

## Review Article

# Review of Medicinal Plants Traditionally Used to Treat Diarrhea by the People in the Amhara Region of Ethiopia

Destaw Damtie 

Department of Biology, College of Sciences, Bahir Dar University, Bahir Dar, Ethiopia

Correspondence should be addressed to Destaw Damtie; zegades96@gmail.com

Received 11 May 2023; Revised 5 August 2023; Accepted 20 November 2023; Published 25 November 2023

Academic Editor: Slim Smaoui

Copyright © 2023 Destaw Damtie. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

**Background.** Diarrheal illness is the second-most common cause of death in under-five children. Worldwide, it results in about 1.7 billion illnesses and 525,000 deaths among under-five children annually. It is the leading cause of malnutrition among under-five children. Different people use medicinal plants to treat diarrhea. The present study aimed to review the medicinal plants used to treat diarrhea by the people in the Amhara region and to diagnose whether the antidiarrheal activities of the medicinal plants have been confirmed by studies using animal models. **Methods.** The author searched 21 articles from worldwide databases up to December 2022 using Boolean operators (“AND” and “OR”) and the terms “ethnobotanical studies,” “ethnobiology,” “traditional medicine,” “ethnobotanical knowledge,” and “Amhara region.” **Results.** From the 21 studies reviewed, 50 plant species grouped into 28 families were reported to treat diarrhea by the people in the Amhara region. The top most used families were *Lamiaceae* (12%), *Fabaceae* (8%), *Asteraceae*, *Cucurbitaceae*, *Euphorbiaceae*, and *Poaceae* (6% each). The modes of administration of the plant parts were orally 98.88% and topically 1.12%. The different extracts of 18 (or 36%) of the medicinal plants traditionally used to treat diarrhea by the people in the Amhara region have been proven experimentally in animal models. **Conclusions.** The people in the Amhara region use different medicinal plants to treat diarrhea. Most of them take the medicinal plants orally. The traditional claim that 60% of medicinal plants are antidiarrheal has been confirmed in *in vitro* studies.

## 1. Background

Diarrhea is the second leading cause of under-five mortality in the world [1]. In 2019 alone, diarrheal diseases resulted in 6.58 billion incident cases, 99 million prevalent cases, 1.53 million deaths, and 80.9 million disability-adjusted life years (DALYs) [2]. Among under-five children, diarrheal diseases resulted in 45.5 million DALYs and 370,000 deaths in 2019 [1, 2]. There are three clinical types of diarrhea, namely, acute watery diarrhea, which may last several hours or days and includes cholera; acute bloody diarrhea, also called dysentery; and persistent diarrhea, lasting 14 days or longer [1].

The Amhara region in Ethiopia experiences varying rates of diarrhea prevalence among under-five children, as indicated by several studies. A systematic review and meta-analysis published in PLOS ONE found that the overall

prevalence of diarrhea in the region was 21%, which closely aligns with the national prevalence of 22% [3]. However, individual studies conducted in specific areas within the Amhara region showed different prevalence rates. For example, studies in Bahir Dar city reported a prevalence of 14.5% [4], while Farta district showed a higher prevalence of 29.9% among under-five children [5]. Other areas such as Jawi district, Debre Berhan town, Woldia town, Bahir Dar Zuria district, the rural area of the North Gondar zone, and flood-prone villages of the Fogera and Libo Kemkem districts also exhibited varying prevalence rates ranging from 15.5% to 29.0% [6–10]. Interestingly, a report suggested that there was no significant variation in prevalence between high and low hotspot districts in the region [11]. By integrating the wisdom and methodologies of traditional and modern medicine, a comprehensive and holistic healthcare approach can be established to prevent and treat diarrheal diseases in

the Amhara region. This collaborative approach has the potential to improve the overall effectiveness of the healthcare system and advance the well-being of the local population.

Herbal medicines are believed to be effective in curing diarrhea, and for many years, plants and plant extracts have been used to treat various gastrointestinal ailments, including diarrhea [12, 13]. However, herbal medicines used in the treatment of diarrhea in African rural communities are unlikely to be replaced soon by modern medicines [14].

Nowadays, the integration of herbal medicine into modern medical practices is highly advocated [15]. Furthermore, herbal medicines have active components that serve as prototype leader compounds for the development of new drugs [16]. Documenting herbal medicines is thus documenting future drugs. Its ecological and cultural diversity make Ethiopia a rich source of herbal medicine [17]. However, due to environmental degradation, deforestation, a lack of recordkeeping, and potential acculturation, the plants and related indigenous knowledge in the nation are steadily diminishing [18]. Therefore, documentation of traditional knowledge regarding the usage of medicinal herbs is crucial to ensure its use by both present and future generations [19]. Hence, the present study aims to document medicinal plants from the Amhara region of Ethiopia that is traditionally used to treat diarrhea.

## 2. Research Methodology

**2.1. Purpose.** Documentation of medicinal plants of anti-diarrheal importance is essential for local knowledge conservation, formulating antidiarrheal drugs from plant extracts, and the isolation of interesting compounds to synthesize future effective antidiarrheal drugs.

**2.2. Search Strategy.** The author searched articles from PubMed/Medline, Science Direct, Web of Science, and Google Scholar up to December 2022 by using Boolean operators (“AND” and “OR”) and the terms “diarrhea,” “dysentery,” “ethnobotanical studies,” “ethnobiology,” “traditional medicine,” “ethnobotanical knowledge,” and “Amhara region.”

**2.3. Eligibility Criteria.** The present study included articles written in English and published until December 2022 dealing with the documentation of indigenous knowledge and articles that possess the scientific names, family names, local names, plant parts used, routes of administration, the way of using plants, and the modes of preparation.

**2.4. Quantitative Analysis of Ethnobotanical Data.** Since the study is a review study, the author faced problems searching for data to compute many of the quantitative parameters. Accordingly, only relative frequency of citation (RFC) and family use value (FUV) are found to be applicable to this study. They were calculated using the following formulae:

$$\text{RFC} = \frac{\text{Number of citations to a species}}{\text{Total number of citations to all the species}}, \quad (1)$$

$$\text{FUV} = \frac{\text{The number of species in each family used to treat diarrhea}}{\text{Total number of species in all the families used to treat diarrhea}}$$

## 3. Results

**3.1. Identification of Relevant Articles.** A literature search by the authors turned up a total of 120 published papers. 21 articles were chosen for this review after removing duplicates and irrelevant articles (Figure 1).

**3.2. List of Identified Plants Used to Treat Diarrhea in the Study Area.** From the 21 studies eligible for this study, 50 plant species were reported to treat diarrhea (Table 1). They are *Acacia abyssinica* [32], *Acacia etbaica* Schweinf [31], *Aloe* spp. [21], *Anogeissus leiocarpa* (A. Rich) Guill. and Perr [23], *Artemisia abyssinica* [24–26], *Balanites aegyptiaca* (L.) Delile [21], *Calpurnia aurea* (Ait.) Benth [20, 22, 29, 30, 32, 35, 36], *Carica papaya* L. [28], *Carissa spinarum* L. [26, 29, 30], *Clutia abyssinica* Jaub. and Spach. [22], *Clutia lanceolata* Forssk. [20], *Coffea arabica* L. [20, 29–31, 39], *Cordia*

*africana* [27], *Croton macrostachyus* De [34], *Cucumis ficifolius* [31, 32], *Eragrostis tef*. (Zucc.) Trotter [33], *Ficus thonningii* Blume [34], *Ficus vasta* Forssk [35, 36], *Heteromorpha arborescens* (Spreng). Cham. and Schitdi. [22], *Hordeum vulgare* L. [31, 32], *Justicia schimperiana* (Hochst. ex Nees) T. Anders. [20], *Leonotis ocyimifolia* [28, 35, 36], *Lepidium sativum* L. [26, 28–30], *Linum usitatissimum* L. [22, 24], *Malva parviflora* L. [21], *Mentha piperita* L. [21, 25], *Momordica foetida* Schumach [20], *Myrtus communis* L. [34], *Ocimum lamiifolium* L. [29, 30], *Gossypium barbadense* L. [37], *Plectranthus lactiflorus* (Vatke) Agnew [26], *Prunus persica* (L.) Batsch [20], *Punica granatum* [32], *Rumex abyssinicus* [27], *Rumex nepalensis* (Spreng) [38], *Ruta chalepensis* L. [24, 29, 30], *Salvia nilotica* Jacq. [22], *Satureja punctata* R. Br. [22], *Senna didymobotrya* (Fresen) [31], *Solanecio gigas* (Vatke) C. Jeffrey [22], *Solanum nigrum* L. [20], *Sorghum bicolor* (Moench) [22],

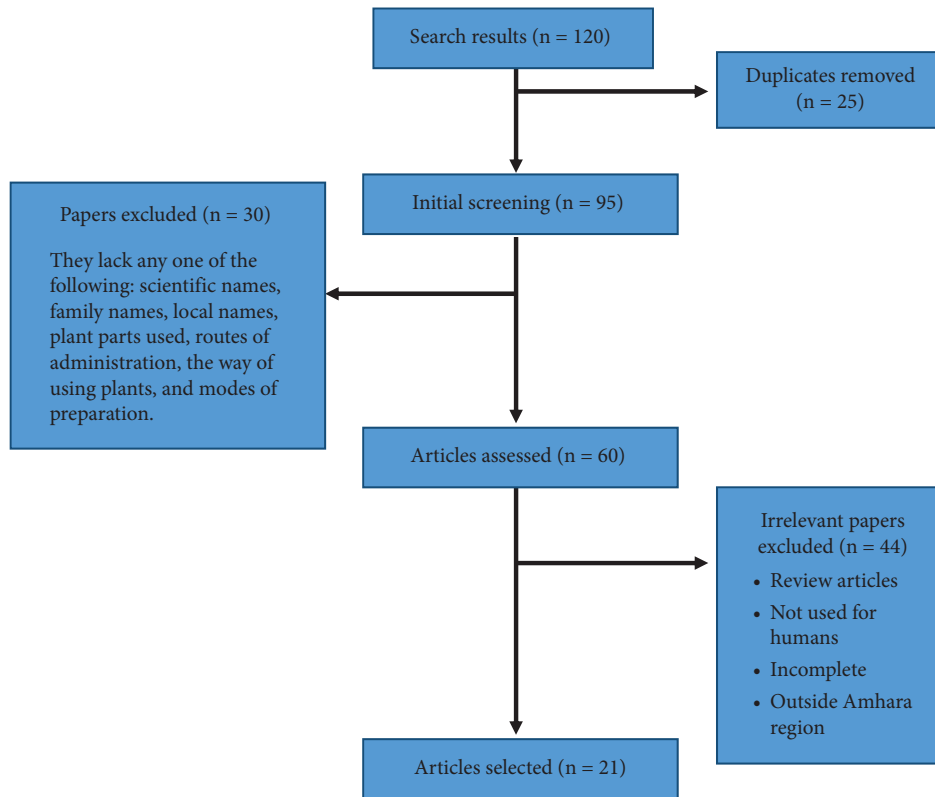


FIGURE 1: Flowchart of the screening process for this review.

*Stephania abyssinica* (Dillon and A. Rich.) Walp. [38], *Syzygium guineense* (Willd.) DC. [23], *Verbascum sinaiticum* Benth [20, 34, 38], *Verbena officinalis* L. [22, 26, 28–30, 40], *Vernonia adoensis* Sch.Bip.exWalp. [23], *Withania somnifera* (L.) Dunal [29, 30, 38, 40], *Zehneria scabra* (Linn. f.) Sond [20, 33], and *Ziziphus spina-christi* (L.) Desf [22].

The medicinal plants used by the population in the Amhara region for the treatment of diarrhea are grouped into 28 families and 50 species, as indicated in Table 1. The *Lamiaceae* family was represented by six (12%) species and the *Fabaceae* family by four (8%) species. *Asteraceae*, *Cucurbitaceae*, *Euphorbiaceae*, and *Poaceae* were represented by three (6%) species each. *Caricaceae*, *Malvaceae*, *Moraceae*, *Myrtaceae*, *Polygonaceae*, and *Solanaceae* were represented by two (4%) species each. *Apiaceae*, *Acanthaceae*, *Aloaceae*, *Boraginaceae*, *Brassicaceae*, *Combretaceae*, *Linaceae*, *Menispermaceae*, *Punicaceae*, *Rhamnaceae*, *Rosaceae*, *Rubiaceae*, *Rutaceae*, *Scrophulariaceae*, *Verbenaceae*, and *Zygophyllaceae* were represented by a single (2%) species each. Only two modes of administration of the plant parts were used to treat diarrhea. Almost all (98.88%) were applied orally, and only 1.12% dermally (topically).

### 3.3. Quantitative Analyses of Ethnobotanical Data

**3.3.1. Relative Frequency of Citations (RFC).** The relative frequency of citations (RFC) ranged from 0.01 to 0.08. The top four cited medicinal plants for their antidiarrheal activities were *Calpurnia aurea* (Ait.) Benth., *Verbena*

*officinalis* L., *Coffea arabica* L., and *Lepidium sativum* L., with RFC values of 0.08, 0.07, 0.06, and 0.05, respectively. *Artemisia abyssinica*, *Carissa spinarum* L., *Leonotis ocymifolia*, *Ruta chalepensis* L., *Verbascum sinaiticum* Benth, and *Withania somnifera* (L.) Dunal all had the same RFC value of 0.03. Furthermore, 14% and 66% of the species had RFC values of 0.02 and 0.01, respectively (Figure 2).

**3.3.2. Family Use Value (FUV).** The family use value (FUV) for the 28 families ranged from 0.01 to 0.12. *Lamiaceae* was the most frequently used plant family to treat diarrhea (FUV=0.12), followed by *Fabaceae* (FUV=0.08), and *Asteraceae*, *Cucurbitaceae*, *Euphorbiaceae*, and *Poaceae*, all with an FUV of 0.06. Additionally, 21.4% and 57.1% of the families had FUVs of 0.04 and 0.02, respectively (Figure 3).

**3.4. Plant Parts Used to Treat Diarrhea.** The top five plant parts used to treat diarrhea were leaves (38.2%), roots (22.47%), stems (21.35%), leaves and fruits (3.37%), and stem bark (3.37%) (Figure 4). It was followed by fruit (2.25%), root (2.25%), and leaf (2.25%), with the remaining plant parts and combinations of plant parts contributing 1.12% each to the treatment of diarrhea.

**3.5. Gap Analysis of Whether the Traditional Claims Are Tested by In Vitro Trials.** No *in vitro* trials have been conducted for *Acacia etbaica*, *Acacia abyssinica*, *Aloe* spp.,

TABLE 1: List of plants identified and reported to be used to treat diarrhea in the study area.

