PARASITIC EXAMINATION OF PROMINENT VEGETABLES SOLD IN DIFFERENT LOCAL MARKETS IN BENIN CITY, EDO STATE.

BY

OBAREWO, PAUL KAYODE

MATRICULATION NO: BMS1806360

(MEDICAL MICROBIOLOGY)

SUPERVISOR:

DR. (MRS.) S.A. AIGBODION

DEPARTMENT OF MEDICAL LABORATORY SCIENCE,

SCHOOL OF BASIC MEDICAL SCIENCES,

COLLEGE OF MEDICAL SCIENCES,

UNIVERSITY OF BENIN.

OCTOBER, 2025.

PARASITIC EXAMINATION OF PROMINENT VEGETABLES SOLD IN DIFFERENT LOCAL MARKETS IN BENIN CITY, EDO STATE.

BY

OBAREWO, PAUL KAYODE

MATRICULATION NO: BMS1806360

BEING A PROJECT SUBMITTED TO THE DEPARTMENT OF MEDICAL LABORATORY SCIENCE IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF BACHELORS DEGREE IN MEDICAL LABORATORY SCIENCE (BMLS) UNIVERSITY OF BENIN, BENIN CITY, NIGERIA.

OCTOBER, 2025

CERTIFICATION

This is to certify that this work carried out by Obarewo, Paul Kayode with matriculation number BMS1806360, under the supervision of Dr. (Mrs.) S. A. Aigbodion, is being submitted to the Department of Medical Laboratory Science, School of Basic Medical Sciences, University of Benin, Benin City, in partial fulfillment of the requirement for the award of Bachelor of Medical Laboratory Science degree.

______________________________ ____________________

DR. (MRS.) S.A. AIGBODION **DATE**
Supervisor

______________________________ ____________________

DR. (MRS) ZAINAB OMORUYI **DATE**
Head of Department

______________________________ ____________________

EXTERNAL EXAMINER **DATE**

DEDICATION

I dedicate this project work to God Almighty for his love, grace, wisdom and knowledge he bestowed upon me throughout my stay in The University of Benin.

ACKNOWLEDGEMENTS

I give thanks to the Almighty God for the strength, perception, courage and grace granted me towards the presentation of this work.

One big thank you to my highly esteemed supervisor, Dr. (Mrs.) S. A. Aigbodion, for the experienced and insightful supervision provided during the period of this work.

I express profound gratitude to Dr. (Mrs.) Zainab Omoruyi, Head of the Department of Medical Laboratory Science, having provided me with all the facilities to carry out this research work. I sincerely appreciate the whole-hearted cooperation and valuable help rendered by my lecturers and the entire staff of the Department of Medical Laboratory Science.

My boundless gratitude, respect, and appreciation goes to my beloved Parents and siblings. Thank you for trusting in me, for encouraging me and carrying the financial burden of this work. Also, to my friends, Amarachi, Eshi and Joshua.

To everyone that has been and are now there for me. You all are my heroes.

I must also appreciate everyone who prayed for me and wished for the success of this work, thank you.

You can now see that God heard you. May God bless and keep you all. Amen!

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDIX

ABSTARCT

Vegetables are plant parts consumed by humans and some animals as food, and they include leaves, roots, and stems or stalks. These parts can become contaminated with gastrointestinal parasites, thereby predisposing individuals to various diseases. The present study was conducted to determine the occurrence of parasites in selected leafy vegetables sold in Ugbodiobo market, Odighi Market, Ugo-Niyekarhiomwom old farm market and Ekiohuon (Ekehuan) market located in Benin City, Edo State). A total of 330 vegetable samples were examined for parasitic presence. Standard parasitological procedure was employed by sedimentation technique. The result revealed that there was even distribution of parasites; *A. lumbricoides* (21%), *S. stercoralis* (9%), Hookworm (13%), *T. trichiura* (13%), *G. lamblia* (10%), *E. histolytica* (25%) *E. vermicularis* (9%). The largest number of parasites in these local markets of Benin city was determined on spinach leaf. Percentage parasite occurrence on other leaves varied significantly ($P<0.05$). The highest parasites recorded on scent leaf was *A. lumbricoides* (46%), on pumpkin leaf was *A. lumbricoides* (29%), on cabbage was *E. histolytica* (44%), on Eboziza leaf was *E. histolytica* (30%), *A. lumbricoides* (28%) and S. stercoralis (24%) on Ebewewie leaf was *A. lumbricoides* (38%), on curry leaf was *A. lumbricoides* (46%) on Waterleaf was *E. histolytica* (36%) and *A. lumbricoides* (32%). The overall highest parasites on leafy vegetable was A. lumbricoides (31%) and *E. histolytica* (27%). The occurrence of parasites in different market was evenly distributed for scent leaf, pumpkin leaf, cabbage, eboziza leaf, waterleaf. Whereas, occurrence of parasite was highest in Ugbodiobo market for spinach leaf, in Ugbodiobo and Odighi for ebewewie leaf and Ugbodiobo for curry leaf. The result indicates that there is high contamination of leafy vegetables in local markets of Benin city where urban center markets traders purchase from. The risk of an epidemic stands a chance and therefore there is need to reduce the risk of infection by enlightenment campaigns to vegetable farmers, vendors and consumers in these local regions on handling and transportation, law enforcement guiding against water contamination by local authorities.

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF STUDY

Vegetable forms a substantial part of the human diet across many regions of the world and are vital to human nutrition, particularly as sources of phytonutriceutical such as vitamins [A, C, B1, B6, B9 and E], minerals, fibers and beneficial Phyto-chemicals (Dias, 2012). Certain Phyto-chemicals found in vegetables acts as powerful antioxidants and are believe to lower the risk of certain chronic diseases. They do so by neutralizing free radicals influencing a better digestive health, detoxification of carcinogens and influencing tumor cell cascade (Ryder *et al*., 2011). Vegetables improved eye sight, lower risk of heart disease, stroke, diabetes and certain cancers (Dias, 2012).

In recent times, the incidence of foodborne illnesses associated with consumption of fresh vegetables has risen. Eating raw vegetables significantly contributes to the spread of parasitic foodborne infections (Al-Megrm, 2010). Intestinal Parasites (IPs) are a major source of morbidity and mortality worldwide, particularly in developing countries (Adejumoke *et al*., 2015). According to (Endale *et al*., 2018), IPs are the second most frequent cause of outpatient morbidity in Nigeria resulting in physical and mental issues, including diarrhea, fatigue, growth retardation in children among others. Intestinal parasites infections affect over 3.5 billion people worldwide; 450 million of them gets sick and 200,000 of them die annually (Duedu *et al*., 2014; Endale *et al*., 2018). Intestinal parasites which infect humans includes Entamoeba histolytica, Enterobius vermicularis, Giardia lamblia, Toxocara spp., Cryptosporidium spp., Ascaris lumbricoides, Trichuri trichiura, Taenia spp., Fasciola spp., hookworms and members of the family Trichostrongylidae all due to the consumption of contaminated, improper washing or improper cooking of vegetables (Kozan *et al*., 2007). In developing countries, most local farmers deploy the use of filthy or untreated water for irrigation as well as polluted or untreated human or animal excrement as natural fertilizer which add to an increase in the prevalence of intestinal parasites (Bakele *et al*., 2017). Furthermore, the circumstances for storage, transportation and marketing as well as hygienic practices used during processing for consumption in food service or domestic settings, are all factors in the post-harvesting phase (Bakele *et al*, 2017). Finally, among the post-harvest practices common with vegetarians, food vendors and home-made meal preparation is the insufficient cooking or raw intake in order to maintain the heat-sensitive nutrients and natural flavour in these edible plant produce (Fallah *et al*., 2012).

1.2 JUSTIFICATION OF STUDY

Vegetables are essential components of balanced diet and are recognized as major sources of vitamins, minerals, antioxidants and dietary fiber. Often consumption has been linked to a reduced risk of several chronic and life-threatening illness including cardiovascular disorder, cancer, obesity and gastrointestinal ailments. Due to this health benefits, they are widely consumed by all age group and socioeconomic classes. This produce can serve as vehicles for transmission of intestinal parasites from sewage-contaminated irrigation water to post-harvest unsanitary handling as well as transportation. The economic impact associated with the treatment of parasitic diseases, loss of productivity and cost of health care underscores the importance of preventive public health care strategy. Therefore, the study is justified as it aims to assess the extent of parasitic contamination in vegetables sold in this market, thereby providing evidence necessary for awareness, policy intervention and improved food safety practices in Benin city, Edo State.

1.3 SCOPE OF STUDY

The study will be limited to markets in Benin city, Edo State, with careful look at Ugbodiobo market, Odighi Market, Ugo-Niyekarhiomwom old farm market and Ekiohuon (Ekehuan) market. The four markets are considered to be the bush markets where every other market across Benin purchase from.

1.4 AIM OF STUDY

The aim of this study is to evaluate the extent of parasitic contamination present in selected vegetables sold in Ugbodiobo market, Odighi Market, Ugo-Niyekarhiomwom old farm market and Ekiohuon (Ekehuan) market located in Benin City, Edo State.

1.5 SPECIFIC OBJECTIVES

The specific objectives of the study are to:

- determine the prevalence of medically important parasites associated with vegetables sold in Ugbodiobo market, Odighi Market, Ugo-Niyekarhiomwom old farm market and Ekiohuon (Ekehuan) market located in Benin City, Edo State
- identify and evaluate risk factors contributing to the contamination of vegetables.
- raise awareness among vendors and customers about the public health risk of consuming contaminated produce and the importance of proper handling and washing practices.
- compare the level of parasitic contamination between the four location of study to identify possible geographic environmental differences in contamination pattern.

1.6 RESEARCH QUESTIONS

- What is the prevalence of medically important intestinal parasites sold across major markets in Benin City?
- What are the risk factors responsible for the contamination of vegetables?
- What knowledge, attitude and practice do vegetable vendors and consumers in Benin city have regarding food hygiene and parasitic transmission?
- Are there significant differences in the level of parasitic contamination among various market within Benin City (e.g Ugbodiobo market, Odighi Market, Ugo-Niyekarhiomwom old farm market and Ekiohuon (Ekehuan) market)?

HYPOTHESIS

The hypothesis is null and it is giving by:

- There is no significant parasitic contamination of raw leafy vegetables in the markets (Ugbodiobo market, Odighi Market, Ugo-Niyekarhiomwom old farm market and Ekiohuon (Ekehuan) market located in Benin City, Edo State).

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 VEGETABLES

The increasing occurrence of chronic and incurable diseases in contemporary society has reinforced the need for healthier diets and natural lifestyles. Among these, vegetables are especially important as they provide the body with essential vitamins and minerals required for adequate nourishment (Abosede *et al*., 2022). The different colors that different vegetable types exhibit reveal the different compositions of phytochemicals that are contained in such vegetables. The different compositions of such compounds are known to help in fighting against illness and lowering occurrences of such illness. Consumption of vegetables in large portions, in due time, enhances metabolism, as such vegetables are usually low in fat, carbohydrate, and high in vitamin, mineral, and dietary fiber (Abosede *et al*., 2022).

Vegetable is any form of plant life or plant product, specifically "vegetable matter". The term "vegetable" typically refers to the fresh edible parts of some herbaceous plants, such as the roots, stems, leaves, flowers, fruit, or seeds (Britannica, 2021). These plant components can be consumed either raw or cooked in a variety of ways, mainly as a savoury dish as opposed to a dessert (Britannica, 2021). Leafy vegetables are those in which the tender shoots, leaves, and sometimes flowers are consumed as food, being recognized for their high nutritional value (Tahreem *et al*., 2020). According to the World Health Organization (WHO),

When such recommendations are made, age, weight, and sex are considered; however, research indicates that in the United States, a vast majority of adults consume less than is required. Only 9.3% consume adequacy of vegetables daily (Meeks, 2021). Studies suggest that only 7% of individuals who live at or below poverty level documented daily intake of needed number of veggies, providing evidence that too much is more of a concern (Terry, 2011).

Eating of hard, challenging-to-chew foodstuffs such as raw leafy greens in early childhood is good to humans and animals because it creates jaws and teeth in correct occlusion. The absence of such food, then jaws will grow without full potential, space shrinking for accommodation of teeth, crowding results. But there are also natural toxins and anti-nutrients in vegetables in the presentation of enzyme inhibitors (e.g., cholinesterase, protease, and amylose inhibitors), cyanide precursors, oxalic acids, and tannins as protection against insects, animals, and fungi. Inasmuch, such compounds in most cases will thereby be inactivated by proper cooking. But, there is also evidence linking leafy greens with virtually half of norovirus-gastrointestinal disease in the United States mainly because green leaves are eaten raw in such cases and get contaminated in handling. Therefore, rigid hygienic practices in kind—such as proper washing, handling, and sorting (e.g., of salad mix) must be observed while preparing vegetable that will be eaten raw.

COMMON LEAFY VEGETABLES

Family	Common Name	Scientific Name	Region/Origin	Common Uses
Asteraceae	Lettuce (Iceberg, Romaine, Butterhead, Leaf types)	*Lactuca sativa*	Temperate regions, global cultivation	Salads, sandwiches, fresh consumption
	Endive, Escarole, Radicchio	*Cichorium endivia*, *C. intybus*	Europe, global	Salads, mixed greens, slightly bitter taste
Brassicaceae	Kale	*Brassica oleracea* var. *acephala*	Europe, now worldwide	Soups, sautés, stews
	Collard greens	*Brassica oleracea* var. *viridis*	Africa, Americas	Cooked greens, stews
	Mustard greens	*Brassica juncea*	Asia, Africa	Salads, soups, stir-fries
	Arugula (Rocket)	*Eruca sativa*	Mediterranean	Salads, garnish, seasoning
Amaranthaceae	Spinach	*Spinacia oleracea*	Persia (Iran), now global	Salads, soups, cooked dishes
	Swiss chard	*Beta vulgaris* subsp. *cicla*	Mediterranean	Cooked greens, soups
	Beet greens	*Beta vulgaris*	Global	Cooked greens, salads
	African spinach/Amaranth	*Amaranthus spp.*	Africa, Asia, Americas	Cooked greens, stews, soups
Basellaceae	Malabar spinach	*Basella alba*	Tropical Africa & Asia	Soups, stews (slimy texture), salads
Cucurbitaceae	Pumpkin leaves	*Cucurbita spp.*	Global	Soups, stews, sautéed

Family	Common Name	Scientific Name	Region/Origin	Common Uses
	Fluted pumpkin ("Ugwu")	*Telfairia occidentalis*	West Africa (Nigeria)	Soups, stews, medicinal uses
Malvaceae	Jute mallow ("Ewedu")	*Corchorus olitorius*	Africa, Asia, Middle East	Soups, stews, sauces (mucilaginous)
Asteraceae	Bitterleaf	*Vernonia amygdalina*	West/Central Africa	Bitter soups (e.g., *ofe onugbu*), medicinal uses
Talinaceae	Waterleaf	*Talinum triangulare*	West Africa, South America	Soups, stews, salads, medicinal
Convolvulaceae	Sweet potato leaves	*Ipomoea batatas*	Africa, Asia	Cooked greens, stir-fries
Apiaceae	Parsley	*Petroselinum crispum*	Mediterranean, global	Garnish, salads, soups
	Celery leaves	*Apium graveolens*	Mediterranean	Soups, salads, stews
	Coriander (Cilantro)	*Coriandrum sativum*	Mediterranean, Asia	Garnish, salads, seasoning

2.2 SOME MEDICINAL LEAFY VEGETABLE PLANTS

2.2.1 SPINACH: Spinach (*Spinacia oleracea*) is one of the most widely consumed leafy vegetables globally, valued both for its nutritional benefits and versatility in diets. However, its cultivation and consumption practices expose it to microbial and parasitic contamination, posing potential public health concerns. Spinach is a nutrient-dense leafy vegetable that supplies essential vitamins and minerals such as vitamin A, vitamin C, vitamin K, folate, iron, calcium, magnesium, and potassium (Slavin & Lloyd, 2022). It also contains dietary fiber, which promotes digestive health, and phytochemicals such as carotenoids (lutein, β-carotene, and zeaxanthin) and flavonoids that function as antioxidants (Liu, 2023). These bioactive compounds have been linked to reduced risks of chronic diseases, including cardiovascular disease, diabetes, and age-related eye disorders (Johnson, 2024). The nutritional value of spinach makes it an important component of balanced diets.

Spinach is commonly consumed both raw, in salads and sandwiches, and cooked in stews, soups, and other dishes. While raw consumption preserves its nutritional quality, it also increases the likelihood of transmitting pathogens and parasites if proper hygiene is not observed during farming, harvesting, and preparation (Erickson & Doyle, 2022). The large surface area and uneven leaf structure of spinach make it particularly prone to retaining contaminated irrigation water, soil particles, and animal manure. These factors create favorable conditions for the survival and adherence of parasitic organisms. Several studies have reported the presence of intestinal parasites on spinach leaves. Protozoan parasites such as *Giardia lamblia*, *Entamoeba histolytica*, and *Cryptosporidium spp.* have been isolated from leafy vegetables, often linked to contaminated irrigation water and poor handling practices (Dorny *et al*., 2020). In addition, helminth eggs such as *Ascaris lumbricoides*, *Trichuris trichiura*, and *Strongyloides stercoralis* can attach to spinach leaves, especially when untreated wastewater or animal manure is used in farming (Uga *et al*., 2020). Such contamination represents a significant route for the transmission of parasitic infections to humans.

Public Health Implications

Consumption of spinach contaminated with parasites poses serious health risks. Infections may result in gastrointestinal symptoms such as diarrhea, abdominal pain, and malnutrition, particularly affecting children, pregnant women, and immunocompromised individuals. Chronic parasitic infections can contribute to anemia and growth retardation due to nutrient malabsorption (Dorny *et al*., 2020). Outbreaks of foodborne illness associated with spinach and other leafy greens underscore the importance of addressing contamination risks in vegetable production and distribution.

Figure 2.1: Spinach Leaf (*Spinacia oleracea*)

2.2.2 SCENT LEAF: Scent leaf (*Ocimum gratissimum*), a member of the Lamiaceae family, is an aromatic leafy vegetable widely cultivated and consumed in tropical and subtropical regions, particularly in Africa and Asia. In Nigeria, it is a popular household vegetable, used both as a spice and for its medicinal value. Like other leafy vegetables, scent leaf contributes significantly to nutrition but may also be a vehicle for parasitic contamination when exposed to unhygienic agricultural and market practices. Scent leaf is rich in vitamins (A, C, and E), minerals (calcium, phosphorus, magnesium, and iron), and dietary fiber (Oluwole *et al*., 2023). It also contains essential oils such as **eugenol, thymol, and ocimene**, which contribute to its characteristic aroma and antimicrobial properties (Akinmoladun *et al*., 2018). Traditionally, scent leaf is used in the management of ailments such as cough, diarrhea, malaria, and respiratory tract infections due to its antibacterial, antifungal, and anti-inflammatory activities (Nwinyi *et al*., 2020). Its bioactive compounds make it not only a nutritional source but also a medicinally relevant plant.

Scent leaf is commonly consumed fresh, either as a vegetable in soups and stews, or as a flavoring agent in sauces. Its tender leaves and rough surfaces, however, make it prone to retaining contaminated water, dust, and soil particles. When grown with untreated manure or irrigated with wastewater, scent leaf can harbor parasites that pose risks to human health (Uga *et al*., 2020). Since it is often consumed with minimal cooking, improper washing increases the chances of parasitic transmission. Research indicates that leafy vegetables, including scent leaf, can act as carriers for intestinal parasites such as *Ascaris lumbricoides*, *Trichuris trichiura*, *Strongyloides stercoralis*, and protozoans like *Giardia lamblia* and *Entamoeba histolytica* (Dorny *et al*., 2009). These parasites are often introduced through contaminated irrigation water, poor sanitation, or unhygienic handling during harvesting and marketing. For scent leaf, open market practices where leaves are exposed to flies, dust, and handling by multiple vendors further increase contamination risks.

Public Health Implications

Consumption of parasite-contaminated scent leaf can lead to gastrointestinal infections, diarrhea, abdominal pain, and malnutrition. Children, pregnant women, and immunocompromised individuals are particularly vulnerable. Chronic infection with helminths can also result in anemia and reduced productivity in affected populations (WHO, 2020). Although scent leaf contains natural antimicrobial compounds, these bioactives are not sufficient to eliminate parasitic contamination acquired from the environment.

Figure 2.2: Curry Leaf (*Ocimum gratissimum*)

2.2.3 PUMPKIN LEAF: Pumpkin leaf (*Telfairia occidentalis*), locally known in Nigeria as "ugu," is one of the most widely consumed leafy vegetables in West Africa. It belongs to the Cucurbitaceae family and is valued for its rich nutritional profile and medicinal importance. Pumpkin leaf is a common ingredient in soups, stews, and other traditional dishes. However, like other leafy vegetables, it is susceptible to contamination by parasites through cultivation, handling, and marketing processes. Pumpkin leaf is a powerhouse of essential nutrients. It is rich in vitamins A, C, and E, which are vital for immune function, vision, and antioxidant defense (Oguntona & Akinyele, 2021). It also provides minerals such as iron, calcium, potassium, magnesium, and phosphorus that support blood formation, bone health, and metabolic processes (Akubugwo *et al*., 2020). Pumpkin leaf is also high in protein compared to many other leafy vegetables, making it an important source of plant-based amino acids.

In traditional medicine, pumpkin leaf has been used to manage anemia, boost fertility, and improve general body strength due to its high iron and folate content (Nwanna *et al*., 2008). Its phytochemicals, including flavonoids and phenolic compounds, further provide antioxidant and anti-inflammatory benefits.

Pumpkin leaf is usually consumed cooked, but in some cases, it may be added fresh to soups or smoothies. The broad and tender surface of its leaves, combined with frequent exposure to soil, irrigation water, and organic fertilizers, makes pumpkin leaf prone to harboring parasites (Odu & Akujobi, 2022). In open markets, pumpkin leaves are often displayed in baskets or on bare surfaces where dust, flies, and repeated handling increase the risk of contamination. Like other leafy vegetables, pumpkin leaf can serve as a carrier for intestinal parasites. Studies have shown that parasites such as *Ascaris lumbricoides*, *Trichuris trichiura*, *Hookworm spp.*, and protozoans like *Entamoeba histolytica* and *Giardia lamblia* can contaminate pumpkin leaves, especially when grown under poor sanitary conditions (Dorny *et al*., 2020; Damen *et al*., 2020). The rough surface of the leaf may facilitate attachment of parasitic eggs, cysts, and larvae, making thorough washing critical before consumption.

Public Health Implications

The consumption of contaminated pumpkin leaves may lead to parasitic infections characterized by diarrhea, abdominal cramps, anemia, and malnutrition. Children and pregnant women are particularly at risk, as nutrient loss due to parasitic infection can affect growth, immunity, and maternal health. The presence of parasites in pumpkin leaf undermines its nutritional benefits and highlights the dual role of leafy vegetables as both health promoters and potential sources of infection (WHO, 2020).

Figure 2.3: Pumpkin leaf (*Telfairia occidentalis*)

2.3.4 WATER LEAF: Waterleaf (*Talinum triangulare*), a member of the Portulacaceae family, is a common leafy vegetable widely cultivated and consumed in tropical regions of Africa, Asia, and South America. In Nigeria, it is popularly used in soups and stews such as "edikaikong" due to its tender leaves, succulent stems, and high-water content. Despite its nutritional benefits, waterleaf is highly susceptible to microbial and parasitic contamination because of its delicate texture and frequent exposure to environmental factors during cultivation and marketing. Waterleaf is a rich source of vitamins A, C, and E, which provide antioxidant protection, improve vision, and strengthen the immune system (Kayode *et al*., 2020). It also contains essential minerals such as calcium, iron, potassium, and magnesium, as well as dietary fiber that aids digestion and supports bowel health (Ekpo & Eddy, 2020). Additionally, waterleaf has been reported to contain phytochemicals like **saponins, flavonoids, and alkaloids** that contribute to its medicinal value. Traditionally, it is used in managing anemia, high blood pressure, and cognitive decline (Akinmoladun *et al*., 2023).

Waterleaf is usually consumed cooked, although in some local settings it may be used raw in salads or juiced for medicinal purposes. Its soft, water-rich leaves and fragile surfaces readily retain soil particles, irrigation water, and organic manure residues. Furthermore, when displayed in open markets, waterleaf is often exposed to flies, dust, and repeated human contact, which increases the risk of contamination (Odu & Akujobi, 2012). Since it is harvested close to the ground, waterleaf is more prone to contamination compared to some other leafy vegetables. Waterleaf has been identified as a potential carrier of intestinal parasites including *Ascaris lumbricoides*, *Trichuris trichiura*, *Strongyloides stercoralis*, and protozoans such as *Entamoeba histolytica* and *Giardia lamblia* (Damen *et al*., 2007). The high moisture content of the leaves provides a favorable environment for the survival of parasitic cysts and eggs, especially when irrigation water is contaminated with sewage or when animal manure is used as fertilizer. Parasite survival is further enhanced by the delicate leaf structure, which retains contaminants even after rinsing.

Public Health Implications

Consumption of waterleaf contaminated with parasites can lead to gastrointestinal disorders, diarrhea, and abdominal pain. Helminth infections may cause malnutrition and anemia, particularly in children and women of reproductive age, due to impaired nutrient absorption. In addition, protozoan infections acquired through contaminated waterleaf may lead to prolonged illness and, in severe cases, complications in immunocompromised individuals. Thus, waterleaf represents both a valuable dietary vegetable and a significant public health concern when not properly handled.

Figure 2.4: Water leaf (*Talinum triangulare*)

2.1.1 NUTRITIONAL VALUES AND HEALTH BENEFITS OF VEGETABLES

Nutritional value refers to the quantity and bioavailability of essential nutrients—such as macronutrients, micronutrients, and bioactive compounds—contained in food, which are necessary for human growth, development, and the preservation of health (Slavin & Lloyd, 2022).

Nutritional profile of some common leafy vegetables. Values are approximate per 100 g of raw leaves, and can vary by variety, soil, and season.

NUTRITIONAL VALUE OF SELECTED LEAFY VEGETABLES

Leafy Vegetable	**Calories (kcal)**	**Key Vitamins**	**Key Minerals**	**Other Notes**
Spinach (*Spinacia oleracea*)	~23	Very high in Vit. A (469 µg), Vit. C (28 mg), Vit. K (483 µg), Folate	Iron (2.7 mg), Magnesium (79 mg), Calcium (99 mg)	Rich in lutein & zeaxanthin (eye health), contains oxalates that reduce calcium/iron absorption
Lettuce (*Lactuca sativa*)	~15	Vit. A (25 µg), Vit. C (9 mg), Vit. K (126 µg), Folate	Potassium (194 mg), Calcium (36 mg)	Low calorie, hydrating (95% water), best for salads
Kale (*Brassica oleracea* var. *acephala*)	~35	Very high Vit. A (241 µg), Vit. C (93 mg), Vit. K (389 µg)	Calcium (150 mg), Potassium (491 mg), Magnesium (47 mg)	High antioxidant capacity (glucosinolates, flavonoids)
Amaranth leaves (*Amaranthus spp.*)	~23	Vit. A (291 µg), Vit. C (43 mg), Folate	Iron (2.3 mg), Calcium (215 mg), Magnesium (55 mg)	Traditional African leafy veg, rich in fiber and protein

Leafy Vegetable	**Calories (kcal)**	**Key Vitamins**	**Key Minerals**	**Other Notes**
Fluted pumpkin (*Telfairia occidentalis*)	~38	Vit. A, Vit. C, Folate	Iron (3.5 mg), Calcium (120 mg)	Popular in Nigeria ("Ugwu"), noted for blood-boosting effect
Jute mallow (*Corchorus olitorius*)	~37	Vit. A (350 µg), Vit. C (52 mg)	Calcium (184 mg), Iron (3.8 mg), Potassium (444 mg)	Mucilaginous, improves digestion; antioxidant-rich
Bitterleaf (*Vernonia amygdalina*)	~50	Vit. A, Vit. C	Iron, Calcium, Potassium	Bitter taste; ethnomedicinal properties (anti-malarial, anti-diabetic)
Waterleaf (*Talinum triangulare*)	~30	Vit. A, Vit. C, Vit. E	Iron, Magnesium, Calcium	Succulent, contains omega-3 fatty acids and soluble fiber

Health benefit describes the advantageous physiological outcomes or protective effects against disease that arise from the consumption of foods, nutrients, or adherence to specific dietary patterns, such as reducing the risk of non-communicable diseases, supporting metabolic health, and promoting overall well-being (Cena & Calder, 2020).

