toxoplasmosis, echinococcus....

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

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