Family	Scientific name	Local name (Amh)	Plant parts used	Route of administration	Plant condition	Mode of preparation	References
Acanthaceae, just to have the column homogenized	<i>Justicia schimperiana</i> (Hochst. ex Nees) T.Anders	Smiza/Sensel	L	Oral	Dry	Smash, mix with water then drink the juice	[20]
Aloaceae	<i>Aloe</i> spp.	Eret	R	Oral	Fresh	Cutting is done to harvest the jelly juice	[21]
Apiaceae	<i>Heteromorpha arborescens</i> (Spreng). Cham. and Schitdi.	Yejob mirkuz	L	Oral	Fresh	Crush	[22]
	<i>Vernonia adoensis</i>	Etse mossie/mererug	R	Oral	Dry	Crashing the root and drinking the decoction	[23]
	<i>Sch.Bip.ex Walp</i>	Chikugn	R and L	Oral	Dry	Crush and mix with water, then drink	[24]
	<i>Artemisia abyssinica</i>	Chikugn	L	Oral	Dry	The dried leaf is ground, mixed with water, and drunk	[25]
Asteraceae	<i>Artemisia abyssinica</i>	Chikugn	L	Oral	Dry	The fresh root and leaves are crushed, mixed with water, and then drunk	[26]
	<i>Artemisia abyssinica</i>	Chikugn	R and L	Oral	Fresh	Crush	[26]
	<i>Solanecio gigas</i> (Vatke) C. jeffrey yeshikoko gomen	Chikugn	L	Oral	Fresh	Crush	[22]
Boraginaceae	<i>Cordia africana</i>	Wanza	Rb	Oral	Dry	Taking the maceration orally once daily until healed	[27]
	<i>Lepidium sativum</i> L.	Feto	S	Oral	Dry	Seeds are ground into a paste-like food and then eaten or mixed with butter and water and then drunk	[28]
Brassicaceae	<i>Lepidium sativum</i> L.	Feto	S	Oral	Dry	The dry seeds are pounded, powdered, and mixed with water, and the solution has to be taken orally	[29]
	<i>Lepidium sativum</i> L.	Feto	S	Oral	Dry	The seeds are crushed and mixed with milk, and then, the mixture is drunk	[26]
	<i>Lepidium sativum</i> L.	Feto	S	Oral	Dry	The dry seeds are pounded, powdered, and mixed with water, and the solution is taken orally	[30]
Caricaceae	<i>Carica papaya</i> L.	Papaya	S	Oral	Fresh	Ingest a few seeds with "Injera" for three days	[28]
	<i>Carissa spinarum</i> L.	Agam	R	Oral	Dry	The dry root is pounded, powdered, salt is added, and it is made into a solution and drunk	[29]
	<i>Carissa spinarum</i> L.	Agam	L	Oral	Dry	The leaf is powdered, mixed with <i>Coffea arabica</i> L., and drunk	[26]
	<i>Carissa spinarum</i> L.	Agam	R	Oral	Dry	The dry root is pounded, powdered, salt is added, and it is made into a solution, which is then drunk	[30]
Combretaceae	<i>Anogeissus leiocarpa</i> (A. Rich) Guill. and Perr	Kekera	Sb	Oral	Oral	Drinking the stem bark decoction	[23]

TABLE 1: Continued.

Family	Scientific name	Local name (Amh)	Plant parts used	Route of administration	Plant condition	Mode of preparation	References
Cucurbitaceae	<i>Cucumis ficifolius</i>	Yemidir embuay	R	Oral	Fresh	The root is crushed and mixed with water before being allowed to drink	[31]
	<i>Zehneria scabra</i> (Linn. f.) Sond	Hareg eresa	L	Oral	Dry	Crush, chew, and then swallow juice	[20]
	<i>Momordica foetida</i> Schumacher	Yekura hareg/ Kuramechat	L	Oral	Fresh	Pound, squeeze, and then drink	[20]
	<i>Cucumis ficifolius</i>	Yemidir embuay	R	Oral	Fresh	The crushed fruits are mixed with water, and then about one liter is drunk	[32]
	<i>Zehneria scabra</i> (Linn. f.) Sond	Hareg eresa	L	Oral	Dry	Leaves are crushed and mixed with some fresh water, and then one cup of it is drunk	[33]
Euphorbiaceae	<i>Clutia lanceolata</i> Forssk	Fiyele fej	R	Dermal	Dry	It is crushed and then tied on the neck region	[20]
	<i>Croton macrostachyus</i> De	Bisana	L	Oral	Dry	Leaf powder mixed with water is taken orally	[34]
	<i>Clutia abyssinica</i> Jaub. and spach	Fiyele fej	L	Oral	Fresh	Crush	[22]
	<i>Acacia etbaica</i> Schweinf	Girar	R	Oral	Dry	One cup of powdered dried root with water is taken	[31]
Fabaceae	<i>Senna didymobotrya</i> (Fresen.)	Yeferenj digita	S	Oral	Dry/fresh	The seed is crushed and roasted, and then it is drunk with coffee	[31]
	<i>Calpurnia aurea</i> (Ait.) Benth	Digita	L	Oral	Fresh	Fresh leaf soaked in water is given orally	[35]
	<i>Calpurnia aurea</i> (Ait.) Benth	Digita	S	Oral	Dry	Grind and eat after pounding with honey	[20]
	<i>Calpurnia aurea</i> (Ait.) Benth	Digita	L	Oral	Fresh	The fresh leaf is crushed, soaked in water for 2-3 hours, and decanted, and one glass is administered orally	[29]
	<i>Calpurnia aurea</i> (Ait.) Benth	Digita	L	Oral	Fresh	The fresh leaf is crushed, soaked in water for 2-3 hours, and decanted, and one glass is administered orally	[36]
	<i>Acacia abyssinica</i>	Girar	R	Oral	Dry	The dried root is powdered and mixed with water, and one cup is drunk	[32]
	<i>Calpurnia aurea</i> (Ait.) Benth	Digita	Fr	Oral	Dry	One dried and powdered pod of fruits is mixed with honey and taken before breakfast until you get relief	[32]
	<i>Calpurnia aurea</i> (Ait.) Benth	Digita	L	Oral	Fresh	The fresh leaf is crushed, soaked in water for 2-3 hours, and decanted, and then one glass is administered orally	[30]
	<i>Calpurnia aurea</i> (Ait.) Benth	Digita	L	Oral	Fresh	Crush and boil	[22]

TABLE 1: Continued.

Family	Scientific name	Local name (Amh)	Plant parts used	Route of administration	Plant condition	Mode of preparation	References
	<i>Leonotis ocymifolia</i>	Yeferes zeng	L and Fr	Oral	Dry	Powder of dried fruit and leaf is mixed with honey and then given	[28]
	<i>Leonotis ocymifolia</i>	Yeferes zeng	L and Fr	Oral	Dry	Dried leaf and fruit powder mixed with honey is given orally	[35]
	<i>Ocimum lamiiifolium</i> L.	Damakesi	L	Oral	Fresh	Fresh leaf is boiled with tea and one cup of tea is drunk	[29]
	<i>Leonotis ocymifolia</i>	Feres zeng	L and Fr	Oral	Dry	The dried leaf and fruits are crushed, powdered, and mixed with honey, and one glass is taken orally	[36]
	<i>Mentha piperita</i> L.	Nana	L and S	Oral	Dry	Pound after mixing it with <i>Nigella sativa</i> and <i>A. sativum</i>	[21]
	<i>Mentha piperita</i> L.	Nana	L	Oral	Fresh	Pound the leaf, mix it with <i>A. sativum</i> and <i>R. chalepensis</i> , and then drink the mixture	[25]
	<i>Plectranthus lactiflorus</i> (Vatke) Agnew	Dibrih	L	Oral	Dry	The roots and leaves of <i>P. lactiflorus</i> are mixed with water, and the filtrate is drunk	[26]
	<i>Ocimum lamiiifolium</i> L.	Damakesi	L	Oral	Fresh	The fresh leaves are boiled with tea, and then one cup of the mixture is drunk	[30]
	<i>Salvia nilotica</i> Jacq	Hulegeb	R	Oral	Fresh	Crush	[22]
	<i>Satureja punctata</i> R.Br	Etse-meaza/lomi kesie	R	Oral	Fresh	Use the unprocessed plant	[22]
Linaceae	<i>Linum usitatissimum</i> L	Telba	S	Oral	Dry	The powder is boiled, and then it is drunk like soup	[24]
	<i>Linum usitatissimum</i> L	Telba	S	Oral	Dry	Powder	[22]
Malvaceae	<i>Gossypium barbadense</i> L	Tite	L	Oral	Dry	Powdered and mixed with water	[37]
	<i>Malva parviflora</i> L.	Zebenya	L	Oral	Fresh	Pound	[21]
Menispermaceae	<i>Stephania abyssinica</i> (Dillon and A. Rich.) Walp	Yedimet Ain	R	Oral	Dry	Chewing	[38]
	<i>Ficus vasta</i> Forssk	Warka	S	Oral	Bark	Dried stem bark powder with salt is given orally for cattle	[35]
	<i>Ficus thonningii</i> Blume	Chibha	R	Oral	Dry	The root is chewed	[34]
	<i>Ficus vasta</i> Forssk	Warka	Sb	Oral	Dry	The bark is crushed, powdered, mixed with salt, and given to eat	[36]
	<i>Syzygium guineense</i> [wild.] DC	Dokima	Sb/Rb	Oral	Dry	Mix the powder with honey/water and then drinking	[23]
Myrtaceae	<i>Myrtus communis</i> L.	Ades	L	Oral	Fresh	The juice of the leaf is taken orally in the morning	[34]

TABLE 1: Continued.

Family	Scientific name	Local name (Amh)	Plant parts used	Route of administration	Plant condition	Mode of preparation	References
Poaceae	<i>Hordeum vulgare</i> L.	Gebis	S	Oral	Dry	Seeds are immersed in water and allowed to germinate before being dried, roasted, and pulverized. The powder is then heated in water and drunk till the pain subsides	[31]
	<i>Hordeum vulgare</i> L.	Tikur gebis	S	Oral	Dry	The seeds are soaked in water and made to germinate, dried, roasted, and powdered. Then the powder is boiled in water and drunk until relief is obtained	[32]
	<i>Eragrostis tef</i> (Zucc.) Trotter	Nech teff	S	Oral	Dry	The floor porridge is eaten three times	[33]
	<i>Sorghum bicolor</i> (Moench)	Zengada	S	Oral	Dry	Powder	[22]
Polygonaceae	<i>Rumex nepalensis</i> Spreng	Yewusha milas	R	Oral	Dry	Crushing	[38]
	<i>Rumex abyssinicus</i>	Mekimeko	R	Oral	Dry	Orally take maceration once daily until the healing process is complete	[27]
Punicaceae	<i>Punica granatum</i>	Roman	Fb	Oral	Fresh	The flesh of the fruit bark is eaten continuously against heavy diarrhea	[32]
Rhamnaceae	<i>Ziziphus spina-christi</i> (L.) Desf	Geba	Sb	Oral	Fresh	Use the unprocessed plant	[22]
Rosaceae	<i>Prunus persica</i> (L.) Batsch	Kega	L	Oral	Dry	Crush, immerse in water then give	[20]
	<i>Coffea arabica</i> L.	Buna	S	Oral	Dry	The powder is mixed with honey and eaten	[31]
Rubiaceae	<i>Coffea arabica</i> L.	Buna	Fr	Oral	Dry	Grind and eat with honey	[20]
	<i>Coffea arabica</i> L.	Buna	S	Oral	Dry	The dry seed is roasted, powdered, mixed with honey, and one or two spoons are taken in the morning for three days	[29]
	<i>Coffea arabica</i> L.	Buna	S	Oral	Dry	Roast the powder and take it with honey on an empty stomach	[39]
	<i>Coffea arabica</i> L.	Buna	S	Oral	Dry	The dry seed is roasted, powdered, mixed with honey, and one or two spoons are taken in the morning for three days	[30]
Rutaceae	<i>Ruta chalepensis</i> L.	Tena Adam	L	Oral	Fresh	The fresh leaf, together with salt (concoction), is chewed	[29]
	<i>Ruta chalepensis</i> L.	Tena Adam	S	Oral	Dry	The pounded seed will be mixed with coffee, then drunk	[24]
	<i>Ruta chalepensis</i> L.	Tena Adam	L	Oral	Fresh	Chewing the fresh leaf together with salt (concoction)	[30]
Scrophulariaceae	<i>Verbascum sinaiticum</i> Benth	qetetina/Daba Keded	R	Oral	Dry	Crush and drink with water	[20]
	<i>Verbascum sinaiticum</i> Benth	qetetina/Daba Keded	R, L, and S	Oral	Dry	Crushing	[38]
	<i>Verbascum sinaiticum</i> Benth	qetetina/Daba Keded	R	Oral	Fresh	The juice of the root is taken orally	[34]

TABLE 1: Continued.

Family	Scientific name	Local name (Amh)	Plant parts used	Route of administration	Plant condition	Mode of preparation	References
Solanaceae	<i>Solanum nigrum</i> L.	Awut	L	Oral	Dry	Leaves are crushed and chewed, and then the juice is swallowed	[20]
	<i>Withania somnifera</i> (L.) Dunal	Giziewa	L	Oral	Fresh/Dry	Squeezing, crushing	[29, 38]
	<i>Withania somnifera</i> (L.) Dunal	Giziewa	L	Oral	Dried or fresh	Mix the powder of 3 leaves with water and drink	[40]
	<i>Withania somnifera</i> (L.) Dunal	Giziewa	L	Oral	Fresh	The fresh leaves are crushed, squeezed, mixed with water, and then drunk	[30]
Verbenaceae	<i>Verbena officinalis</i> -L	Atuch	R	Oral	Fresh	Sap of the fresh root is chewed and swallowed for three days	[28]
	<i>Verbena officinalis</i> -L	Atuch	L	Oral	Fresh	The fresh leaves are crushed, mixed with water, and given orally	[29]
	<i>Verbena officinalis</i> -L	Atuch	R & S	Oral	Fresh	Pound the leaf, stem, and root, mix them with water, and then drink	[26]
	<i>Verbena officinalis</i> -L	Atuch	R	Oral	Fresh	Extract the root powder with water, filter it, and take the filtrate on an empty stomach	[40]
	<i>Verbena officinalis</i> -L	Atuch	L	Oral	Fresh	The fresh leaves are crushed, mixed with water, and given orally	[30]
	<i>Verbena officinalis</i> -L	Atuch	R	Oral	Fresh	Crush	[22]
Zygophyllaceae	<i>Balanites aegyptiaca</i> (L.) Delile (Zygophyllaceae)	Bedena	L	Oral	Fresh	Crush to collect juice	[21]

Note. Plant parts used (Fb = fruit bark, Fr = fruit, L = Leaf, R = root, Rb = root bark, S = seed, and Sb = stem bark).



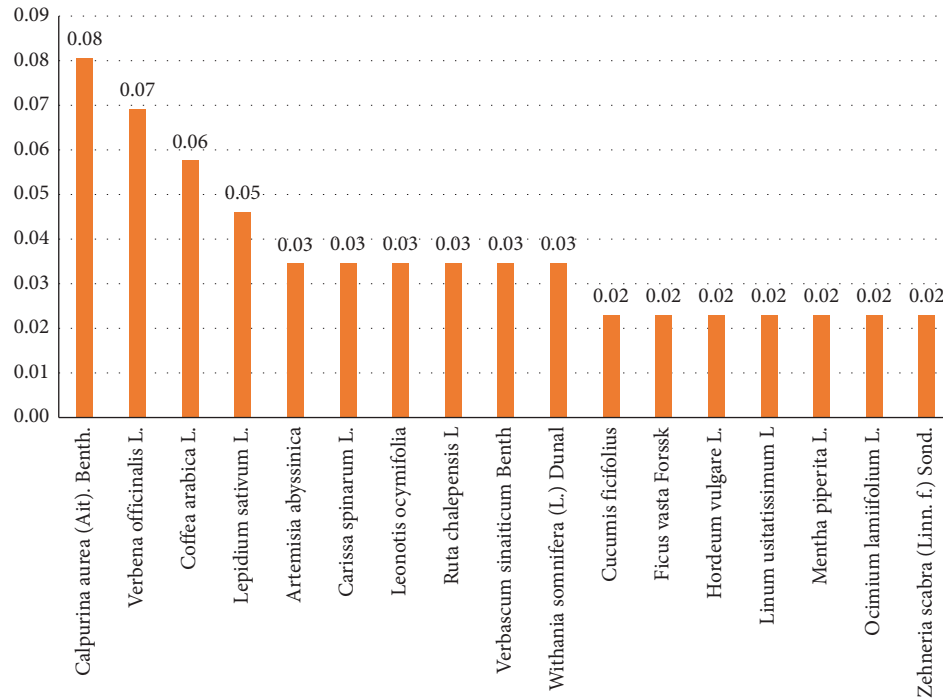


FIGURE 2: Relative frequency of citations (RFC) of 17 of the 50 species.