1) Rich in Micronutrients: Provide vitamins A, C, K, and folate, which support vision, immunity, blood clotting, and cell growth. Minerals such as calcium, magnesium, potassium, and iron help in bone health, blood pressure regulation, and oxygen transport. Dark green vegetables like kale and amaranth are excellent sources of calcium, vitamin K, and antioxidants, contributing to bone health and immune support (Aune *et al*., 2017).

2) Support Digestive Health: High in **dietary fiber**, both soluble and insoluble. Fiber improves bowel movement, prevents constipation, and supports a healthy gut microbiome. In West Africa, indigenous vegetables such as fluted pumpkin (*Telfairia occidentalis*), jute mallow (*Corchorus olitorius*), and bitter leaf (*Vernonia amygdalina*) are widely consumed for their nutritional and medicinal properties (Odiaka, Akoroda, & Odiaka, 2008).

3) Cardiovascular Protection: Leafy greens are abundant in nitrates, which improve blood vessel function and lower blood pressure. Antioxidants (like carotenoids and flavonoids) help reduce oxidative stress and lower risk of heart disease. Regular consumption of leafy greens is associated with improved cardiovascular outcomes due to their nitrate and fiber content (Wang *et al*., 2021).

4) Weight Management and Metabolic Health: Very low in calories and fat but high in volume and water content → promote satiety. Assist in regulating blood sugar levels and reducing the risk of type 2 diabetes. Other health benefits includes **Bone and Blood Health , Immune System Support, Anti-inflammatory and Antioxidant Effects** for which some contain bioactive compounds (polyphenols, carotenoids, glucosinolates) that reduce inflammation and protect against chronic diseases like cancer.

2.2.1.1 Pharmacological Health Benefit of leafy vegetable

1) Cardiovascular and Blood Pressure

High blood pressure (BP) affects more than 1 billion adults worldwide and represents the leading risk factor for cardiovascular disease (1). High-normal BP is defined as a systolic BP (SBP) of 130–139 and/or diastolic BP (DBP) 85–89 mm Hg and grade 1 hypertension as SBP 140–159 mmHg and/or DBP 90–99 mm Hg, according to guidelines frothed European Society of Cardiology.

Leafy vegetables such as spinach (*Spinacia oleracea*), scent leaf (*Ocimum gratissimum*), pumpkin leaf (*Telfairia occidentalis*), and waterleaf (*Talinum triangulare*) contain bioactive compounds that influence blood pressure regulation, lipid metabolism, endothelial function, and oxidative stress, thereby contributing to cardiovascular health. Spinach is rich in nitrates, which are converted to nitric oxide in the body, leading to vasodilation and improved blood flow. Studies have shown that dietary nitrate intake from spinach reduces blood pressure and enhances endothelial function (Lidder & Webb, 2023). Spinach also provides antioxidants such as lutein and β-carotene, which reduce oxidative stress and inflammation, processes linked to atherosclerosis. Its magnesium and potassium content further support heart rhythm regulation and blood pressure control (Slavin & Lloyd, 2022). Scent leaf contains essential oils such as *eugenol and thymol,* which possess vasorelaxant and anti-inflammatory properties (Nwinyi *et al*., 2009). The antioxidant activity of its flavonoids and phenolic compounds helps prevent oxidative damage to blood vessels, thereby reducing the risk of hypertension and vascular stiffness (Akinmoladun *et al*., 2018). Animal studies have also indicated hypolipidemic effects of scent leaf, with reductions in serum cholesterol and triglycerides (Oluwole *et al*., 2013). These effects suggest its protective role against cardiovascular complications.

2) Cancer

Their anti-cancer properties are largely attributed to antioxidants, phytochemicals, dietary fiber, and micronutrients that modulate oxidative stress, inflammation, and cell proliferation. Spinach (*Spinacia oleracea*) is rich in carotenoids such as lutein and β-carotene, which act as antioxidants and reduce DNA damage, thereby lowering cancer risk (Slavin & Lloyd, 2022). It also contains flavonoids that inhibit tumor growth and protect against oxidative stress (Liu, 2023). Scent leaf (*Ocimum gratissimum*) contains essential oils such as eugenol and thymol, as well as phenolic compounds, which exhibit cytotoxic effects on cancer cells and suppress tumor-promoting pathways (Akinmoladun *et al*., 2018). Its strong antioxidant activity helps neutralize free radicals implicated in carcinogenesis. Pumpkin leaf (*Telfairia occidentalis*) has been shown to contain flavonoids and phenolic acids with chemopreventive potential. These compounds scavenge free radicals, reduce lipid peroxidation, and modulate enzymes involved in carcinogen metabolism (Nwanna *et al*., 2020). Waterleaf (*Talinum triangulare*) also demonstrates anti-cancer potential through its high vitamin C, flavonoid, and saponin content. These phytochemicals prevent oxidative DNA damage and induce apoptosis in abnormal cells, offering protective effects against colorectal and other cancers (Akinmoladun *et al*., 2021).

3) Diabetes

Diabetes mellitus is a global health concern that is characterized as a non-communicable disease, and it has been estimated that by 2025, about 300 million individuals may be affected. Leafy green vegetables are rich in minerals, flavonoids, α-linolenic acid, alpha-tocopherols, and other phytochemicals, as well as in vitamins. Epidemiological research proved that women who consumed green leafy vegetables daily had minimized risks of developing diabetes of type 2 (Tahreem *et al*., 2020). The protection against this disease is attributed in part to the content of magnesium in such vegetables, as it has been shown that consumption of magnesium lowers the risk of diabetes of type 2 (Tahreem *et al*., 2020).

4) Weight

Phytochemicals in leafy vegetables also contribute to **metabolic regulation.** Compounds such as flavonoids and carotenoids improve insulin sensitivity and lipid metabolism, reducing fat accumulation and lowering obesity risk (Liu, 2023). Moreover, the potassium and magnesium content of these vegetables support fluid balance and reduce bloating, which can aid in body weight maintenance.

5) Gastrointestinal Health

Dietary fiber in vegetables exists as soluble and insoluble forms. Insoluble fiber, found in spinach and pumpkin leaves, adds bulk to stool, accelerates intestinal transit, and helps prevent constipation (Anderson *et al*., 2020). Soluble fiber, abundant in waterleaf (*Talinum triangulare*), absorbs water to form a gel-like substance, which improves stool consistency and relieves conditions such as constipation and hemorrhoids (Slavin, 2023). Leafy vegetables also support a healthy gut microbiota. Fiber and phytochemicals act as prebiotics, promoting the growth of beneficial bacteria such as *Bifidobacterium* and *Lactobacillus*, which enhance digestion and protect against pathogenic organisms (Flint *et al*., 2022). Scent leaf (*Ocimum gratissimum*), due to its essential oils (eugenol and thymol), further exhibits antimicrobial activity against harmful gut pathogens, contributing to intestinal balance (Nwinyi *et al*., 2020).

Indesgitble fibre, found in vegetables absorbs water and expands as it travels through the digestive. By causing regular bowel movements, this can ease the symptoms of an irritable bowell and treat or avoid constipation (Marsu *et al*., 2023).

6) Vision

One of the key compounds found in leafy greens such as spinach (*Spinacia oleracea*) and kale (*Brassica oleracea var. sabellica*) is **lutein** and **zeaxanthin**, carotenoids that accumulate in the retina, especially the macula, where they filter harmful blue light and reduce oxidative stress. This protects against age-related macular degeneration (AMD) and cataracts (Johnson, 2014). Vitamin A, obtained from leafy vegetables through its precursor **β-carotene**, is essential for the formation of rhodopsin, a pigment in the retina that is critical for night vision. Deficiency in vitamin A can cause night blindness and other ocular complications (West *et al*., 2020). Waterleaf (*Talinum triangulare*) and pumpkin leaf (*Telfairia occidentalis*) are also rich in vitamin C and E, which act as antioxidants, preventing oxidative damage to eye tissues and reducing the risk of cataracts (Slavin & Lloyd, 2022). Scent leaf (*Ocimum gratissimum*), with its antioxidant phytochemicals, further contributes to protecting retinal cells from oxidative stress and inflammation, thereby supporting overall visual function (Akinmoladun *et al*., 2018).

2.3 FARMING PROCESS

2.3.1 CULTIVATION

Since the beginning of time, humans have consumed vegetables. Some foods are staples, but the majority of foods are accessories that vary meals with their distinctive flavours while also supplying essential nutrients for wellness (Britannica, 2021). Most vegetables are annuals or biennials, usually harvested a year after planting or sowing (Britannica, 2021). Some vegetables are perennials. Whatever method is used to cultivate crops, the process is the same: the soil is prepared by loosening it, removing or burying weeds, and adding organic manures or fertilisers; seeds are sown or young plants are planted; the crop is tended as it grows to reduce weed competition, control pests, and provide enough water; the crop is harvested when it is ready; and then it is sorted, stored, and marketed or eaten fresh from the ground (Britannica, 2021).

Different soil types are better suited for different crops, but generally speaking in temperate regions, sandy soils are more suited for early crops because they dry out rapidly but warm up quickly in the spring, while heavy clays are better suited for late-season crops because they better hold moisture. By using fleece, cloches, plastic mulch, polytunnels, and greenhouses, the growing season can be extended (Britannica, 2021).

The climate, notably the pattern of rainfall, affects vegetable output in hotter areas whereas temperature and day length affect it in temperate areas (Britannica, 2021). The preferred tools on a residential scale are the spade, fork, and hoe, although a variety of automated equipment is available on commercial farms. In addition to tractors, these include harvesters, transplanters, cultivators, drills and irrigation equipment (Rickman *et al*., 2020). With computer monitoring systems, GPS locators and self-steer programmes for driverless machinery providing economic benefits, new techniques are revolutionizing the cultivation operations involved in growing vegetables (Thompson *et al*., 2020).

2.3.2 HARVESTING

When a vegetable is harvested, it is cut off from its source of water and nourishment. It continues to transpire and loses moisture as it does so, a process most noticeable in the wilting of green leafy crops (Britannica, 2021). Harvesting root vegetables when they are fully mature improves their storage life, but alternatively, these root crops can be left in the ground and harvested over an extended period (Britannica, 2021).

The harvesting process should seek to minimize damage and bruising to the crop. Onions and garlic can be dried for a few days in the field and root crops such as potatoes benefit from a short maturation period in warm, moist surroundings, during which time wounds heal and the skin thickens up and hardens (Britannica, 2021). Before marketing or storage, grading needs to be done to remove damaged goods and select produce according to its quality, size, ripeness and color (Britannica, 2021).

2.3.3 STORAGE

All vegetables benefit from proper post-harvest care. A large proportion of vegetables and perishable foods are lost after harvest during the storage period (Britannica, 2021). These losses may be as high as thirty to fifty percent in developing countries where adequate cold storage facilities are not available. The main causes of loss include spoilage caused by moisture, moulds, micro-organisms, and vermin (Britannica, 2021). Storage can be short-term or long-term. Most vegetables are perishable and short-term storage for a few days provides flexibility in marketing. During storage, leafy vegetables lose moisture, and the vitamin C in them degrades rapidly. A few products such as potatoes and onions have better keeping qualities and can be sold when higher prices may be available, and by extending the marketing season, a greater total volume of crop can be sold. If refrigerated storage is not available, the priority for most crops is to store high-quality produce, to maintain a high humidity level, and to keep the produce in the shade (Britannica, 2021).

2.3.4 PRESERVATION

Proper post-harvest storage aimed at extending and ensuring shelf life is best ensured by efficient cold chain application (Britannica, 2021). Cold storage is particularly useful for vegetables such as cauliflower, eggplant, lettuce, radish, spinach, potatoes, and tomatoes, the optimum temperature depending on the type of produce (Britannica, 2021). There are temperature-controlling technologies that do not require the use of electricity such as evaporative cooling (Britannica, 2021). Storage of fruit and vegetables in controlled atmospheres with high levels of carbon dioxide or high oxygen levels can inhibit microbial growth and extend storage life (Thompson *et al*., 2010). The irradiation of vegetables and other agricultural produce by ionizing radiation can be used to preserve it from both microbial infection and insect damage, as well as from physical deterioration. It can extend the storage life of food without noticeably changing its properties (Thompson *et al*., 2020).

Rain and attack by rodents, birds, and insects. These disadvantages can be alleviated by using solar powered driers (Thompson *et al*., 2020). High concentrations of salt and sugar can preserve food by limiting the growth of microorganisms. The pods of green beans can be salted by piling salt on top of them, although most vegetables cannot be preserved in this way. Jams can be made by boiling marrows, beets, carrots, and various other vegetables with sugar (Thompson *et al*., 2010). A sufficient quantity of acetic acid prevents the formation of harmful microorganisms, a fact employed in the creation of pickles, chutneys, and relishes (Rickman *et al*., 2020). Fermentation is another method of preserving vegetables for later use. Sauerkraut is made from chopped cabbage and relies on lactic acid bacteria which produce compounds that are inhibitory to the growth of other microorganisms (Thompson *et al*., 2020). As shown in Figure 2.3, the image of varieties of vegetables (Britannica, 2021).

Helminths live in the intestine and their eggs are passed in the feces of infected persons (CDC, 2020). If an infected person defecates outside (near bushes, in a garden, or field) or if the feces of an infected person are used as fertilizer, eggs are deposited on soil (CDC, 2020). Ova of Ascaris lumbricoides and hookworm eggs become infective as they mature in soil. People are infected with Ascaris and whipworm when the eggs are ingested (CDC, 2020). This can happen when hands or fingers that have contaminated dirt on them are put in the mouth or by consuming vegetables and fruits that have not been carefully cooked, washed or peeled (CDC, 2020). Hookworm eggs are not infective (CDC, 2020). They hatch in soil, releasing larvae (immature worms) that mature into a form that can penetrate the skin of humans (CDC, 2020). Hookworm infection is transmitted primarily by walking barefoot on contaminated soil (CDC, 2020). One kind of hookworm (Ancylostoma duodenale) can also be transmitted through the ingestion of larvae (CDC, 2020).

2.4 SOME COMMON INTESTINAL HELMINTHES AND PROTOZOA: AN EMPIRICAL REVIEW

Soil-transmitted helminths refer to the intestinal worms infecting humans that are transmitted through contaminated soil ("helminth" means parasitic worm): *Ascaris lumbricoides*, whipworm (*Trichuris trichiura*), and hookworm (*Ancylostoma duodenale* and *Necator americanus*) (CDC, 2020). An estimated third of the world population is infected with one or multiple of these soil-transmitted helminths: 807–1,121 million with *Ascaris lumbricoides*, 604–795 million with whipworm, and 576–740 million with hookworm (CDC, 2020).

2.4.1.1 *Ascaris lumbricoides*

According to Fahim et al. (2018), Ascaris lumbricoides infects over one billion individuals worldwide and kills over 60,000 each year. It mostly affects tropical and subtropical nations worldwide, with Sub-Saharan Africa, Latin America, China, and East Asia being frequent reporting regions (Darlington *et al*., 2018). Sadly, it is a neglected tropical disease that is thought to result in a loss of 1.2 to 1.5 years of life with a disability (Zakzuk *et al*., 2018). When the host consumes eggs located in feces-infested soil or infected fruits and vegetables, an infection result. Pneumonitis and eosinophilia can be visible, as well as a considerable number of larvae travelling through the lung (also known as the Loeffler syndrome). Wheezing, dyspnea, coughing, hemoptysis, and fever are among the symptoms (Adu-Gyasi *et al*., 2018). According to Sharman *et al*., (2017), an adult parasite has an average lifespan of one year before dying and being naturally expelled through the digestive system. Pneumonitis and eosinophilia can be visible, as well as a considerate.

Number of larvae travelling through the lung (also known as the Loeffler syndrome). Wheezing, dyspnea, coughing, hemoptysis and fever are among the symptoms. To cause cholecystitis, cholangitis, pancreatitis, small intestinal blockage, volvulus, appendicitis, and intussusception, adult worms can move to tubular tissues during superinfection, including the biliary and pancreatic systems (Gosh *et al*., 2018). The preferred medical therapy is albendazole 400 mg given as a single dosage, followed by mebendazole 100 mg given twice daily for three days, 500 mg given as a single dose, or ivermectin 100 microgram/kg to 200 microgram/kg given once (Bharti *et al*., 2018). In cases of pregnancy, pyrantel pamoate (11 mg/kg up to a maximum of 1 g) or piperazine (50 mg/kg/day for five days or 75 mg/kg in one dosage) are provided as single doses (Wright *et al*., 2018). As shown in Figure 2.4, the Life cycle of Ascaris lumbricoides (CDC, 2020).

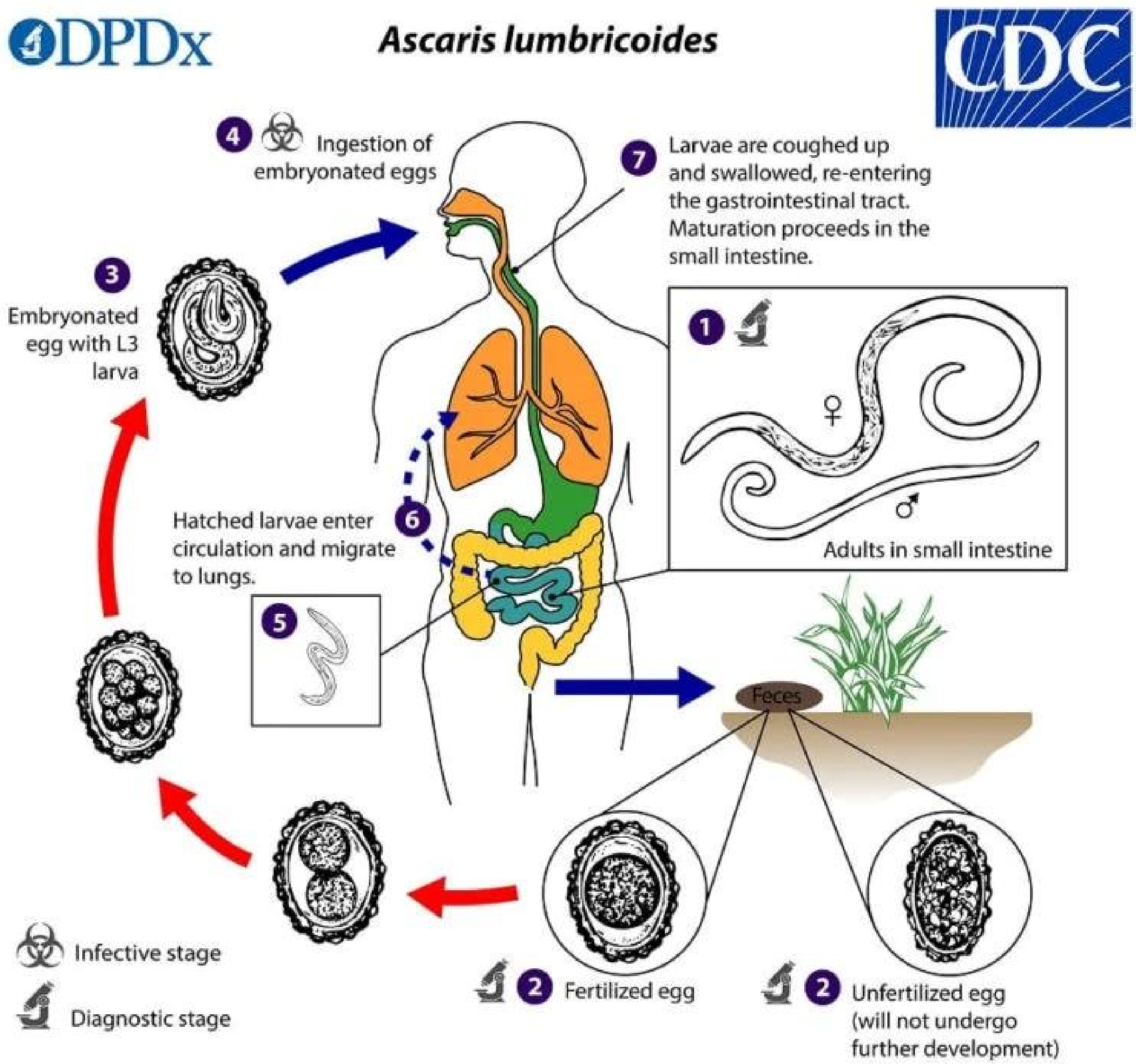


Figure 2.5: Diagram of the Life Cycle of *Ascaris lumbricoides* (CDC, 2020).

2.4.1.2 *Strongyloides Stercoralis*

Strongyloides stercoralis or threadworm is a soil-transmitted nematode parasite infecting human. The global burden of this parasite is currently underestimated even though it is virtually everywhere established except in the extreme north and south (Schär *et al.*, 2023). This is due to a lack of reliable information coming from endemic areas. Thus, in the 'neglected tropical diseases' (NTDs), *S. stercoralis* is one of the parasite infections mostly neglected (Czeresnia *et al*., 2022). Symptoms in the digestive system are diarrhoea and epigastric discomfort and vomiting. Hyperinfection syndrome presents as septicaemia and gram-negative bacteremia and fever with features of end-organ damage (ileus, hyponatremia and bleeding from the gut and hemoptysis) (Puthiyakunnon *et al*., 2024). The human infections by *Strongyloides stercoralis* often last several years. The symptoms of *Strongyloides stercoralis* infections are anorexia and diarrhoea and./constipation and abdominal pain and dyspnoea and cough (Tamarozzi *et al*., 2019). In chronic forms, respiratory and gastrointestinal symptoms are frequently modest, although dermatological features like urticaria and larva currents can still be detected. Using concentration and sedimentation techniques, light microscopy can be utilised to find *Strongyloides stercoralis* eggs and larva (Arifin *et al.*, 2019). The aim of the therapy is to get rid of the parasite irrespective of immunological status, and is appropriate for both symptomatic and asymptomatic individuals (Nutman *et al.*, 2017; Mirzaei *et al.*, 2021). Treatment options for uncomplicated strongyloidiasis include thiabendazole (25 mg/kg/day for three days) and ivermectin (200 micrograms/kg for two days), thiabendazole (25 mg/kg/day for three days), or albendazole (400 mg twice a day for 3–7 days) (Luviraage *et al.*, 2024; Page *et al*, 2018). As shown in Figure 2.5, the diagram of the Life cycle of *Strongyloides stercoralis* (CDC, 2020).

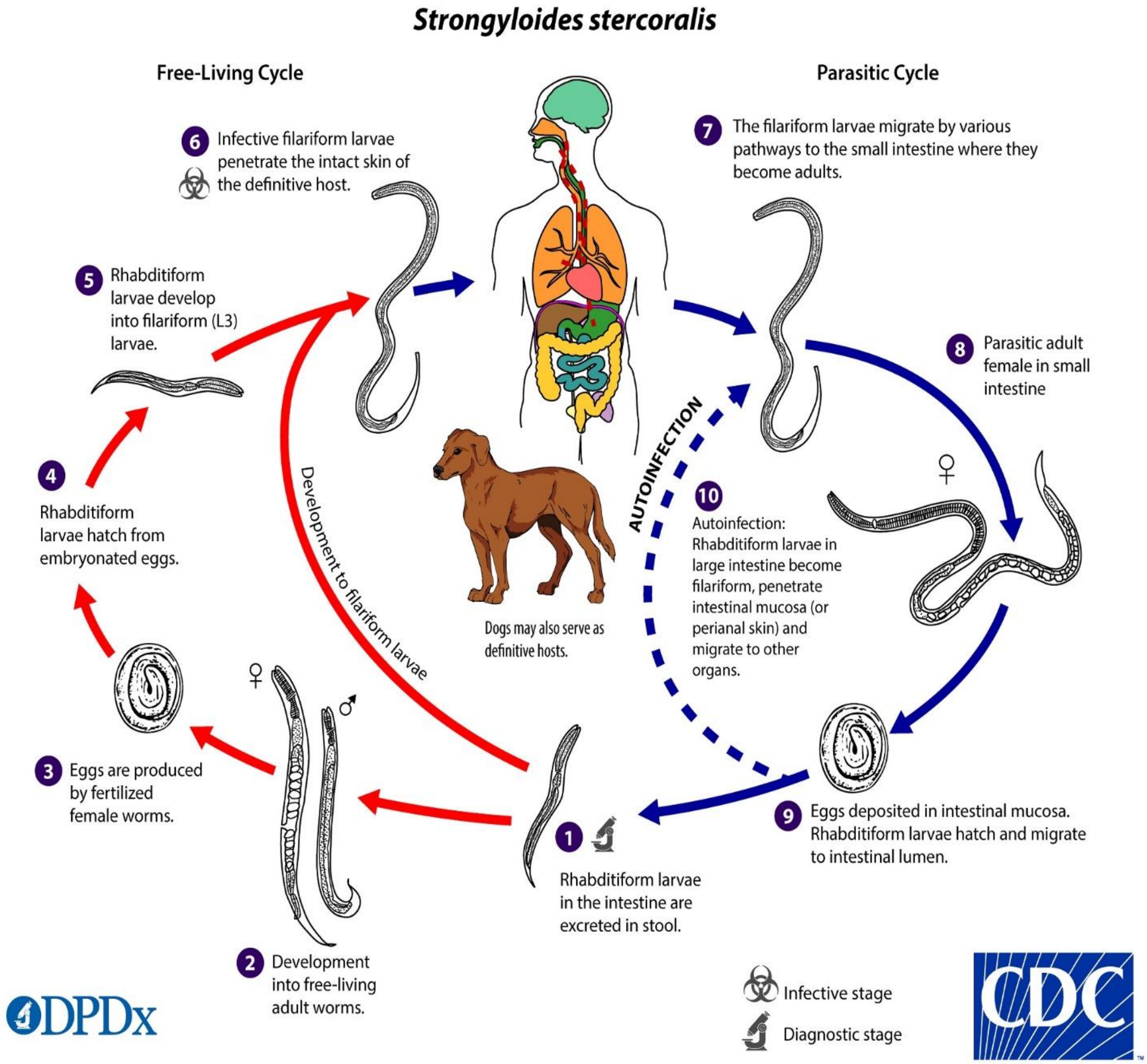


Figure 2.6: Diagram of the Life Cycle of *Strongyloides stercoralis* (CDC, 2020).

2.5.1.3 *Trichuris trichiura*

The roundworm *Trichuris trichiura*, often known as the human whipworm, causes trichuriasis in people. The reason it is called the whipworm is that it resembles a whip and has wide handles on the back end (Bansal *et al*., 2018). Most larvae travel to the cecum, enter the mucosa, and develop into adults. Distal portions of the large intestine are frequently involved in infections with a high worm burden (Bansal *et al*., 2018). The consumption of infected eggs found in soil is the most frequent cause of trichuriasis. This is frequently caused by unsanitary conditions, such as open defecation and the use of human waste as fertilizer and According to current research, individuals with specific chromosome features may be predisposed to developing trichuriasis or may be more susceptible to doing so (William-Blangero *et al*., 2018). Infected eggs are frequently consumed by a human host by ingesting contaminated food or water (Else *et al*., 2020). The larvae hatch in the small intestine after the embryonated eggs are swallowed. The anterior ends of these organisms then travel to the large intestine, where they settle within the mucosa (Bansal *et al*., 2018). As a result, cells are destroyed and the host immune system is activated, drawing in eosinophils, lymphocytes, and plasma cells. Rectal bleeding and abdominal pain are the typical symptoms that are brought on by this (Bansal *et al*., 2018).

