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THE THERAPEUTIC ROLE OF THE ALCOHOLIC EXTRACT OF *GUNDELIA TOURNEOFORTTI* L. IN *SALMONELLA* TYPHIMURIUM INFECTION AND ITS HEALTH EFFECTS IN LABORATORY RATS

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Keywords: *Gundelia tournefortii L., Salmonella Typhimurium, children, health effects*

Abstract

This study investigates the effectiveness of the alcoholic extract of Gundelia tournefortii L. in mitigating the effects of Salmonella Typhimurium infection on hematological parameters and liver and kidney function in laboratory animals. S. Typhimurium was isolated from 23 samples of food and stool collected from pediatric patients (aged 1–6 years) with diarrhea at Salah al-Din Hospital. The findings indicate that infection with S. Typhimurium led to a significant increase ($P < 0.05$) in total white blood cell (WBC) and platelet counts, reaching $28.16 \times 10^3/\mu L$ and $713 \times 10^3/\mu L$, respectively, compared to the control values of $8.50 \times 10^3/\mu L$ and $658 \times 10^3/\mu L$. Conversely, red blood cell (RBC) and hemoglobin (Hb) levels were significantly reduced ($P < 0.05$) in infected animals, measuring $5.79 \times 10^6/\mu L$ and 13.0 g/dL, respectively, compared to $4.60 \times 10^6/\mu L$ and 14.10 g/dL in the control group. Liver function tests revealed elevated levels of alkaline phosphatase (ALP), aspartate aminotransferase (AST), and alanine aminotransferase (ALT) in infected rats, with values of 164.0, 142.0, and 66.0 IU/L, respectively, compared to the control values. Renal function analysis showed a significant increase ($P < 0.05$) in urea concentration in the infected group (48.5 mg/dL) relative to the controls (41.2 mg/dL), while no significant differences were observed in creatinine levels between groups. Notably, administration of the alcoholic extract at doses of 200 and 400 μg/kg significantly mitigated the adverse effects of infection, demonstrating its potential therapeutic efficacy.

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Introduction

Salmonella spp. are recognized as significant zoonotic pathogens, posing serious threats to public health and contributing to substantial economic burdens globally, both in developing and industrialized nations, due to the high costs associated with disease treatment, prevention, and control efforts [1]. The genus encompasses over 2,500 serovars, each varying in its ecological niche and pathogenic potential, although only a limited number are responsible for the majority of human infections [2].

Members of the genus *Salmonella* are Gram-negative, facultatively anaerobic, rod-shaped, and non-spore-forming bacteria belonging to the family *Enterobacteriaceae*. Most strains are motile via peritrichous flagella and can metabolize substrates through oxidative pathways. Furthermore, many strains characteristically produce hydrogen sulfide during metabolism [3]. The genus *Salmonella* includes numerous pathogenic serovars implicated in both human and animal diseases. A notable serovar is *Salmonella enterica* serovar Typhimurium (*S.* Typhimurium) [4].

Salmonella spp. are notorious for causing gastroenteritis and systemic infections, frequently associated with symptoms such as abdominal cramps, fever, and diarrhea [5]. These pathogens have a broad host range and can contaminate a variety of foods, particularly meats from poultry and cattle, often without producing overt signs of disease in the animal reservoir [6,7].

Typhoidal serovars, such as *Salmonella enterica* serovar Typhi (*S.* Typhi) and *S.* Paratyphi, are responsible for typhoid and paratyphoid fevers, which are life-threatening

systemic infections disproportionately affecting populations in low- and middle-income countries [8]. Globally, *Salmonella* is consistently ranked among the most common causes of foodborne illnesses [9]. According to estimates from CDC, *Salmonella* is responsible for more foodborne illnesses than any other bacterial pathogen, with poultry, particularly chicken, being a major source. It is estimated that approximately 1 in every 25 packages of raw chicken sold in grocery stores contains *Salmonella* [10].

Despite its well-established status as a public and veterinary health concern, the taxonomy of *Salmonella* remains complex and often confusing for clinicians, veterinarians, and microbiologists due to its constantly evolving nomenclature [11].

The majority of the approximately 2.500 serovars are capable of causing self-limiting gastroenteritis in both humans and animals. However, certain serovars have evolved host-specific adaptations, resulting in systemic, extraintestinal infections in particular species [12]. For instance, *S.* Typhimurium and *S.* Enteritidis circulate among diverse vertebrate hosts and are leading agents of foodborne infections in humans. Non-typhoidal *Salmonella* (NTS) serovars are estimated to cause around 75 million cases of gastroenteritis annually, resulting in approximately 27.000 deaths worldwide [13]. Conversely, typhoidal serovars, such as *S.* Typhi and *S.* Paratyphi A, are strictly human-adapted and cause about 2.5 million infections annually, leading to roughly 65,000 deaths due to typhoid and paratyphoid fevers [8]. Other host-adapted serotypes include *S.* Gallinarum in poultry and *S.* Dublin in cattle, each associated with invasive systemic infections in their respective hosts [12].