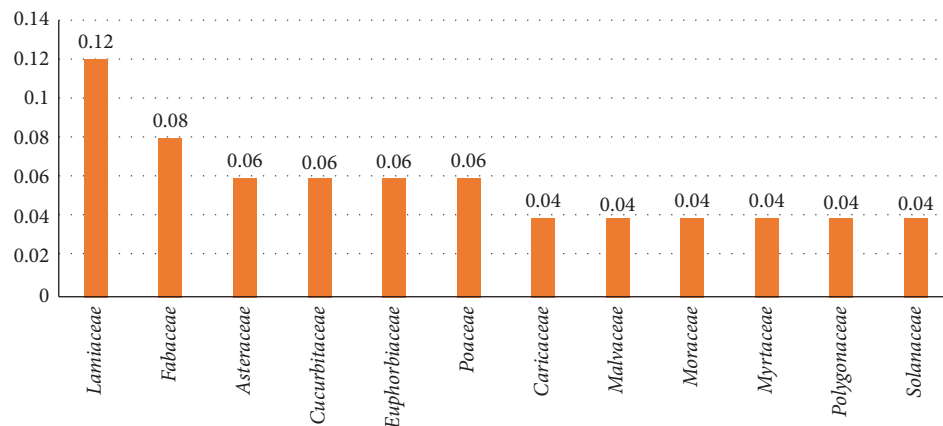


FIGURE 3: Family use values of 12 of the 28 families.

*Anogeissus leiocarpa*, *Artemisia abyssinica*, *Balanites aegyptiaca*, *Carissa spinarum*, *Cucumis ficifolius*, *Eragrostis tef*, *Ficus vasta*, *Heteromorpha arborescens*, *Hordeum vulgare*, *Justicia schimperiana*, *Linum usitatissimum*, *Malva parviflora*, *Mentha piperita*, *Momordica foetida*, *Gossypium barbadense*, *Prunus persica*, *Satureja punctata*, *Senna didymobotrya*, *Solanecio gigas*, *Solanum nigrum*, *Verbascum sinaiticum*, *Verbena officinalis*, and *Vernonia adoensis* (Table 2). Therefore, future research studies can test their effectiveness against castor oil-induced diarrhea in animal models.

However, different extracts of 18 medicinal plants traditionally used to treat diarrhea by the people in Amhara region (36%) have been proved experimentally in animal models. They are *Calpurnia aurea* [41], *Clutia abyssinica* [42], *Coffea arabica* [43], *Cordia africana* [44], *Croton macrostachyus* [45], *Ficus thonningii* [46], *Leonotis ocyimifolia* [47], *Lepidium sativum* [48], *Myrtus communis* [49], *Ocimum lamiifolium* [50], *Punica granatum* [51], *Ruta chalepensis* [52], *Sorghum bicolor* [53], *Stephania abyssinica* [54], *Syzygium guineense* [55], *Withania somnifera* [56], *Zehneria scabra* [57], and *Ziziphus spina-christi* [58] (Table 2).

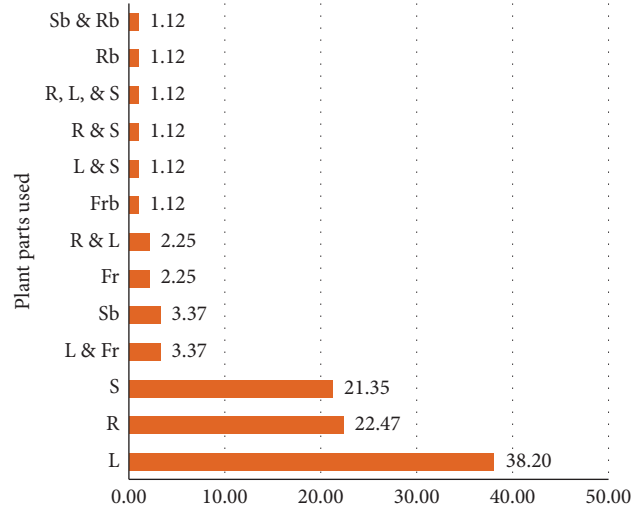


FIGURE 4: Plant parts used for the treatment of diarrhea. Note: plant parts used (Fb = fruit bark, Fr = fruit, L = Leaf, R = root, Rb = root bark, S = seed, and Sb = stem bark).

#### 4. Discussion

Traditionally, the people in the Amhara region use different plants to treat diarrhea. In the following paragraphs, the plants used to treat diarrhea, their active components, their mechanisms of action, and, if confirmed, *in vivo* trials are discussed.

*Acacia etbaica* Schweinf and *Acacia abyssinica* may contain a variety of secondary metabolites, including alkaloids, flavonoids, tannins, saponins, anthraquinones, triterpenes, and glycosides, as shown in *Acacia etbaica* [59]. *Acacia nilotica* Willd's bark methanol extract demonstrated *in vivo* antidiarrheal activity against castor oil and magnesium sulfate-induced diarrhea, as well as barium chloride-induced peristalsis, using Swiss albino mice. It also exhibited *in vitro* antimicrobial activity against common diarrhea-causing microorganisms [60]. Similar effects could be attributed to *Acacia etbaica* and *Acacia abyssinica* extracts. The antidiarrheal activity of *Acacia etbaica* and *Acacia abyssinica* is likely attributed to their ability to modulate intestinal motility, preserve intestinal mucosal integrity, promote fluid absorption, activate antioxidant pathways, exert anti-inflammatory effects, demonstrate antimicrobial activity against diarrheal pathogens, suppress intestinal secretion, and modulate gut microflora.

*Aloe* spp. contains aloe emodin, aloin, aloesin, emodin, and acemannan as major active compounds [61]. Its antidiarrheal activity may be due to the anti-inflammatory, intestinal motility modulatory, antimicrobial, intestinal mucosal protection, and ion transport regulatory activities of its active components.

*Anogeissus leiocarpa* (A. Rich) Guill and Perr's bark decoction is drunk to treat diarrhea [23]. Its aqueous leaf extract significantly inhibited castor oil-induced diarrhea in rats through the inhibition of intestinal transit and reduction of the volume of the intestinal content [62]. This effect may

be attributed to the activities of its components such as alkaloids, flavonoids, saponins, tannins, phenols, and glycosides [63], which act as its active constituents.

The dry or fresh leaves and roots of *Artemisia abyssinica* are ground, mixed with water, and drunk [25, 26] to treat diarrhea, and the active components of the genus, including 1,8-cineole,  $\beta$ -pinene, thujone, artemisia ketone, camphor, caryophyllene, camphene, and germacrene D [64], may contribute to its antidiarrheal activity.

The fresh leaves of *Balanites aegyptiaca* (L.) Delile are crushed, and the juice is swallowed to treat diarrhea [21]. The antidiarrheal activities of this plant may be attributed to its phytochemicals such as saponins, coumarins, triterpenes, tannins, and steroids [65].

The leaves, seeds, and fruits of *Calpurnia aurea* (Ait) Benth (Fabaceae) are applied to treat diarrhea. The antidiarrheal activity of the 80% methanol extract of this plant has been proven by its effect on castor oil-induced diarrhea in mice, which significantly reduced the time of onset of diarrhea, the frequency of defecation (total number of fecal output), and the weight of feces. The extract also showed good antimicrobial activity against all tested organisms [41]. The antidiarrheal activities of this plant may be attributed to its secondary metabolites, including alkaloids, tannins, flavonoids, saponins, steroids, and phlobatannins [66].

The roots and leaves of *Carissa spinarum* L. (*Apocynaceae*) are utilized for managing diarrhea. Its potential antidiarrheal properties may be attributed to its bioactive constituents, such as acids, glycosides, terpenoids, alkaloids, tannins, and saponins [67]. The juice of the fresh leaves of *Clutia abyssinica* Jaub and Spach is taken orally as a remedy for diarrhea. This practice is supported by an *in vivo* study, where its hydromethanolic root extract significantly delayed the onset of diarrhea and reduced the number of wet and total stools in a castor oil-induced diarrheal model [42]. Conversely, the crushed roots of *Clutia*

TABLE 2: *In vivo* trials of medicinal plants to confirm the traditional claim of their utilization in treating diarrhea.

Medicinal plant	Plant parts used	Extraction method	The effects obtained	Chemical composition	Proposed mechanism of action	References for trial
<i>Calpurnia aurea</i>	Leaves	Maceration in 80% methanol	Reduced the time of diarrhea onset, defecation frequency, and fecal weight	Alkaloids, flavonoids, tannins, terpenoids, and saponins	Antimicrobial activity	[41]
<i>Clusia abyssinica</i>	Roots	Cold maceration in 80% methanol	Prolonged the onset of diarrhea, and significantly reduced the number of wet and total stools at doses of 200 and 400 mg/kg	Tannins, flavonoids, alkaloids, saponins, phenols, terpenoids, anthraquinones, and glycosides	Antisecretory effect, anti-inflammatory activity, and inhibition of peristaltic movements	[42]
<i>Coffea arabica</i>	Seeds	Cold maceration in 80% methanol	At a dosage of 400 mg/kg, there was a significant prolongation of the onset of diarrhea and a decrease in the total number of feces	Alkaloids, flavonoids, phenols, tannins, saponins, steroids, anthraquinones, glycosides, and terpenoids	Anti-inflammatory activity, increased sympathetic nerve activity, antioxidant activity, increase of the intestinal absorption of water and electrolytes	[43]
<i>Cordia africana</i>	Bark	Maceration in 80% methanol	Reduction in castor oil-induced diarrhea and intestinal fluid accumulation in a dose-dependent manner	Phenols, flavonoids, terpenoids, and saponins	Increase in water and electrolyte absorption or decrease the secretion of fluid and electrolytes, blocking the prostaglandin receptors	[44]
<i>Croton macrostachyus</i>	Leaves	Soxhlet extraction with chloroform and methanol	Delayed onset of diarrhea, reduced stool frequency, and lighter feces	Alkaloids, steroids, and terpenoids in the chloroform fraction; alkaloids, saponins, tannins, flavonoids, and cardiac glycosides in methanol fraction; and saponins, tannins, and alkaloids in aqueous fraction	Inhibition of intestinal motility and hydro-electrolytic secretion, inhibition of the intestinal secretory response induced by prostaglandins E <sub>2</sub> , promotion of fluid and electrolyte absorption	[45]
<i>Ficus thonningii</i>	Leaves	Aqueous methanolic extraction	An initial increase in purgation was observed by the 2nd hour of the test, followed by a subsequent period of constipation	Tannins, flavonoids, saponins, and anthraquinone glycosides	A dose-related reduction in intestinal motility	[46]
<i>Leonotis ocyimifolia</i>	Leaves and fruits	Cold maceration in 80% methanol	Reduced diarrhea frequency, delayed onset of diarrhea, and decreased number of defecation occurrences	Alkaloids, tannins, flavonoids, and saponins	The antisecretory effect, antimotility effect, and reduction of intestinal transit	[47]
<i>Lepidium sativum</i>	Seeds	Maceration in 70% methanol	The doses of 100 and 300 mg/kg exhibited a significant antidiarrheal effect	Alkaloids, saponins, and anthraquinones	Reversing the CCh and high K <sup>+</sup> - induced contractions, dual blockade of muscarinic receptors, and Ca <sup>++</sup> channels	[48]
<i>Myrtus communis</i>	Leaves	Maceration in 80% methanol	Significant delays of the onset of diarrhea and decreases of the frequency and weight of fecal outputs, at 200 and 400 mg/kg extract. A significant effect on the frequency and weight of wet feces, as well as the total fecal output, at 100 mg/kg of the extract	Terpenoids, flavonoids, tannins, glycosides, and saponins	Anti-inflammatory activity, suppression of the biosynthesis of eicosanoids, reduction of gastrointestinal motility	[49]

TABLE 2: Continued.

Medicinal plant	Plant parts used	Extraction method	The effects obtained	Chemical composition	Proposed mechanism of action	References for trial
<i>Ocimum lamifolium</i>	Leaves	Maceration in 80% methanol	The intervention resulted in a reduction in the onset of diarrhea, the number of wet feces, the weight of fresh feces, and the fluid content of feces, as well as reductions in both the volume and weight of intestinal content	Alkaloids, flavonoids, phenols, tannins, saponins, steroids, glycosides, anthraquinones, terpenoids	Anti-inflammatory activity, antioxidant activities, inhibition of prostaglandin synthesis, reduction of intestinal secretion, decrease in the synthesis of nitric oxide, and inhibition of intracellular $Ca^{2+}$ inward current	[50]
<i>Punica granatum</i>	Peels	Aqueous extract (decoction)	Reduction in diarrhea, inhibition of wet or unformed feces production, and suppression of gastrointestinal propulsive action	Tannins, alkaloids, and flavonoids	Inhibition of intestinal motility and accumulation of intestinal fluid	[51]
<i>Ruta chalepensis</i>	Leaves	Maceration in 80% methanol	Prolonged the onset time of diarrhea and decreased the stooling frequency at 200 mg/kg and 400 mg/kg. Additionally, there was a reduction in the percentage of mean fecal output	Alkaloids, tannins, saponins, flavonoids, cardiac glycosides, terpenoids, and steroids	Inhibition of the production of prostaglandin E2 and an antispasmodic effect	[52]
<i>Sorghum bicolor</i>	Seeds	Maceration in 80% methanol	Observation of reduced intestinal fluid weight (in grams) and delayed charcoal meal propulsion through the gastrointestinal tract	Phenols, flavonoids, tannins, terpenoids, and steroids	Inhibition of motility and secretion of the gastrointestinal tract	[53]
<i>Stephania abyssinica</i>	Leaves and roots	Methanol and aqueous extract	Exhibiting an inhibitory effect on both gastrointestinal propulsion and fluid secretion, as well as demonstrating antispasmodic activity	Isoquinol alkaloids	Decrease of hypermotility, inhibition of prostaglandin biosynthesis, anticholinergic effect, and histamine decrease	[54]
<i>Syzgium guineense</i>	Leaves	Maceration in 80% ethanol	Inhibition of intestinal propulsion, reduction in the number of watery stools, reduction of intraintestinal fluid volume, and passage of watery stool	Pentacyclic triterpenes and luteolin	Inhibition of acetylcholine-mediated intestinal smooth muscle contraction; stimulation of dopamine D2 receptor; and degradation of acetylcholinesterase	[55]

TABLE 2: Continued.