The terminal ileum and cecum are where the parasite typically settles. The worm may be present throughout the entire colon and rectum in some cases (Else *et al*., 2020). Without treatment, the worm might survive anywhere from one to four years. Unembryonated eggs are excreted in the host's faeces. In 2–4 weeks, the eggs will become embryonated and become infectious (Else *et al*., 2020). *Trichuris trichiura* eggs and larva can be found in contaminated fruit and vegetable samples by microscopic examination (Else *et al*., 2020). The medication used to treat trichuriasis is with mebendazole or albendazole (Else *et al*.,2020). As shown in figure 2.6 the diagram of the life circle of *Trichuris trichiura* (CDC, 2020).

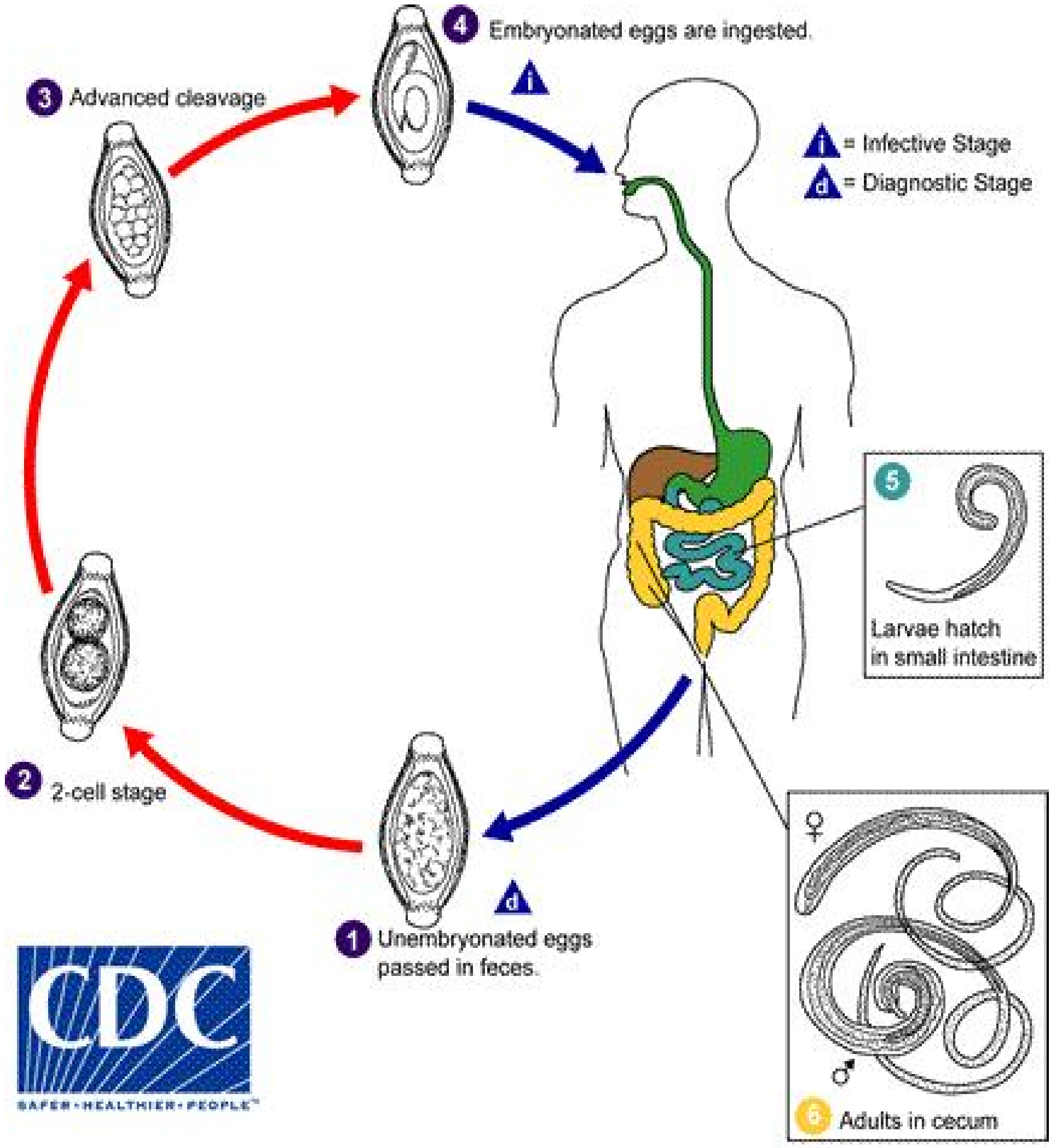


Figure 2.7: Diagram of the Life Cycle of *Trichuris trichiura* (CDC, 2020).

2.4.1.4 *Enterobius vermicularis*

Pinworm, also known as *Enterobius vermicularis*, is one of the most prevalent nematode infections in the world. Oxyuris vermicularis was the original name for *E. vermicularis* (Cook, 1994). As the only naturally occurring host for this infection, humans, transmission occurs among those who live in crowded conditions and typically within families (Cook, 1994). The name of the worm comes from the distinctive pin-like tail that is found on the posterior section of female worms. The worms are small, thread-like, and white (Markell *et al.,* 1985). The most typical method of transmission is fecal-oral. In rare cases, eggs can transmit disease through inhalation mode when they are breathed and then eaten (Yang *et al.,* 2017). The ileum and cecum are the primary habitats of the organism known as *Enterobius vermicularis*. After being consumed, *E. vermicularis* eggs take between one to two months to mature into adult worms in the small intestine (Yang *et al.,* 2017). When contained to the ileocecal region, they typically do not result in any symptoms (Yang *et al.,* 2017). The female adult worms and ova migrate to the anal area mostly at night time to deposit thousands of eggs in the perianal area (Yang *et al.,* 2017). Female genitourinary infections have also been reported in the literature (Yang *et al.,* 2017). Watery diarrhea has been reported in some patients and a superficial bacterial infection can occur at the scratching sites resulting in erythema and warmth with persistent itching can cause disturbances in sleep which may lead to insomnia (Yang *et al.,* 2017). Sometimes abdominal pain and other serious complications like appendicitis can occur due to worms blocking the lumen in the appendix or lead to inflammation around the appendix and sometimes, tiny thread-like worms may be visible to the naked eye in the perianal area (Dahlstrom *et al.,* 1994). As shown in Figure 2.7, the diagram of the Life cycle of *Enterobius vermicularis* (CDC, 2020).

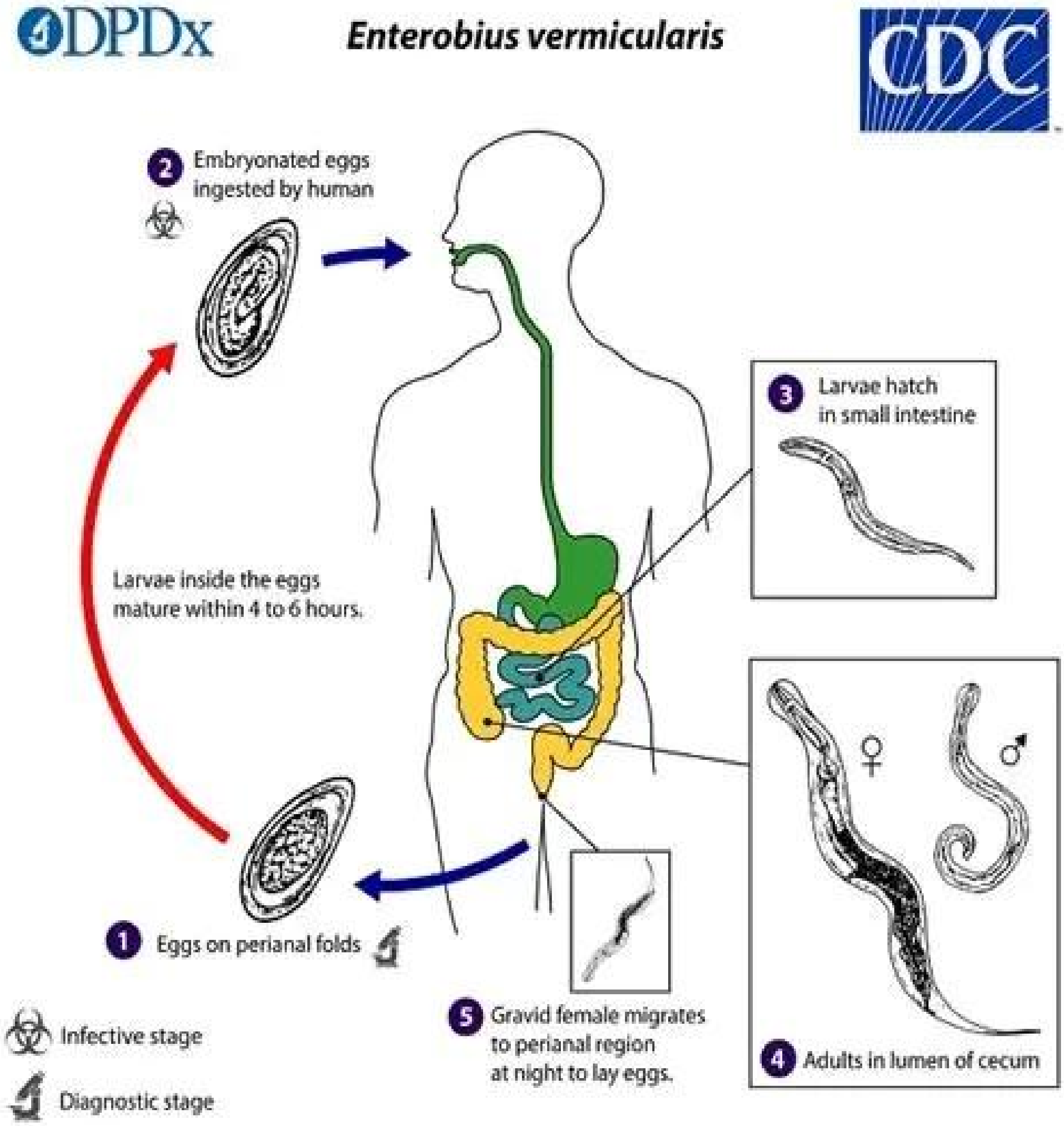


Figure 2.8: Diagram of the Life Cycle of *Enterobius vermicularis* (CDC, 2020).

2.4.1.5 Hookworm

Hookworms are nematode parasites that are typically spread through contaminated fertiliser and infested soil used to grow fruits and vegetables (Loukas *et al.,* 2016). Two species, *Ancylostoma duodenale* and *Necator americanus*, are primarily responsible for human infections and typically afflict the most vulnerable people in tropical and subtropical regions (Feldmeier *et al.,* 2012; Wei *et al.,* 2017). The major feature of hookworm infection is iron deficiency anemia secondary to blood loss, either through direct parasite consumption or blood leakage from the parasite attachment site to the gut (Loukas *et al.,* 2017). Additionally, hypoalbuminemia might lead to edema formation and generalized anasarca (Jourdan *et al.,* 2018). Occasionally, some patients crave soil and ingest dirt (geophagia) (Loukas *et al.,* 2016). Clinical features of hookworm infections are usually non-specific and could be misleading. Proper understanding of the epidemiology, clinical features, and laboratory findings is crucial in diagnosis (Jourdan *et al.,* 2018). Light microscopy can be used to view the eggs or larva of Hookworm in contaminated vegetables. The main drugs used for hookworm infections are mebendazole and albendazole. Data support 400mg single-dose albendazole therapy over a 500mg single dose of mebendazole (Pearson *et al.,* 2012). Three consecutive daily doses of either drug demonstrate superior cure and egg reduction rates, but it is less convenient for mass treatment campaigns (Wu *et al.,* 2016). Alternatively, a 3-day regimen of 100mg twice daily, mebendazole, is suitable for stable uncomplicated cases. Also, pyrantel pamoate 11 mg/kg (up to a maximum of 1 g) orally daily for three days could be an option (Loukas *et al.,* 2016). As shown in Figure 2.8, the diagram of the Life cycle of Hookworm (CDC, 2020).

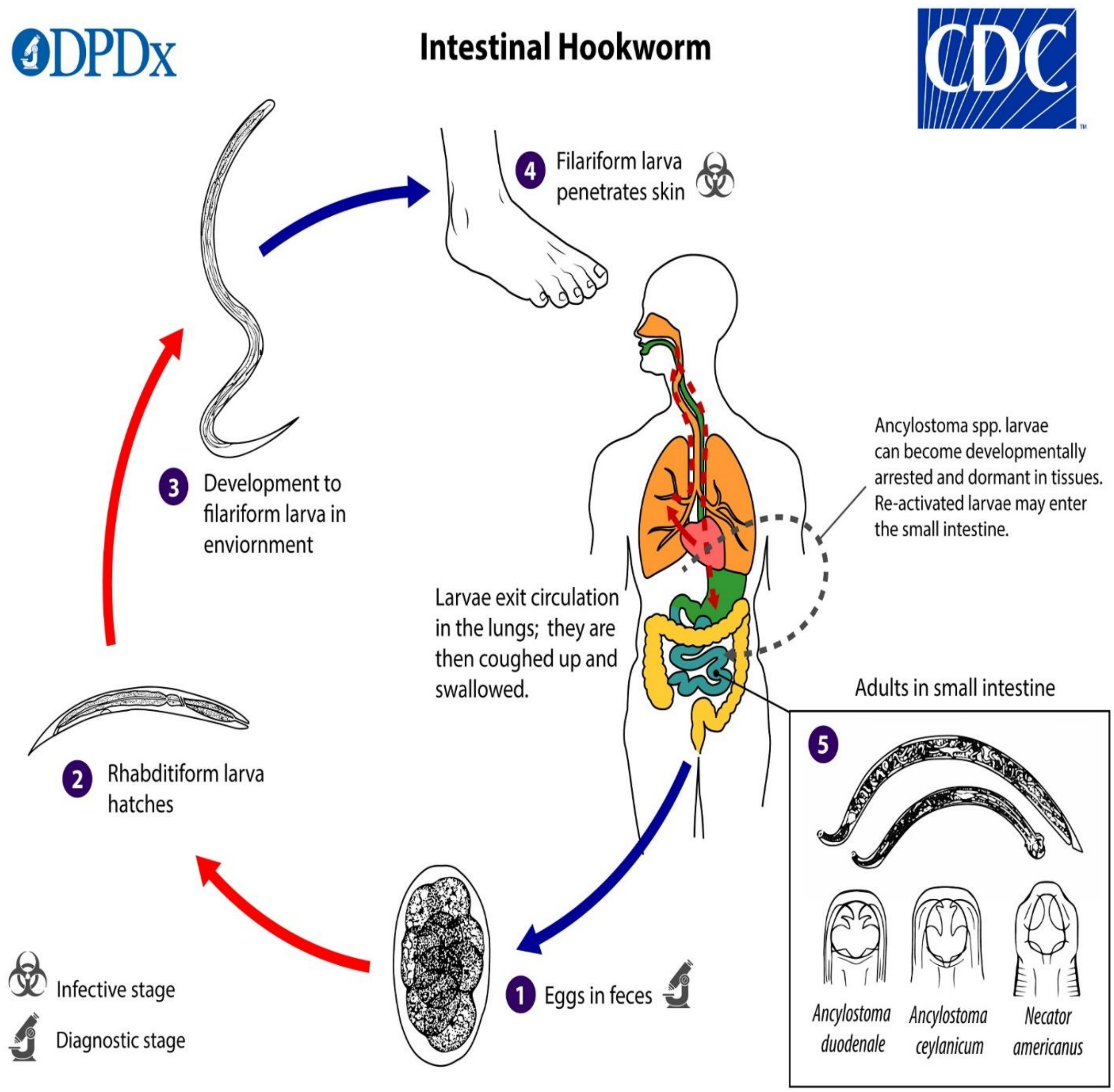


Figure 2.9: Diagram of the Life Cycle of Hookworm (CDC, 2020).

2.4.2 CONTAMINATION OF LEAFY VEGETABLES WITH INTESTINAL PROTOZOAN PARASITES

2.4.2.1 *Cryptosporidium* species

The second most frequent cause of diarrhoea in children after rotavirus is a widespread protozoan parasite called *Cryptosporidium* species (Bouziad *et al.,* 2018). There are currently 38 species divided by at least 60 genotypes of the parasite *Cryptosporidium*, which is characterised by its vast genetic variety (Feng *et al.,* 2018). According to Khan *et al.,* (2018) there are at least 20 different species that can cause mild or severe infections in people, with *Cryptosporidium hominis* and *Cryptosporidium parvum* serving as the primary culprits. Light microscopy is straightforward, practical, and a direct method for detecting *Cryptosporidium* oocysts in vegetable and fruit samples; however, it requires a high level of expertise to interpret the slides whereas an immunofluorescence assay is routine and more sensitive (Ahmed *et al.,* 2018). For effective detection, oocysts are concentrated by immunomagnetic separation (IMS) (Robertson *et al.,* 2001; Kezzatka *et al.,* 2016; Dudu *et al.,* 2018). The most accurate approach of identifying human pathogenic and zoonotic species is the PCR amplification and sequencing of particular genes of *Cryptosporidium* isolated from contaminated vegetables and fruits (Simi *et al.,* 2017). Although PCR is frequently employed in affluent nations, the majority of surveillance studies in developing countries involve microscopy (Cacciadonna *et al.,* 2017). The contamination of vegetables and fruits with *Cryptosporidium* species has been documented in many countries. Among the *Cryptosporidium* species, *C. parvum*, *C. hominis*, and *C. ubiquitum* were detected in the contaminated vegetable and fruit samples (Li *et al.,* 2019). As shown in Figure 2.9, the diagram of the Life cycle of *Cryptosporidium* species (CDC, 2020).

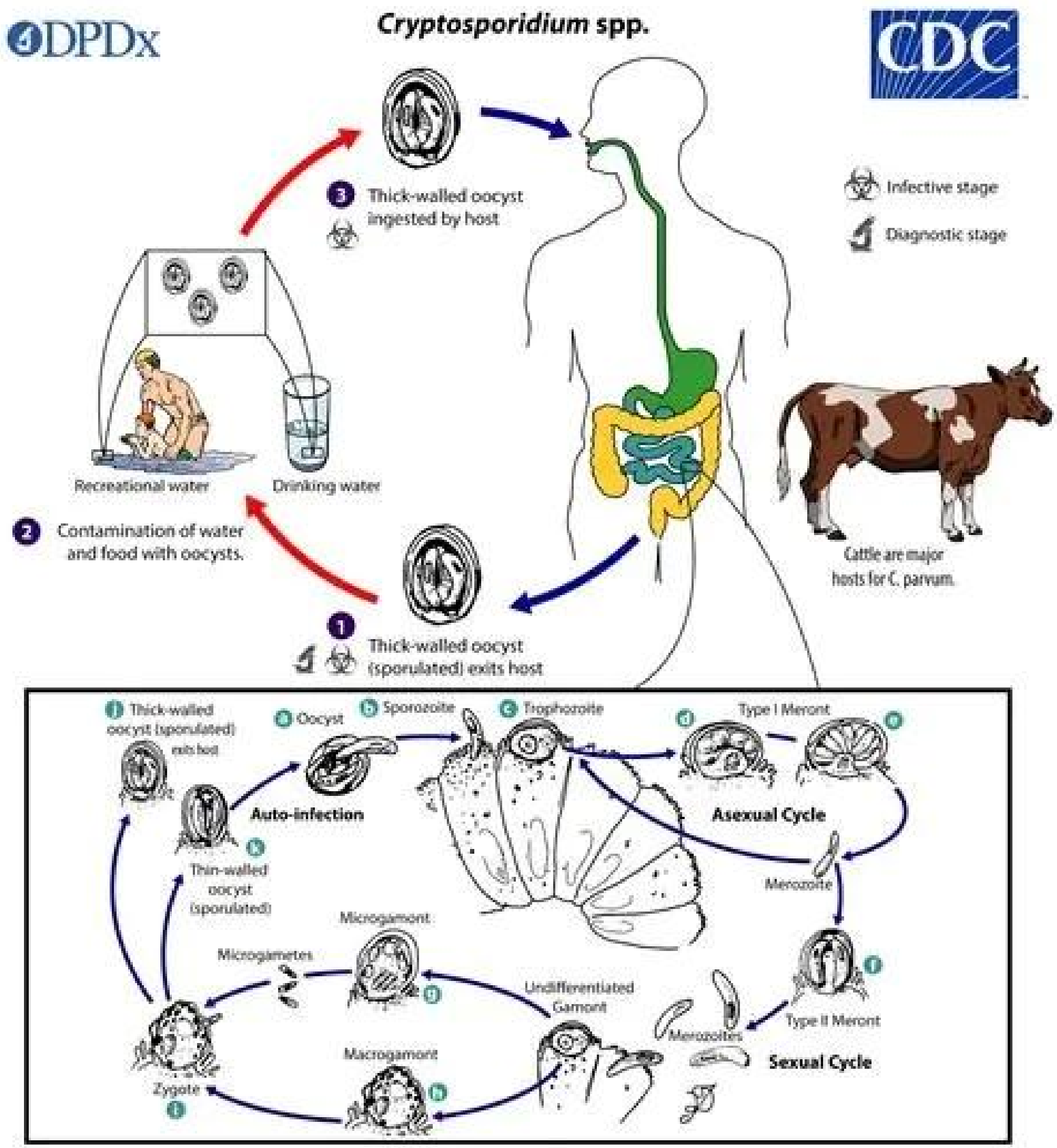


Figure 2.10: Diagram of the Life Cycle of *Cryptosporium species* (CDC, 2020).

2.4.2.2 *Giardia lamblia*

Giardia duodenalis is a non-invasive protozoan parasite that attaches to and colonises the upper small intestines, resulting in acute watery diarrhea in both people and animals (Einarsson *et al.,* 2016). *Giardia duodenalis* is also known as *Giardia intestinalis* and *Giardia lamblia*. Public health is at risk since it is a significant zoonotic protozoan and the principal cause of human giardiasis (Colli *et al.,* 2015). *Giardia duodenalis* has been classified into eight genetically different assemblages (A to H). Two zoonotic assemblages, however, are primarily unique in both humans and other animals (Sou *et al.,* 2018).

According to Ryan *et al.,* (2018), this epidemic agent is responsible for at least 280 million instances of diarrhea each year and it does not spare either developed or developing nations. *Giardia* epidemics have also been linked to several processed foods, primarily uncooked. *Giardia duodenalis* infection instances could be traced to contaminated water or parasite-laden foods. *Giardia* zoonotic epidemics have also been linked to several processed foods including fresh produce.

Light microscopy can identify *Giardia duodenalis* cysts based on their morphological characteristics (Shahnazi *et al.,* 2010; Bekselaer *et al.,* 2019); however, the detection of *Giardia duodenalis* cysts almost always involves staining with standard Lugol's iodine (Eraky *et al.,* 2014; Garbe *et al.,* 2016; Mohdanel *et al.,* 2016; Alemu *et al.,* 2019). However, an immunofluorescence assay is usually applied for the detection of *Giardia* cysts in food items with more sensitivity (Ryan *et al.,* 2018). The immunomagnetic separation method is also applied to concentrate *G. duodenalis* cysts for further detection (Armon *et al.,* 2010). The PCR amplification and sequencing of specific *G. duodenalis* genes recovered from contaminated food are also commonly used for the confirmatory detection of this parasite (Colli *et al.,* 2015; Tiyo *et al.,* 2010). The contamination of vegetables and fruits with *G. duodenalis* zoonotic assemblages A and B has been documented in several studies.

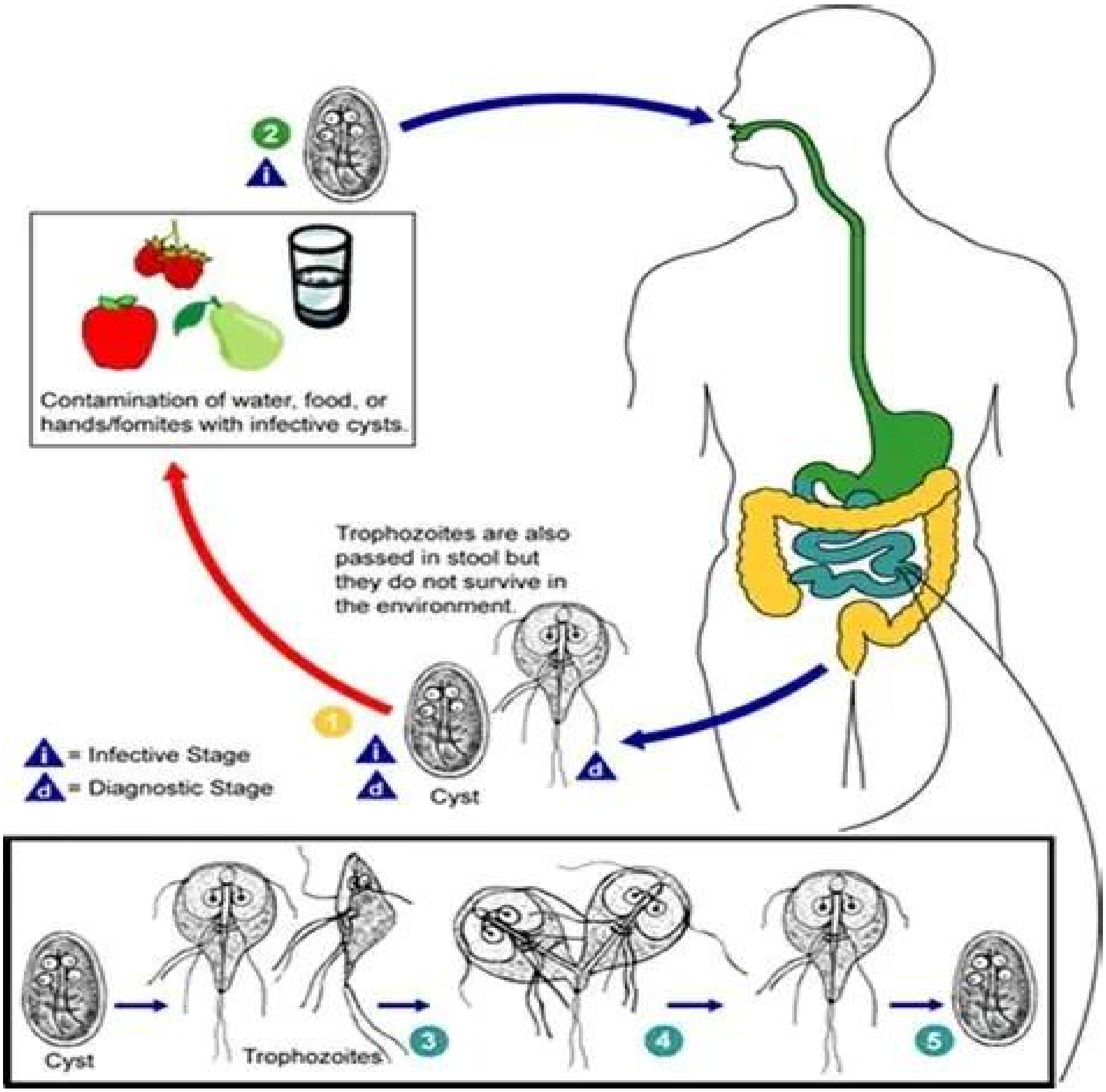


Figure 2.11: Diagram of the Life Cycle of *Giardia lamblia* (CDC, 2020).

2.4.2.3 *Cyclospora cayetanensis*

Another significant protozoan parasite that typically spreads through food and causes immunocompromised cyclosporiasis is *Cyclospora cayetanensis* (Ortega *et al.,* 2010; Giangaspero *et al.,* 2019). Globally, *C. cayetanensis* is a significant human protozoan that is transmitted by food (Giangaspero *et al.,* 2019). The food-borne cyclosporiasis epidemics linked to the ingestion of contaminated raw fruits or vegetables have been the subject of numerous reports (Giangaspero *et al.,* 2019).