Traditionally, culture-based techniques have been regarded as the gold standard for the isolation and identification of foodborne pathogens, including *Salmonella* [14]. Nevertheless, alternative methods such as immunoassays and nucleic acid-based techniques have also been employed to detect foodborne microorganisms [15], although these approaches may be hindered by limitations in sensitivity and specificity [16]. Polymerase chain reaction (PCR) is widely recognized for its rapidity and high sensitivity in detecting foodborne pathogens. However, its performance can be compromised by inhibitors commonly present in complex food matrices [17]. Consequently, PCR-based detection is often supplemented with conventional culture methods to confirm the presence of target organisms [14].

The extensive use of chemical compounds in food production and preservation has led to numerous health concerns. Therefore, humans have been searching for natural sources, including medicinal plants or their extracts. Some plants have been used in herbal medicine for therapeutic purposes in various disease conditions to reduce symptoms due to their content of effective compounds against many pathogens, in addition to their direct use in food [18]. The plant produces these compounds as by-products and they are called phytochemicals. They are biologically active components and have multiple therapeutic properties. These compounds protect the plants themselves from various parasites, and these compounds can be divided on the basis of their chemical composition into multiple compounds [19,20]. Because of their biological effectiveness due to their content of active compounds (phytochemicals), such as phenols, alkaloids, flavonoids, essential oils and resins, these plants have confirmed their ability to treat many pathological conditions and inhibit the growth of many microbial pathogens [20,21,22]. It may be any part of the plant that contains the aforementioned components such as seeds, leaves, roots, coat, and flowers [23].

The increasing prevalence of antibiotic resistance among various types of microbes, has intensified the search for effective natural alternatives. One of these plants is *Gundelia tournefortii L.* It is a valuable wild herbaceous spiny perennial plant with a height of about 60 cm, which belongs to the *Asteraceae* family and grows in semi-desert or sandy plains in Palestine, Jordan, Syria, Iran, Iraq, Azerbaijan, temperate regions in West Asia, Armenia, Turkey and other regions. Its leaves are leathery and hard with thorny serrated lobes, and their color alternates between yellow and red [24]. Its flowers can be hermaphrodite and can be yellow, white, green or red [25].

Traditionally, G. *tournefortii* has been consumed as food in Palestine, Syria, Turkey and Jordan in particular [25,26]. Due to its high economic values for culinary uses, it is used as a food ingredient in making pickles, appetizers, and soups [23]. This plant is characterized by its nutritional benefits. It has been used as food for more than 2000 years in the Babylonian civilization and continues to provide food, medicine, and income to local communities, especially the poorest, in an economically, socially and environmentally sustainable manner [27]. *G. tournefortii* is a rich source of minerals, vitamins and essential fatty acids, and the oil extracted from its flowers is also a rich source of essential fatty acids such as linoleic acid, and oleic acid [28]. Additionally, arachidic acid was also found. *G. tournefortii* contains b-sitosterol as the dominant sterol, which represents more than 51.76 % of the total sterols in the extracted oil, as well as other sterols, such as stigmasterol, 5-avenasterol, campesterol, 7-stigmastenol and 7-avenasterol [29,30,31].

As for its therapeutic or medicinal properties, this plant has been used in the treatment of many diseases, as it reduces the content of fats, cholesterol and blood sugar. Additionally, diarrhea, fever, cough, cold, stomach infections, kidney pains, intestinal disorders [25,32] and toothache [33] are treated with it. It also contributes to protect the liver [32], and acts as an antimicrobial, antiparasitic, and antioxidant due to its ability to inhibit and destroy free radicals. *G. tournefortii* also has anti-inflammatory properties and contributes to purify the blood and treat bronchitis, respiratory diseases, skin diseases, angina pectoris, cancer and stroke [34,35,36]. Its dry seeds are also effective in treating vitiligo and it is also used as a diuretic [37].

Therefore, the aim of this study was to determine the efficacy of the alcoholic extract of *G. tourneofortti L.* plant in diarrhea caused by *S.* Typhimurium in terms of its health effects on blood profile, liver and renal functions in laboratory animals.

Materials and methods

Identification of Salmonella Typhimurium

Food and stool samples were collected from autistic children under school age (1–6) years who had diarrhea while in the hospital at Salah al-Din Hospital during the period from October 1, 2022 to December 30, 2022. Twenty-three food and stool samples were collected.

Serial dilutions of the samples were prepared, the last two dilutions were grown on appropriate culture media (MacConkey agar, Nutrient agar, SS agar, Manitol salt agar and Blood agar) made by Oxoid (USA), they were cultured on the media for each species. Then, a number of diagnostic tests were performed to determine phenotypic, cultural and microscopic characteristics. Several biochemical tests, such as catalase, oxidase, urease, coagulase, IMViC, and fermentation of sugars (glucose, mannitol, sucrose, lactose, arabinose, galactose and sorbitol) were carried out for the colonies, depending on the Bergey's manual. The tests were performed as follows.