Medicinal plant	Plant parts used	Extraction method	The effects obtained	Chemical composition	Proposed mechanism of action	References for trial
<i>Withania somnifera</i>	Leaves	Maceration in 80% methanol	Delayed the diarrhea onset at 200 and 400 mg/kg; reduced defecation of diarrheal stools (number of wet stools), total stools (wet and dry), and weight of fresh stools; decreased intraluminal fluid accumulation and charcoal meal movement	Flavonoids, alkaloids, tannins, steroids, phenols, terpenoids, and saponins	Antisecretory action, enhancing of absorption, and/or anti-motility action, anti-inflammatory activity, antispasmodic activity, calcium antagonism action	[56]
<i>Zehmeria scabra</i>	Leaves	Maceration in 80% methanol	Reduced the mean stool score, wet feces, defecations, stool fluid content, intestinal motility, and weight of intestinal content	Tannins, saponins, anthraquinones, O-anthraquinones, and phenols	Inhibition of secretion, reducing intraluminal fluid accumulation, or enhancing water absorption but not delaying motility	[57]
<i>Ziziphus spina-christi</i>	Stem bark	Soxhlet extraction with methanol	Copious diarrhea was inhibited, intraluminal accumulation of fluid volume was reduced, and intestinal transit of charcoal meal decreased	Glycosides, resins, saponins, and tannins	Tannins inhibit electrolyte permeability and prostaglandin release and display antimicrobial activity. They also reduce secretion and enhance intestinal mucus resistance through protein tannate formation	[58]

*lanceolata* Forssk (*Euphorbiaceae*) are applied to the neck to treat diarrhea [20]. The antidiarrheal activities of this plant may be attributed to its secondary metabolites, including 5-methylcoumarins, diterpenes with a secolabdane skeleton, essential oils, alkaloids, anthraquinones, cardiac glycosides, flavonoids, phenolics, saponins, steroids, tannins, and terpenoids [68].

The dried seeds and fruits of *Coffea arabica* L. are used in coffee preparations mixed with honey, which is taken orally to treat diarrhea. The antidiarrheal activity of *C. arabica* was confirmed by an *in vivo* study against castor oil-induced diarrhea in Swiss albino mice [43]. Coffee's antidiarrheal effects are likely attributed to its bioactive constituents, such as chlorogenic acids and catechins [69].

The dried root bark of *Cordia africana* (*Boraginaceae*) is macerated and taken orally once daily to treat diarrhea. This practice has been supported by an *in vivo* study, where *C. africana* prevented castor oil-induced diarrhea and regulated intestinal motility [44]. This effect may be due to the individual, additive, or synergistic activities of its active components, such as flavonoids, alkaloids, tannins, terpenoids, saponins, steroids, anthraquinones, carbohydrates, and proteins [70].

The dry leaves of *Croton macrostachyus* De. (*Euphorbiaceae*) are powdered, mixed with water, and taken orally to treat diarrhea [34]. In the castor oil-induced model, the chloroform and methanol fractions of this plant significantly delayed diarrheal onset and decreased stool frequency and weight of feces [45]. Its activity may be due to individuals or combinations of its active components, such as flavonoids, alkaloids, tannins, saponins, terpenoids, and phenols [71].

The fresh root juice of *Cucumis ficifolius* (*Cucurbitaceae*) is taken orally to treat diarrhea. The *Cucurbitaceae* family is rich in terpenoids, glycosides, alkaloids, saponins, tannins, and steroids [72]. The antidiarrheal activities of this plant may be attributed to the mentioned secondary metabolites.

Porridge made from the seeds of *Eragrostis tef* (Zucc.) is eaten three times a day to treat diarrhea. The antidiarrheal activity of *E. tef* may be attributed to its polyphenols, including the phenolic acids p-coumaric, ferulic, protocatechuic, gentisic, vanillic, syringic, caffeic, cinnamic, and p-hydroxybenzoic, and the flavonoids apigenin, luteolin, and quercetin [73].

Chewing the dry roots of *Ficus thonningii* Blume is practiced to treat diarrhea. The antidiarrheal activity of this plant may be due to its phytochemicals such as tannins, flavonoids, saponins, and anthraquinone glycosides [46].

*Heteromorpha arborescens* (Spreng.) is utilized to treat diarrhea which may be due to its active components such as phenols, proanthocyanidins, flavonoids, alkaloids, and saponins [74]. *Justicia schimperiana* (*Hochst. ex Nees*) T. Anders is used for the treatment of diarrhea that may be due to its active components, such as flavonoids, alkaloids, glycosides, phenols, saponins, steroids, and terpenoids [75].

The traditional application of *Leonotis ocyimifolia* for diarrhea treatment is supplemented by a study conducted in Ethiopia. According to this study, 80% methanol leaf and fruit extracts of *L. ocyimifolia* reduced the frequency of wet stools, the watery content of diarrhea, and delayed the onset

of diarrhea [47]. Its antidiarrheal activity may be attributed to its chemical constituents, such as phenolics, flavonoids, and alkaloids [76]. *Linum usitatissimum* L. has traditionally been used to treat diarrhea, and this may be due to its components such as methyl linolenate, methyl linoleate,  $\alpha$ -linolenic acid,  $\alpha$ -terpinene, terpinen-4-ol, 4-cymene, and  $\alpha$ -pinene [77].

The leaves of *Malva parviflora* L. are used to treat diarrhea which may be due to its active components such as sterols, hydroxycinnamic, anthocyanins, and ferulic acid [78]. The fresh leaves of *Momordica foetida* Schumacher are used to treat diarrhea. Its antidiarrheal activity may be associated with its active components, such as methyldecanoate, methyl dodecanoate, methyl tetradecanoate, methyl hexadecanoate, ethyl hexadecanoate, methyl-9-octadecenoate, methyl-8,11-octadecadienoate, methyl-9,12,15-octadecatrienoate, bis(2-ethylhexyl) phthalate, and methyl-18-methylnonadecanoate [79].

Similarly, the leaves of *Myrtus communis* L. [34] are utilized for the treatment of diarrhea. The traditional claim was confirmed by a study where the 80% methanol extract, as well as the chloroform (CF) and methanol (MF) fractions, of this plant significantly prolonged the onset of diarrhea, reduced the frequency of bowel movements, and decreased fecal output weight [49]. These antidiarrheal properties can be attributed to the presence of active components, including polyphenols, myrtucommulone, semi-myrtucommulone, 1,8-cineole,  $\alpha$ -pinene, myrtenyl acetate, limonene, linalool, and  $\alpha$ -terpinolene [80].

The fresh leaves of *Ocimum lamiifolium* L. are used to manage diarrhea by boiling them with tea and consuming a cup of the prepared infusion. This was corroborated by an *in vivo* study in which the 80% methanol extract and fractions of this plant demonstrated a substantial impact on the fluid content of feces across all tested doses. Additionally, the n-butanol and distilled water fractions exhibited significant effects on the onset of diarrhea, whereas the n-hexane fraction displayed noteworthy effects on the number of wet feces, onset of diarrhea, and fluid content of feces at all tested doses [50]. The antidiarrheal activities of this plant may be attributed to its phytochemicals, such as tricyclene, bornyl acetate,  $\alpha$ -pinene,  $\alpha$ -terpinene, isodene, and  $\beta$ -pinene.

The roots and leaves of *Plectranthus lactiflorus* (Vatke) Agnew are mixed with water, and the filtrate is consumed to treat diarrhea. The antidiarrheal activities of this plant may be attributed to its active components such as carvacrol,  $\gamma$ -terpinene, caryophyllene, p-cymene, trans- $\alpha$ -bergamotene, and thymoquinone [81]. The flesh fruit bark of *Punica granatum* is consumed to combat severe diarrhea [32]. Its aqueous extract displayed antidiarrheal activities against castor oil-induced diarrhea in rats [51] which may be due to its chemical components, such as hydrolyzable tannins (punicalin, punicalagin, ellagic acid, and gallic acid) and flavonoids (anthocyanins and catechins) [82].

The crushed dry roots of *Rumex nepalensis* (Spreng) are taken orally to treat diarrhea [38]. In an *in vivo* study, its hydromethanolic extract markedly delayed the onset of

diarrhea and reduced the weight of wet and total feces at the test doses in a castor oil-induced diarrheal model [83]. The possible antidiarrheal activities of this plant may be related to its active components such as anthraquinones, naphthalenes, stilbenoids, flavonoids, terpenoids, phenols, and their derivatives [84].

The fresh leaves of *Ruta chalepensis* L. together with salt are chewed to treat diarrhea. Its hydromethanol (80% ME) extract prolonged the onset of diarrhea in mice and significantly reduced the frequency of stooling and weight of feces in a castor oil-induced diarrheal model [52]. The antidiarrheal activity of this medicinal plant may be ascribed to its chemical constituents such as 2-undecanone, piperonyl piperazine, 2-decalone, 2-dodecanone, decipidone, and 2-tridecanone [85]. The fresh roots of *Salvia nilotica* Jacq. are crushed and taken orally to treat diarrhea. The hydroalcoholic extract of another *Salvia* species (*S. schimperi*) exerted significant and dose-related antidiarrheal activity [86]. The antidiarrheal activity of this plant may be related to its constituents, including  $\beta$ -phellandrene,  $\delta$ -3-carene, and caryophyllene oxide, which may have antidiarrheal properties [87].

The seed of *Senna didymobotrya* (Fresen.) is crushed, roasted, and drunk with coffee as a treatment for diarrhea. The antidiarrheal activity of this plant has not yet been tested. Its potential antidiarrheal activities may be associated with its phytochemicals, such as steroids, terpenoids, anthraquinones, tannins, saponins, glycosides, flavonoids, alkaloids, and phenols [88]. Traditionally, the leaves of *Solanecio gigas* (Vatke) C. Jeffrey are crushed and taken orally to treat diarrhea. Its antidiarrheal activity may be related to its active components such as methylene chloride, sabinene, 1-nonene, terpinen-4-ol, camphene,  $\gamma$ -terpinene,  $\alpha$ -phellandrene,  $\beta$ -myrcene, 1,2,5-oxadiazol-3-carboxamide, 4,4'-azobis-2,2'-dioxide,  $\alpha$ -terpinene, 1-octanamine, N-methyl, and  $\rho$ -cymene [89].

The dried leaves of *Solanum nigrum* L. are crushed and chewed, and the juice is swallowed to treat diarrhea. The methanol extracts of the roots and leaves of another *Solanum* species (*S. asterophorum* Mart) significantly and dose-relatedly inhibited the frequency of both solid and liquid stools in mice [90]. Its components, such as steroidal saponins, steroidal alkaloids, flavonoids, coumarin, lignin, organic acids, volatile oils, and polysaccharides [91], may contribute to the antidiarrheal activity of *S. asterophorum*.

Traditionally, the seed powder of *Sorghum bicolor* (Moench) is taken orally to treat diarrhea. An *in vivo* evaluation of the 80% methanol crude extract of the seeds of *this plant* in mice demonstrated inhibitory activity against castor oil-induced diarrhea, castor oil-induced enteropooling, and castor oil-induced gastrointestinal transit [53]. The antidiarrheal activity of *this plant* may be linked to its active constituents such as proteins, lipids, ash, calcium, copper, iron, zinc, gallic acid, and ferulic acids [92].

The dry roots of *Stephania abyssinica* (Dillon and A. Rich) Walp are chewed to treat diarrhea. The traditional claim was also evaluated in an *in vivo* study in mice using castor oil-induced diarrhea, which significantly prolonged the time of diarrheal induction, increased diarrhea-free time,

reduced the frequency of diarrhea episodes, decreased the weight of stool, and decreased the general diarrheal score in a dose-dependent way [54]. The antidiarrheal activities of *S. abyssinica* could be attributed to the active components, including alkaloids, flavonoids, lignans, steroids, terpenoids, and coumarins [93].

*Syzygium guineense* (Willd.) DC's root or stem bark is dried, powdered, mixed with honey, and drunk orally as a treatment for diarrhea [23]. Its antidiarrheal activity may be attributed to its constituents, such as caryophyllene oxide, d-cadinene, viridiflora, epi-a-cadinol, a-cadinol, cis-calamenen-10-ol, citronellyl pentanoate, b-caryophyllene, and a-humulene [94].

The dry root of *Verbascum sinaiticum* Benth and *Verbena officinalis* L. is crushed and drunk with water to halt diarrhea. The traditional claim for the antidiarrheal activity of this plant has not yet been tested. The antidiarrheal activities of this plant may be attributed to its active compounds, such as sterols, saponins, flavonoids, phenylethanoids, and iridoid glycosides [95]. To treat diarrhea, the root decoction of *Vernonia adoensis* Sch.Bip.exWalp is taken orally [23]. Its active components phenols, saponins, flavonoids, glycosides, and tannins [96] may contribute to the antidiarrheal activities of this plant.

Fresh/dry leaves of *Withania somnifera* (L.) Dunal are crushed or squeezed and taken orally to treat diarrhea [29, 38]. In Swiss albino mice, an 80% methanol extract and solvent fractions of the leaves of this plant have been found to significantly delay the onset of diarrhea, decrease the number and weight of stools, reduce the volume and weight of intestinal contents, and decrease the motility of charcoal meal [56]. The antidiarrheal activity of this plant may be attributed to its active compounds, such as withanolides, condensed tannins, flavonoids, glycosides, free amino acids, alkaloids, steroids, volatile oils, and reducing sugars [97].

The dry leaves of *Zehneria scabra* (Linn. f.) Sond are crushed and chewed, and the juice is swallowed to stop diarrhea. The 80% methanolic leaf extract of this plant in mice resulted in a significant reduction in mean stool score, stool frequency, and fecal fluid content [57]. Its antidiarrheal activity may be due to its chemical composition, such as 3,10-dihydroxy-5,6-epoxy- $\beta$ -ionol; 3,10-dihydroxy-5,6-epoxy- $\beta$ -ionyl-10-O- $\beta$ -D-glucopyranoside; cucumegastigmane I; corchoionoside C; indole-3-carboxylic acid; methyl indole-3-carboxylate; and benzyl-O- $\beta$ -D-glucopyranoside [98]. The fresh stem bark of *Ziziphus spina-christi* (L.) Desf is taken orally as a treatment for diarrhea. Its antidiarrheal activities may be attributed to its active components such as alkaloids, sterols ( $\beta$ -sitosterol), flavonoids, triterpenoids, saponins, and saponins [99].

Plant secondary metabolites play their antidiarrheal roles using various mechanisms. For example, plants containing alkaloids, flavonoids, saponins, glycosides, and terpenoids modulate intestinal motility [100–104]; tannins and saponins preserve intestinal mucosal integrity [105, 106]; alkaloids, flavonoids, coumarins, glycosides, and terpenoids promote fluid absorption [101, 107, 108], flavonoids activate antioxidant pathways [109]; flavonoids, coumarins, glycosides, and terpenoids exert anti-inflammatory effects

[110–114]; flavonoids, saponins, glycosides, and terpenoids demonstrate antimicrobial activity against diarrheal pathogens [115–118], tannins, saponins, and terpenoids suppress intestinal secretions [105, 119]; and terpenoids modulate gut microflora [108].

*Acacia etbaica*, *Acacia abyssinica*, *Anogeissus leiocarpa*, *Calpurnia aurea*, *Carissa spinarum*, *Clutia lanceolata*, *Cordia Africana*, *Croton macrostachyus*, *Cucumis ficifolius*, *Heteromorpha arborescens*, *Justicia schimperiana*, *Leonotis ocyimifolia*, *Senna didymobotrya*, *Solanum nigrum*, *Stephania abyssinica*, *Withania somnifera*, and *Ziziphus spina-christi* have alkaloids as their active components. Therefore, they may modulate intestinal motility and promote fluid absorption. Alkaloids interact with opioid receptors in the gastrointestinal system, reducing bowel movement frequency [100, 120].

*Acacia etbaica*, *Acacia abyssinica*, *Anogeissus leiocarpa*, *Calpurnia aurea*, *Clutia lanceolata*, *Cordia Africana*, *Croton macrostachyus*, *Eragrostis tef*, *Ficus thonningii*, *Heteromorpha arborescens*, *Justicia schimperiana*, *Leonotis ocyimifolia*, *Punica granatum*, *Rumex nepalensis*, *Senna didymobotrya*, *Solanum nigrum*, *Stephania abyssinica*, *Verbascum sinaiticum*, *Vernonia adoensis*, *Withania somnifera*, and *Ziziphus spina-christi* possess flavonoids. Consequently, their antidiarrheal activities may be achieved through the modulation of intestinal motility, promotion of fluid absorption, activation of antioxidant pathways, exertion of anti-inflammatory effects, and antimicrobial activity against diarrheal pathogens.