If there are many *Cyclospora cayetanensis* oocysts present in the fruits and vegetables, they can be easily and immediately recognised with light microscopy (Einarsson *et al.,* 2016; Cacciadonna *et al.,* 2017). There are no immunofluorescence tests, although modified Ziehl–Neelsen staining and autofluorescence or immunofluorescence assays are frequently utilised for their detection (Fram *et al.,* 2008; Duddet *et al.,* 2014). Furthermore, PCR amplification and sequencing of *C. cayetanensis* genes have currently been used for the specific detection of this organism in contaminated food samples (Giangaspero *et al.,* 2015; Simi *et al.,* 2017).

As shown in Figure 2.11, the diagram of the Life cycle of *Cyclospora cayetanensis* (CDC, 2020).

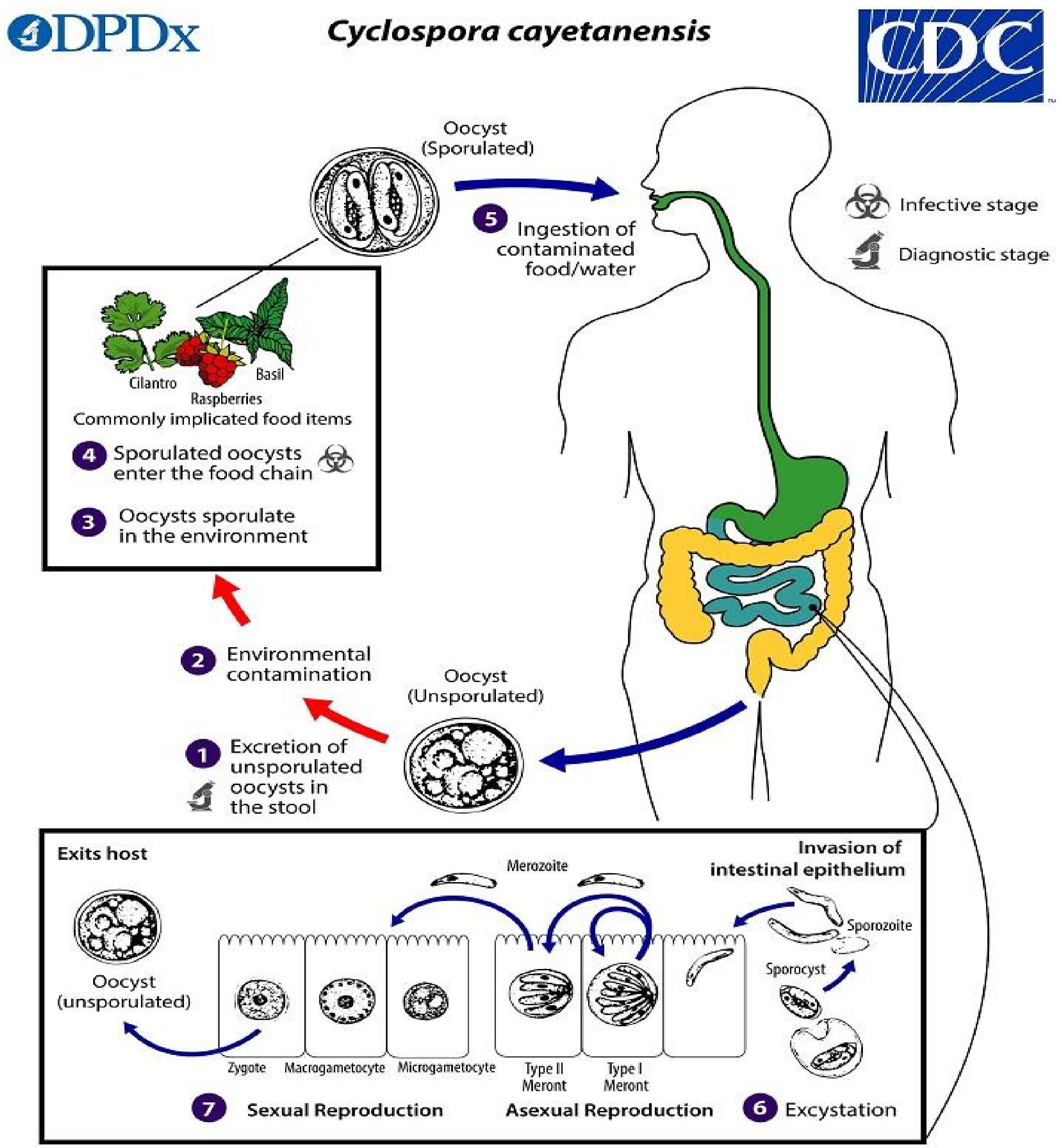


Figure 2.12: Diagram of the Life Cycle of *Cyclospora cayetanesis* (CDC, 2020).

2.4.2.4 *Entamoeba* contamination

The majority of human amebiasis infections among *Entamoeba* species are caused by *E. histolytica* which is one of the top three parasitic killers globally (Cui *et al.,* 2019). Even while some *E. histolytica* infections are asymptomatic, many infections have the potential to cause disseminated illness and severe amoebic colitis (Kantor *et al.,* 2018). Consuming contaminated fruits and vegetables is strongly linked to *Entamoeba* species infections (Kantor *et al.,* 2014; Alemu *et al.,* 2019; Bekele *et al.,* 2019). To find *Entamoeba* species cysts based on their physical characteristics is frequently performed (Alemu *et al.,* 2019). The best technique uses Lugol's iodine solution to detect *Entamoeba* spp. in food items (Alemu *et al.,* 2019). PCR techniques are also commonly used to detect *Entamoeba* spp. in fruits and vegetables based on amplification and sequencing of specific genes (Mardal *et al.,* 2020). Many reports of *Entamoeba* cysts worldwide are found in contaminated food samples (Mardal *et al.,* 2020). As shown in Figure 2.12, the diagram of the Life cycle of *Entamoeba histolytica* (CDC, 2020).

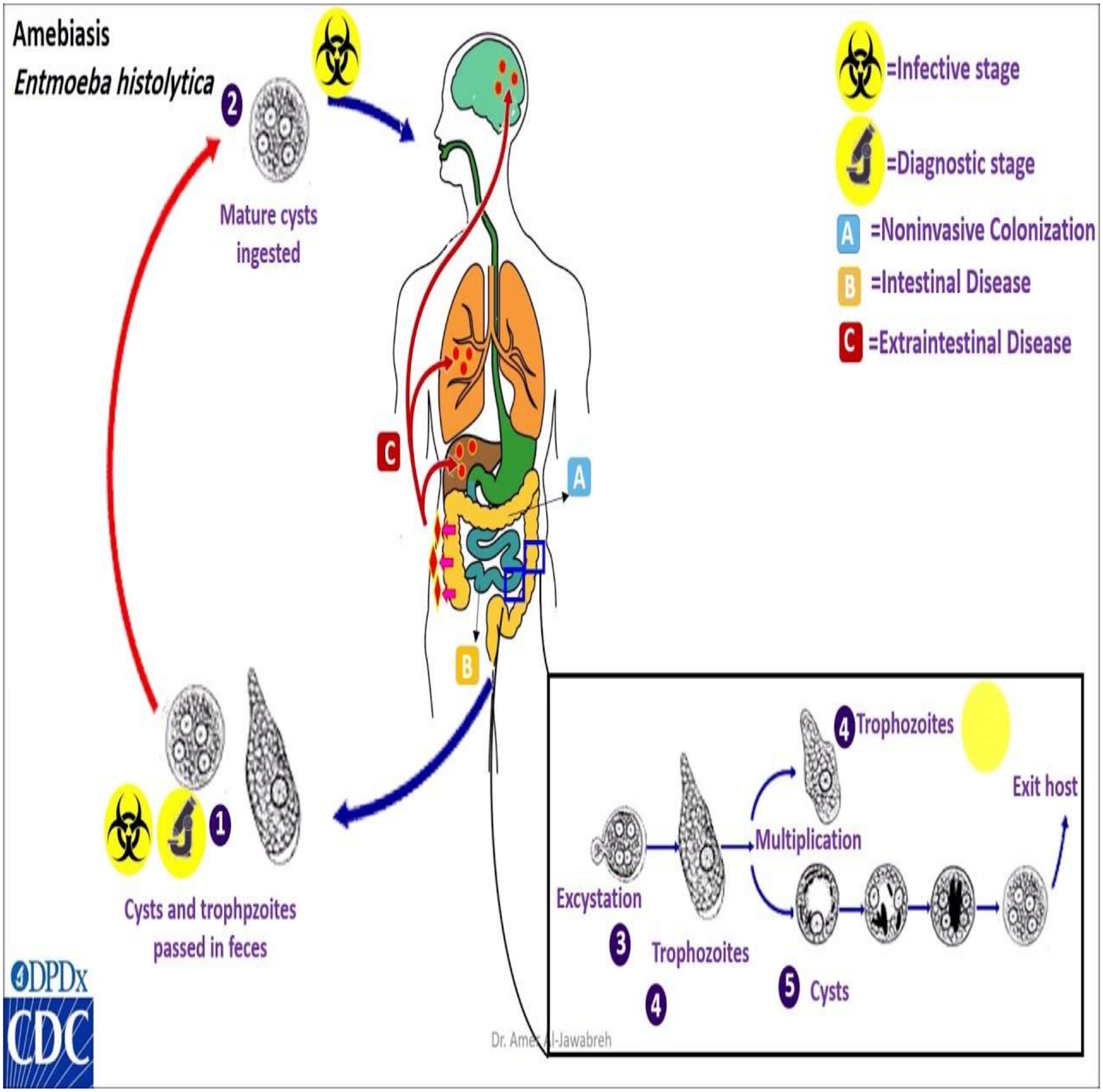


Figure 2.13: Diagram of the Life Cycle of *Entamoeba histolytica* (CDC, 2020).

2.4.2.5 *Toxoplasma gondii*

Toxoplasma gondii is a ubiquitous protozoan parasite capable of infecting virtually all warm-blooded animals (Innes *et al.,* 2019). According to a new nomenclature system, *T. gondii* genotypes are classified as: Type I, Type II or Type III. Other atypical or exotic genotypes include Chinese 1, Type Br I, Type Br II, Type Br III, Type Br IV and Type 12 (Shwab *et al.,* 2018).

Among the three principal routes of toxoplasmosis transmission, the consumption of unwashed vegetables and fruits contaminated with cat feces is an important one that sometimes may lead to food-borne outbreaks (Hussein *et al.,* 2017). The significant association of *T. gondii* infections with the consumption of contaminated raw vegetables is also observed in previous studies (Mahmoud *et al.,* 2016; Paul *et al.,* 2018; Teweededm *et al.,* 2019). The detection of *Toxoplasma gondii* in contaminated vegetables and fruits is usually performed by PCR amplification (Machado *et al.,* 2016; Lass *et al.,* 2019).

As shown in Figure 2.13, the diagram of the Life-cycle of *Toxoplasma gondii* (CDC, 2020).

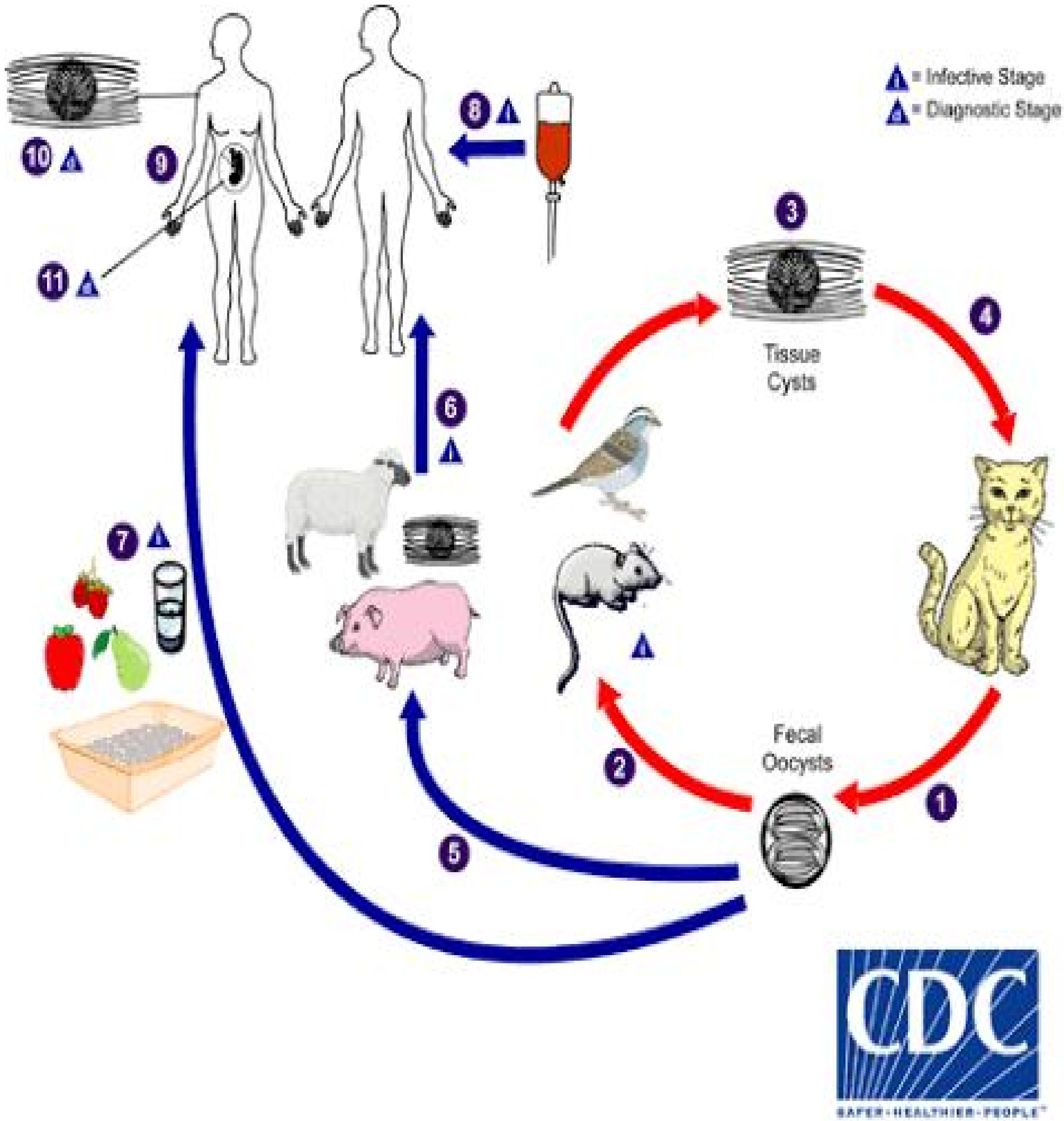


Figure 2.14: Diagram of the Life Cycle of *Toxoplasma gondii* (CDC, 2020).

2.4.2.6 *Balantidium coli*

Although uncommon in the U.S, the intestinal protozoan parasite *Balantidium coli* can infect people (Lass *et al.,* 2019). By consuming infected food and drink, these parasites can spread in the fecal-oral pathway (Alemu *et al.,* 2019). While most patients with a *Balantidium coli* infection don't show any symptoms, those who have other serious conditions may endure ongoing diarrhea, very severe stomach pain, and occasionally a perforated colon (Machado *et al.,* 2018). Balantidium coli infection can be avoided when proper hygiene (Schuster *et al.,* 2008). Even if visiting endemic tropical areas by fruits and vegetables is cleaned water before cooking or consuming vegetables, several errors have documented *B. coli* contamination of vegetables (Kudahi *et al.,* 2018).

Balantidium coli is usually detected on vegetables and fruits with light microscopy (Kudahi *et al.,* 2018). Few studies have evidenced *B. coli* contamination of fruits and vegetables but they have a detectable presence (Stenzel *et al.,* 2012).

As shown in Figure 2.14, the diagram of the Life cycle of *Balantidium coli* (CDC, 2020).

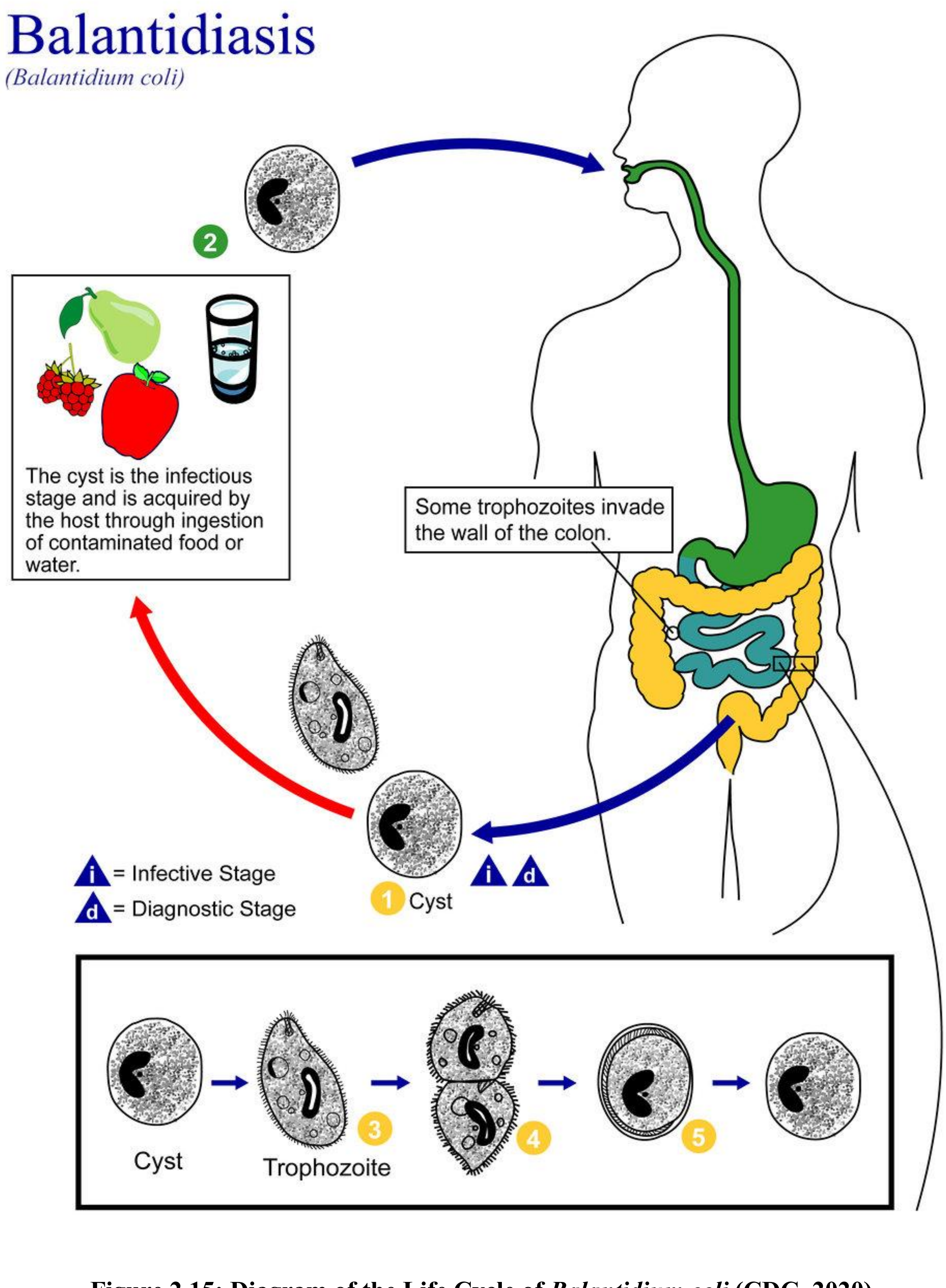


Figure 2.15: Diagram of the Life Cycle of *Balantidium coli* (CDC, 2020).

2.4.2.7 *Cystoisospora belli*

The causative pathogen of cystoisosporiasis is *C. belli*, a protozoan that belongs to the subclass Coccidia in the phylum Apicomplexa (Legua *et al.,* 2013). The mode of transmission of cystoisosporiasis is fecal-oral, i.e. through food or water contaminated with human faeces (Legua *et al.,* 2013). In immunocompetent hosts, *C. belli* infection causes a self-limited diarrheal illness. In individuals with immunocompromises, it may cause chronic life-threatening diarrhea and dehydration (Legua *et al.,* 2013). Exposure to contaminated food or water predisposes to this infection; also, an external stage in the environment is required for the oocysts to mature, direct person-to-person transmission is unlikely (Legua *et al.,* 2013). Accordingly, isosporiasis is more common in areas with poor sanitation. The disease is more common in patients with AIDS and *Cystoisospora belli* infection is commonly reported in tropical and subtropical areas of the world (Legua *et al.,* 2018).

Cystoisosporiasis can be acquired through the ingestion of contaminated food. *Cystoisospora belli* is commonly detected with modified Ziehl–Neelsen staining, followed by microscopy (Bekele *et al.,* 2019). As shown in Figure 2.16, the diagram of the Life cycle of *Cystoisospora belli* (CDC, 2020).

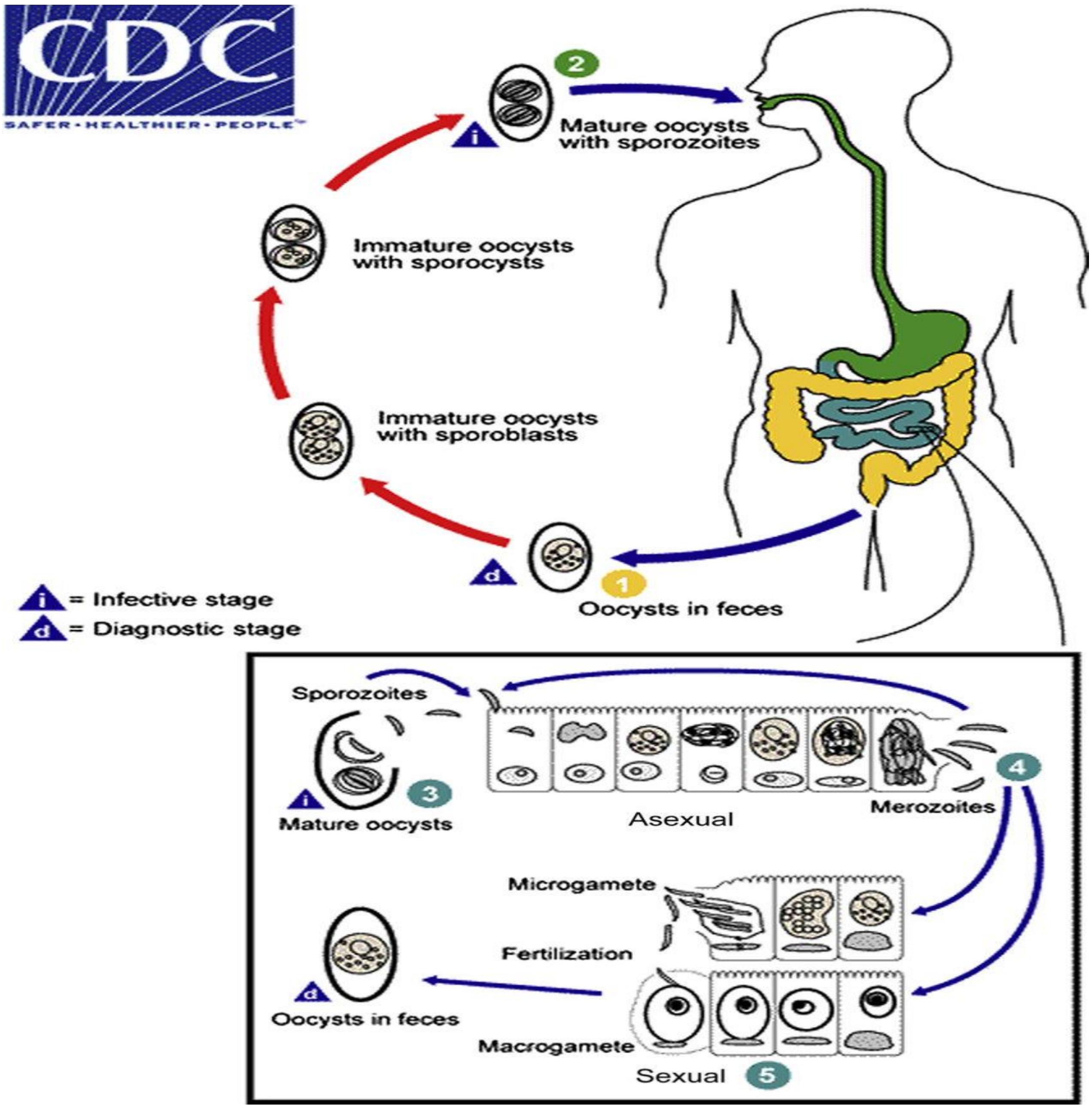


Figure 2.16: Diagram of the Life Cycle of *Cystoisospora belli* (CDC, 2020).

2.4 ECONOMIC IMPORTANCE OF VEGETABLES

Leafy vegetables such as spinach (*Spinacia oleracea*), lettuce (*Lactuca sativa*), fluted pumpkin (*Telfairia occidentalis*), amaranths (*Amaranthus* spp.), and African indigenous varieties (e.g., *Vernonia amygdalina*, *Celosia argentea*) play an essential role in both household food security and national economies. Beyond their nutritional and health value, leafy vegetables are economically significant in terms of employment creation, income generation, and contribution to gross domestic product (GDP) in many low- and middle-income countries.

1) Contribution to household income and poverty reduction

Leafy vegetables are often cultivated as short-cycle crops, requiring minimal land and inputs compared to staple cereals. This makes them an accessible income source for smallholder farmers, urban dwellers, and women who dominate the vegetable trade in many African and Asian countries (Weinberger & Lumpkin, 2007). For households with limited access to formal employment, the production and sale of leafy vegetables serve as a critical poverty-alleviation strategy, providing cash for school fees, healthcare, and reinvestment in agriculture (Adeoye *et al*., 2019).

2) Employment and livelihood creation

The production, processing, and marketing of leafy vegetables create jobs along the value chain—from farm labor to transportation and market vending. In Nigeria, for example, vegetable farming and trading contribute significantly to rural and peri-urban employment, particularly among women and youth (Oladejo & Adetunji, 2012). Studies show that vegetable production is often one of the few agricultural activities where returns to labor are immediate and relatively high, making it attractive for vulnerable groups (Weinberger & Lumpkin, 2007).

3) Market demand and urban food systems

Leafy vegetables are a staple component of urban diets, ensuring steady demand throughout the year. Their short production cycle enables farmers to supply markets more frequently than staple crops, providing continuous cash flow (Adeoye *et al*., 2019). In many urban centers, informal markets for leafy vegetables thrive, supporting microenterprises, hawkers, and wholesalers who benefit economically from daily turnover.

4) Export potential and agribusiness opportunities

While most leafy vegetables are consumed locally, some species (e.g., spinach, kale, and lettuce) have entered regional and international markets, offering foreign exchange earnings. The growing global demand for fresh and organic produce presents opportunities for leafy vegetable farmers and agribusinesses in developing countries (Weinberger & Lumpkin, 2007). In addition, processed forms—such as dried fluted pumpkin leaves in Nigeria—create niche export markets targeting diaspora communities.

THEORETICAL FRAMEWORK

Two interrelated theories provide the framework for explaining the phenomenon: The **Chain of Infection Model** and the **Fecal–Oral Contamination Theory**. These frameworks clarify the pathways through which parasitic organisms reach leafy vegetables and subsequently infect human hosts, while also highlighting the environmental and behavioral factors that sustain the cycle of transmission.