Microscopic tests

A microscopic examination of active bacterial cells at the age of 18 hours was performed to determine result of Gram staining and cell shapes.

Cultural characteristics

The cultural and morphological characteristics of the growing colonies included the shape of the colonies, their color, edges, size, and height.

Biochemical tests

Catalase test

A portion of the colonies at the age of 18–24 hours was transferred to a sterile glass slide and a drop of hydrogen peroxide reagent at a concentration of 3 % was added to it. The appearance of air bubbles is an indication of the positivity of the test and the production of the catalase enzyme from the tested bacterial species [38].

Oxidase test

The test was performed by adding many drops of oxidase reagent to a Whattman No 1 filter paper to the point of saturation. A wooden stick was then used to transfer a touch of active bacterial growth to the surface of the reagent-saturated filter paper. The appearance of the purple color within a few seconds was evidence of the species' ability to produce oxidase enzyme [38].

Urease test

The test was conducted by inoculating the colonies of bacteria on urea agar (slants) and incubating the tubes with urea agar for 24 hours at 37 °C. The color of the medium changed from yellow to pink, indicating that the test was positive, because of the change in the pH of the medium to alkaline due to the ammonia formed [39].

Coagulase test

The test was performed using the slide test method, where a drop of blood plasma was placed on a glass slide, then a part of a colony growing on a solid nutrient medium was taken by a sterile carrier and mixed with the drop. The reaction was considered positive if the plasma clotted within 20 seconds, indicating the presence of the bound coagulase enzyme [40].

Methyl red test

The MRVP (5g glucose, 5g peptone and 5g and K_2HPO_4) was prepared according to what was stated in [41], inoculated with bacteria, then incubated at 35 °C for 24 h. After that, the methyl red indicator was added. If the color changes from red to orange, the test is negative, and if the color remains red, the test is positive.

Voges–Proskauer test

This test was performed according to the method of [42], which was used to detect the ability of bacteria to produce acetone.

Citrate utilization test

The plates containing Simmons citrate media were inoculated with the colonies of bacteria under study, after which they were incubated at 37 °C for 24 h. The evidence of a positive result was the change in the color of the medium from green to blue [43].

Carbohydrate fermentation test

The isolates were inoculated into tubes containing the sugar fermentation medium, and incubated at 37 °C for 24 h. The change in the color of the medium from red to yellow color is evidence of a positive test [38].

The diagnosis was confirmed to the level of species by the Vitek 2 Compact system (64 cards) and the serovar was determined using the Kauffmann-White scheme [44,45,46].

Samples collection

Gundelia tourneofortti L. samples were collected from the central regions in Iraq and were diagnosed based on the taxonomic keys of the flora of Iraq [47].

Preparation of the alcoholic extract

The alcoholic extract was prepared by weighing 50 g of plant powder with 500 ml of ethanol alcohol (80 %) and holding overnight, after which it was filtered using layers of gauze for the purpose of getting rid of unwanted parts and then centrifugated (Compact Tabletop Centrifuge 2010, Kubota, Japan) for 15 minutes at 3000 rpm. Then, it was filtered using Whatman No. paper to obtain a clear liquid. The resulting filtrate was concentrated and dried in a rotary vacuum evaporator (IKA-Werke, Staufen, Germany). The dry plant extract was collected and kept in the refrig-

erator in opaque and tightly closed glass bottles [48], as shown in Figure 1.

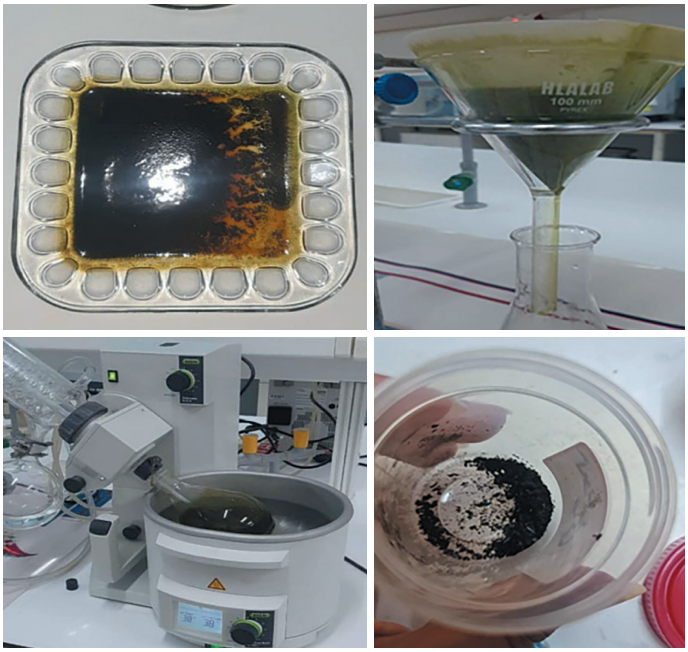

Figure 1. Preparation of the alcoholic extract of *Gundelia tourneofortti* L.