*Acacia etbaica*, *Acacia abyssinica*, *Anogeissus leiocarpa*, *Balanites aegyptiaca*, *Calpurnia aurea*, *Carissa spinarum*, *Clutia lanceolata*, *Cordia Africana*, *Croton macrostachyus*, *Cucumis ficifolius*, *Ficus thonningii*, *Heteromorpha arborescens*, *Justicia schimperiana*, *Senna didymobotrya*, *Solanum nigrum*, *Verbascum sinaiticum*, and *Ziziphus spina-christi* contain saponins. As a result, these plants may treat diarrhea by modulating intestinal motility, preserving intestinal mucosal integrity and antimicrobial activity against diarrheal pathogens, and suppressing intestinal secretions.

*Acacia etbaica*, *Acacia abyssinica*, *Anogeissus leiocarpa*, *Carissa spinarum*, *Clutia lanceolata*, *Cucumis ficifolius*, *Ficus thonningii*, *Justicia schimperiana*, *Senna didymobotrya*, *Verbascum sinaiticum*, *Vernonia adoensis*, and *Withania somnifera* have glycosides as their active components. Therefore, they may modulate intestinal motility, promote fluid absorption, exert anti-inflammatory effects, and exert antimicrobial activity against diarrheal pathogens.

*Carissa spinarum*, *Clutia lanceolata*, *Cordia Africana*, *Croton macrostachyus*, *Cucumis ficifolius*, *Justicia schimperiana*, *Rumex nepalensis*, *Senna didymobotrya*, *Stephania abyssinica*, and *Ziziphus spina-christi* own terpenoids in their active components. Thus, their antidiarrheal activities may be achieved through the following mechanisms: modulation of intestinal motility, promotion of fluid absorption, exertion of anti-inflammatory effects,

antimicrobial activity against diarrheal pathogens, suppression of intestinal secretions, and modulation of gut microflora.

*Acacia etbaica*, *Acacia abyssinica*, *Anogeissus leiocarpa*, *Balanites aegyptiaca*, *Calpurnia aurea*, *Carissa spinarum*, *Clutia lanceolata*, *Cordia Africana*, *Croton macrostachyus*, *Cucumis ficifolius*, *Ficus thonningii*, *Punica granatum*, *Senna didymobotrya*, *Vernonia adoensis*, and *Withania somnifera* contain tannins in their active components. Subsequently, they treat diarrhea by preserving intestinal mucosal integrity. Tannins are known for their astringent properties, which allow them to bind and precipitate proteins. This astringency can potentially result in the reduction of inflammation and mucosal irritation. The astringent properties of tannins have been suggested as a possible mechanism underlying their antidiarrheal effects. By decreasing intestinal secretions and promoting the tightening of the intestinal mucosa, tannins may contribute to the alleviation of diarrhea [105, 121].

*Balanites aegyptiaca*, *Clutia lanceolata*, and *Stephania abyssinica* have coumarins as their active components. Hence, they promote fluid absorption and exert anti-inflammatory effects to halt diarrhea. Germacrene D of *Artemisia abyssinica* exhibits antimicrobial effects against diarrhea-causing pathogens [109].

The antidiarrheal activity of the chemical components of *Aloe* spp. includes polysaccharides, glycoproteins, and anthraquinones, exhibits anti-inflammatory effects [122], modulates intestinal motility [123], possesses antimicrobial activity [124], protects the intestinal mucosa [125], and regulates ion transport [126].

Essential oils in medicinal plants exhibit antimicrobial properties, targeting pathogens involved in diarrhea, while their anti-inflammatory effects can reduce gut inflammation. Furthermore, essential oils with antispasmodic activity relax smooth muscles, thereby reducing bowel spasms and the frequency of bowel movements. Some essential oils enhance fluid absorption, resulting in firmer stools and decreased diarrhea. Additionally, essential oils may have a modulating effect on the gut microbiota [127–131].

Coffee is rich in various polyphenols, such as chlorogenic acids and catechins, which possess antioxidant and anti-inflammatory properties [69]. These polyphenols demonstrate notable antidiarrheal properties through diverse mechanisms. One significant mechanism involves their antimicrobial activity [132], as well as their anti-inflammatory effects within the gastrointestinal tract, which help attenuate gut inflammation, a contributing factor to the occurrence of diarrhea. Additionally, polyphenols can modulate intestinal motility [133].

Phenols in *Croton macrostachyus*, *Eragrostis tef*, *Heteromorpha arborescens*, and *Leonotis ocyimifolia* possess antimicrobial properties and can alleviate inflammation in the gastrointestinal tract, which is a contributing factor to diarrhea. They also influence intestinal motility, help mitigate



toxin-induced diarrhea, and contribute to restoring the balance of fluid and electrolytes by enhancing their absorption [69, 132–135].

Certain steroids, including glucocorticoids in *Justicia schimperiana*, have been demonstrated to possess anti-inflammatory properties [136]. These properties can be advantageous in the management of conditions associated with diarrhea, such as inflammatory bowel disease. By mitigating inflammation within the gastrointestinal tract, steroids contribute to the modulation of diarrhea symptoms.

Methyl linolenate and methyl linoleate of *Linum usitatissimum* may exert their antidiarrheal action by reducing inflammation [137] in the gastrointestinal tract. Additionally, they could modulate intestinal motility [138], promoting normal bowel movements and reducing excessive stool frequency. Hydroxycinnamic acids (caffeic acid and chlorogenic acid) in *Malva parviflora* exhibit pronounced anti-inflammatory properties [139], thereby ameliorating gastrointestinal inflammation commonly associated with diarrhea.

Unsaturated fatty acid methyl esters (methyl-9-octadecenoate, methyl-8,11-octadecadienoate, and methyl-9,12,15-octadecatrienoate) in *Momordica foetida* Schumacher have shown potential anti-inflammatory effects and the ability to modulate inflammatory pathways [140, 141]. These compounds thereby have the potential to ameliorate gastrointestinal inflammation commonly associated with diarrhea. Additionally, they may possess antioxidant properties [142], which can safeguard the gastrointestinal mucosa, mitigate oxidative stress, and modulate immune responses. These combined effects have the potential to contribute to the management of diarrhea.

1,8-cineole,  $\alpha$ -pinene, myrtenyl acetate, limonene, linalool, and  $\alpha$ -terpinolene represent volatile compounds of *Myrtus communis* [143]; tricyclene, bornyl acetate,  $\alpha$ -pinene,  $\alpha$ -terpinene, isodene, and  $\beta$ -pinene in *Ocimum lamiifolium* [144]; carvacrol,  $\gamma$ -terpinene, caryophyllene, p-cymene, trans- $\alpha$ -bergamotene, and thymoquinone in *Plectranthus lactiflorus* [81] demonstrate discernible antimicrobial properties [145–149], effectively impeding the proliferation of diarrhea-causing pathogens.

Hydrolyzable tannins in *Punica granatum* (punicalin, punicalagin, ellagic acid, and gallic acid) and flavonoids (anthocyanins and catechins) have shown antimicrobial properties, potentially aiding in the elimination of bacteria, viruses, or parasites that can cause diarrhea [150, 151]. Additionally, their anti-inflammatory effects [152–154] may help alleviate inflammation in the gastrointestinal tract, which can be a contributing factor to diarrhea. Furthermore, their antioxidant activity [152, 155] could play a role by protecting the gastrointestinal mucosa from oxidative damage and helping to prevent or manage diarrhea.

Anthraquinones in *Rumex nepalensis* exert their antidiarrheal effects predominantly through the inhibition of intestinal motility [156], thereby reducing the frequency and intensity of bowel movements associated with diarrhea.

Phytochemicals in *Ruta chalepensis* such as 2-undecanone, piperonyl piperazine, 2-decalone, 2-dodecanone, decipidone, and 2-tridecanone [85] may exhibit notable antimicrobial properties, thereby exerting inhibitory effects against diarrhea-causing pathogens, encompassing bacteria, viruses, or parasites. Moreover, these compounds could modulate intestinal motility, potentially ameliorating hypermotility and reducing the frequency of bowel movements associated with diarrhea. Additionally, the presence of antispasmodic properties among these compounds might contribute to the attenuation of intestinal spasms, thereby alleviating abdominal cramping and ameliorating diarrhea-related symptoms. Furthermore, their anti-inflammatory properties could potentially play a role in mitigating inflammation within the gastrointestinal tract, consequently aiding in the management of diarrhea. Lastly, the possibility of interference with ion transport in the intestines by these compounds may influence fluid balance regulation, thus affording relief from diarrhea symptoms.

Active components of *Salvia nilotica* such as  $\beta$ -phellandrene,  $\delta$ -3-carene, and caryophyllene may exhibit antimicrobial properties [157–159], potentially inhibiting the growth and proliferation of diarrhea-causing pathogens such as bacteria, viruses, or parasites.

Lignin in *Solanum nigrum* possesses insoluble fiber characteristics, thereby enhancing stool bulk and viscosity, which in turn promotes regular bowel movements and potentially reduces the incidence of loose stools [160]. The increased fecal bulk facilitates the expulsion of toxins and pathogens from the intestines. Moreover, lignin acts as a prebiotic [161], providing nourishment to beneficial gut bacteria that produce short-chain fatty acids (SCFAs), including butyrate. These SCFAs are pivotal in maintaining intestinal integrity and mitigating intestinal inflammation. Furthermore, lignin exhibits antioxidant properties [162], enabling it to scavenge harmful free radicals, potentially ameliorating oxidative stress in the gastrointestinal tract, and safeguarding the integrity of the intestinal mucosa.

Zinc in *Sorghum bicolor* exhibits diverse mechanisms in its potential antidiarrheal activities. It plays a vital role in preserving the integrity of the intestinal barrier by facilitating the repair of damaged intestinal epithelial cells [163] and reinforcing tight junctions, thus preventing the escape of water and electrolytes into the intestinal lumen and consequently reducing the severity and duration of diarrhea. Additionally, zinc regulates ion transport across the intestinal epithelium, curbing excessive fluid secretion by modulating the activity of specific ion channels and transporters involved in fluid secretion [164]. This restoration of ion transport balance normalizes fluid absorption and diminishes stool volume during diarrhea. Furthermore, zinc exerts immunomodulatory effects which are frequently elevated during diarrheal episodes [92]. Through the mitigation of the inflammatory response [165], zinc contributes to the resolution of diarrhea. Additionally, zinc exhibits direct antimicrobial properties [166], particularly against

enteropathogens such as *Escherichia coli*, rotavirus, and *Giardia lamblia*, effectively inhibiting their proliferation and growth. Thus, zinc aids in the management of infection and alleviation of diarrhea symptoms.

Caryophyllene oxide in *Syzygium guineense* exerts potential antidiarrheal activity through various mechanisms. Its anti-inflammatory properties [167] reduce gastrointestinal tract inflammation, thereby alleviating diarrhea symptoms. Caryophyllene oxide also exhibits antimicrobial effects [159] against specific bacteria and parasites, aiding in infection control and diarrhea resolution. Additionally, its antioxidant properties [168] counteract harmful free radicals, mitigating oxidative stress and safeguarding intestinal cells, thus contributing to diarrhea management.

Withanolides in *Withania somnifera* are recognized for their anti-inflammatory and immunomodulatory properties [169], which have the potential to mitigate inflammation in the gastrointestinal tract and modulate immune responses implicated in the pathogenesis of diarrhea.

## 5. Conclusion

Many plants from the Amhara region in Ethiopia exhibited potential antidiarrheal activities, which can be attributed to their diverse secondary metabolites, including alkaloids, flavonoids, tannins, saponins, terpenoids, glycosides, and phenolics. Among the top ten cited plants, *Calpurnia aurea* contains alkaloids that interact with opioid receptors, reducing bowel movement frequency. *Verbena officinalis* contains flavonoids that modulate intestinal motility, promote fluid absorption, activate antioxidant pathways, exert anti-inflammatory effects, and exhibit antimicrobial activity against diarrheal pathogens. *Coffea arabica* is rich in polyphenols (chlorogenic acids and catechins) with antimicrobial and anti-inflammatory properties, which modulate intestinal motility and attenuate gut inflammation. *Lepidium sativum* contains terpenoids that modulate intestinal motility, promote fluid absorption, exert anti-inflammatory effects, exhibit antimicrobial activity against diarrheal pathogens, suppress intestinal secretions, and modulate gut microflora. *Artemisia abyssinica*'s germacrene D exhibits antimicrobial effects against diarrhea-causing pathogens. *Carissa spinarum* contains alkaloids, flavonoids, glycosides, and terpenoids, which may modulate intestinal motility and promote fluid absorption. *Leonotis ocyimifolia* contains terpenoids that modulate intestinal motility, promote fluid absorption, exert anti-inflammatory effects, and possess antimicrobial activity against diarrheal pathogens. *Ruta chalepensis* contains 2-undecanone, piperonyl piperazine, and other compounds with antimicrobial properties, antispasmodic effects, anti-inflammatory properties, and potential interference with ion transport in the intestines. *Verbascum sinaiticum* contains flavonoids, saponins, glycosides, and terpenoids, which may modulate intestinal motility, promote fluid absorption, exert anti-inflammatory effects, and exhibit antimicrobial activity against diarrheal pathogens. *Withania somnifera*'s withanolides exhibit anti-inflammatory and immunomodulatory properties, mitigating inflammation in the gastrointestinal tract and modulating immune responses involved in diarrhea.

## Abbreviations

CF: Chloroform fraction  
 DALYs: Disability-adjusted life years  
 ME: Methanol  
 MF: Methanol fraction.

## Data Availability

This published article contains all the data that were generated or analyzed during the course of this study.

## Conflicts of Interest

The authors declare that they have no conflicts of interest.

## Authors' Contributions

DD collected, analyzed, and interpreted data and prepared the manuscript.

## References

- [1] Who, "Diarrhoea," 2019, [https://www.who.int/health-topics/diarrhoea#tab=tab\\_1](https://www.who.int/health-topics/diarrhoea#tab=tab_1).
- [2] The Institute for Health Metrics and Evaluation, "Diarrheal diseases—level 3 cause," 2019, [https://www.healthdata.org/results/gbd\\_summaries/2019/diarrheal-diseases-level-3-cause](https://www.healthdata.org/results/gbd_summaries/2019/diarrheal-diseases-level-3-cause).
- [3] A. Alebel, C. Tesema, B. Temesgen, A. Gebrie, P. Petrucka, and G. D. Kibret, "Prevalence and determinants of diarrhea among under-five children in Ethiopia: a systematic review and meta-analysis," *PLoS One*, vol. 13, no. 6, Article ID e0199684, 2018.
- [4] A. B. Dagne, T. Tewabe, Y. Miskir et al., "Prevalence of diarrhea and associated factors among under-five children in Bahir Dar city, Northwest Ethiopia, 2016: a cross-sectional study," *Bone Marrow Concentrate Infectious Diseases*, vol. 19, pp. 417–7, 2019.
- [5] Y. Tafere, B. Abebe Abate, H. Demelash Enyew, and A. Belete Mekonnen, "Diarrheal diseases in under-five children and associated factors among Farta district rural community, Amhara regional state, north central Ethiopia: a comparative cross-sectional study," *Journal of Environmental and Public Health*, vol. 2020, Article ID 6027079, 7 pages, 2020.
- [6] T. A. Birhan, B. D. Bitew, H. Dagne et al., "Prevalence of diarrheal disease and associated factors among under-five children in flood-prone settlements of Northwest Ethiopia: a cross-sectional community-based study," *Frontiers in Pediatrics*, vol. 11, Article ID 1056129, 2023.
- [7] S. Shine, S. Muhamud, S. Adanew, A. Demelash, and M. Abate, "Prevalence and associated factors of diarrhea among under-five children in Debre Berhan town, Ethiopia 2018: a cross sectional study," *Bone Marrow Concentrate Infectious Diseases*, vol. 20, pp. 174–176, 2020.
- [8] W. Getahun and M. Adane, "Prevalence of acute diarrhea and water, sanitation, and hygiene (WASH) associated factors among children under five in Woldia Town, Amhara Region, northeastern Ethiopia," *Bone Marrow Concentrate Pediatrics*, vol. 21, no. 1, pp. 227–315, 2021.
- [9] D. T. Asnakew, M. G. Teklu, and S. A. Woreta, "Prevalence of diarrhea among under-five children in health extension model households in Bahir Dar Zuria district, north-western Ethiopia," *Edorium Journal of Public Health*, vol. 4, pp. 1–9, 2017.