The **Chain of Infection Model** is a classical epidemiological concept that outlines six essential elements in the transmission of infectious agents: the infectious agent, the reservoir, the portal of exit, the mode of transmission, the portal of entry, and the susceptible host. Applying this model to parasitic contamination of vegetables, the infectious agents are the intestinal parasites of public health concern, such as *Ascaris lumbricoides*, *Trichuris trichiura*, *Entamoeba histolytica*, *Giardia lamblia*, and *Cryptosporidium* species (Karshima, 2018). The reservoirs for these parasites are primarily contaminated soil, water bodies, untreated manure, and infected humans or animals. Parasite eggs, cysts, or oocysts exit the reservoir through fecal matter and can contaminate the environment. The mode of transmission is chiefly through irrigation of vegetables with contaminated water, the use of raw animal manure as fertilizer, soil particles that adhere to vegetable surfaces, and unhygienic handling during harvest, transportation, and marketing (Alemu *et al*., 2020). Humans become infected when they ingest raw or inadequately washed vegetables, which serves as the portal of entry. Finally, susceptible hosts include consumers—particularly children, the elderly, and immunocompromised individuals—who suffer the health consequences of consuming contaminated produce. By breaking any of these links, such as improving irrigation water quality, practicing safe handling, or ensuring thorough washing of vegetables, the cycle of infection can be disrupted (World Health Organization [WHO], 2020).

Closely related to this is the **Fecal–Oral Contamination Theory**, which explains the fundamental mechanism of transmission of intestinal parasites. This theory posits that infections occur when materials contaminated with fecal matter are ingested by a susceptible host. In the case of vegetables, contamination often occurs when eggs, cysts, or oocysts from human or animal feces are introduced into the food chain. Leafy vegetables, in particular, are especially vulnerable due to their broad leaf surfaces and natural folds, which facilitate the adhesion of parasitic stages (El Safadi *et al*., 2023). Agricultural practices such as the use of untreated wastewater for irrigation or the application of improperly composted manure contribute significantly to this process (Santos *et al*., 2024). In addition, open defecation, poor sanitation systems, and unhygienic handling in markets create environments where fecal–oral transmission is almost inevitable

Public-health consequences

Consumption of contaminated leafy vegetables can cause acute gastroenteritis (protozoal infections), chronic intestinal helminthiasis (leading to anemia, growth retardation, impaired cognitive development) and occasional outbreaks (e.g., cryptosporidiosis linked to ready-to-eat produce). The burden is highest where baseline rates of parasitic infections are already elevated and where vulnerable populations (children, immunocompromised persons, pregnant women) consume raw vegetables without adequate washing or processing.

Systematic reviews and many cross-sectional surveys show a wide range of contamination rates: from low percentages in some settings to very high prevalence (30–70% or more) in others, reflecting methodological differences, local practices, and environmental conditions. Several recent multi-country and local studies highlight that leafy greens are more frequently contaminated than other produce and that wastewater irrigation and poor handling are consistent predictors of higher contamination.

However, gaps remain:

(1) few longitudinal studies that link farm-level contamination to actual human infection outcomes

(2) limited molecular surveillance to identify zoonotic vs. anthroponotic sources

(3) scarcity of standardized sampling and detection protocols that would allow robust meta-analysis across regions. These gaps justify targeted local studies that measure occurrence, identify predictors (water, soil, handling), and recommend context-appropriate mitigation.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 STUDY AREA

- The study was carried out in Ugbodiobo market, Odighi Market, Ugo-Niyekarhiomwom old farm market and Ekiohuon (Ekehuan) market located in Benin City, Edo State). Ugbogiobo Market and Odighi market are located in Ovia North-East Local Government Area (LGA) with a population of 153,849 (National population Census, 2006). Ugo-Niyekorhiomwom market is located at Orhionmwon LGA, with a population of 206,717 (National population Census, 2006). Ekiohuon (Ekehuan) market is located at Oredo LGA, with a population of 374,671 (National population Census, 2006).

3.2 SELECTION CRITERIA

3.2.1 Inclusive Criteria

- Only fresh samples of leafy vegetables will be considered for this study.
- Only samples from within Benin City will be considered for this study.

3.2.2 Exclusion Criteria

- Non-leafy vegetables (e.g. tomatoes, carrot, onion, etc.)
- Stale, spoilt or cooked leafy vegetables.
- Leafy vegetables not from within Benin City.

3.3 SAMPLE SIZE

The sample size for this study was determined using single population proportion estimate, considering the level of significance at 5% and the prevalence of parasites in leafy vegetables from two previous studies conducted elsewhere to be 29.5% (Kemajou *et al*., 2017) and a prevalence mean of 33% (Akinseye *et al*., 2017).

$$\text{Mean Prevalence} = \frac{29.5\% + 33\%}{2} = 31.25\%$$

The sample size was calculated according to the following formula,

$$N = \frac{Z^2 P (1-P)}{D^2}$$

Where,

N= required sample size

Z = Confidence level interval at 95% (standard value of 1.96)

P = Overall mean prevalence rate across Nigeria (31.25% = 0.3125)

D = margin of error at 5% (standard value of 0.05)

$$N = \frac{1.92^2 \text{ X } 0.3125 (1- 0.3125)}{0.05^2} = 330.1$$

N (Minimum Sample Size) = 330.1

~ N (Minimum Sample Size) = 330

Therefore, 330 samples of vegetables will be collected in Ugbodiobo market, Odighi Market, Ugo-Niyekarhiomwom old farm market and Ekiohuon (Ekehuan) market

3.4 SAMPLE COLLECTION

A total of 8 different leafy vegetable were purchased from farm produce sellers at the four different bush markets in the morning hours between 7am – 10am. Each of the leaf samples were collected separately into different new polybags which were labelled accordingly and transported to the University of Benin Microbiology laboratory for the research processing.

- Spinach leaf (*Amaranthus hybridus or Amarantus Spp.*)
- Scent leaf (*Ocimum gratissimum*)
- Pumpkin leaf (*Telfairia occidentalis*)
- Cabbage (*Brassica oleracea*)
- Eboziza leaf (*Alchornea cordifolia*)
- Ebewiewe leaf (*Gongronema latifolium*)
- Curry leaf (Murraya koenigii)
- Waterleaf (*Talinum fruticosum*)

3.5 SAMPLE PRESERVATION AND HANDLING

Upon arrival at the laboratory, samples will be stored temporarily in a refrigerator at 4°C before processing which was done almost immediately. Proper aseptic handling will be ensured throughout the procedures to prevent cross-contamination particularly clean surfaces of the benches while sorting. All glassware and plasticware will be sterilized before use, along with the use of clean grease-free glass slides and cover slips. Personal protective equipment (PPE) such as gloves and laboratory coats will be engaged during handling.

3.6 SAMPLE ANALYSIS

3.6.1 Parasitological Examination of Specimens

One hundred gram (100g) of each sample was washed separately in beakers containing 100mls of normal saline for a duration of 30 minutes with agitation of the sample and normal saline every 10minutes. The resulting suspension was sieved to remove debris. Each filtrate was then transferred to a clean labelled specimen bottle (universal container).

3.6.1.1 Concentration by Sedimentation Method

A clean, sterile centrifuge test tube half-filled with the suspension from the washing of the vegetable will be centrifuged at 3000rpm for fifteen minutes. The supernatant was decanted and about 1gram of the sediment will be placed on a clean glass slide, covered with a cover slip and examined under a 10X objective of the microscope (Cheesebrough, 2006).

3.6.1.2 Iodine Wet Mount

A drop of Lugol's iodine will be added through the edge of the cover slip, then re-examined under 40X objective lens (Cheesebrough, 2006).

3.7 STATISTICAL ANALYSIS

The descriptive analysis of the data was carried out and summarized by percentage representation using **Kolmogorov–Smirnov (K–S) one-sample test** and a ratio 1:1 deviation.

CHAPTER 4

4.0 RESULTS

A total of 330 vegetable samples were examined for parasitic presence. A total of seven (7) parasites were observed from the samples all together. Below is a narrative of the findings:

The Occurrence of Parasites in Spinach leaf *(Amaranthus hybridus)* In Benin City is Shown in Table 1. The occurrence of the ova of *Ascaris lumbricoides* (21%), larva of *Strongyloides stercoralis* (9%), ova of hookworm (13%), ova of *Trichuris trichiura* (13%), cyst of *Giardia lamblia* (10%), ova of *Enterobium vermicularis* (9%) and cyst of *Entamoeba histolytica* (25%) varied non-significantly (P> 0.005). This indicates that the parasites maintained even distribution in the various markets.

The percentage occurrence in the markets varied accordingly; Ugbodiobo, Odighi, Ugi-Niyekarhiomwom and Ekiohuon which had 41%, 25%, 16% and 18% respectively. The highest being recorded in Ugbodiobo market (41%).

The Occurrence of Parasites in Scent leaf *(Ocimum gratissimum)* In Benin City is Shown in Table 2. The occurrence of the ova of *Ascaris lumbricoides* (46%), larva of *Strongyloides stercoralis* (19%), ova of Hookworm (24%), ova of *Trichuris trichiura* (0%), cyst of *Giardia lamblia* (11%), ova of *Enterobium vermicularis* (0%) and cyst of *Entamoeba histolytica* (0%) was not statistically significant (P> 0.005). This indicates that the parasites maintained even distribution in the various markets.

The percentage occurrence in the markets are as follows; Ugbodiobo, Odighi, Ugi-Niyekarhiomwom and Ekiohuon which had 30%, 16%, 30% and 24% respectively. This indicates that there is an even distribution across the markets.

The Occurrence of Parasites in Pumpkin leaf *(Telfaria occidentalis)* In Benin City is Shown in Table 3. The occurrence of the ova of *Ascaris lumbricoides* (38%), larva of *Strongyloides stercoralis* (26%), ova of Hookworm (18%), ova of *Trichuris trichiura* (18%), cyst of *Giardia lamblia* (0%), ova of *Enterobium vermicularis* (0%) and cyst of *Entamoeba histolytica* (0%) varied significantly ($P<0.05$) with the highest, *Ascaris lumbricoides (38%)*.

The percentage occurrence in the markets are as follows; Ugbodiobo, Odighi, Ugi-Niyekarhiomwom and Ekiohuon which had 24%, 18%, 38% and 20% respectively which is non-significantly difference ($P>0.05$). This indicates that there was constant distribution of parasites across the markets.

The Occurrence of Parasites in Cabbage *(Brassica Oleraca)* In Benin City is Shown in Table 4. The occurrence of the ova of *Ascaris lumbricoides* (29%), larva of *Strongyloides stercoralis* (0%), ova of Hookworm (0%), ova of *Trichuris trichiura* (0%), cyst of *Giardia lamblia* (27%), ova of *Enterobium vermicularis* (0%) and cyst of *Entamoeba histolytica* (44%) which varied significantly ($P< 0.005$). The highest being *E. histolytica* (44%).

The percentage occurrence in the markets are as follows; Ugbodiobo, Odighi, Ugi-Niyekarhiomwom and Ekiohuon which had 32%, 15%, 29% and 24% respectively which shows non-significant difference. This indicates even distribution across the markets.

The Occurrence of Parasites in Eboziza leaf *(Alchornea cordifolia)* In Benin City is Shown in Table 5. The occurrence of the ova of *Ascaris lumbricoides* (28%), larva of *Strongyloides stercoralis* (24%), ova of Hookworm (18%), ova of *Trichuris trichiura* (0%), cyst of *Giardia lamblia* (0%), ova of *Enterobium vermicularis* (0%) and cyst of *Entamoeba histolytica* (30%) which shows a significant difference (P< 0.005), the highest being *E. histolytica* (30%), *A. lumbricoides* (28%) and *S. stercoralis* (24%).

The percentage occurrence in the markets are as follows; Ugbodiobo, Odighi, Ugi-Niyekarhiomwom and Ekiohuon which had 26%, 15%, 33% and 26% respectively varied non-significantly, indicating even distribution from market to market.

The Occurrence of Parasites in Ebewewie leaf *(Gongronema latifolium*) In Benin City is Shown in Table 6. The occurrence of the ova of *Ascaris lumbricoides* (22%), larva of *Strongyloides stercoralis* (24%), ova of Hookworm (16%), ova of *Trichuris trichiura* (0%), cyst of *Giardia lamblia* (0%), ova of *Enterobium vermicularis* (0%) and cyst of *Entamoeba histolytica* (38%) varied significantly (P< 0.005), the highest being *E. histolytica* (38%).

The percentage occurrence in the markets are as follows; Ugbodiobo, Odighi, Ugi-Niyekarhiomwom and Ekiohuon which had 38%, 31%, 20% and 11% respectively, varied significantly (P< 0,05), the highest being Ugbodiobo and Odighi.

The Occurrence of Parasites in Curryleaf *(Murraya koemigii*) In Benin City is Shown in Table 7. The occurrence of the ova of *Ascaris lumbricoides* (46%), larva of *Strongyloides stercoralis* (25%), ova of Hookworm (0%), ova of *Trichuris trichiura* (0%), cyst of *Giardia lamblia* (0%), ova of *Enterobium vermicularis* (0%) and cyst of *Entamoeba histolytica* (29%), varied significantly (P< 0.005), the highest being *A. lumbricoides* (46%).

The percentage occurrence in the markets are as follows; Ugbodiobo, Odighi, Ugi-Niyekarhiomwom and Ekiohuon which had 38%, 31%, 20% and 11% respectively, varied significantly (P< 0,05), the highest being Ugbodiobo.

The Occurrence of Parasites in Waterleaf *(Talinum*) In Benin City is Shown in Table 8. The percentage occurrence of the ova of *Ascaris lumbricoides* (32%), larva of *Strongyloides stercoralis* (7%), ova of Hookworm (13%), ova of *Trichuris trichiura* (0%), cyst of *Giardia lamblia* (4%), ova of *Enterobium vermicularis* (8%) and cyst of *Entamoeba histolytica* (36%) varied significantly (P< 0.005), the highest being *E. histolytica* (38%) and A. lumbricoides

The percentage occurrence in the markets are as follows; Ugbodiobo, Odighi, Ugi-Niyekarhiomwom and Ekiohuon which had 30%, 26%, 25% and 19% respectively, varied non-significantly (P>0.05), indicating even distribution from market to market.

The mean number of parasites occurring on leafy vegetables in Benin City is Shown in Table 9. The percentage occurrence of the ova of *Ascaris lumbricoides* (31%), larva of *Strongyloides stercoralis* (16%), ova of Hookworm (13%), ova of *Trichuris trichiura* (4%), cyst of *Giardia lamblia* (6%), ova of *Enterobium vermicularis* (3%) and cyst of *Entamoeba histolytica* (27%) varied significantly (P< 0.005), the highest being *E. histolytica* (38%) and *A. lumbricoides* (31%)

The percentage occurrence in the markets are as follows; Ugbodiobo, Odighi, Ugi-Niyekarhiomwom and Ekiohuon which had 34%, 20%, 26% and 20% respectively, varied non-significantly (P> 0.05), indicating even distribution from market to market.

Table 4.1: Occurrence of Parasites on Spinach Leaf (*Amaranthus hybridus*) In Benin City

Markets (n=3)	Ova of *Ascaris lumbricoides*	Larva of *Strongyloides stercoralis*	Ova of Hookworm	Ova of *Trichuris trichiura*	Cyst of *Giardia lamblia*	Ova of *Enterobius vermicularis*	*Cyst of Entamoeba histolytica*	Total No (%)
Ugbodiobo	4	2	4	1	4	2	6	23 (41%)
Odighi	3	2	3	0	1	1	4	14 (25%)
Ugi-Niye Karhiomwom	3	0	0	4	0	1	1	9 (16%)
Ekiohuon	2	1	0	2	1	1	3	10 (18%)
Total No (%)	**12 (21%)**	**5 (9%)**	**7 (13%)**	**7 (13%)**	**6 (10%)**	**5 (9%)**	**14 (25%)**	**56**

Table 4.2: Occurrence of Parasites on Scent Leaf (*Ocimum gratissimum*) in Benin City

Markets (n=3)	Ova of *Ascaris lumbricoides*	Larva of *Strongyloides stercoralis*	Ova of Hookworm	Ova of *Trichuris trichiura*	Cyst of *Giardia lamblia*	Ova of *Enterobius vermicularis*	*Cyst of Entamoeba histolytica*	Total No (%)
Ugbodiobo	6	1	2	0	2	0	0	11 (30%)
Odighi	2	0	3	0	1	0	0	6 (16%)
Ugi-Niye Karhiomwom	4	6	1	0	0	0	0	11 (30%)
Ekiohuon	5	0	3	0	1	0	0	9 (24%)
Total No (%)	**17 (46%)**	**7 (19%)**	**9 (24%)**	**0 (0%)**	**4 (11%)**	**0 (0%)**	**0 (0%)**	**37**

Table 4.3: Occurrence of Parasites on Pumpkin Leaf (*Telfaria occidentalis*) in Benin City

Markets (n=3)	Ova of *Ascaris lumbricoides*	Larva of *Strongyloides stercoralis*	Ova of Hookworm	Ova of *Trichuris trichiura*	Cyst of *Giardia Lamblia*	Ova of *Enterobius vermicularis*	*Cyst of Entamoeba histolytica*	Total No (%)
Ugbodiobo	4	3	0	1	0	0	0	8 (24%)
Odighi	2	1	3	0	0	0	0	6 (18%)
Ugi-Niye Karhiomwom	5	4	2	2	0	0	0	13 (38%)
Ekiohuon	2	1	1	3	0	0	0	7 (20%)
Total No (%)	**13 (38%)**	**9 (26%)**	**6 (18%)**	**6 (18%)**	**0 (0%)**	**0 (0%)**	**0 (0%)**	**34**

Table 4.4: Occurrence of Parasites on Cabbage (*Brassica oleracea*) in Benin City

Markets (n=3)	Ova of *Ascaris lumbricoides*	Larva of *Strongyloides stercoralis*	Ova of Hookworm	Ova of *Trichuris trichiura*	Cyst of *Giardia Lamblia*	Ova of *Enterobius vermicularis*	*Cyst of Entamoeba histolytica*	Total No (%)
Ugbodiobo	3	0	0	0	3	0	5	11 (32%)
Odighi	3	0	0	0	0	0	2	5 (15%)
Ugi-Niye Karhiomwom	3	0	0	0	2	0	5	10 (29%)
Ekiohuon	1	0	0	0	4	0	3	8 (24%)
Total No (%)	10 (29%)	0 (0%)	0 (0%)	0 (0%)	9 (27%)	0 (0%)	15 (44%)	**34**

Table 4.5: Occurrence of Parasites on Eboziza (*Alchornea cordifolia*) in Benin City

Markets (n=3)	Ova of *Ascaris lumbricoides*	Larva of *Strongyloides stercoralis*	Ova of Hookworm	Ova of *Trichuris trichiura*	Cyst of *Giardia lamblia*	Ova of *Enterobius vermicularis*	*Cyst of Entamoeba histolytica*	Total No (%)
Ugbodiobo	3	4	4	0	0	0	1	12 (26%)
Odighi	1	3	2	0	0	0	1	7 (15%)
Ugi-Niye Karhiomwom	4	3	1	0	0	0	7	15 (33%)
Ekiohuon	5	1	1	0	0	0	5	12 (26%)
Total No (%)	**13 (28%)**	**11 (24%)**	**8 (18%)**	**0 (0%)**	**0 (0%)**	**0 (0%)**	**14 (30%)**	**46**

Table 4.6: Occurrence of Parasites on Ebewewie (*Gongronema latifolium*) in Benin City

Markets (n=3)	**Ova of *Ascaris lumbricoides***	**Larva of *Strongyloides stercoralis***	**Ova of Hookworm**	**Ova of *Trichuris trichiura***	**Cyst of *Giardia lamblia***	**Ova of *Enterobius vermicularis***	***Cyst of Entamoeba histolytica***	**Total No (%)**
Ugbodiobo	4	3	4	0	0	0	6	17 (38%)
Odighi	4	3	1	0	0	0	6	14 (31%)
Ugi-Niye Karhiomwom	0	4	1	0	0	0	4	9 (20%)
Ekiohuon	2	1	1	0	0	0	1	5 (11%)
Total No (%)	**10 (22%)**	**11 (24%)**	**7 (16%)**	**0 (0%)**	**0 (0%)**	**0 (0%)**	**17 (38%)**	**45**

Table 4.7: Occurrence of Parasites on Curry leaf (*Murraya koenigii*) in Benin City

Markets (n=3)	Ova of *Ascaris lumbricoides*	Larva of *Strongyloides stercoralis*	Ova of Hookworm	Ova of *Trichuris trichiura*	Cyst of *Giardia lamblia*	Ova of *Enterobius vermicularis*	*Cyst of Entamoeba histolytica*	Total No (%)
Ugbodiobo	5	1	0	0	0	0	6	12 (43%)
Odighi	1	2	0	0	0	0	0	3 (11%)
Ugi-Niye Karhiomwom	3	3	0	0	0	0	0	6 (21%)
Ekiohuon	4	1	0	0	0	0	2	7 (25%)
Total No (%)	**13 (46%)**	**7 (25%)**	**0 (0%)**	**0 (0%)**	**0 (0%)**	**0 (0%)**	**8 (29%)**	**28**

Table 4.8: Occurrence of Parasites on Water leaf (*Talinum fruticosum*) in Benin City

Markets (n=3)	Ova of *Ascaris lumbricoides*	Larva of *Strongyloides stercoralis*	Ova of Hookworm	Ova of *Trichuris trichiura*	Cyst of *Giardia lamblia*	Ova of *Enterobius vermicularis*	*Cyst of Entamoeba histolytica*	Total No (%)
Ugbodiobo	4	1	3	0	1	1	6	16 (30%)
Odighi	6	1	1	0	0	1	5	14 (26%)
Ugi-Niye Karhiomwom	5	1	1	0	0	1	5	13 (25%)
Ekiohuon	2	1	2	0	1	1	3	10 (19%)
Total No (%)	**17 (32%)**	**4 (7%)**	**7 (13%)**	**0 (0%)**	**2 (4%)**	**4 (8%)**	**19 (36%)**	**53**

Table 4.9: Mean number of parasites occurring on leafy vegetables in Benin City

Markets (n=3)	Ova of *Ascaris lumbricoides*	Larva of *Strongyloides stercoralis*	Ova of Hookworm	Ova of *Trichuris trichiura*	Cyst of *Giardia lamblia*	Ova of *Enterobius vermicularis*	*Cyst of Entamoeba histolytica*	Total No (%)
Ugbodiobo	11	5	5.7	0.7	3.3	1	12	38.7 (34%)
Odighi	7.3	4	4.3	0	0.7	0.7	6	23 (20%)
Ugi-Niye Karhiomwom	9	7	2	2	0.7	0.7	7.3	28.7 (25%)
Ekiohuon	7.7	2	2.7	1.7	2.3	0.7	5.7	22.8 (20%)
Total No (%)	**35 (31%)**	**18 (16%)**	**14.7 (13%)**	**4.4 (4%)**	**7 (6%)**	**3.1 (3%)**	**31 (27%)**	**113.2**

CHAPTER FIVE

5.1 DISCUSSION

The consumption of leafy vegetables, though nutritionally beneficial, presents significant public health challenges due to their role as vehicles for parasitic transmission. This study, which examined 330 samples of leafy vegetables sold in Benin City, Edo State, revealed a high level of parasitic contamination, identifying seven parasites: *Ascaris lumbricoides*, *Strongyloides stercoralis*, *Hookworm*, *Trichuris trichiura*, *Giardia lamblia*, *Enterobius vermicularis*, and *Entamoeba histolytica*.

The predominance of *A. lumbricoides* (31%) aligns with earlier findings in Nigeria and other developing regions. Adejumoke and Morenikeji (2021) reported *Ascaris* as the leading contaminant in vegetables sold in Ibadan, while Kemajou et al. (2020) confirmed similar dominance in Port Harcourt markets. Internationally, Uga et al. (2019) found high *Ascaris* prevalence in Vietnam, attributing it to the resilience of its ova against environmental stress. Alemu et al. (2020) in Ethiopia also associated the persistence of *Ascaris* eggs with the use of untreated wastewater and animal manure. These corroborations indicate that poor agricultural practices and unsanitary environmental conditions are major determinants of vegetable-borne parasitic contamination.

Similarly, protozoan parasites such as *Entamoeba histolytica* were also prominent, ranking second overall (27%). The highest contamination levels were observed in cabbage (44%) and waterleaf (36%). These findings concur with those of Fallah et al. (2012) in Iran and Duedu et al. (2014) in Ghana, who reported *E. histolytica* as a major contaminant in raw-consumed vegetables. The structural features of cabbage — its broad leaves and overlapping layers — promote soil and water retention, while waterleaf's succulent nature and high moisture content create favorable microenvironments for cyst survival. Damen et al. (2007) similarly emphasized that leaf morphology and surface texture significantly influence parasite adhesion and survival.

Although the level of contamination varied among the four markets studied — Ugbodiobo, Odighi, Ugo-Niyekarhiomwom, and Ekiohuon — statistical analysis revealed no significant difference ($P > 0.05$). The Ugbodiobo market recorded the highest contamination (34%), which could be attributed to its nature as a bush market where vegetables are sourced from multiple farms, increasing the likelihood of cross-contamination. Bello et al. (2021) in Ogun State and Endale et al. (2018) in Ethiopia similarly reported widespread contamination across different markets, indicating that the issue transcends individual points of sale and reflects systemic weaknesses in cultivation, handling, and distribution practices.

The persistence of parasitic contamination is strongly linked to environmental and behavioral factors. The use of untreated wastewater for irrigation, application of raw manure, and poor market sanitation are major contributors. Santos et al. (2024) identified irrigation water as a leading global contributor to parasitic contamination, while El Safadi et al. (2023) demonstrated that the microstructure of leafy vegetables aids in cyst and egg adhesion. In addition, unhygienic handling by vendors — such as sorting with unwashed hands or displaying vegetables on bare ground — further amplifies the risk of transmission to consumers.

The diversity of parasites detected in this study mirrors global observations. A study in Birjand, Iran (2021) found 78.5% contamination in raw vegetables, while Al-Megrin (2023) in Saudi Arabia identified *Ascaris*, *Trichuris*, and *Giardia* species. Alemu et al. (2020) in Ethiopia and

Duedu et al. (2014) in Ghana reported similar parasitic spectra, even in vegetables sold in supermarkets, demonstrating that contamination is not restricted to open-air markets but extends to formal retail systems. Comparable findings in Jimma (Oromia region), where 56.1% of vegetables and 36.2% of fruits were contaminated, reinforce that vegetable-borne parasitism is a global concern, particularly in developing regions lacking stringent sanitation and regulatory frameworks.

The public health implications of these results are profound. Continuous exposure to contaminated vegetables can cause malnutrition, anemia, growth retardation, impaired cognition, and reduced productivity. According to the World Health Organization (2020), foodborne parasitic infections are classified among neglected tropical diseases, with children, pregnant women, and immunocompromised individuals being most vulnerable. In the context of Benin City, the high prevalence of *A. lumbricoides* and *E. histolytica* underscores the risk of sustained household transmission, especially where vegetables are consumed raw without adequate washing or disinfection.

In summary, this study justifies the urgent need for public health interventions, including improved farming hygiene, safe irrigation practices, vendor education, and public awareness campaigns to mitigate parasitic contamination of vegetables. The findings also call for strengthened food safety regulations and routine monitoring by health authorities to protect consumers and curb the spread of parasitic infections through fresh produce.

5.2 Limitations of the Study

A strength of this study lies in its focus on Benin City, where limited contemporary data exist, thereby filling a gap in local epidemiological knowledge. The use of both sedimentation and flotation techniques improved detection sensitivity compared to single-method studies and also provides important insights into the parasitic contamination of leafy vegetables sold in Benin City, certain limitations must be acknowledged. First, the research relied solely on microscopic examination techniques, namely sedimentation, for parasite detection. While these methods are widely accepted, they are less sensitive than molecular approaches such as polymerase chain reaction (PCR) or immunofluorescence, which may have resulted in an underestimation of protozoan parasites in particular. Secondly, the study employed a cross-sectional design and was conducted at a single time point. As such, it did not account for seasonal variations, which could influence the extent of contamination due to differences in rainfall patterns, irrigation practices, and farming activities. Similarly, the geographical scope was limited to four major markets within Benin City. While these markets serve as major distribution centers, the findings may not fully reflect contamination patterns in other parts of Edo State or across Nigeria.