In vivo experiment

The study utilized twenty male rats, weighing 140–149 g and aged 8–10 weeks. They were housed in stainless steel cages in conditions that were suitable for them, such as 25 °C, humidity levels of 50–70 %, controlled lighting, and proper ventilation. A nutritionally adequate diet was provided, and cage cleanliness was maintained by regularly changing the sawdust, as mentioned in [49]. The experiment was designed by dividing the rats into four groups, with five replications per group, as follows: first treatment (T1), the control group second treatment (T2), rats with diarrhea caused by *Salmonella* Typhimurium; third treatment (T3), rats with diarrhea caused by *S.* Typhimurium and treated with an alcoholic extract of *G. tournefortii* at 200 µg/kg; and fourth treatment (T4), rats with diarrhea caused by *S.* Typhimurium and treated with the alcoholic extract of *G. tournefortii* at 400 µg/kg. The extract was administered orally at a dose of 2 mL. Diarrhea was induced in rats by experimental infection with *S.* Typhimurium suspension (1.5×10^8 CFU/mL) prepared using the McFarland turbidity standard for comparison and the experiment continued for 28 days. At the end of the experimental period, the animals were fasted for 20 hours, anesthetized with chloroform, and then dissected. Blood samples were collected directly from the heart for various tests, including blood profile analysis [WBC], [RBC], [PLT], [HB], and [HCT%], as well as assessment of liver enzyme activity [ALT], [AST], and [ALP]) and function of renal markers (urea and creatinine).

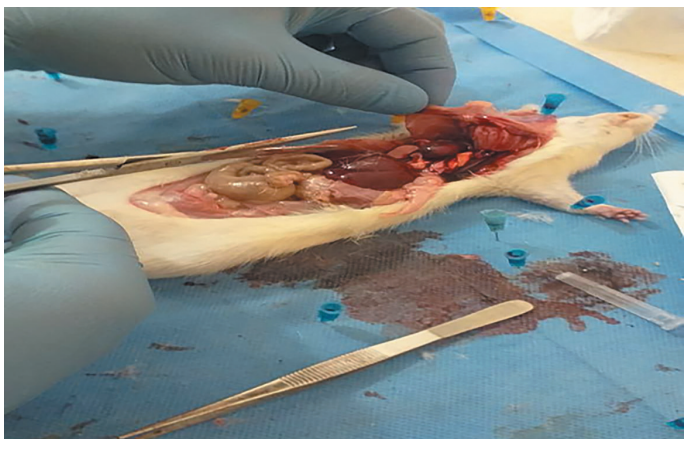

Figure 2. Anatomy of rats

Blood profile

The total counts of WBC, RBC, PLT, and HG were measured using Complete Blood Count (CBC) device.

The activity of liver enzymes

The activity of liver enzymes was estimated using analysis kits prepared by BIOLABO (France), following the method described by [32]. Aspartate aminotransferase (AST) activity was determined using these kits, while alanine aminotransferase (ALT) activity was measured based on the formation of pyruvate hydrazone through the transamination process in the presence of ALT and 2,4-dinitrophenylhydrazine, with absorbance recorded at 546 nm using the spectrophotometer (V-1100D, EMCLAB, Germany). Alkaline phosphatase (ALP) activity was also assessed using BIOLABO kits, adhering to the methodology outlined by [50].

Renal functions

Creatinine was estimated using a ready-made kit from BIOLABO (France), following the manufacturer's instructions. The absorbance was measured at 490 nm (V-1100D, EMCLAB, Germany) [32], and creatinine concentration was determined using the formula: Concentration of creatinine (20 mg/dl) = absorbance of sample / standard solution absorbance × standard solution concentration. Similarly, urea was estimated using an analysis kit from BIOLABO (France), following the supplier's instructions as described by [50].

Statistical analysis

The experimental system was analyzed using the statistical program [51] with CRD. The means were compared using Duncan's test [52] to determine the significance of differences among the factors influencing the study's traits, with a probability level of 0.05.

Results and discussion

Isolation and identification of bacteria causing diarrhea in children

Samples were collected and bacteria were cultivated using appropriate culture media, including MacConkey agar, Nutrient Agar, SS Agar, Mannitol Salt Agar, and Blood Agar. The identification of bacteria was performed by comparing the results of phenotypic, microscopic, and biochemical tests with Bergey's Manual [53] and confirmed

using the Vitek 2 compact system and the Kauffmann-White technique was used to determine the serovar. This scheme divides Salmonella enterica into six subspecies and several serotypes. A recent revision to the White-Kauffmann-Le Minor scheme was made by the World Health Organization (WHO) collaborating center for the reference and investigation of Salmonella [44,45,46]. The following bacteria contaminating meat samples were identified: *Escherichia coli, Staphylococcus aureus, Enterococcus faecalis,* and *Salmonella* Typhimurium as shown in Table 1.