- [10] A. Getachew, A. Tadie, M. G. Hiwot et al., "Environmental factors of diarrhea prevalence among under five children in rural area of North Gondar zone, Ethiopia," *The Italian journal of pediatrics*, vol. 44, no. 1, pp. 1–7, 2018.
- [11] M. Azage, A. Kumie, A. Worku, and A. C. Bagtzoglou, "Childhood diarrhea in high and low hotspot districts of Amhara Region, northwest Ethiopia: a multilevel modeling," *Journal of Health, Population and Nutrition*, vol. 35, pp. 13–14, 2016.
- [12] M. Akram, M. Daniyal, A. Ali et al., "Current knowledge and therapeutic strategies of herbal medicine for acute diarrhea," *Perspective of Recent Advances in Acute Diarrhea*, Intechopen, London, UK, 2020.
- [13] J. D. Dubreuil, "Antibacterial and anti-diarrheal activities of plant products against enterotoxinogenic *Escherichia coli*," *Toxins*, vol. 5, no. 11, pp. 2009–2041, 2013.
- [14] C. Njume and N. I. Goduka, "Treatment of diarrhoea in rural African communities: an overview of measures to maximise the medicinal potentials of indigenous plants," *International Journal of Environmental Research and Public Health*, vol. 9, no. 11, pp. 3911–3933, 2012.
- [15] H. H. Fong, "Integration of herbal medicine into modern medical practices: issues and prospects," *Integrative Cancer Therapies*, vol. 1, no. 3, pp. 287–293, 2002.
- [16] A. M. Clark, "Natural products as a resource for new drugs," *Pharmaceutical Research*, vol. 13, no. 8, pp. 1133–1144, 1996.
- [17] D. Tegen, K. Dessie, and D. Damtie, "Candidate anti-COVID-19 medicinal plants from Ethiopia: a review of plants traditionally used to treat viral diseases," *Evidence-based Complementary and Alternative Medicine*, vol. 2021, Article ID 6622410, 20 pages, 2021.
- [18] M. Giday, Z. Asfaw, Z. Woldu, and T. Teklehaymanot, "Medicinal plant knowledge of the Bench ethnic group of Ethiopia: an ethnobotanical investigation," *Journal of Ethnobiology and Ethnomedicine*, vol. 5, no. 1, pp. 34–40, 2009.
- [19] A. A. Boadu and A. Asase, "Documentation of herbal medicines used for the treatment and management of human diseases by some communities in southern Ghana," *Evidence-based Complementary and Alternative Medicine*, vol. 2017, Article ID 3043061, 12 pages, 2017.
- [20] G. Chekole, Z. Asfaw, and E. Kelbessa, "Ethnobotanical study of medicinal plants in the environs of Tara-gedam and Amba remnant forests of Libo Kemkem District, northwest Ethiopia," *Journal of Ethnobiology and Ethnomedicine*, vol. 11, pp. 4–38, 2015.
- [21] A. Osman, D. B. Sbhatu, and M. Giday, "Medicinal plants used to manage human and livestock ailments in raya kobo district of Amhara regional state, Ethiopia," *Evidence-based Complementary and Alternative Medicine*, vol. 2020, Article ID 1329170, 19 pages, 2020.
- [22] A. Asfaw, E. Lulekal, T. Bekele, A. Debella, A. Abebe, and S. Degu, *Ethnobotanical Investigation on Medicinal Plants Traditionally Used against Human Ailments in Ensaro District, north Shewa Zone, Amhara Regional State, Ethiopia*, Europe PMC, London, UK, 2021.
- [23] T. Mekuanent, A. Zebene, and Z. Solomon, "Ethnobotanical study of medicinal plants in Chilga district, Northwestern Ethiopia," *Journal of Natural Remedies*, vol. 15, no. 2, pp. 88–112, 2015.
- [24] A. A. Haile, "Ethnobotanical study of medicinal plants used by local people of mojana wadera woreda, north shewa zone, Amhara region, Ethiopia," *Asian Journal of Ethnobiology*, vol. 5, no. 1, 2022.
- [25] E. Mazengia, T. Beyene, and B. A. Tsegay, "Diversity of medicinal plants used to treat human ailments in rural Bahir Dar, Ethiopia," *Archives*, vol. 3, 2019.
- [26] M. Megersa and N. Tamrat, "Medicinal plants used to treat human and livestock ailments in basona werana district, north shewa zone, Amhara region, Ethiopia," *Evidence-based Complementary and Alternative Medicine*, vol. 2022, Article ID 5242033, 18 pages, 2022.
- [27] T. J. Aragaw, D. T. Afework, and K. A. Getahun, "Assessment of knowledge, attitude, and utilization of traditional medicine among the communities of Debre Tabor Town, Amhara Regional State, North Central Ethiopia: a cross-sectional study," *Evidence-based Complementary and Alternative Medicine*, vol. 2020, Article ID 6565131, 10 pages, 2020.
- [28] N. Amsalu, Y. Bezie, M. Fentahun, A. Alemayehu, and G. Amsalu, "Use and conservation of medicinal plants by indigenous people of Gozamin Wereda, East Gojjam Zone of Amhara region, Ethiopia: an ethnobotanical approach," *Evidence-based Complementary and Alternative Medicine*, vol. 2018, Article ID 2973513, 23 pages, 2018.
- [29] A. B. Mekonnen, A. S. Mohammed, and A. K. Tefera, "Ethnobotanical study of traditional medicinal plants used to treat human and animal diseases in sedie muja district, south gondar, Ethiopia," *Evidence-based Complementary and Alternative Medicine*, vol. 2022, Article ID 7328613, 22 pages, 2022.
- [30] K. Abeba, "Ethnobotanical study of traditional medicinal plants used to treat human and animal diseases in sedie muja woreda, south gondar, Ethiopia," *Evidence-Based Complementary and Alternative Medicine*, vol. 2022, Article ID 7328613, 22 pages, 2022.
- [31] M. Yimam, S. M. Yimer, and T. B. Beressa, "Ethnobotanical study of medicinal plants used in artuma fursi district, Amhara regional state, Ethiopia," *Tropical Medicine and Health*, vol. 50, no. 1, pp. 85–23, 2022.
- [32] A. Nigussie, *An Ethno Botanical Study of Medicinal Plants in Farta Wereda, South Gondar Zone of Amhara Region Ethiopia*, Addis Ababa University, Addis Ababa, Ethiopia, 2010.
- [33] M. Wubetu, T. Abula, and G. Dejenu, "Ethnopharmacologic survey of medicinal plants used to treat human diseases by traditional medical practitioners in Dega Damot district, Amhara, Northwestern Ethiopia," *Bone Marrow Concentrate Research Notes*, vol. 10, no. 1, pp. 157–213, 2017.
- [34] T. Teklehaymanot and M. Giday, "Ethnobotanical study of medicinal plants used by people in Zegie Peninsula, Northwestern Ethiopia," *Journal of Ethnobiology and Ethnomedicine*, vol. 3, no. 1, pp. 12–11, 2007.
- [35] A. Enyew, Z. Asfaw, E. Kelbessa, and R. Nagappan, "Ethnobotanical study of traditional medicinal plants in and around Fiche District, Central Ethiopia," *Current Research Journal of Biological Sciences*, vol. 6, no. 4, pp. 154–167, 2014.
- [36] G. Gebeyehu, "An ethnobotanical study of traditional use of medicinal plants and their conservation status in Mecha Wereda, West Gojam Zone of Amhara Region, Ethiopia," MSc Thesis, Addis Ababa University, Addis Ababa, Ethiopia, 2011.
- [37] G. Alemayehu, Z. Asfaw, and E. Kelbessa, "Ethnobotanical study of medicinal plants used by local communities of minjar-shenkora district, north shewa zone of Amhara region, Ethiopia," *Journal of Medicinal Plants Studies*, vol. 3, no. 6, pp. 1–11, 2015.
- [38] D. Alemneh, "Ethnobotanical study of plants used for human ailments in Yilmana densa and Quarit districts of west

- Gojjam Zone, Amhara region, Ethiopia,” *BioMed Research International*, vol. 2021, Article ID 6615666, 18 pages, 2021.
- [39] Z. Birhanu, “Traditional use of medicinal plants by the ethnic groups of Gondar Zuria District, North-Western Ethiopia,” *Journal of Natural Remedies*, vol. 13, pp. 46–53, 2013.
- [40] Z. Birhanu, A. Endale, and Z. Shewamene, “An ethno-medicinal investigation of plants used by traditional healers of Gondar town, North-Western Ethiopia,” *Journal of Medicinal Plants Studies*, vol. 3, no. 2, pp. 36–43, 2015.
- [41] S. Umer, A. Tekewe, and N. Kebede, “Antidiarrhoeal and antimicrobial activity of *Calpurnia aurea* leaf extract,” *Bone Marrow Concentrate Complementary and Alternative Medicine*, vol. 13, pp. 21–25, 2013.
- [42] D. Zayede, T. Mulaw, and W. Kahaliw, “Antidiarrheal activity of hydromethanolic root extract and solvent fractions of *clutia abyssinica* jaub. and spach.(Euphorbiaceae) in mice,” *Evidence-based Complementary and Alternative Medicine*, vol. 2020, Article ID 5416749, 9 pages, 2020.
- [43] M. A. Alemu, Z. Birhanu Wubneh, and M. Adugna Ayanaw, “Antidiarrheal effect of 80% methanol extract and fractions of the roasted seed of *coffea arabica* linn (rubiaceae) in Swiss albino mice,” *Evidence-based Complementary and Alternative Medicine*, vol. 2022, Article ID 9914936, 12 pages, 2022.
- [44] A. B. Asrie, M. Abdelwuhab, Z. Shewamene, D. A. Gelayee, G. M. Adinew, and E. M. Birru, “Antidiarrheal activity of methanolic extract of the root bark of *Cordia africana*,” *Journal of Experimental Pharmacology*, vol. 8, pp. 53–59, 2016.
- [45] A. Degu, E. Engidawork, and W. Shibeshi, “Evaluation of the anti-diarrheal activity of the leaf extract of *Croton macrostachyus* Hocsht. ex Del.(Euphorbiaceae) in mice model,” *Bone Marrow Concentrate Complementary and Alternative Medicine*, vol. 16, pp. 379–411, 2016.
- [46] D. Onwkaeme and F. Udoh, “Pharmacognostic and anti-diarrhoeal studies of leaves of *Ficus thonningii*,” *Nigerian Journal of Natural Products and Medicine*, vol. 4, no. 1, pp. 27–29, 2000.
- [47] T. Mengie Ayele, E. Chekol Abebe, and A. Bogale Kassie, “Investigation of antibacterial and anti-diarrhoeal activities of 80% methanol leaf and fruit extract of *Leonotis ocyimifolia* (Burm. F) Iwarsson (Lamiaceae),” *Journal of Experimental Pharmacology*, vol. 13, pp. 613–626, 2021.
- [48] N. Rehman, M. H. Mehmood, K. M. Alkharfy, and A. H. Gilani, “Studies on antidiarrheal and antispasmodic activities of *Lepidium sativum* crude extract in rats,” *Phytotherapy Research*, vol. 26, no. 1, pp. 136–141, 2012.
- [49] M. Sisay, E. Engidawork, and W. Shibeshi, “Evaluation of the antidiarrheal activity of the leaf extracts of *Myrtus communis* Linn (Myrtaceae) in mice model,” *BMC Complementary and Alternative Medicine*, vol. 17, pp. 103–111, 2017.
- [50] M. Adela Alemu, Y. Andargie, W. Sisay et al., “Antidiarrheal effect of 80% methanol extract and fractions of the leaves of *Ocimum lamiifolium* in Swiss albino mice,” *Evidence-based Complementary and Alternative Medicine*, vol. 2022, Article ID 6838295, 9 pages, 2022.
- [51] E. Qnais, A. Elokda, Y. Abu Ghalyun, and F. Abdulla, “Antidiarrheal activity of the aqueous extract of *Punica granatum* (pomegranate) peels,” *Pharmaceutical Biology*, vol. 45, no. 9, pp. 715–720, 2007.
- [52] A. Degu, B. Kefale, D. Alemayehu, and G. T. Tegegne, “Evaluation of the antidiarrheal activity of hydromethanol crude extracts of *Ruta chalepensis* and *Vernonia amygdalina* in mice,” *Evidence-based Complementary and Alternative Medicine*, vol. 2020, Article ID 8318713, 6 pages, 2020.
- [53] Z. Hunegnaw, G. Asmelashe, and Z. S. Sabe, “In vivo antidiarrheal activity evaluation of the seeds of *Sorghum bicolor* L.(Poaceae),” *Discovery Phytomedicine*, vol. 3, no. 4, p. 22, 2016.
- [54] T. Deneke, *Antidiarrheal and Antispasmodic Activities of Stephania Abyssinica (Minspermaseae) Used in Ethiopian Traditional Medicine*, Addis Ababa University, Addis Ababa, Ethiopia, 2010.
- [55] I. C. Ezenyi and J. O. Igoli, “Antidiarrhoeal properties of *Syzygium guineense* leaf extract and identification of chemical constituents in its active column fractions,” *Journal of Complementary and Integrative Medicine*, vol. 16, no. 2, 2018.
- [56] G. Tessema Desta, Y. Andargie Ferede, W. Sisay Zewdu, and M. Adela Alemu, “Evaluation of antidiarrheal activity of 80% methanol extract and solvent fractions of the leaves of *withania somnifera* (L.) dunal in Swiss albino mice,” *Evidence-based Complementary and Alternative Medicine*, vol. 2022, Article ID 7968973, 11 pages, 2022.
- [57] W. T. Tadesse, A. E. Hailu, A. E. Gurmu, and A. F. Mechesso, “Experimental assessment of antidiarrheal and antisecretory activity of 80% methanolic leaf extract of *Zehneria scabra* in mice,” *Bone Marrow Concentrate Complementary and Alternative Medicine*, vol. 14, pp. 460–468, 2014.
- [58] B. Adzu, S. Amos, M. Amizan, and K. Gamaniel, “Evaluation of the antidiarrhoeal effects of *Zizyphus spina-christi* stem bark in rats,” *Acta Tropica*, vol. 87, no. 2, pp. 245–250, 2003.
- [59] N. A. Galib, K. Ali, R. T. Munaieim, and A. S. Mohammed, “Phytochemical Screening and thin layer chromatography of *Acacia etbaica* ssp. *Uncinata* leaves,” *World Journal of Pharmaceutical Research*, vol. 6, no. 2, pp. 1278–1283, 2017.
- [60] A. Misar, R. Bhagat, and A. Mujumdar, “Antidiarrhoeal activity of *Acacia nilotica* Willd. bark methanol extract,” *Hindustan Antibiotics Bulletin*, vol. 49-50, no. 1-4, pp. 14–20, 2007.
- [61] M. Sánchez, E. González-Burgos, I. Iglesias, and M. P. Gómez-Serranillos, “Pharmacological update properties of *Aloe vera* and its major active constituents,” *Molecules*, vol. 25, no. 6, p. 1324, 2020.
- [62] M. A. Fokam Tagne, Y. Rékabi, P. A. Noubissi et al., “Evaluation of antidiarrheal activity of aqueous leaf extract of *Anogeissus leiocarpus* on Castor oil-induced diarrhea in RatsMice,” *American Journal of Biomedical Science and Research*, vol. 3, no. 1, pp. 27–34, 2019.
- [63] J. Kuiseu, T. T. B. A. Sounkere, P. A. Olounlade et al., “*Anogeissus leiocarpus* (DC.) Guill. and Perr. (Combretaceae), a medicinal plant traditionally used in small ruminant breeding in West and Central Africa: zootechnical performances, pharmacological activities and chemical compositions (bibliography synthesis),” *International Journal of Biosciences*, vol. 19, no. 5, pp. 10–26, 2021.
- [64] A. K. Pandey and P. Singh, “The genus *Artemisia*: a 2012–2017 literature review on chemical composition, antimicrobial, insecticidal and antioxidant activities of essential oils,” *Medicine (Baltimore)*, vol. 4, no. 3, p. 68, 2017.
- [65] K. Anani, Y. Adjarah, Y. eacutepapoh et al., “Antimicrobial activities of *Balanites aegyptiaca* (L.) Delile (Balanitaceae) on bacteria isolated from water well,” *Journal of Applied Pharmaceutical Science*, vol. 5, no. 10, pp. 52–58, 2015.
- [66] G. Mulatu, “Antibacterial activities of *Calpurnia aurea* against selected animal pathogenic bacterial strains,” *Advances in Pharmacological and Pharmaceutical Sciences*, vol. 2020, Article ID 8840468, 9 pages, 2020.