Another limitation relates to the range of vegetables examined. The focus was restricted to eight leafy vegetable species, excluding other commonly consumed vegetables such as tomatoes, onions, and carrots that may also serve as vehicles for parasitic transmission. Additionally, while the study established the presence of parasites, it did not directly evaluate the environmental sources of contamination such as irrigation water, soil, or handling practices at farms and markets. This restricted the ability to link contamination to specific risk factors in the production and distribution chain. Furthermore, there were constraints in sample preservation and handling.

Although samples were stored at 4°C before processing, delays during transportation and handling could have influenced parasite recovery rates. Finally, the study focused on the detection of parasites in vegetables but did not assess their direct impact on public health outcomes. In other words, while contaminated vegetables were identified, the actual infection rates among consumers of these vegetables in Benin City were not evaluated.

5.3 CONCLUSION

This study demonstrated a high level of parasitic contamination in leafy vegetables sold across major markets in Benin City which are potential source of disease transmission. The findings indicate that commonly consumed vegetables such as spinach, cabbage, pumpkin, waterleaf, and scent leaf may serve as significant vehicles for the transmission of intestinal parasites. The ingestion of parasitic infective stages such as eggs, oocytes, cysts or spores with contaminated leafy vegetable causes disease that may lead to serious health problems although contamination levels varied across vegetable types, no significant difference was observed between markets, suggesting that contamination is widespread and largely influenced by common agricultural and market practices. These results underscore the dual role of leafy vegetables as both vital dietary components and potential public health risks. Ensuring proper washing, improved sanitation, and safer farming practices is essential to reduce the burden of vegetable-borne parasitic infections in Benin City and beyond.

5.4 RECOMMENDATION

- Continuous enlightenment campaigns should be organized by health authorities and community leaders to educate both vegetable vendors and consumers on the risks associated with consumption of contaminated vegetables and the importance of proper hygiene practices.
- Local government authorities should ensure that markets are provided with clean water sources, proper drainage, and waste disposal systems to reduce environmental contamination that predisposes vegetables to parasitic infestation.
- Consumers should be encouraged to thoroughly wash vegetables with clean running water and, where possible, apply safe disinfectants such as vinegar or salt solution before consumption, especially when eaten raw.
- Vegetable vendors should be trained on good handling and storage practices to minimize contamination. This includes avoiding display of vegetables on bare ground and ensuring that vegetables are protected from dust, flies, and wastewater.
- Relevant health agencies should strengthen regulatory frameworks for food safety by enforcing periodic inspection of vegetables in markets to ensure compliance with hygiene standards.
- More extensive studies should be conducted in other regions of Nigeria and across different vegetable types, seasons, and cultivation practices to provide broader data for public health planning and intervention.

REFRENCES

Abosede, E., & Raimot, A. (2022). Nutritional value of vegetables: Benefits and cultivation. *Biomedical Centre Research Notes, 7*(1), 89–97.

Adejumoke, A., & Morenikeji, O. (2021). Prevalence of intestinal parasites in vegetables sold in major markets in Ibadan City, South-west Nigeria. *Global Journal of Pure and Applied Science, 21*(1), 7–12.

Adeoye, I. B., Adebisi-Adelani, O., Olajide-Taiwo, F. B., & Ezekiel-Adewoyin, D. T. (2019). Economic analysis of indigenous leafy vegetable production and marketing in Southwest Nigeria. *Journal of Agricultural Extension, 23*(3), 12–24.

Akinseye, J. F., Ayuba, S. B., Adewuyi, I. K., & Agunlejika, R. A. (2017). Isolation of intestinal parasites from vegetables irrigated with contaminated wastewaters used for agricultural purposes in Afyonkarahisar, Turkey. *Biomedical Research, 28*(3), 89–97

Akinseye, J. F., Ayuba, S. B., Adewuyi, I. K., & Agunlejika, R. A. (2017). Isolation of intestinal parasites from vegetables sold in selected markets in Ilorin, Nigeria. *International Journal of Applied Biological Research, 8*(1), 68–74.

Akubugwo, I. E., Obasi, A. N., & Ginika, S. C. (2007). Nutritional potential of the leaves and seeds of *Telfairia occidentalis*. *Journal of Biology Sciences, 7*(2), 379–383.

Alemu, G., Mama, M., Alemu, M., & Abossie, A. (2020). Parasitic contamination of fruits and vegetables collected from local markets in Arba Minch town, Southern Ethiopia. *BMC Research Notes, 13*(1), 186.

Al-Megrin, W. A. (2010). Prevalence of intestinal parasites in leafy vegetables in Riyadh, Saudi Arabia. *International Journal of Zoological Research, 6*(1), 34–39.

Ayeh-Kumi, P. F. (2014). A comparative survey of the prevalence of human parasites found in fruits and vegetables collected from local markets in Accra, Ghana. *International Journal of Microbiology and Immunology Research,* 2(3), 28–33.

Bello, A. O., Kolapo, A. L., & Adeoye, T. E. (2017). Microbiological quality of some leafy vegetables sold in markets in Ogun State, Nigeria. *African Journal of Food Science, 11*(3), 55–61.

Bello, A. O., Kolapo, A. L., & Adeoye, T. E. (2017). Microbiological quality of some leafy vegetables sold in markets in Ogun State, Nigeria. *African Journal of Food Science, 11*(3), 55–61.

Cena, H., & Calder, P. C. (2020). Defining a healthy diet: Evidence for the role of contemporary dietary patterns in health and disease. *Nutrients,* 12(2), 334.

Damen, J. G., Banwat, E. B., Egah, D. Z., & Allanana, J. A. (2007). Parasitic contamination of vegetables in Jos, Nigeria. *Annals of African Medicine, 6*(3), 115–118.

Dias, J. S. (2012) Major Classes of Phytonutriceutical in Vegetables and Health Benefits*: A*

Dorny, P., Praet, N., Deckers, N., & Gabriel, S. (2009). Emerging food-borne parasites. *Veterinary Parasitology,* 163(3), 196–206.

Duedu, K. O., Yarnie, E. A., Tetteh-Quarcoo, P. B., Attah, S., Donkor, E. S., & Ayeh-Kumi, P. F. (2014). A comparative survey of the prevalence of human parasites found in fresh vegetables sold in supermarkets and open-air markets in Accra, Ghana. *BMC Research Notes,* 7(1), 836–867.

Duedu, K. O., Yarnie, E., Tetteh-Quarcoo, P. B., Attah, S. K., Donkor, E. S., & Ayeh-Kumi, P. F. (2020). Parasites and enteric bacterial contamination of raw vegetables in open markets in Accra, Ghana. *BioMed Research International,* 20(20), 1–9.

El Safadi, D., Gaayeb, L., Meloni, D., Cian, A., Poirier, P., Wawrzyniak, I., … Delhaes, L. (2023). Parasitic contamination of fresh leafy green vegetables: Prevalence and public health implications. *Parasite,* 30(5), 1–12.

Encyclopaedia Britannica. (2021). *Vegetable*. In *Encyclopaedia Britannica*.

Endale, A., Tafa, B., Bekele, D., & Tesfaye, F. (2018). Detection of medically important parasites in fruits and vegetables collected from local markets in Dire Dawa, Eastern Ethiopia. *Global Journal of Medical Research,* 18(1), 29–36.

Erickson, M. C., & Doyle, M. P. (2012). Food as a vehicle for transmission of Shiga toxin producing *Escherichia coli*. *Journal of Food Protection, 75*(1), 136–142.

Ethiopia. *Global Journal of Medical Research.* 18(1):29-36.

Fallah, A., Pirali-Kheirabadi, K., Shirvani, F., & Saei-Dehkordi, S. (2012). Prevalence of parasitic contamination in vegetables used for raw consumption in Shahrekord, Iran: Influence of season and washing procedure. *Food Control,* 25(2), 617–620.

Food and Agriculture Organization [FAO] & World Health Organization [WHO]. (2019).

Johnson, E. J. (2014). Role of lutein and zeaxanthin in visual and cognitive function throughout the lifespan. *Nutrition Reviews, 72*(9), 605–612.

Karshima, S. N. (2018). Parasites of importance for human health on edible fruits and vegetables in Nigeria: A review. *Journal of Tropical Medicine, 2018,* 4567064.

Kayode, A. A. A., Kayode, O. T., & Odetola, A. A. (2010). Therapeutic effect of *Talinum triangulare* on experimental anemia. *Journal of Medicinal Food,* 13(2), 479–483.

Kemajou, S. T., Ajugwo, A. O., Nsa, M., Oshoma, C. E., Dunga, K. E., & Ikenazo, H. (2020). Prevalence of intestinal parasites in vegetables sold in some local markets in Port Harcourt. *International Journal of Health Sciences and Research,* 7(8), 203–208.

Kozan, E., Sevimli, F. K., Köse, M., Eser, M., & Çiçek, H. (2005). Examination of helminth contamination of various vegetables grown in Afyonkarahisar. *Turkish Journal of Parasitology, 29*(4), 217–220.

Li, J., Wang, Y., Jin, Y., Zhang, H., Ning, C., & Feng, Y. (2019). Molecular detection of

Cryptosporidium spp. and Giardia duodenalis in fresh vegetables sold in China. *Food Control, 104,* 153–158.

Lidder, S., & Webb, A. J. (2013). Vascular effects of dietary nitrate (*as found in spinach and beetroot*) via the nitrate–nitrite–nitric oxide pathway. *British Journal of Clinical Pharmacology, 75*(3), 677–696.

Liu, R. H. (2013). Dietary bioactive compounds and their health implications. *Journal of Food Science, 78*(1), A18–A25.

National Population Commission (NPC) (2006). National Population Commission, Abuja, *Nigeria Population Census Report,* 21-27.

Nwanna, E. E., Oboh, G., & Ayodele, J. T. (2008). Antioxidant and hepatoprotective properties of *Telfairia occidentalis* leaf extract. *Journal of Medicinal Food, 11*(3), 532–538.

Nwinyi, O. C., Chinedu, N. S., & Ajani, O. O. (2009). Evaluation of antibacterial activity of *Ocimum gratissimum* and *Gongronema latifolium*. *Journal of Medicinal Plants Research, 3*(4), 163–166.

Oda, T. A., & Esayas, A. (2017). Parasitic contamination of fruits and vegetables collected from local markets in Dire Dawa, Eastern Ethiopia. *International Journal of Public Health Science, 6*(4), 283–289

Odu, N. N., & Akujobi, C. O. (2012). Microbiological quality of leafy vegetables sold in Port Harcourt, Nigeria. *African Journal of Food Science and Technology, 3*(9), 273–277.

of fresh, frozen and can vegetables. II. Vitamin A and carotenoids, Vitamin E, minerals and fibers". Journal of the science of food and Agriculture. 87(7):1187-1196.

Oguntona, T., & Akinyele, I. O. (1995). Nutrient composition of commonly eaten foods in Nigeria – Raw, processed and prepared. *Food Basket Foundation International, Ibadan,* 12(3), 85-96.

Oladejo, J. A., & Adetunji, M. O. (2012). Economic analysis of leafy vegetable production in Southwestern Nigeria. *International Journal of Agricultural Economics and Rural Development, 5*(1), 18–24.

Oluwole, O. B., Taiwo, K. A., & Obadina, A. O. (2013). Nutritional and phytochemical composition of *Ocimum gratissimum*. *Food Science and Quality Management, 15*, 45–53.

Omowaye, O. S., & Audu, P. A. (2012). Parasites in vegetables sold in major markets in Akure, Ondo State, Nigeria. *Continental Journal of Biomedical Sciences, 6*(1), 29–36.

Rickman, J. C., Barrett, D. M., & Bruhn, C. M. (2007). Nutritional comparison of fresh, frozen and canned fruits and vegetables. *Part 1. Vitamins C and B and phenolic compounds. Journal of the Science of Food and Agriculture, 87*(6), 930–944.

Robertson, L. J., Gjerde, B., Hansen, E. F., & Stachurska-Hagen, T. (2001). A comparative study of Giardia duodenalis cysts and Cryptosporidium parvum oocysts in environmental water samples: Concentration and detection. *Applied and Environmental Microbiology, 67*(2), 706–710.

Ryder, E. and Dias, J. S. (2011) World Vegetable Industry: Production, Breeding, Trends.
Santos, D. E. O., de Oliveira, D. C., Fiuza, V. R. S., & Guimarães, A. T. B. (2024). Occurrence of parasites in waters used for crop irrigation and vegetables: A systematic review. *Environmental Science and Pollution Research, 31*(15), 22675–22692.

Santos, D. E. O., de Oliveira, D. C., Fiuza, V. R. S., & Guimarães, A. T. B. (2024). Occurrence of parasites in waters used for crop irrigation and vegetables: A systematic review. *Environmental Science and Pollution Research, 31*(15), 22675–22692.

Slavin, J. L., & Lloyd, B. (2012). *Health benefits of fruits and vegetables*. Advances in Nutrition, 3(4), 506–516.

Thompson, A. and Keith, B. (2010). Controlled atmosphere storage of fruits and vegetables. Center for Agriculture and biosciences international. 7:18-34

Uga, S., Hoa, N. T. V., Noda, S., Moji, K., Cong, L., Aoki, Y., & Fujimaki, Y. (2009). Parasite egg contamination of vegetables from a suburban market in Hanoi, Vietnam. *Nepal Medical College Journal, 11*(2), 75–78.

Weinberger, K., & Lumpkin, T. A. (2007). Diversification into horticulture and poverty reduction: A research agenda. *World Development, 35*(8), 1464–1480.

World Health Organization (WHO). (2020). *Healthy diet*. Geneva: WHO.

APPENDIX A: Result Charts

Chart A1

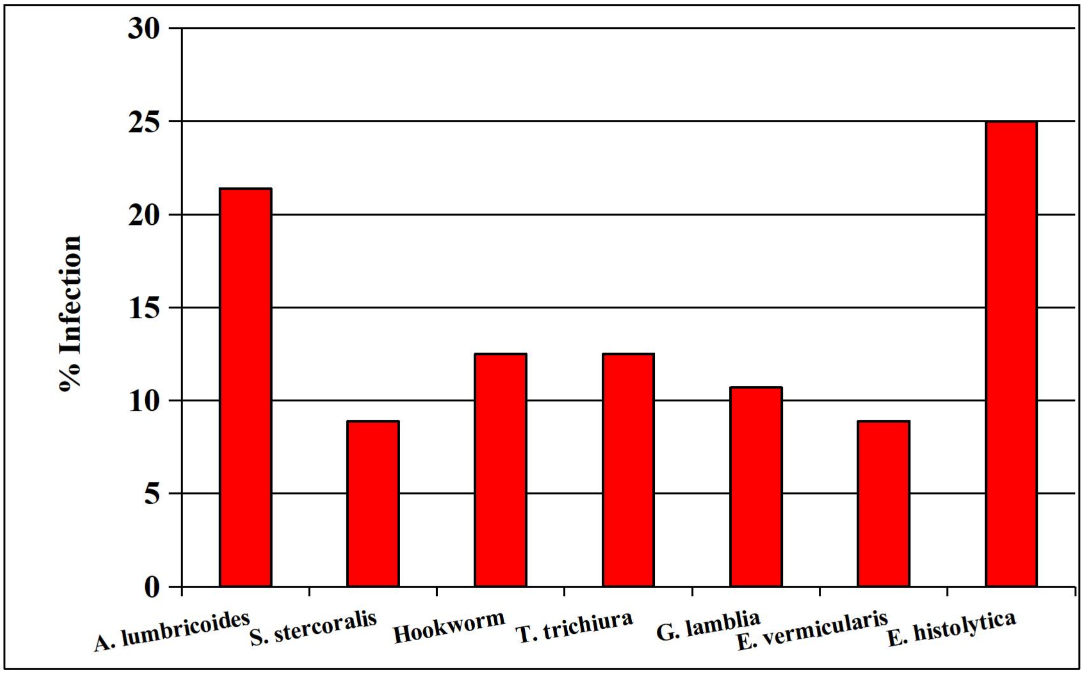


Figure 4.1: Parasites Infection on Spinach Leaf (*Amaranthus hybridus*) in Benin City

Chart A2

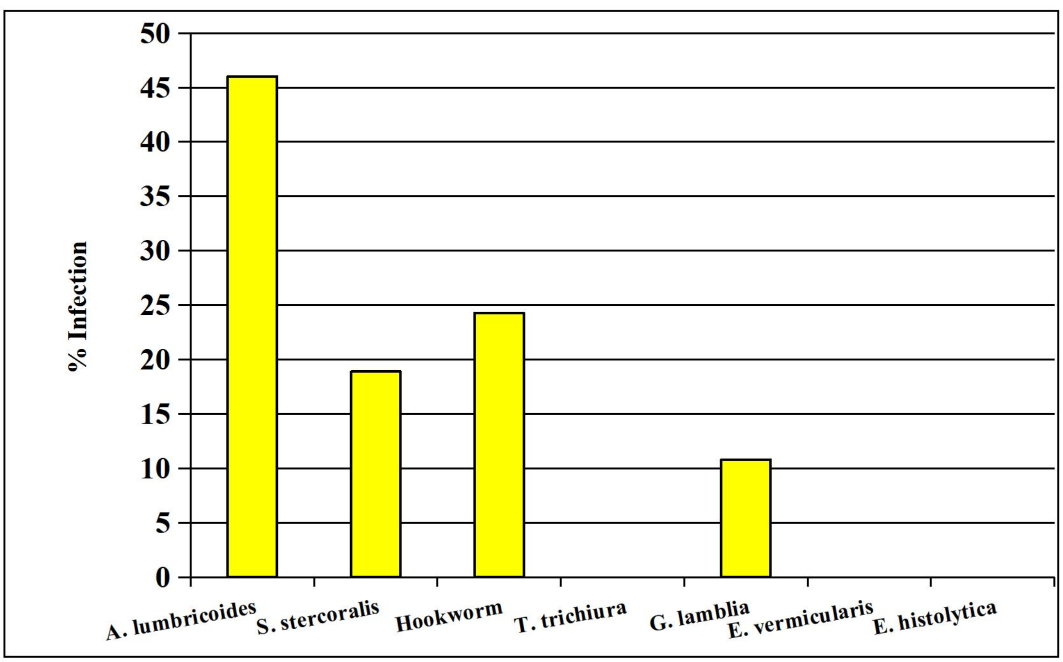


Figure 4.2: Parasites Infection on Scent Leaf (*Ocimum gratissimum*) in Benin City

Chart A3

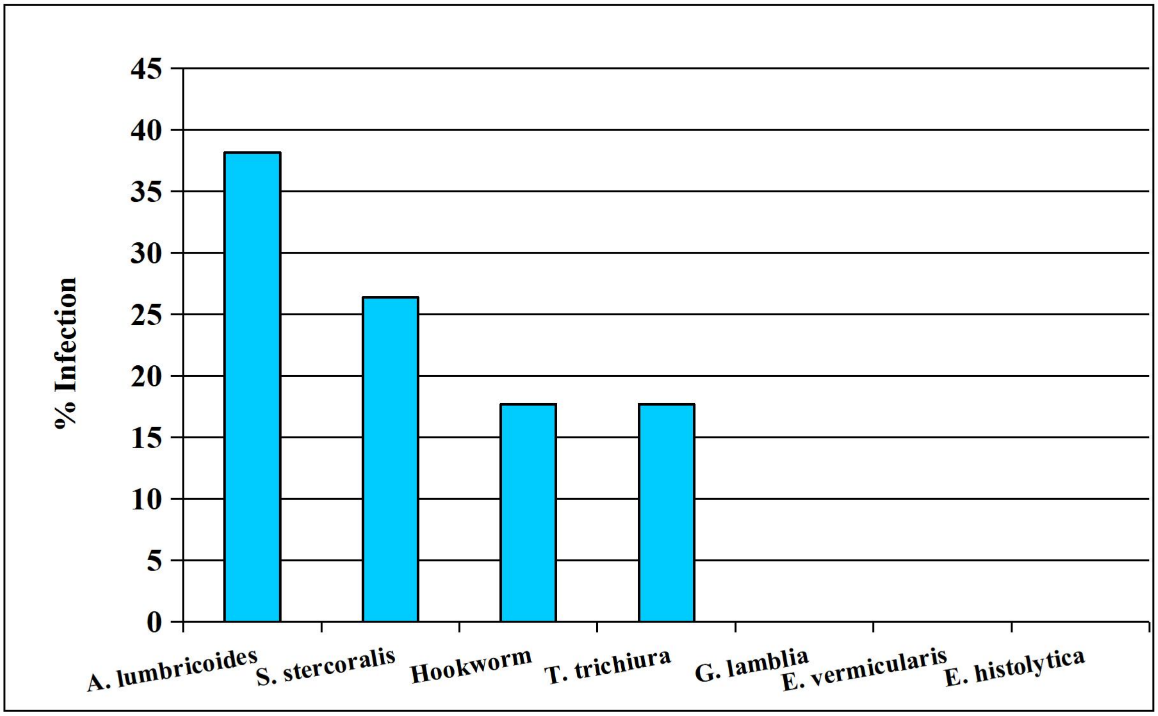


Figure 4.3: Parasites Infection on Pumpkin Leaf (*Telfaria occidentalis*) in Benin City

Chart A4

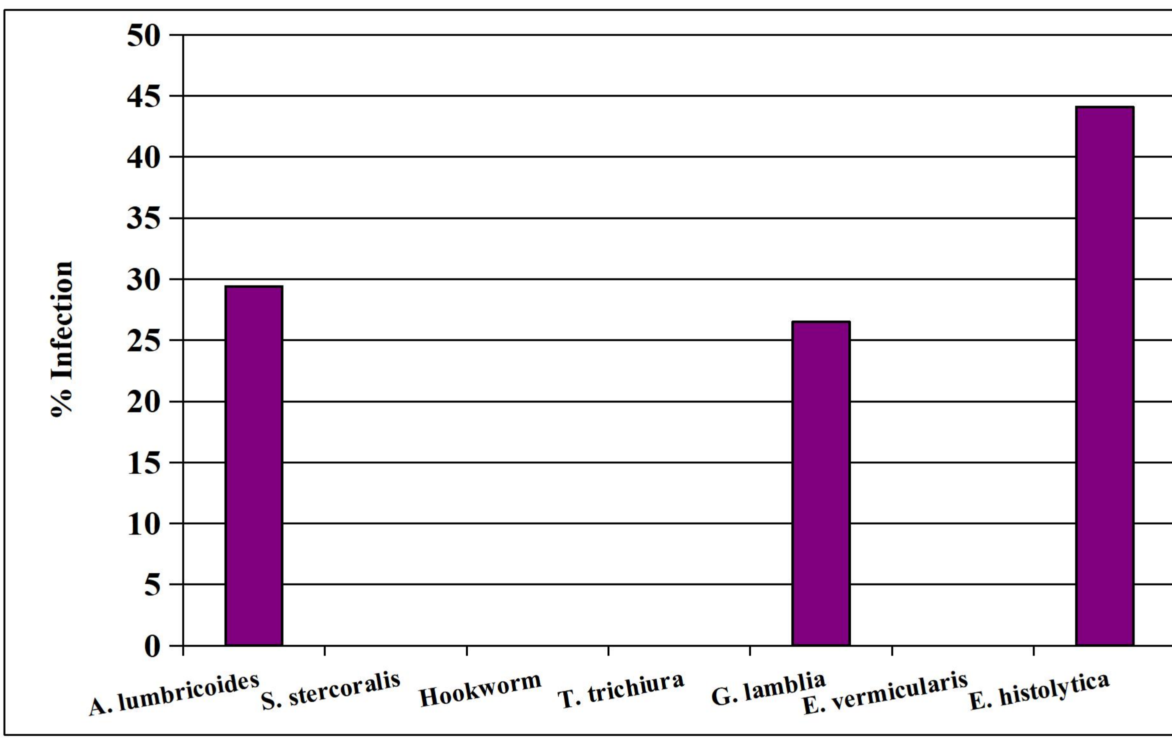


Figure 4.4: Parasites Infection on Cabbage (*Brassica oleracea*) in Benin City

Chart A5

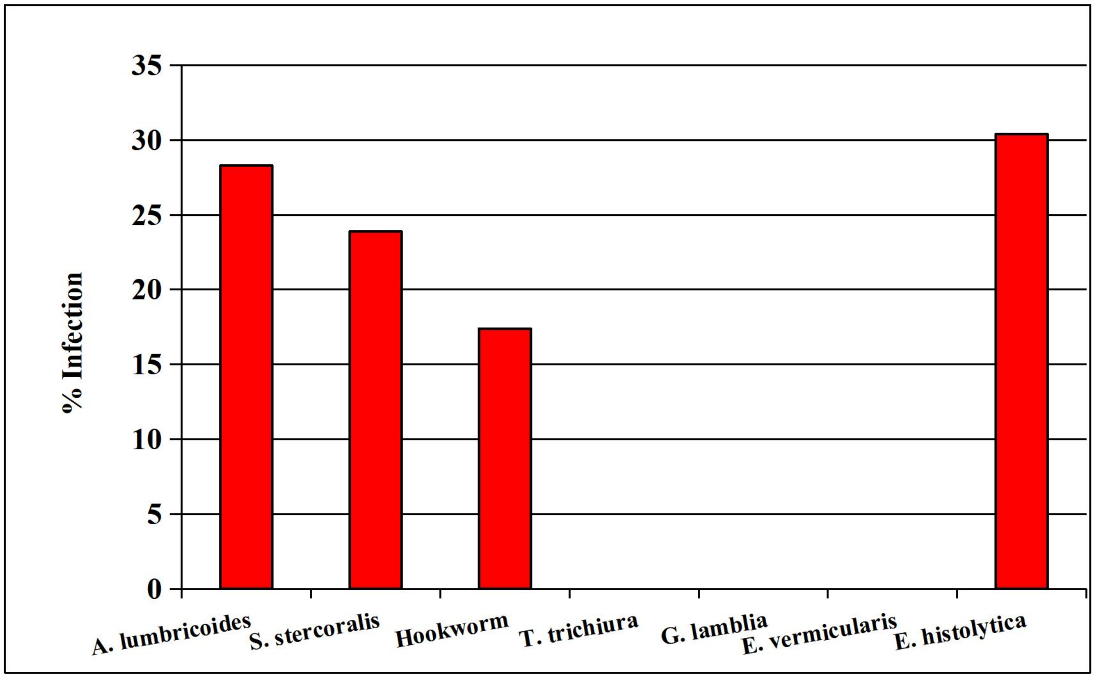


Figure 4.5: Parasites Infection on Eboziza (*Alchornea cordifolia*) in Benin City