Table 1. Biochemical tests of isolated bacteria

Bacteria	Gram	Catalase	Oxidase	Urease	Coagulase	Simmons citrate	Voges Proskauer	Indole test	Methyl red	Fermentation of sugars						
										Glucose	Mannitol	Sucrose	Lactose	Arabinose	Galactose	Sorbitol
Staph. aureus	+	+	–	+	+	+	+	–	–	+	+	+	+	+	+	+
E. coli	–	–	–	–	V	–	–	–	+	–	+	–	–	+	V	V
Ent. faecalis	+	–	–	–	+	–	+	–	–	+	+	+	+	+	+	+
S. Typhimurium	–	+	–	–	–	–	–	–	–	+	V	+	+	V	V	V

(+) Positive for the test, (–) Negative for the test, (V) Differential results

Effect of the alcoholic extract of Gundelia tournefortii L. on blood profile of rats

Table 2 shows a significant increase at ($P<0.05$) in WBC count in laboratory rats exposed to experimental infection with *S.* Typhimurium without treatment, reaching 28.16 10^3/mm^3 compared to the control group (8.50). Additionally, the platelet count significantly increased to 713 in the infected and untreated group. Conversely, RBC and hemoglobin levels significantly decreased to 5.79 and 13.0, respectively, compared to the control group (6.40 and 14.10, respectively). However, when the extract was administered at concentrations of 200 and 400 µg/mg to infected rats, WBC counts significantly decreased, while RBC and hemoglobin levels increased compared to the infected group that did not receive the extract. Notably, the T4 treatment, which involved administering the extract at 400 µg/mg, demonstrated superior efficacy. Regarding red blood cell HCT%, no significant differences were observed among the treatments. These findings align with several studies [54,55,56], which concluded that a decrease in RBC counts due to bacterial infection results from impaired or lost cells, with bone marrow unable to generate or replace them. The reduced RBC count is attributed to hemolytic anemia, where RBC destruction leads to decreased hemoglobin concentration, impairing its function in transporting nutrients, ultimately affecting cellular activity and potentially leading to cell death [57,58]. The increase in WBC count is likely due to bone marrow stimulation, promoting cell production, while peripheral blood changes may result from activated helper T lymphocytes, which can elevate eosinophil levels and increase vascular permeability to facilitate cell migration to inflammation sites [54,57,59]. The reduction in leukocyte values following oral extract administration is attributed to its bioactive compounds, particularly polyphenols and glycosides, known for their anti-inflammatory properties by inhibiting cytokine activity [36]. This study is consistent with [60], who reported a significant difference in various blood indicators between the control and infected groups treated with the extract at 250 and 500 mg/kg.

Table 2. Impact of the alcoholic extract of *Gundelia tourneofortti L.* on blood profile of rats exposed to experimental infection with *S.* Typhimurium

Treatments	WBC (10^3/mm^3)	RBC (10^6/mm^3)	HB (G/dl)	HCT %	PLT (10^3/mm^3)
T1	8.50^c	6.40^b	14.10^a	44.06^a	658^b
T2	28.16^a	5.79^{ab}	13.0^c	47.80^a	713^a
T3	12.86^b	6.20^{ab}	13.7^{ab}	39.00^a	711^a
T4	11.00^b	6.33^a	13.40^b	42.26^a	652^b

At a probability threshold of 0.05, similar letters in the same column indicate that there were no significant differences between them.
T1 — control group; T2 — rats with diarrhea caused by *S.* Typhimurium; T3 — rats with diarrhea caused by *S.* Typhimurium and treated with the alcoholic extract of *G. tournefortii* at 200 µg/kg; T4 — rats with diarrhea caused by *S.* Typhimurium and treated with the alcoholic extract of *G. tournefortii* at 400 µg/kg.

Effect of the alcoholic extract of Gundelia tournefortii L. on liver activity in rats exposed to experimental infection with S. Typhimurium

Table 3 shows a significant increase in the values of liver enzymes (ALP, ALT, and AST) for the group of rats exposed to *S.* Typhimurium infection, with values of 164.0, 66.0, and 142 IU/L, respectively, compared to the control group, which had values of 104, 51.0, and 115 IU/L. However, when the rats were dosed with *Gundelia tournefortii* L. extract at concentrations of 200 and 400 µg/kg along with the infection, this treatment led to a significant decrease in the enzyme concentrations in the group treated with the extract at 400 µg/kg, with values of 159.7, 135, and 48.0 IU/L, respectively. As for the group treated with the extract at 200 µg/kg, no significant differences were recorded in the enzyme values compared to the infected group.