- [67] I. Ansari and D. Patil, "A brief review on phytochemical and pharmacological profile of *Carissa spinarum* L.," *Asian Journal of Pharmaceutical and Clinical Research*, vol. 11, no. 9, pp. 12–18, 2018.
- [68] A. Maroyi, "Clusia abyssinica Jaub. and Spach (Euphorbiaceae): medicinal uses, phytochemistry and pharmacological properties," *Medicinal Plants-International Journal of Phytomedicines and Related Industries*, vol. 12, no. 3, pp. 338–348, 2020.
- [69] M. M. Rahman, M. S. Rahaman, M. R. Islam et al., "Role of phenolic compounds in human disease: current knowledge and future prospects," *Molecules*, vol. 27, no. 1, p. 233, 2021.
- [70] G. Nigussie, F. Ibrahim, and S. Neway, "A phytopharmacological review on a medicinal plant: *Cordia africana* lam.," *Journal of Tropical Pharmacy and Chemistry*, vol. 5, no. 3, pp. 254–263, 2021.
- [71] Y. M. Bayisa and T. A. Bullo, "Optimization and characterization of oil extracted from *Croton macrostachyus* seed for antimicrobial activity using experimental analysis of variance," *Heliyon*, vol. 7, no. 9, Article ID e08095, 2021.
- [72] P. K. Mukherjee, S. Singha, A. Kar et al., "Therapeutic importance of Cucurbitaceae: a medicinally important family," *Journal of Ethnopharmacology*, vol. 282, Article ID 114599, 2022.
- [73] Z. Teitel, *Effect of Teff Plant Nutrition on its Functional Food Properties*, Center for Fertilization and Plant Nutrition, Negev, Israel, 2016.
- [74] T. O. Abifarin, G. A. Otunola, and A. J. Afolayan, "Assessment of the phytochemical, antioxidant and antibacterial activities of *Heteromorpha arborescens* (Spreng.) Cham and Schltdl. leaf extracts," *F1000Research*, vol. 9, p. 1079, 2020.
- [75] S. Tesfaye, A. Belete, E. Engidawork, T. Gedif, and K. Asres, "Ethnobotanical study of medicinal plants used by traditional healers to treat cancer-like symptoms in eleven districts, Ethiopia," *Evidence-Based Complementary and Alternative Medicine*, vol. 2020, Article ID 7683450, 23 pages, 2020.
- [76] S. Tonisi, K. Okaiyeto, H. Hoppe, L. V. Mabinya, U. U. Nwodo, and A. I. Okoh, "Chemical constituents, antioxidant and cytotoxicity properties of *Leonotis leonurus* used in the folklore management of neurological disorders in the Eastern Cape, South Africa," *3 Biotech*, vol. 10, pp. 141–214, 2020.
- [77] P. Nand, S. Drabu, and R. K. Gupta, "Antimicrobial investigation of *Linum usitatissimum* for the treatment of acne," *Natural Product Communications*, vol. 6, no. 11, Article ID 1934578X1100601, 2011.
- [78] F. Al-Otibi, K. Perveen, N. A. Al-Saif et al., "Biosynthesis of silver nanoparticles using *Malva parviflora* and their antifungal activity," *Saudi Journal of Biological Sciences*, vol. 28, no. 4, pp. 2229–2235, 2021.
- [79] B. T. Badede, *Phytochemical Investigation And Antimicrobial Activities Of Leaf Extracts Of Momordica Foetida*, 2019.
- [80] G. Alipour, S. Dashti, and H. Hosseinzadeh, "Review of pharmacological effects of *Myrtus communis* L. and its active constituents," *Phytotherapy Research*, vol. 28, no. 8, pp. 1125–1136, 2014.
- [81] N. S. Ashaari, N. E. Mohamad, A. H. Afzinizam, M. H. Ab Rahim, K. S. Lai, and J. Ong Abdullah, "Chemical composition of hexane-extracted *Plectranthus amboinicus* leaf essential oil: maximizing contents on harvested plant materials," *Applied Sciences*, vol. 11, no. 22, Article ID 10838, 2021.
- [82] A. Saparbekova, G. Kantureyeva, D. Kudasova, Z. Konarbayeva, and A. Latif, "Potential of phenolic compounds from pomegranate (*Punica granatum* L.) by-product with significant antioxidant and therapeutic effects: a narrative review," *Saudi Journal of Biological Sciences*, vol. 30, no. 2, Article ID 103553, 2023.
- [83] Y. Andargie, W. Sisay, M. Molla, and M. Adela, "Evaluation of in vivo antidiarrheal activity of hydro-methanolic extract of the root of *Rumex nepalensis* in Swiss Albino mice," *Metabolism Open*, vol. 15, Article ID 100197, 2022.
- [84] Y. H. Gonfa, F. Beshah, M. G. Tadesse, A. Bachheti, and R. K. Bachheti, "Phytochemical investigation and potential pharmacologically active compounds of *Rumex nepalensis*: an appraisal," *Beni-Suef University Journal of Basic and Applied Sciences*, vol. 10, no. 1, pp. 18–11, 2021.
- [85] M. Najem, M. Bammou, L. Bachiri, E. H. Bouiamrine, J. Ibjibjen, and L. Nassiri, "Ruta chalepensis L. Essential oil has a biological potential for a natural fight against the pest of stored foodstuffs: *Tribolium castaneum* herbst.," *Evidence-based Complementary and Alternative Medicine*, vol. 2020, Article ID 5739786, 11 pages, 2020.
- [86] S. Umer, G. Andualem, F. Getnet, H. Alemayehu, A. Tekewe, and N. Kebede, "Antidiarrheal and antibacterial activities of hydroalcoholic extracts of *Salvia schimperii* benth from Ethiopia," *International Journal of Pharmacognosy*, vol. 2, pp. 290–295, 2015.
- [87] C. T. Nyabayo, J. C. Matasyoh, and C. Mwendia, "Chemical composition and acaricidal activity of *Salvia nilotica* essential oil against *Rhipicephalus appendiculatus*," *Advancement in Medicinal Plant Research*, vol. 3, pp. 46–54, 2015.
- [88] B. L. Nyamwamu, M. Ngeiywa, M. Mulaa, A. E. Lelo, J. Ingonga, and A. Kimutai, "Phytochemical constituents of *Senna didymobotrya* Fresen irwin roots used as a traditional Medicinal plant in Kenya," *International Journal of Educational Research*, vol. 3, 2015.
- [89] M. Molla Yitayeh and A. Monie Wassihun, "Chemical composition and antibacterial and antioxidant activities of stem bark essential oil and extracts of *Solanecio gigas*," *Biochemistry Research International*, vol. 2022, Article ID 4900917, pp. 1–10, 2022.
- [90] P. C. B. Silva, J. Clementino Neto, A. D. S. D. Silva et al., "Antidiarrheal activity of *Solanum asterophorum* in mice," *Revista Brasileira de Farmacognosia*, vol. 22, no. 1, pp. 131–136, 2012.
- [91] X. Chen, X. Dai, Y. Liu et al., "*Solanum nigrum* linn.: an insight into current research on traditional uses, phytochemistry, and pharmacology," *Frontiers in Pharmacology*, vol. 13, Article ID 918071, 2022.
- [92] S. Mawouma, N. N. Condurache, M. Turturică, O. E. Constantin, C. Croitoru, and G. Rapeanu, "Chemical composition and antioxidant profile of sorghum (*sorghum bicolor* (L.) moench) and pearl millet (*Pennisetum glaucum* (L.) R. Br.) grains cultivated in the far-North region of Cameroon," *Foods*, vol. 11, no. 14, p. 2026, 2022.
- [93] D. K. Semwal, R. Badoni, R. Semwal, S. K. Kothiyal, G. J. P. Singh, and U. Rawat, "The genus *Stephania* (Menispermaceae): chemical and pharmacological perspectives," *Journal of Ethnopharmacology*, vol. 132, no. 2, pp. 369–383, 2010.
- [94] J.-P. Noudogbessi, P. Yédomonhan, D. C. Sohounlhoué, J.-C. Chalchat, and G. Figuéredo, "Chemical composition of essential oil of *Syzygium guineense* (Willd.) DC. var. *guineense* (Myrtaceae) from Benin," *Records of Natural Products*, vol. 2, no. 2, 2008.

- [95] H. El Gizawy, M. A. Hussein, and E. Abdel-Sattar, "Biological activities, isolated compounds and HPLC profile of *Verbascum nubicum*," *Pharmaceutical Biology*, vol. 57, no. 1, pp. 485–497, 2019.
- [96] S. T. Anthoney, J. K. Obey, and N. C. Mutuku, "Phytochemical analysis of *Vernonia adoensis* leaves and roots used as a traditional medicinal plant in Kenya," *International Journal of Pharmacy and Biological Sciences*, vol. 3, 2013.
- [97] M. T. Abdelwahed, M. A. Hegazy, and E. H. Mohamed, "Major biochemical constituents of *Withania somnifera* (ashwagandha) extract: a review of chemical analysis," *Reviews in Analytical Chemistry*, vol. 42, no. 1, Article ID 20220055, 2023.
- [98] V. Ayam, Z. Ali, I. Khan, and S. Ross, "Chemical constituents from the aerial parts of *Zehneria scabra* Sond," *Planta Medica*, vol. 82, no. 5, p. PC12, 2016.
- [99] A. B. Hassan, S. A. Al Maiman, M. A. Mohammed et al., "Effect of natural fermentation on the chemical composition, mineral content, phytochemical compounds, and antioxidant activity of *Ziziphus spina-christi* (L.) 'Nabag' seeds," *Processes*, vol. 9, no. 7, p. 1228, 2021.
- [100] F. Zhang, P. Yang, Q. He, X. Dong, and S. Zhang, "Is gastrointestinal motility related to alkaloids of Charred Semen *Arecae*?" *Journal of Ethnopharmacology*, vol. 257, Article ID 112825, 2020.
- [101] M. J. Fanning, P. Macander, G. Drzewiecki, E. Middleton Jr, and Elliott, "Quercetin inhibits anaphylactic contraction of Guinea pig ileum smooth muscle," *International Archives of Allergy and Immunology*, vol. 71, no. 4, pp. 371–373, 1983.
- [102] P. Klita, G. Mathison, T. Fenton, and R. Hardin, "Effects of alfalfa root saponins on digestive function in sheep," *Journal of Animal Science*, vol. 74, no. 5, pp. 1144–1156, 1996.
- [103] Y. Sohji, K. Kawashima, and M. Shimizu, "Pharmacological studies of loperamide, an anti-diarrheal agent. II. Effects on peristalsis of the small intestine and colon in Guinea pigs (author's transl)," *Nihon Yakurigaku Zasshi*, vol. 74, no. 1, pp. 155–163, 1978.
- [104] G. Jalilzadeh-Amin and M. Maham, "The application of 1, 8-cineole, a terpenoid oxide present in medicinal plants, inhibits castor oil-induced diarrhea in rats," *Pharmaceutical Biology*, vol. 53, no. 4, pp. 594–599, 2015.
- [105] A. T. B. Sibarani, H. T. Hutami, N. Maharani, and Y. Nindita, "Antidiarrheal effect of lime peel extract on bisacodyl-induced mice," *Jurnal Kedokteran Diponegoro (Diponegoro Medical Journal)*, vol. 10, no. 6, pp. 438–444, 2021.
- [106] Z. Shi, X. Long, Y. Li et al., "Protective effect of tea saponins on alcohol-induced gastric mucosal injury in mice," *American Chemical Society Omega*, vol. 8, no. 1, pp. 673–681, 2022.
- [107] Y. Zhang, X. Wang, S. Sha et al., "Berberine increases the expression of NHE3 and AQP4 in senenosideA-induced diarrhoea model," *Fitoterapia*, vol. 83, no. 6, pp. 1014–1022, 2012.
- [108] J. Luo, X. Lin, M. Bordiga, C. Brennan, and B. Xu, "Manipulating effects of fruits and vegetables on gut microbiota—a critical review," *International Journal of Food Science and Technology*, vol. 56, no. 5, pp. 2055–2067, 2021.
- [109] C. M. Perez Zamora, C. A. Torres, and M. B. Nuñez, "Antimicrobial activity and chemical composition of essential oils from Verbenaceae species growing in South America," *Molecules*, vol. 23, no. 3, p. 544, 2018.
- [110] S. R. Kang, K. I. Park, H. S. Park et al., "Anti-inflammatory effect of flavonoids isolated from Korea *Citrus aurantium* L. on lipopolysaccharide-induced mouse macrophage RAW 264.7 cells by blocking of nuclear factor-kappa B (NF- $\kappa$ B) and mitogen-activated protein kinase (MAPK) signalling pathways," *Food Chemistry*, vol. 129, no. 4, pp. 1721–1728, 2011.
- [111] J. M. Al-Khayri, G. R. Sahana, P. Nagella, B. V. Joseph, F. M. Alessa, and M. Q. Al-Mssallem, "Flavonoids as potential anti-inflammatory molecules: a review," *Molecules*, vol. 27, no. 9, p. 2901, 2022.
- [112] L. C. Di Stasi, "Coumarin derivatives in inflammatory bowel disease," *Molecules*, vol. 26, no. 2, p. 422, 2021.
- [113] L. Račková, V. Jančinová, M. Petříková et al., "Mechanism of anti-inflammatory action of liquorice extract and glycyrrhizin," *Natural Product Research*, vol. 21, no. 14, pp. 1234–1241, 2007.
- [114] V. Prakash, "Terpenoids as source of anti-inflammatory compounds," *Asian Journal of Pharmaceutical and Clinical Research*, vol. 10, no. 3, pp. 68–76, 2017.
- [115] T. T. Cushnie and A. J. Lamb, "Antimicrobial activity of flavonoids," *International Journal of Antimicrobial Agents*, vol. 26, no. 5, pp. 343–356, 2005.
- [116] C. N. Tagousop, J.-D.-D. Tamokou, I. C. Kengne, D. Ngnokam, and L. Voutquenne-Nazabadioko, "Antimicrobial activities of saponins from *Melanthera elliptica* and their synergistic effects with antibiotics against pathogenic phenotypes," *Chemistry Central Journal*, vol. 12, no. 1, pp. 97–99, 2018.
- [117] P. R. Vuddanda, S. Chakraborty, and S. Singh, "Berberine: a potential phytochemical with multispectrum therapeutic activities," *Expert Opinion on Investigational Drugs*, vol. 19, no. 10, pp. 1297–1307, 2010.
- [118] G. Saxena, S. Kalra, and N. Gupta, "Antimicrobial activity pattern of certain terpenoids," *International Journal of Pharmacy and Biological Sciences*, vol. 2, no. 1, pp. 87–91, 2011.
- [119] M. T. Yakubu, Q. O. Nurudeen, S. S. Salimon et al., "Antidiarrhoeal activity of *Musa paradisiaca* sap in wistar rats," *Evidence-based Complementary and Alternative Medicine*, vol. 2015, Article ID 683726, 9 pages, 2015.
- [120] M. Sobczak, M. Sałaga, M. A. Storr, and J. Fichna, "Physiology, signaling, and pharmacology of opioid receptors and their ligands in the gastrointestinal tract: current concepts and future perspectives," *Journal of Gastroenterology*, vol. 49, no. 1, pp. 24–45, 2014.
- [121] P. K. Ashok and K. Upadhyaya, "Tannins are astringent," *Journal of Pharmacognosy and Phytochemistry*, vol. 1, no. 3, pp. 45–50, 2012.
- [122] M. A. Naini, A. Zargari-Samadnejad, S. Mehrvarz et al., "Anti-inflammatory, antioxidant, and healing-promoting effects of Aloe vera extract in the experimental colitis in rats," *Evidence-based Complementary and Alternative Medicine*, vol. 2021, Article ID 9945244, 12 pages, 2021.
- [123] R. Tang, J. Zhang, H. Nan et al., "Exploring Molecular mechanisms of *aloe barbadensis* miller on diphenoxylate-Induced constipation in mice," *Evidence-based Complementary and Alternative Medicine*, vol. 2022, Article ID 6225758, 16 pages, 2022.
- [124] P. Danish, Q. Ali, M. Hafeez, and A. Malik, "Antifungal and antibacterial activity of aloe vera plant extract," *Biological and Clinical Sciences Research Journal*, vol. 2020, no. 1, 2020.
- [125] S. Yusuf, A. Agunu, and M. Diana, "The effect of Aloe vera *A. Bergeri* (Liliaceae) on gastric acid secretion and acute gastric mucosal injury in rats," *Journal of Ethnopharmacology*, vol. 93, no. 1, pp. 33–37, 2004.