Chart A6

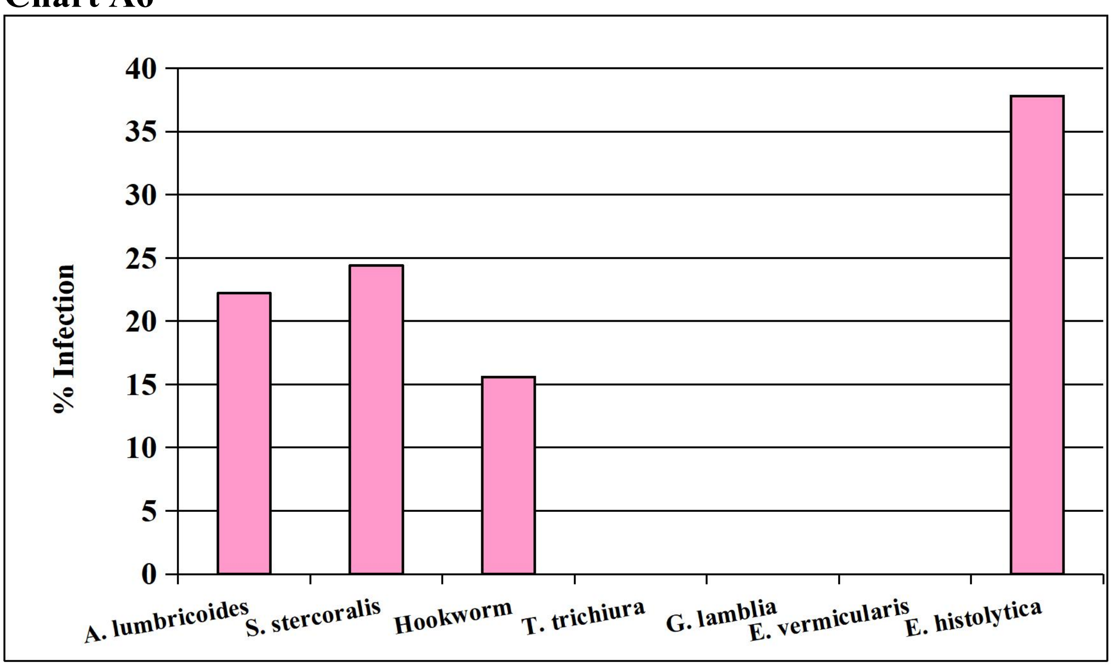


Figure 4.6: Parasites Infection on Ebewewie (*Gongronema latifolium*) in Benin City

Chart A7

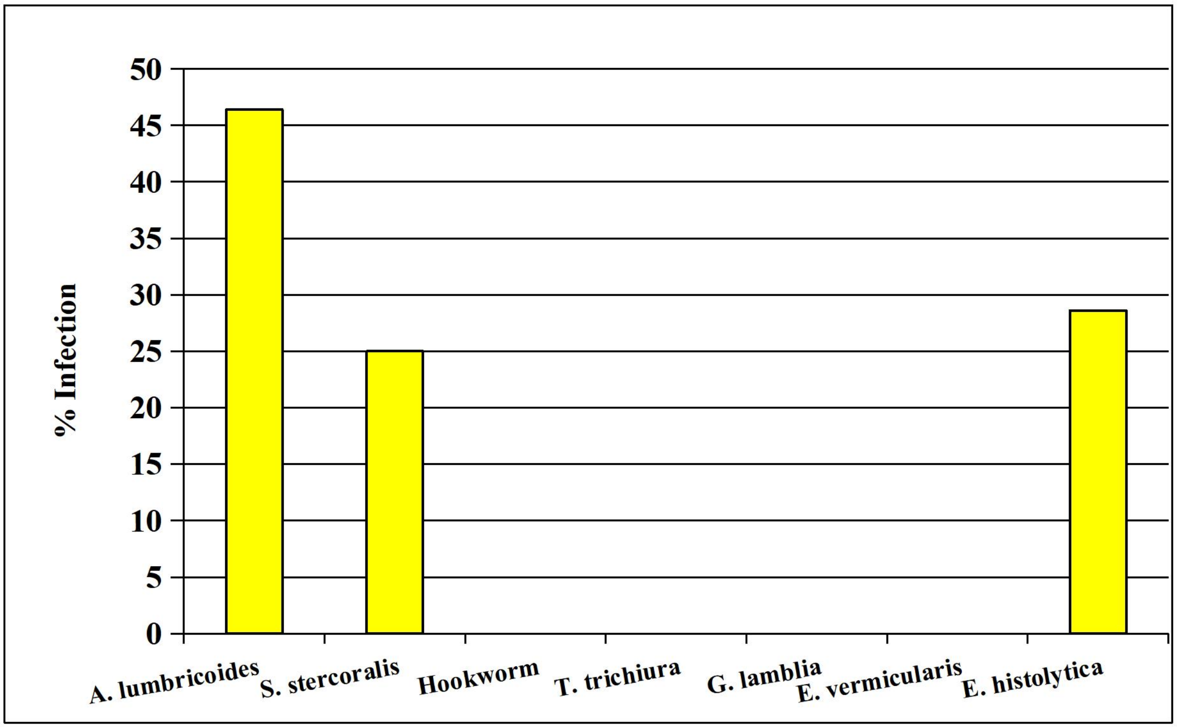


Figure 4.7: Parasites Infection on Curry leaf (*Murraya koenigii*) in Benin City

Chart A8

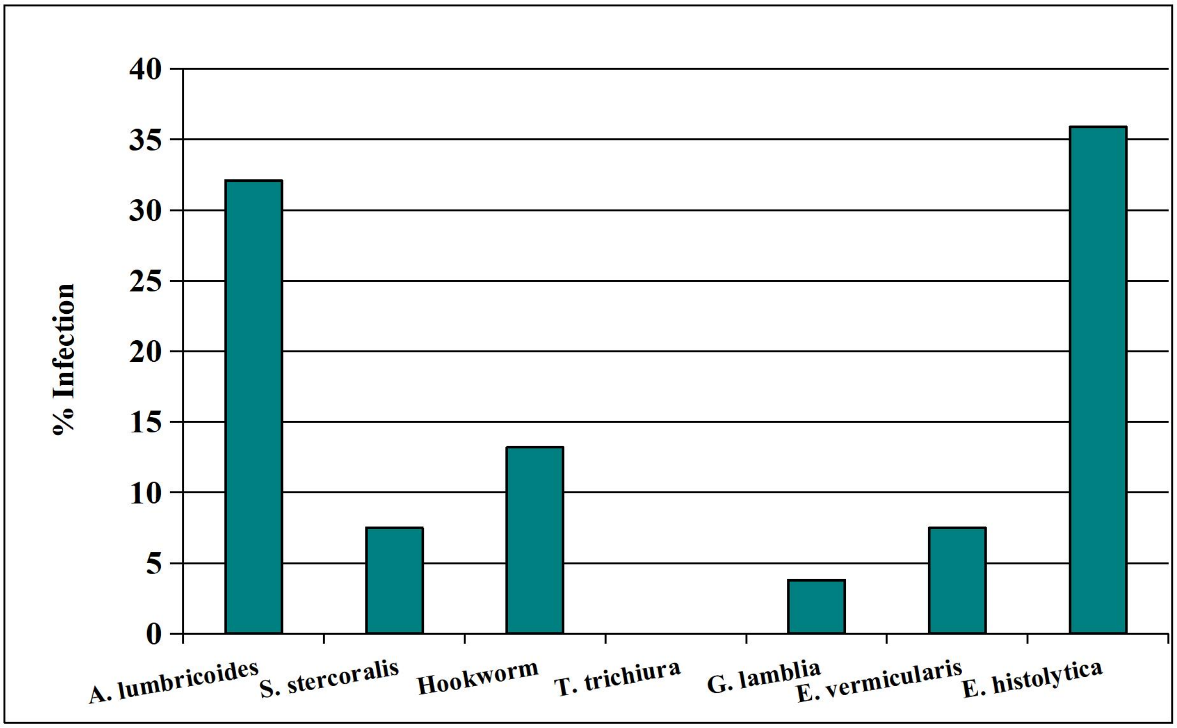


Figure 4.8: Parasites Infection on Water leaf (*Talinum fruticosum*) in Benin City

Chart A9

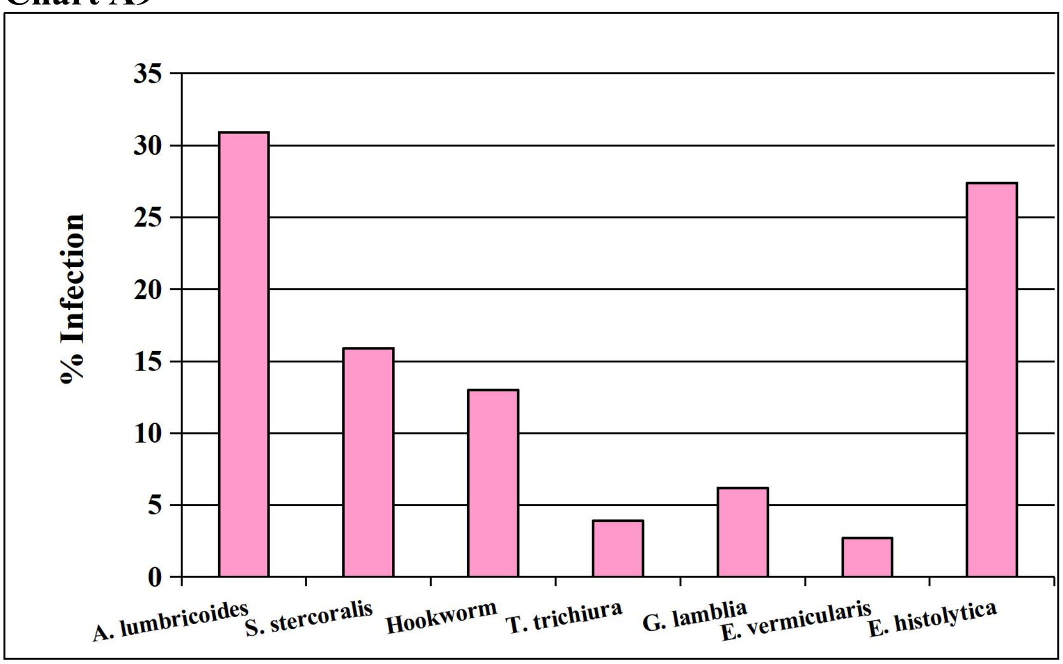
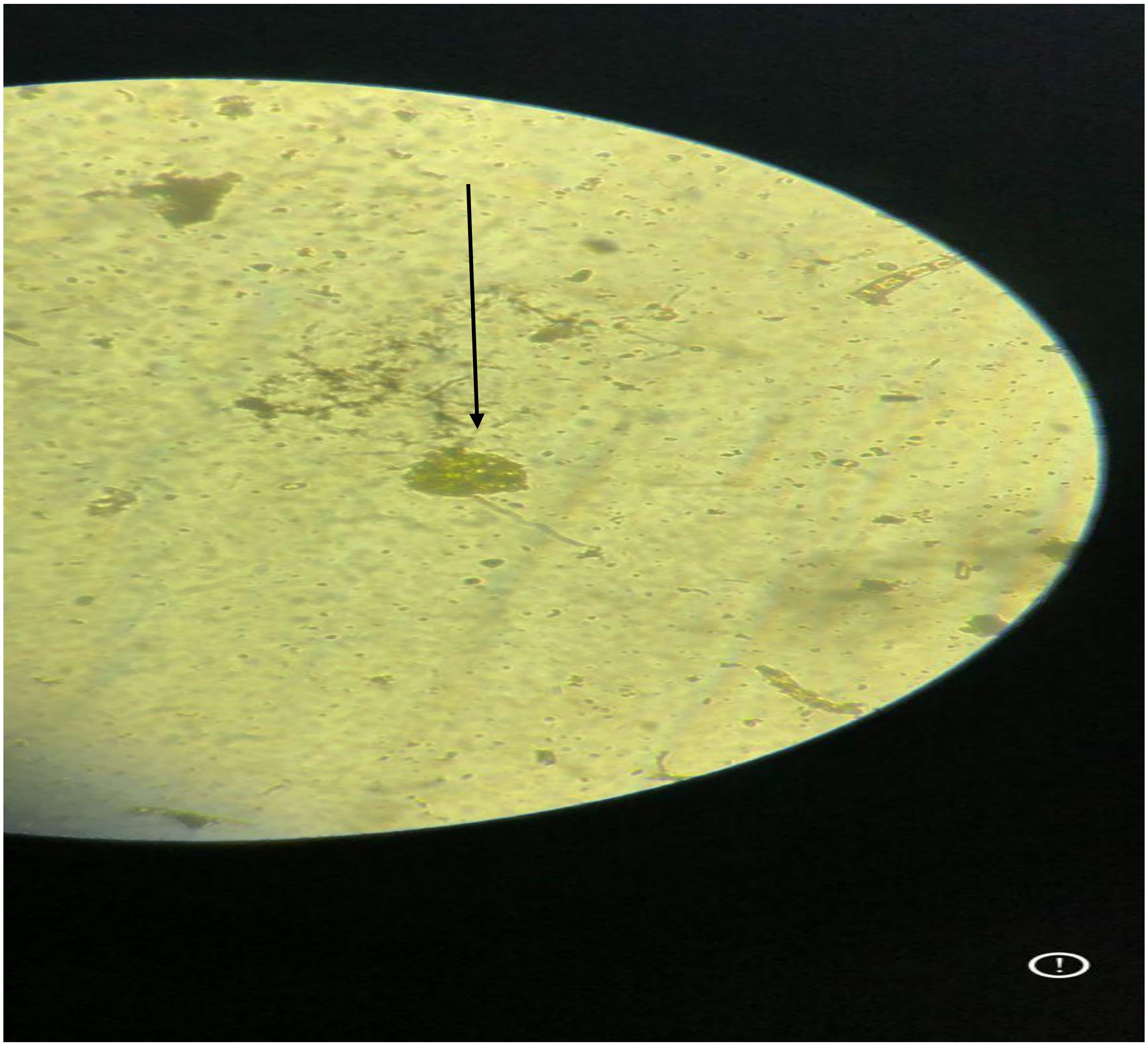


Figure 4.9: Parasites Infection on Leafy Vegetables in Benin City

APPENDIX B: Microscopic Images

Image B1

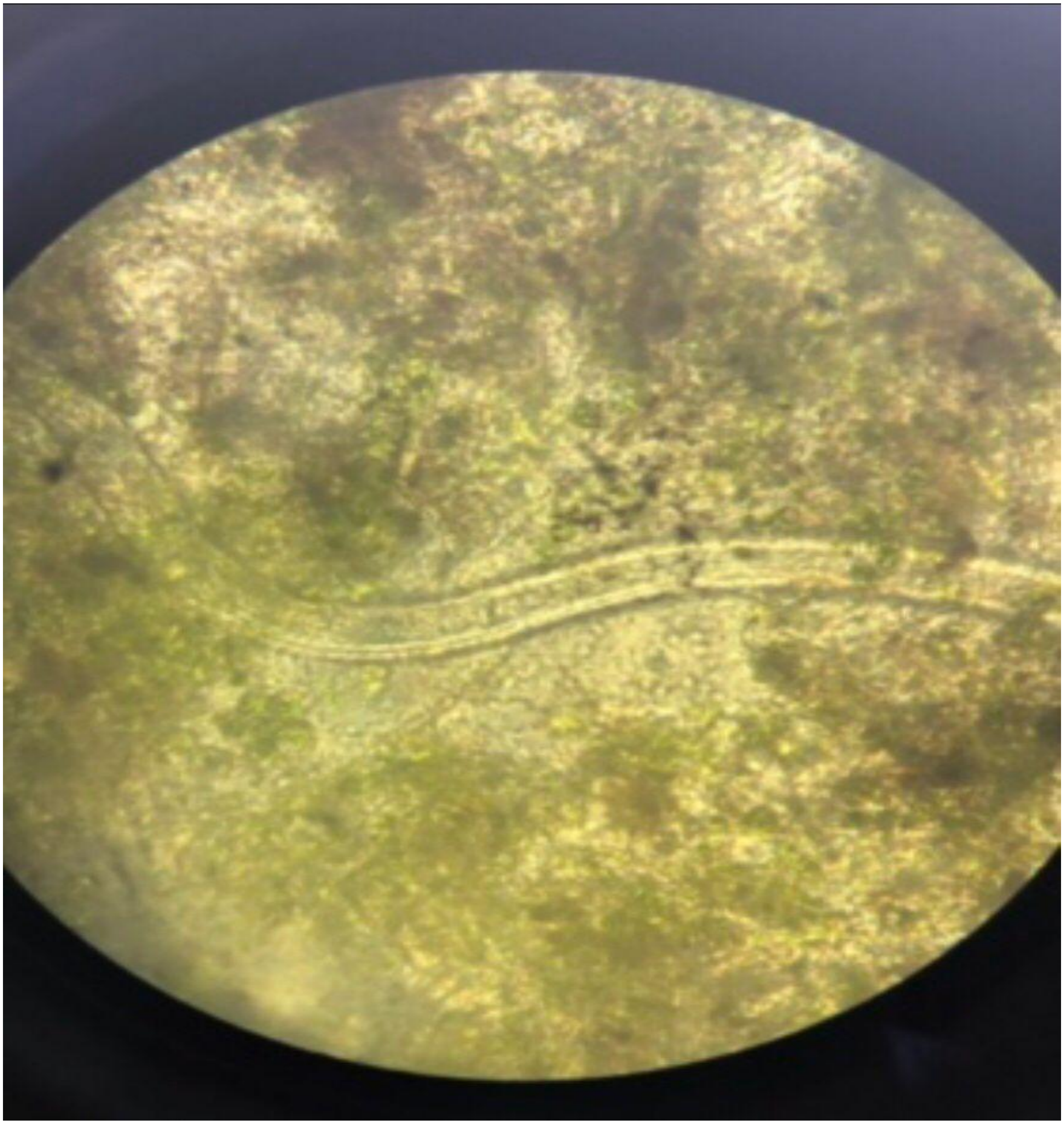


Ova of *Ascaris lumbricoides* (X10 Objective lens)

Image B2

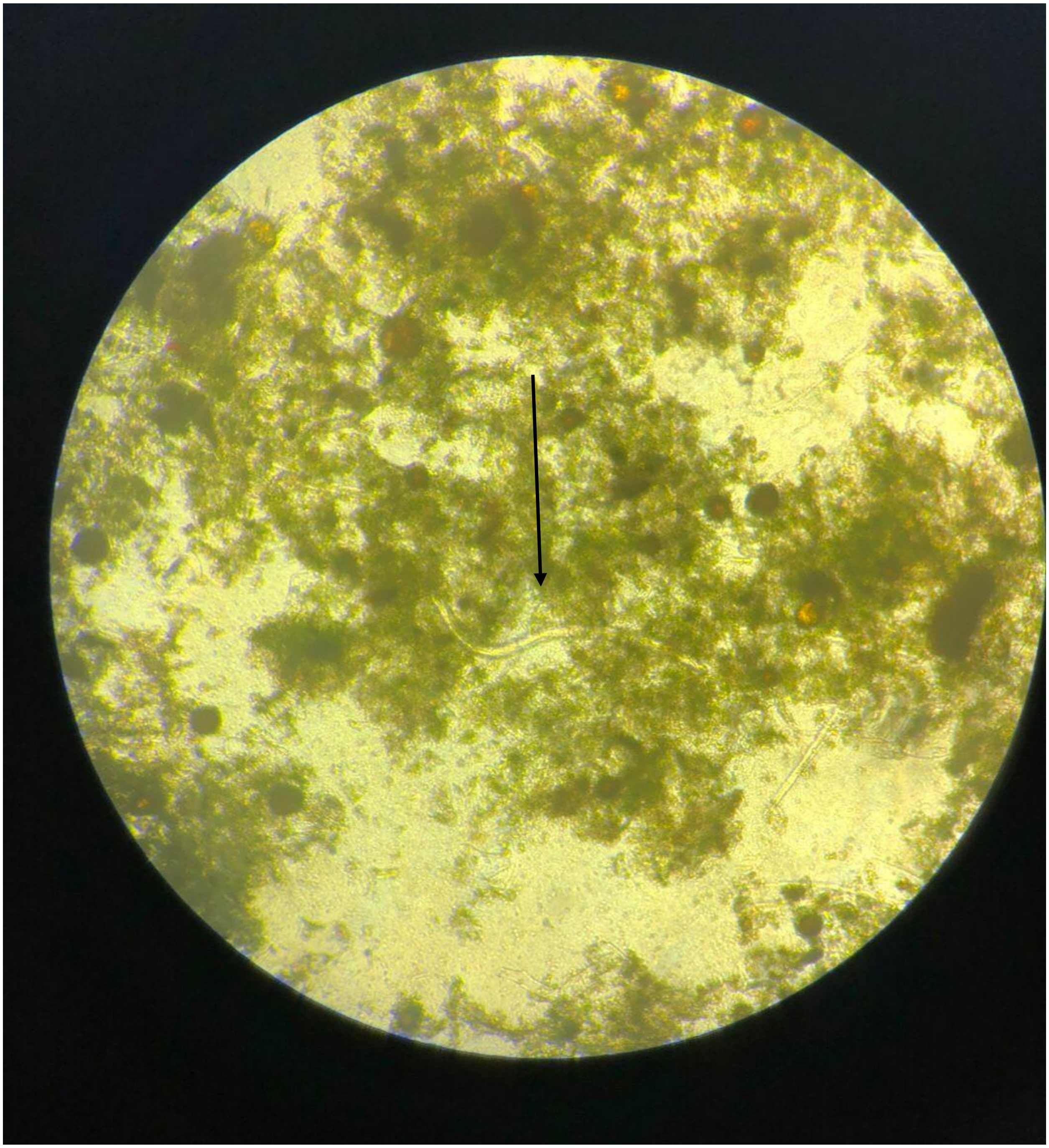
Larva of *Stronyloides stercoralis* (X10 Objective lens)

Image B3



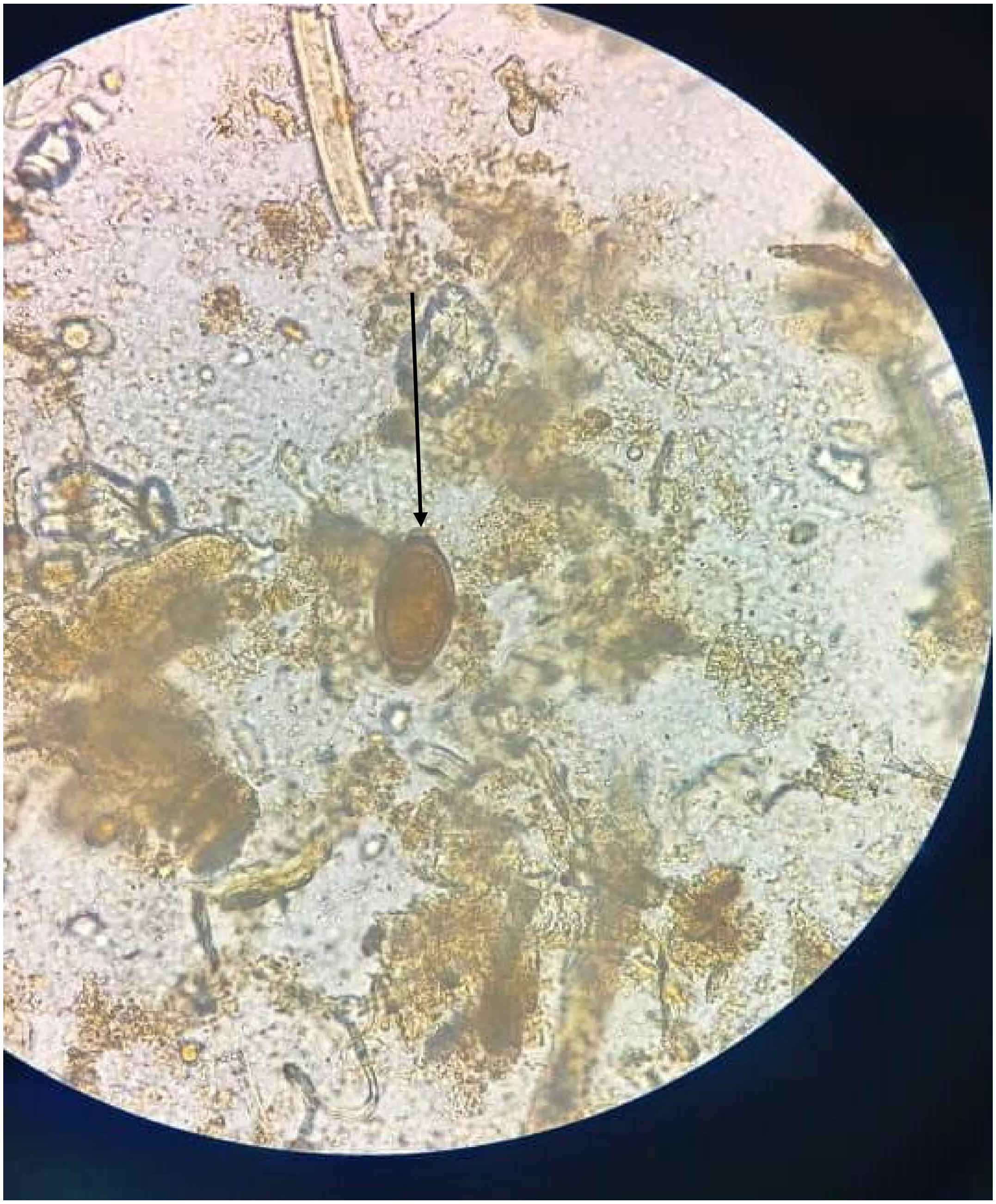
Hookworm (X40 Objective lens)

Image B4



Hookworm (X10 Objective lens)

Image B5



Ova of *Trichuri trichiura* (X10 Objective lens)