The elevated concentrations of liver enzymes ALT and AST in the infected rat group indicate the extent of damage occurring in the liver tissue, which causes the breakdown of the cell membrane and the release of these enzymes into the bloodstream. This results in increased enzyme concentrations in the blood serum and reflects a clear effect on the liver's various functions. The rise in AST levels could also

be attributed to metabolic alterations in the liver, followed by the production of toxins, and various pathological conditions such as acute bacterial infections and tumors, affecting organs such as the heart and muscles [61].

As for the rise in alkaline phosphatase enzyme ALP, it is due to pathological conditions, including biliary stasis, partial or complete obstruction of the bile duct, and neoplastic liver disease. On the other hand, this increase in the concentration of this enzyme may be attributed to the increase in the activity of lysosomes, which is one of the important changes before cell death [47].

The decrease in these enzyme levels in the serum of rats treated with the extract, along with the return of enzyme levels to their normal state, suggests the potential use of the alcoholic extract to support the maintenance of liver function [62]. The results of this study are consistent with those observed by Saleh et al. [63], who indicated a significant decrease in liver enzymes in rats treated with *Gundelia tournefortii* L. This plant is considered to have protective properties in supporting liver health [25,64].

Table 3. Impact of the alcoholic extract of *Gundelia tourneofortti L.* on the liver activity of rats exposed toexperimental infection with *S.* Typhimurium

Treatments	ALP	ALT	AST
	(IU/L)		
T1	104.0^{c}	51.0^{b}	115^{c}
T2	164.0^{a}	66.0^{a}	142^{a}
T3	179.0^{a}	61.0^{a}	140^{a}
T4	159.7^{b}	48.0^{b}	135^{b}

At a probability threshold of 0.05, similar letters in the same column indicate that there were no significant differences between them.
T1 — control group; T2 — rats with diarrhea caused by *S.* Typhimurium; T3 — rats with diarrhea caused by *S.* Typhimurium and treated with the alcoholic extract of *G. tournefortii* at 200 µg/kg; T4 — rats with diarrhea caused by *S.* Typhimurium and treated with the alcoholic extract of *G. tournefortii* at 400 µg/kg.

Effect of the alcoholic extract of G. tournefortii on kidney function in rats exposed to experimental infection with S. Typhimurium

Table 4 shows that in rats infected with *S.* Typhimurium, the urea level was significantly higher (48.5 mg/dL) than in the control group (41.2 mg/dL). Treatment with the *Gundelia tournefortii* L. extract at 200 and 400 µg/kg for the infected rats led to a signifiicant decrease in urea concentration, reaching 41.7 and 43.6 mg/dL, respectively. However, there were no appreciable variations in creatinine levels between the different treatments in the experiment.

The rise in urea levels is attributed to damage to renal tissues or a physiological defect in renal function, which results in a reduction in its efficiency [65]. Additionally, an increase in the concentration of free radicals in the body and oxidative stress lead to oxidation of proteins, which results in an increase in urea in the blood. The kidney removes urea from the blood, and the damage to the renal or its failure to remove urea may lead to an increase in blood urea level [66]. The results agree with [67]. Based on the results of these tests, we concluded that this plant is considered to have therapeutic and preventive properties against *Salmonella* infection. These findings align with those of Ayoubi and Baradari [7], who indicated that the plant has the bactericidal activity against *Salmonella* spp. In addition, the results are also in agreement with those of Rabizadeh and Mirian [68], who showed that natural plant extracts hold promise for preventing and treating liver diseases.

Table 4. Impact of the alcoholic extract of *G. tourneofortti* L. on the activity of kidney function of animals exposed to experimental infection with *S.* Typhimurium

Treatments	Urea	Creatinine
	mg/Di	
T1	41.2^{b}	0.3^{a}
T2	48.5^{a}	0.2^{a}
T3	41.7^{b}	0.3^{a}
T4	43.6^{ab}	0.3^{a}

At a probability threshold of 0.05, similar letters in the same column indicate that there were no significant differences between them.
T1 — control group; T2 — rats with diarrhea caused by *S.* Typhimurium; T3 — rats with diarrhea caused by *S.* Typhimurium and treated with the alcoholic extract of *G. tournefortii* at 200 µg/kg; T4 — rats with diarrhea caused by *S.* Typhimurium and treated with the alcoholic extract of *G. tournefortii* at 400 µg/kg.

Conclusion

Based on the study's findings, we concluded that infection with *S.* Typhimurium significantly reduced the total number of red blood cells and hemoglobin concentration and increased the activity of liver enzymes and the concentration of urea. Treatment of infected rats with an oral dose of the *Gundelia tourneofortti L.* alcoholic extract at 400 µg/kg had a significant effect leading to an increase in the number of RBC and haemoglobin concentration, reduction of the activity of liver enzymes and regulation of renal functions due to its content of effective compounds such as phenols, flavonoids, tannins, turbines and resins.