- [126] K. Amber, R. Nofel, R. Ghanem et al., "Enhancing the growth rate, biochemical blood indices, and antioxidative capacity of broilers by including aloe vera gel in drinking water," *Frontiers in Veterinary Science*, vol. 7, Article ID 632666, 2020.
- [127] M. K. Swamy, M. S. Akhtar, and U. R. Sinniah, "Antimicrobial properties of plant essential oils against human pathogens and their mode of action: an updated review," *Evidence-based Complementary and Alternative Medicine*, vol. 2016, Article ID 3012462, 21 pages, 2016.
- [128] M. G. Miguel, "Antioxidant and anti-inflammatory activities of essential oils: a short review," *Molecules*, vol. 15, no. 12, pp. 9252–9287, 2010.
- [129] L. Rombolà, M. Straface, D. Scuteri et al., "Antispasmodic effect of bergamot essential oil on rat isolated gut tissues," *Pharmaceutics*, vol. 14, no. 4, p. 775, 2022.
- [130] X. Peng, Q. Zhou, C. Wu et al., "Effects of dietary supplementation with essential oils and protease on growth performance, antioxidation, inflammation and intestinal function of weaned pigs," *Animal Nutrition*, vol. 9, pp. 39–48, 2022.
- [131] H. Iqbal, A. Rahman, S. Khanum et al., "Effect of essential oil and organic acid on performance, gut health, bacterial count and serological parameters in broiler," *Brazilian Journal of Poultry Science*, vol. 23, no. 3, 2021.
- [132] M. Takó, E. B. Kerekes, C. Zambrano et al., "Plant phenolics and phenolic-enriched extracts as antimicrobial agents against food-contaminating microorganisms," *Antioxidants*, vol. 9, no. 2, p. 165, 2020.
- [133] K. Kasprzak-Drozd, T. Oniszczyk, M. Stasiak, and A. Oniszczyk, "Beneficial effects of phenolic compounds on gut microbiota and metabolic syndrome," *International Journal of Molecular Sciences*, vol. 22, no. 7, p. 3715, 2021.
- [134] G. Rocchetti, R. P. Gregorio, J. M. Lorenzo et al., "Functional implications of bound phenolic compounds and phenolics–food interaction: a review," *Comprehensive Reviews in Food Science and Food Safety*, vol. 21, no. 2, pp. 811–842, 2022.
- [135] P. Cherubin, *The Anti-toxin Properties of Grape Seed Phenolic Compounds*, University of Central Florida, Orlando, FL, USA, 2014.
- [136] S. Vandevyver, L. Dejager, J. Tuckermann, and C. Libert, "New insights into the anti-inflammatory mechanisms of glucocorticoids: an emerging role for glucocorticoid-receptor-mediated transactivation," *Endocrinology*, vol. 154, no. 3, pp. 993–1007, 2013.
- [137] Y. P. Yoon, J. Ryu, S. H. Park et al., "Effects of lobetyolin, lobetyol and methyl linoleate on secretion, production and gene expression of MUC5AC mucin from airway epithelial cells," *Tuberculosis and Respiratory Diseases*, vol. 77, no. 5, pp. 203–208, 2014.
- [138] M. Adnan, M. Nazim Uddin Chy, A. Mostafa Kamal et al., "Investigation of the biological activities and characterization of bioactive constituents of *Ophiorrhiza rugosa* var. *prostrata* (D. Don) and *Mondal* leaves through in vivo, in vitro, and in silico approaches," *Molecules*, vol. 24, no. 7, p. 1367, 2019.
- [139] E. O. Kim, K. J. Min, T. K. Kwon, B. H. Um, R. A. Moreau, and S. W. Choi, "Anti-inflammatory activity of hydroxycinnamic acid derivatives isolated from corn bran in lipopolysaccharide-stimulated Raw 264.7 macrophages," *Food and Chemical Toxicology*, vol. 50, no. 5, pp. 1309–1316, 2012.
- [140] A. Elwekeel, M. H. Hassan, E. Almutairi et al., "Anti-inflammatory, anti-oxidant, GC-MS profiling and molecular docking analyses of non-polar extracts from five *salsola* species," *Separations*, vol. 10, no. 2, p. 72, 2023.
- [141] M. Dong, Y. Oda, and M. Hirota, "(10E, 12Z, 15Z)-9-hydroxy-10, 12, 15-octadecatrienoic acid methyl ester as an anti-inflammatory compound from *Ehretia dicksonii*," *Bioscience Biotechnology and Biochemistry*, vol. 64, no. 4, pp. 882–886, 2000.
- [142] A. S. M. A. Reza, M. A. Haque, J. Sarker et al., "Anti-proliferative and antioxidant potentials of bioactive edible vegetable fraction of *Achyranthes ferruginea* Roxb. in cancer cell line," *Food Science and Nutrition*, vol. 9, no. 7, pp. 3777–3805, 2021.
- [143] S. Anwar, N. Ahmed, N. Al Awwad, S. Y. Ansari, and M. E. Wagih, "Myrtle (*Myrtus communis* L.) oils," in *Essential Oils in Food Preservation, Flavor and Safety*, pp. 581–592, Elsevier, Amsterdam, Netherlands, 2016.
- [144] E. E. Essien, S. O. Aboaba, and I. A. Ogunwande, "Constituents and antimicrobial properties of the leaf essential oil of *Gossypium barbadense* (Linn.)," *Journal of Medicinal Plants Research*, vol. 5, pp. 702–705, 2011.
- [145] G. Magi, E. Marini, and B. Facinelli, "Antimicrobial activity of essential oils and carvacrol, and synergy of carvacrol and erythromycin, against clinical, erythromycin-resistant Group A Streptococci," *Frontiers in Microbiology*, vol. 6, p. 165, 2015.
- [146] L. G. Sousa, J. Castro, C. Cavaleiro et al., "Synergistic effects of carvacrol,  $\alpha$ -terpinene,  $\gamma$ -terpinene,  $p$ -cymene and linalool against *Gardnerella* species," *Scientific Reports*, vol. 12, no. 1, p. 4417, 2022.
- [147] A. Marchese, C. R. Arciola, R. Barbieri et al., "Update on monoterpenes as antimicrobial agents: a particular focus on  $p$ -cymene," *Materials*, vol. 10, no. 8, p. 947, 2017.
- [148] B. B. Thinh, R. V. Doudkin, L. D. Chac et al., "Chemical composition and antimicrobial activity of essential oils from the leaves and stems of *Tinomisium petiolare* Hook. f. and Thomson from Vietnam," *Journal of Essential Oil Bearing Plants*, vol. 24, no. 3, pp. 461–468, 2021.
- [149] L. Guzman, L. S. Nerio, W. Venturini, J. P. Macias, W. Donoso, and O. Forero-Doria, "Antiplaquet and antibacterial activities of Essential Oils obtained from rhizomes and leaves of *Hedychium coronarium* J. Koenig," *Anais da Academia Brasileira de Ciências*, vol. 92, 2020.
- [150] P. Buzzini, P. Arapitsas, M. Goretti et al., "Antimicrobial and antiviral activity of hydrolysable tannins," *Mini-Reviews in Medicinal Chemistry*, vol. 8, no. 12, pp. 1179–1187, 2008.
- [151] P. Karak, "Biological activities of flavonoids: an overview," *International Journal of Pharma Sciences and Research*, vol. 10, no. 4, pp. 1567–1574, 2019.
- [152] R. Amarowicz and M. Janiak, *Hydrolysable Tannins*, Elsevier, Amsterdam, Netherlands, 2019.
- [153] Z. Ma, B. Du, J. Li, Y. Yang, and F. Zhu, "An insight into anti-inflammatory activities and inflammation related diseases of anthocyanins: a review of both in vivo and in vitro investigations," *International Journal of Molecular Sciences*, vol. 22, no. 20, Article ID 11076, 2021.
- [154] F.-Y. Fan, L.-X. Sang, and M. Jiang, "Catechins and their therapeutic benefits to inflammatory bowel disease," *Molecules*, vol. 22, no. 3, p. 484, 2017.
- [155] T. Anggraini, S. Wilma, D. Syukri, and F. Azima, "Total phenolic, anthocyanin, Catechins, DPPH radical scavenging activity, and toxicity of *Lepisanthes alata* (Blume) Leenh,"

- International Journal of Food Science*, vol. 2019, Article ID 9703176, 7 pages, 2019.
- [156] R. Garcia-Villar, E. Leng-Peschlow, and Y. Ruckebusch, "Effect of anthraquinone derivatives on canine and rat intestinal motility," *Journal of Pharmacy and Pharmacology*, vol. 32, no. 1, pp. 323–329, 2011.
- [157] G. İscan, N. Kırimer, F. Demirci, B. Demirci, Y. Noma, and K. H. C. Başer, "Biotransformation of (–)-(R)- $\alpha$ -phellandrene: antimicrobial activity of its major metabolite," *Chemistry and Biodiversity*, vol. 9, no. 8, pp. 1525–1532, 2012.
- [158] G.-Q. Kang, W.-G. Duan, G.-S. Lin, Y.-P. Yu, X.-Y. Wang, and S.-Z. Lu, "Synthesis of bioactive compounds from 3-carene (II): synthesis, antifungal activity and 3D-QSAR study of (Z)- and (E)-3-carene-5-one oxime sulfonates," *Molecules*, vol. 24, no. 3, p. 477, 2019.
- [159] J. C. Matasyoh, J. J. Kiplimo, N. M. Karubiu, and T. P. Hailstorks, "Chemical composition and antimicrobial activity of the essential oil of *Satureja biflora* (Lamiaceae)," *Bulletin of the Chemical Society of Ethiopia*, vol. 21, no. 2, pp. 249–254, 2007.
- [160] T. Thilagavathi, M. Pandiyan, M. Suganyadevi, M. Sivaji, M. Yuvaraj, and R. Sasmita, "Dietary fibre-health benefits," *Biotica Research Today*, vol. 2, no. 6, pp. 519–522, 2020.
- [161] M. Ayyachamy, F. E. Cliffe, J. M. Coyne, J. Collier, and M. G. Tuohy, "Lignin: untapped biopolymers in biomass conversion technologies," *Biomass Conversion and Biorefinery*, vol. 3, pp. 255–269, 2013.
- [162] G. L. Catignani and M. E. Carter, "Antioxidant properties of lignin," *Journal of Food Science*, vol. 47, no. 5, p. 1745, 1982.
- [163] A. Finamore, M. Massimi, L. Conti Devirgiliis, and E. Mengheri, "Zinc deficiency induces membrane barrier damage and increases neutrophil transmigration in Caco-2 cells," *Journal of Nutrition*, vol. 138, no. 9, pp. 1664–1670, 2008.
- [164] K. Inoue, Z. O'Bryant, and Z.-G. Xiong, "Zinc-permeable ion channels: effects on intracellular zinc dynamics and potential physiological/pathophysiological significance," *Current Medicinal Chemistry*, vol. 22, no. 10, pp. 1248–1257, 2015.
- [165] M. Jarosz, M. Olbert, G. Wyszogrodzka, K. Młyniec, and T. Librowski, "Antioxidant and anti-inflammatory effects of zinc. Zinc-dependent NF- $\kappa$ B signaling," *Inflammopharmacology*, vol. 25, no. 1, pp. 11–24, 2017.
- [166] M. Lazzarini and H. Wanzira, "Oral zinc for treating diarrhoea in children," *Cochrane Database of Systematic Reviews*, vol. 12, no. 12, Article ID CD005436, 2016.
- [167] M. Chavan, P. Wakte, and D. Shinde, "Analgesic and anti-inflammatory activity of Caryophyllene oxide from *Annona squamosa* L. bark," *Phytomedicine*, vol. 17, no. 2, pp. 149–151, 2010.
- [168] S. Karakaya, S. V. Yilmaz, Ö. Özdemir et al., "A caryophyllene oxide and other potential anticholinesterase and anticancer agent in *Salvia verticillata* subsp. *amasiaca* (Freyn and Bornm.) Bornm. (Lamiaceae)," *Journal of Essential Oil Research*, vol. 32, no. 6, pp. 512–525, 2020.
- [169] J. Wu, T. Zhang, M. Yu et al., "Anti-inflammatory withanolides from *Physalis minima*," *American Chemical Society Omega*, vol. 5, no. 21, pp. 12148–12153, 2020.