Image B6

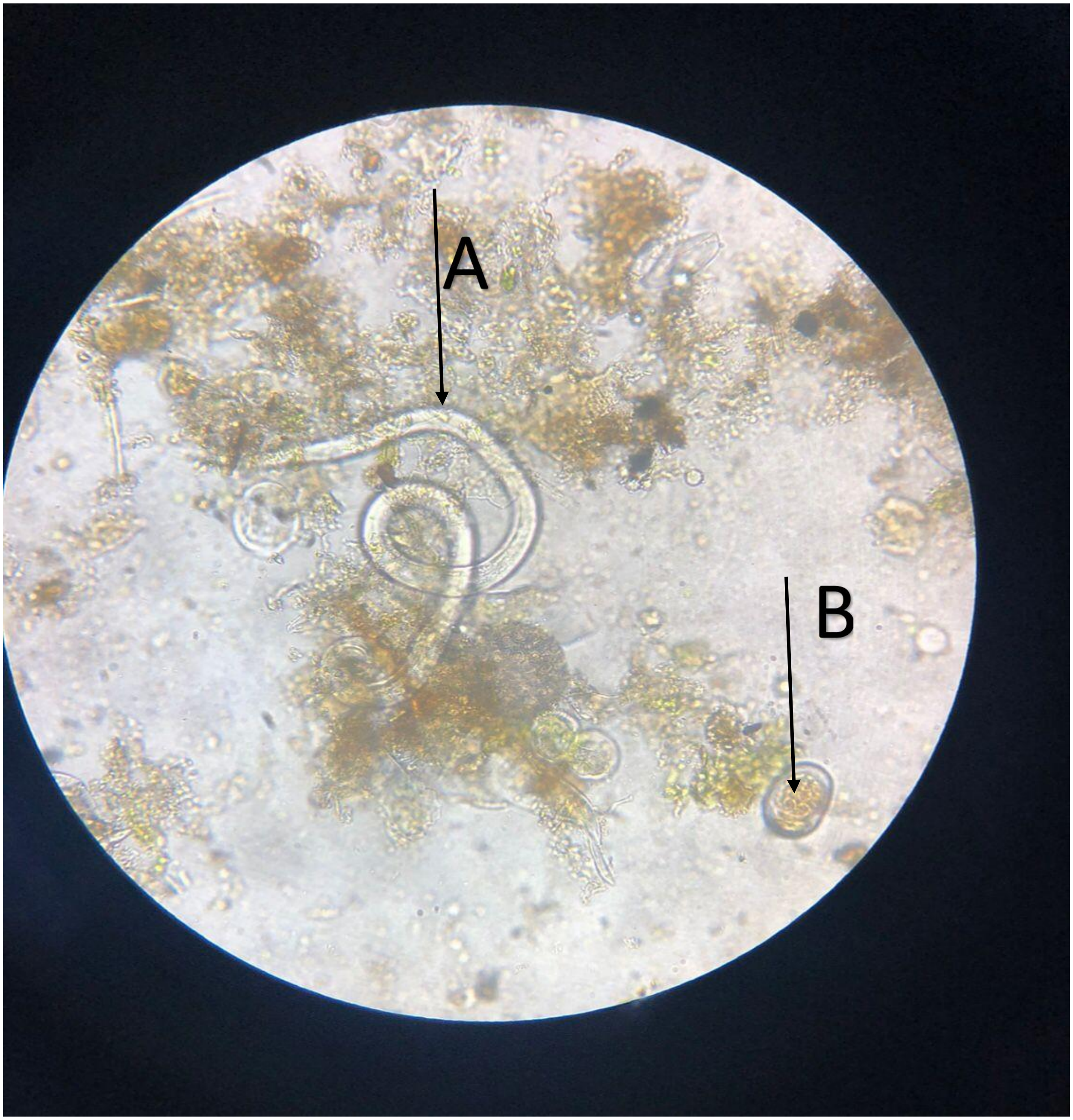
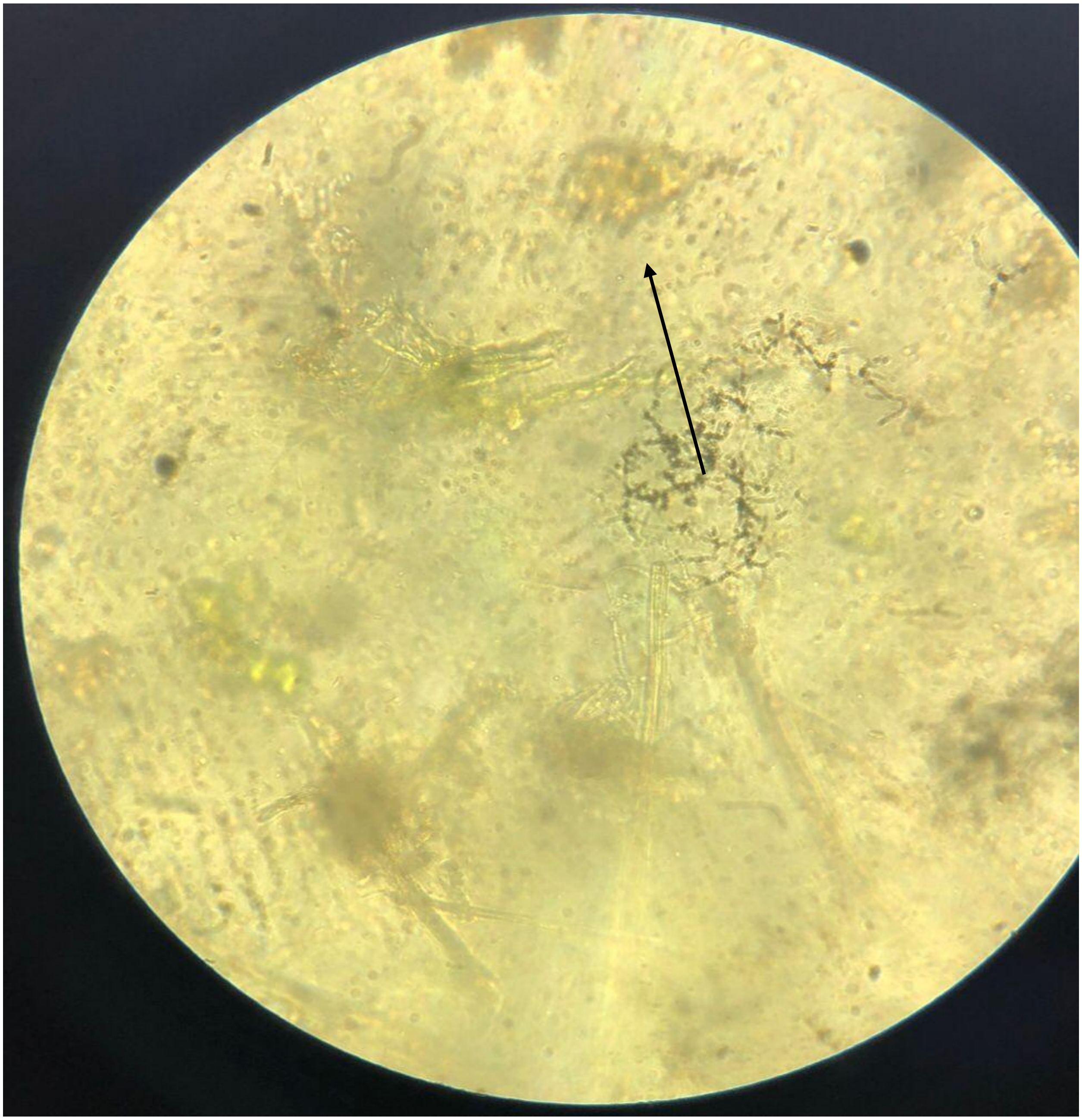


Image A: Hookworm (X10 Objective lens)

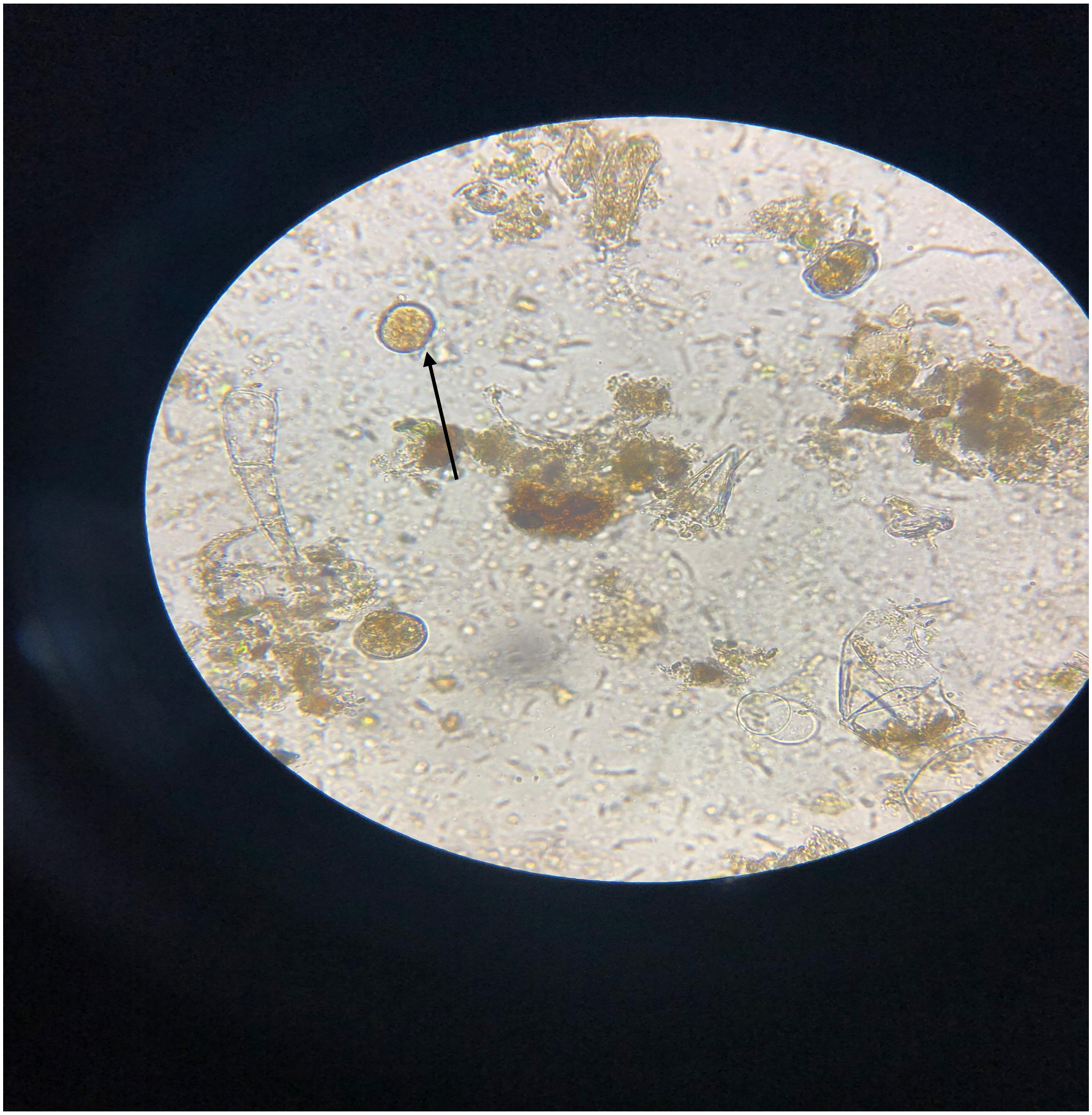
Image B: Ova of Hookworm (X10 Objective lens)

Image B7



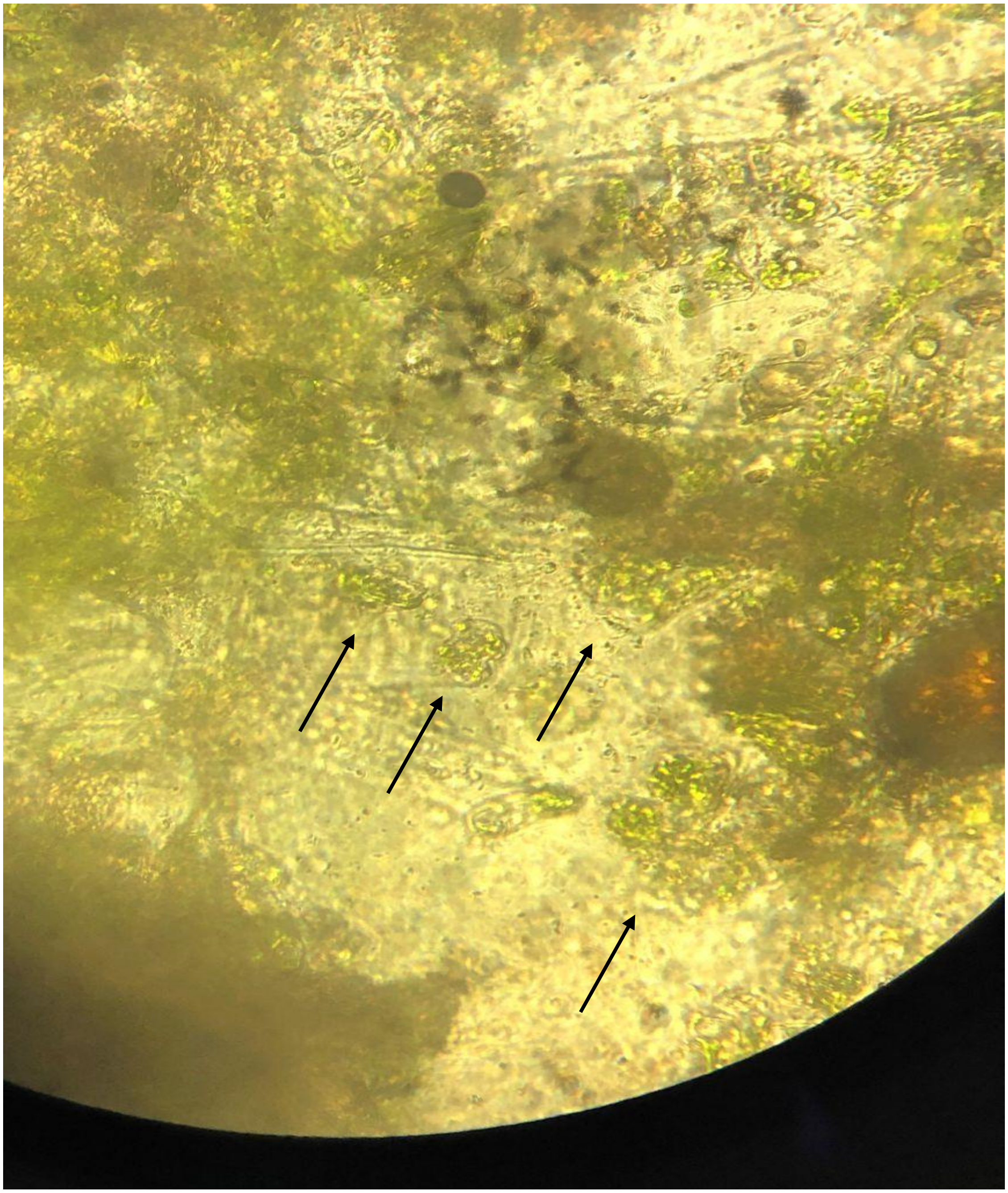
Cyst of Giardia lamblia (X10 Objective lens)

Image B8



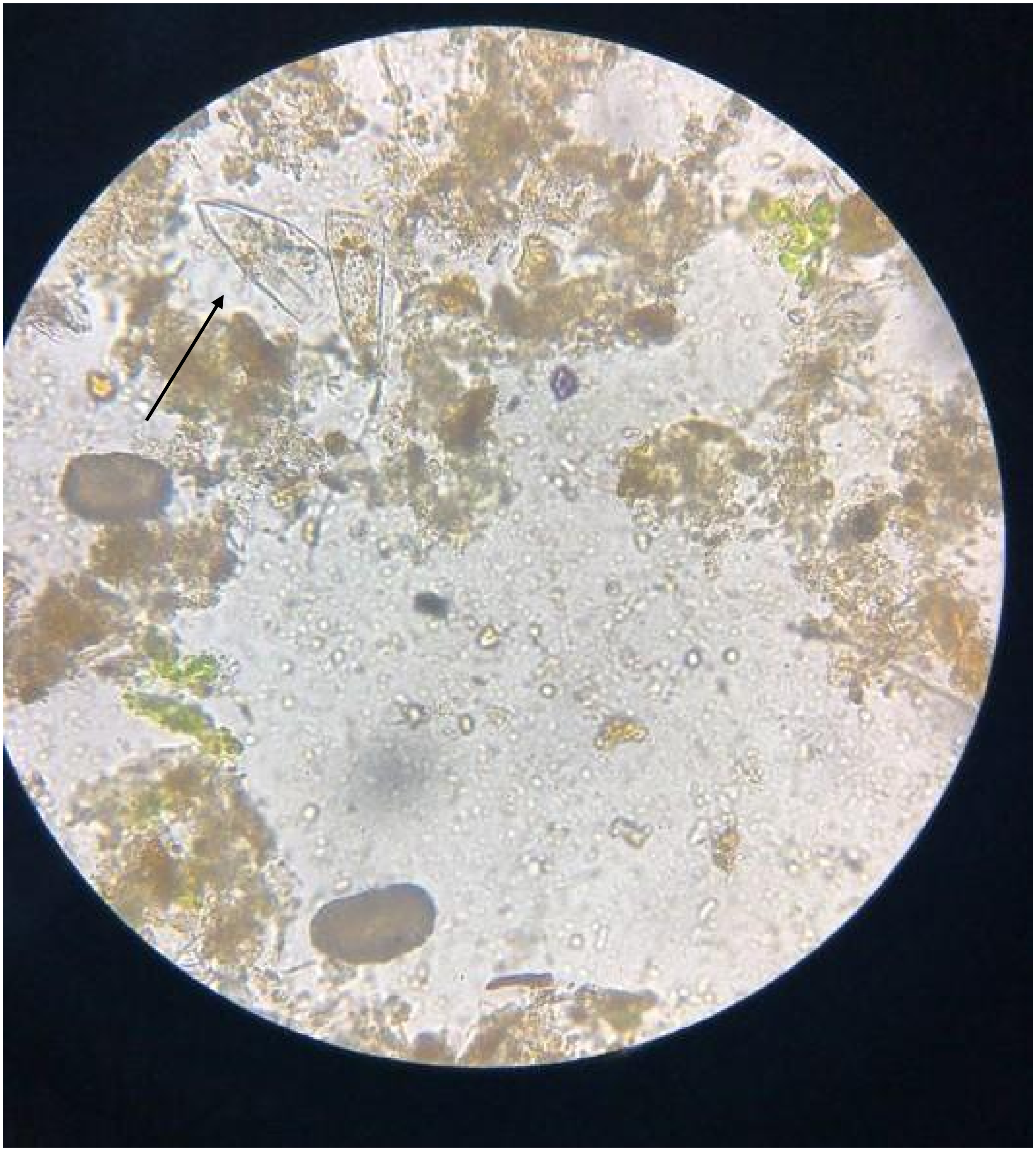
Cyst of *Entamoeba histolytica* (X10 Objective lens)

Image B9



Ova of Ascaris lumbricoides (X10 Objective lens)

Image B10



Ova of *Enterobius vermicularis* (X10 Objective lense)

Microscopic examination of samples collected

APPENDIX C: Analysis Table Using Kolmogorov-Smirnov Test (K-S Test)

Table 1: On Spinach Leaf

Market Test	1	2	3	4	N
Observed Frequency (O.F)	41	25	16	18	100
Expected Frequency (E.F)	25	25	25	25	100
Cumulative Observed Frequency (C.O.F)	41	66	82	100	
Cumulative Expected Frequency (C.E.F)	25	50	75	100	
(C.O.F) – (C.E.F)	16	16	7	0	

Calculated Difference = 16/100 = 0.160

Tabulated Difference = 1.36/ √100 =0.136

P < 0.05

41/25 = 1.640

Parasite Test	1	2	3	4	5	6	7	N
Observed Frequency (O.F)	21	9	13	13	10	9	25	100
Expected Frequency (E.F)	14.3	14.3	14.3	14.3	14.3	14.3	14.3	100
Cumulative Observed Frequency (C.O.F)	21	30	43	56	66	75	100	
Cumulative Expected Frequency (C.E.F)	14.3	28.6	42.9	57.2	71.5	85.3	100	
(C.O.F) – (C.E.F)	6.7	1.4	0.1	1.2	5.5	10.3		

Calculated Difference = 10.3/100 =0.103

Tabulated Difference = 1.36/ √100 =0.136

P > 0.05

Table 2: On Scent Leaf

Market Test	1	2	3	4	N
Observed Frequency (O.F)	30	16	30	24	100
Expected Frequency (E.F)	25	25	25	25	100
Cumulative Observed Frequency (C.O.F)	30	46	76	100	
Cumulative Expected Frequency (C.E.F)	25	50	75	100	
(C.O.F) – (C.E.F)	5	4	1	0	

Calculated Difference = 5/100 = 0.05

Tabulated Difference = 1.36/ √100 =0.136

$P > 0.05$

30/25 =1.2

Parasite Test	1	2	3	4	5	6	7	N
Observed Frequency (O.F)	46	19	24	0	11	0	0	100
Expected Frequency (E.F)	14.3	14.3	14.3	14.3	14.3	14.3	14.3	100
Cumulative Observed Frequency (C.O.F)	46	65	89	89	100	100	100	
Cumulative Expected Frequency (C.E.F)	14.3	28.6	42.9	57.2	71.5	85.3	100	
(C.O.F) – (C.E.F)	31.7	36.4	42.9	57.2	71.5	85.3	100	

Calculated Difference = 46.1/100 = 0.461

Tabulated Difference = 1.36/ √100 =0.136

$P < 0.05$

46/24 =1.90

$P < 0.05$ (1.548 equivalent of mean)

Table 3: On Pumpkin Leaf

Market Test	1	2	3	4	N
Observed Frequency (O.F)	24	18	38	20	100
Expected Frequency (E.F)	25	25	25	25	100
Cumulative Observed Frequency (C.O.F)	24	42	80	100	
Cumulative Expected Frequency (C.E.F)	25	50	75	100	
(C.O.F) – (C.E.F)	1	8	5	0	

Calculated Difference = 8/100 = 0.08

Tabulated Difference = 1.36/ √100 =0.136

$P > 0.05$

38/24 = 1.58

Parasite Test	1	2	3	4	5	6	7	N
Observed Frequency (O.F)	38	26	18	18	0	0	0	100
Expected Frequency (E.F)	14.3	14.3	14.3	14.3	14.3	14.3	14.3	100
Cumulative Observed Frequency (C.O.F)	38	64	82	100	100	100	100	
Cumulative Expected Frequency (C.E.F)	14.3	28.6	42.9	57.2	71.5	85.3	100	
(C.O.F) – (C.E.F)	23.7	35.4	39.1	42.8	28.5	14.7	0	

Calculated Difference = 42.8/100 = 0.428

Tabulated Difference = 1.36/ √100 =0.136

$P < 0.05$

38/26 = 1.5

$P < 0.05$

Table 4: On Cabbage

Market Test	1	2	3	4	N
Observed Frequency (O.F)	32	15	29	24	100
Expected Frequency (E.F)	25	25	25	25	100
Cumulative Observed Frequency (C.O.F)	32	47	46	100	
Cumulative Expected Frequency (C.E.F)	25	50	75	100	
(C.O.F) – (C.E.F)	7	3	1	0	

Calculated Difference =7 /100 = 0.07

Tabulated Difference = 1.36/ √100 =0.136

P > 0.05 (Even distribution)

Parasite Test	1	2	3	4	5	6	7	N
Observed Frequency (O.F)	29	0	0	0	27	0	44	100
Expected Frequency (E.F)	14.3	14.3	14.3	14.3	14.3	14.3	14.3	100
Cumulative Observed Frequency (C.O.F)	29	29	29	29	56	56	100	
Cumulative Expected Frequency (C.E.F)	14.3	28.6	42.9	57.2	71.5	85.3	100	
(C.O.F) – (C.E.F)	14.7	0.4	13.9	38.2	15.5	29.3	0	

Calculated Difference = 29.3/100 = 0.293

Tabulated Difference = 1.36/ √100 =0.136

P < 0.05

44/29 = 1.52

P< 0.05

Table 5: On Eboziza Leaf

Market Test	1	2	3	4	N
Observed Frequency (O.F)	26	15	33	26	100
Expected Frequency (E.F)	25	25	25	25	100
Cumulative Observed Frequency (C.O.F)	26	41	74	100	
Cumulative Expected Frequency (C.E.F)	25	50	75	100	
(C.O.F) – (C.E.F)	1	9	1	0	

Calculated Difference = 9/100 = 0.09

Tabulated Difference = 1.36/ √100 =0.136

P > 0.05 (Even distribution)

Parasite Test	1	2	3	4	5	6	7	N
Observed Frequency (O.F)	28	24	18	0	0	0	30	100
Expected Frequency (E.F)	14.3	14.3	14.3	14.3	14.3	14.3	14.3	100
Cumulative Observed Frequency (C.O.F)	28	52	70	70	70	70	100	
Cumulative Expected Frequency (C.E.F)	14.3	28.6	42.9	57.2	71.5	85.3	100	
(C.O.F) – (C.E.F)	13.7	23.4	27.1	12.8	1.5	15.3	0	

Calculated Difference = 27.1/100 = 0.271

Tabulated Difference = 1.36/ √100 =0.136

P < 0.05

30/28 = 1.07 (P> 0.05)

30/28 = 1.25 (P> 0.05)

30/18 = 1.66 (P< 0.05)

Table 6: On Ebewewie Leaf

Market Test	1	2	3	4	N
Observed Frequency (O.F)	38	31	20	11	100
Expected Frequency (E.F)	25	25	25	25	100
Cumulative Observed Frequency (C.O.F)	38	69	89	100	
Cumulative Expected Frequency (C.E.F)	25	50	75	100	
(C.O.F) – (C.E.F)	13	19	14	0	

Calculated Difference = 19/100 = 0.19

Tabulated Difference = 1.36/ $\sqrt{100}$ =0.136

$P < 0.05$

38/31 = 1.22 ($P > 0.05$)

38/20 = 1.90 ($P < 0.05$)

Parasite Test	1	2	3	4	5	6	7	N
Observed Frequency (O.F)	22	24	16	0	0	0	38	100
Expected Frequency (E.F)	14.3	14.3	14.3	14.3	14.3	14.3	14.3	100
Cumulative Observed Frequency (C.O.F)	22	46	62	62	62	62	100	
Cumulative Expected Frequency (C.E.F)	14.3	28.6	42.9	57.2	71.5	85.3	100	
(C.O.F) – (C.E.F)	7.7	17.4	19.1	4.8	9.5	23.3	0	

Calculated Difference = 23.3/100 = 0.233

Tabulated Difference = 1.36/ $\sqrt{100}$ =0.136

$P < 0.05$

38/24 =1.67 ($P < 0.05$)

Table 7: On Curry leaf

Market Test	1	2	3	4	N
Observed Frequency (O.F)	43	11	21	25	100
Expected Frequency (E.F)	25	25	25	25	100
Cumulative Observed Frequency (C.O.F)	43	54	75	100	
Cumulative Expected Frequency (C.E.F)	25	50	75	100	
(C.O.F) – (C.E.F)	18	4	0	0	

Calculated Difference = 18/100 = 0.18

Tabulated Difference = 1.36/ √100 =0.136

P < 0.05

43/25 = 1.72 (P< 0.05>)

Parasite Test	1	2	3	4	5	6	7	N
Observed Frequency (O.F)	46	25	0	0	0	0	29	100
Expected Frequency (E.F)	14.3	14.3	14.3	14.3	14.3	14.3	14.3	100
Cumulative Observed Frequency (C.O.F)	46	71	71	71	71	71	100	
Cumulative Expected Frequency (C.E.F)	14.3	28.6	42.9	57.2	71.5	85.3	100	
(C.O.F) – (C.E.F)	31.7	42.6	28.1	13.8	0.5	14.3	0	

Calculated Difference = 42.6/100 = 0.426

Tabulated Difference = 1.36/ √100 =0.136

P < 0.05

46/29 = 1.67 (P< 0.05)

Table 8: On Waterleaf

Market Test	1	2	3	4	N
Observed Frequency (O.F)	30	26	35	19	100
Expected Frequency (E.F)	25	25	25	25	100
Cumulative Observed Frequency (C.O.F)	30	56	81	100	
Cumulative Expected Frequency (C.E.F)	25	50	75	100	
(C.O.F) – (C.E.F)	5	6	6	0	

Calculated Difference = 6/100 = 0.06

Tabulated Difference = 1.36/ √100 =0.136

P > 0.05 (Even distribution)

Parasite Test	1	2	3	4	5	6	7	N
Observed Frequency (O.F)	32	7	13	0	4	8	36	100
Expected Frequency (E.F)	14.3	14.3	14.3	14.3	14.3	14.3	14.3	100
Cumulative Observed Frequency (C.O.F)	32	39	52	52	56	64	100	
Cumulative Expected Frequency (C.E.F)	14.3	28.6	42.9	57.2	71.5	85.3	100	
(C.O.F) – (C.E.F)	17.7	10.4	9.1	5.2	15.5	21.3	0	

Calculated Difference = 21.3/100 = 0.213

Tabulated Difference = 1.36/ √100 =0.136

P < 0.05

36/32 = 1.15 (P> 0.05)

36/13 = 3.0 (P> 0.05)

Table 9: On Leafy Vegetable

Market Test	1	2	3	4	N
Observed Frequency (O.F)	34	20	26	20	100
Expected Frequency (E.F)	25	25	25	25	100
Cumulative Observed Frequency (C.O.F)	34	54	80	100	
Cumulative Expected Frequency (C.E.F)	25	50	75	100	
(C.O.F) – (C.E.F)	9	4	5	0	

Calculated Difference = 9/100 = 0.09

Tabulated Difference = 1.36/ √100 =0.136

P > 0.05 (Even distribution)

Parasite Test	1	2	3	4	5	6	7	N
Observed Frequency (O.F)	31	16	13	4	6	3	27	100
Expected Frequency (E.F)	14.3	14.3	14.3	14.3	14.3	14.3	14.3	100
Cumulative Observed Frequency (C.O.F)	31	47	60	64	70	73	100	
Cumulative Expected Frequency (C.E.F)	14.3	28.6	42.9	57.2	71.5	85.3	100	
(C.O.F) – (C.E.F)	16.7	18.4	17.1	6.8	1.5	12.3	0	

Calculated Difference = 18.4/100 = 0.184

Tabulated Difference = 1.36/ √100 =0.136

P < 0.05

31/27 = 1.15 (P> 0.05)

31/16 = 1.93 (P< 0.05)

APPENDIX D: Field Documentation

Image D1

At one of the markets to collect vegetable samples

Image D2

Market women displaying vegetables on the ground, a site for contamination.

Image D3

Market women sorting vegetables with unwashed hands, a means for contamination