REFERENCES

1. Nair, D.V.T., Venkitanarayanan, K., Johny, A.K. (2018). Antibiotic — resistant *Salmonella* in the food supply and the potential role of antibiotic alternatives for control. *Foods,* 7(10), Article 167. https://doi.org/10.3390/foods7100167
2. Jackson, B. R., Griffin, P. M., Cole, D., Walsh, K. A., Chai, S. J. (2013). Outbreak-associated *Salmonella enterica* serotypes and food commodities, United States, 1998–2008. *Emerging Infectious Diseases*, 19(8), 1239–1244. https://doi.org/10.3201/eid1908.121511
3. Fasciano, A., Hallenbeck, P.C. (1991). Mutations in trans that affect formate dehydrogenase (fdhF) gene expression in *Salmonella typhimurium*. *Journal of Bacteriology*, 173(18), 5893–5900. https://doi.org/10.1128/jb.173.18.5893-5900.1991
4. Brenner, F.W., Villar, R.G., Angulo, F.J., Tauxe. R., Swaminathan. B. (2000). *Salmonella* nomenclature. *Journal of Clinical Microbiology*, 38(7), 2465–2467. https://doi.org/10.1128/JCM.38.7.2465-2467.2000

5. Settanni, L., Corsetti, A. (2007). The use of multiplex PCR to detect and differentiate food- and beverage-associated microorganisms: A review. *Journal of Microbiological Methods*, 69(1), 1–22. https://doi.org/10.1016/j.mimet.2006.12.008
6. Gantois, I., Ducatelle, R., Pasmans, F., Haesebrouck, F., Van Immerseel, F. (2008). *Salmonella enterica* serovar Enteritidis genes induced during oviduct colonization and egg contamination in laying hens. *Applied and Environmental Microbiology,* 74(21), 6616–6622. https://doi.org/10.1128/AEM.01087-08
7. Da Ayoubi, A. Baradari, B. (2015). Antibacterial Activity of *Gundelia tournefortii* Compounds against *Salmonella choleraesuis. Biological Forum — An International Journal,* 7(2), 1076–1081.
8. Gal-Mor, O., Boyle, O.E., Grassl. G.A. (2014). Same species, different diseases: How and why typhoidal and non-typhoidal *Salmonella enterica* serovars differ. *Frontiers in Microbiology*, 5(1), Article 391. https://doi.org/10.3389/fmicb.2014.00391
9. Pal, M., Merera, O., Abera, F., Rahman, M. T., Hazarika, R. A. (2015). Salmonellosis: A major foodborne disease of global significance. *Beverage Food World*, 42(12), 21–24.
10. CDC. (2024). Chicken and Food Poisoning Retrieved from https://www.cdc.gov/food-safety/foods/chicken.html Accessed January 25, 2025.
11. Ryan, M.P., O'Dwyer, J., Adley C.C. (2017). Evaluation of the complex nomenclature of the clinically and veterinary significant pathogen *Salmonella. BioMed Research International,* 2017, Article 3782182. https://doi.org/10.1155/2017/3782182
12. Kingsley, R.A., Bäumler, A.J. (2000). Host adaptation and the emergence of infectious disease: The *Salmonella* paradigm. *Molecular Microbiology*, 36, 1006–1014. https://doi.org/10.1046/j.1365-2958.2000.01907.x
13. Kirk, M.D., Pires, S. M. Black, R.E., Caipo, M., Crump, J.A., Devleesschauwer, B. et al. (2015). World Health Organization estimates of the global and regional disease burden of 22 foodborne bacterial, protozoal, and viral diseases, 2010: A data synthesis. *PLOS Medicin*, 12(12), Article e1001921. https://doi.org/10.1371/journal.pmed.1001921
14. Malorny, B., Tassios, P.T., Rådström, P., Cook, N., Wagner, M. Hoorfar, J. (2003). Standardization of diagnostic PCR for the detection of foodborne pathogens. *International Journal Food Microbiology*, 83(1), 39–48. https://doi.org/10.1016/s0168-1605(02)00322-7
15. Lampel, K.A., Orlandi, P.A., Kornegay, L. (2000). Improved template preparation for PCR-based assays for detection of food-borne bacterial pathogens. *Applied and Environmental Microbiology*, 66, 4539–4542. https://doi.org/10.1128/AEM.66.10.4539-4542.2000
16. ISO 6579–1:2017. Microbiology of the food chain — Horizontal method for the detection, enumeration and serotyping of Salmonella. Part 1: Detection of Salmonella spp.
17. Jeníková, G., Pazlarová, J., Demnerová, K. (2000). Detection of Salmonella in food samples by the combination of immunomagnetic separation and PCR assay. *International Microbiology,* 3(4), 225–229.
18. Greenwell, M., Rahman, P.K.S.M. (2017). Medicinal plants: Their use in their use in anti-cancer treatment. *International Journal of Pharmaceutical Sciences and Research*, 6(2), 4103–4112. http://doi.org/10.13040/IJPSR.0975-8232.6(10).4103-12
19. Nelson, S. (2019). The antibacterial activity of essential oils from *Tagetes erecta* and *Thuja occidentalis. Cantaurus,* 27, 29–33.
20. Al-Hadidy, Y. I., Yaseen, S.S., Saleh, G.M. (2019). The inhibitory effect of some plant extracts on some pathogenic bacteria. *Tikrit Journal of Pure Science*, 24(1), 62–69. http://doi.org/10.25130/tjps.v24i1.331
21. Mustafa, H.H., Elahmar, M.A.I., Hameed, R.T., Alsultan, M., Nesseef, L. Swiegers, G.F. (2022). Extraction and identification of effective compounds from natural plants. *Journal of Composites Science*, 6(5), Article 149. https://doi.org/10.3390/jcs6050149
22. Salih, A. I., Saleh, H.M., Khalaf, A.S., Ayed, S.H. (2022). Effect of Moringa oleifera leaves against hepatotoxicity induced by Bisphenol A. *Archives of Razi Institute*, 77(3), 1083–1089. https://doi.org/10.22092/ARI.2022.357
23. Hani, N., Abulaila, K., Howes, M., Mattana, E., Bacci, S., Sleem, K. et al. (2024). *Gundelia tournefortii* L. (Akkoub): A review of a valuable wild vegetable from Eastern Mediterranean. *Genetic Resources and Crop Evolution,* 71(8), 3987–3995. http://doi.org/10.1007/s10722-024-01927-2
24. Hadi, S.T., Hussien, H.D., Abed, M.A., Alhadithi, A.J. (2020). Chemical analysis of ginger rhizomes and sensory and microbial evaluation of Ginger Juice during storage. *International Journal of Pharmaceutical Quality Assurance*, 11(4), 534–537. https://doi.org/10.25258/ijpqa.11.4.14
25. Asadi-Samani, M., Rafieian-Kopaei, M., Azimi, N. (2013). Gundelia: A systematic review of medicinal and molecular perspective. *Pakistan Journal of Biological Sciences*, 16(21), 1238–1247. https://doi.org/10.3923/pjbs.2013.1238.1247
26. Nadiroğlu, M., Behçet, L. (2018). Traditional food uses of wild plants among the Karlıova (Bingöl-Turkey). *International Journal of Nature Life Sciences*, 2(2), 57–71.
27. FAO. (2017). The future of food and agriculture — Trends and challenges. Rome. Retrieved from https://openknowledge.fao.org/items/ede32306-aeec-4891-9fe6-7e4f2fd93143 Accessed January 15, 2025.
28. Kawarty, A.M.A.M., Behçet, L., Çakılcıoğlu, U. (2020). An ethnobotanical survey of medicinal plants in Ballakayati (Erbil, North Iraq). *Turkish Journal of Botany,* 44(3), 345–357. https://doi.org/10.3906/bot-1910-39
29. Farhang, H.R., Vahabi, M.R., Allafchian, A.R. (2016). Chemical compositions of the essential oil of *Gundelia tournefortii L.* (Asteraceae) from central Zagros, Iran, *Journal of Herbal Drugs,* 6(4), 227–233.
30. Ziabaree, M. H. (2001). The Oil Refining and Technology. Olome Keshavarzee Publications, Tehran, Iran, 2001.
31. Matthäus, B., Özcan, M. M. (2011). Chemical evaluation of flower bud and oils of tumbleweed (*Gundelia tournefortii* L.) as a new potential nutrition sources. *Journal of Food Biochemistry*, 35(4), 1257–1266. https://doi.org/10.1111/j.1745-4514.2010.00449.x
32. Abu-Lafi, S., Rayan, B., Kadan S, Abu-Lafi, M., Rayan, A. (2019) Anticancer activity and phytochemical composition of wild Gundelia tournefortii. *Oncology Letters*, 17(1), 713–717. https://doi.org/10.3892/ol.2018.9602
33. Baydoun, S., Chalak, L., Dalleh, H., Arnold, N. (2015). Ethnopharmacological survey of medicinal plants used in traditional medicine by the communities of Mount Hermon, Lebanon. *Journal of Ethnopharmacology,* 173, 139–156. https://doi.org/10.1016/j.jep.2015.06.052
34. Jassim R. S., Badawy A., Maaroof M. N. (2019). Use of orange husk and watercress (Eruca sativa) seed extracts as antimicrobial natural preservative for fruit juices. *Tikrit Journal for Agricultural Sciences*, 19(1), 69–76. https://doi.org/10.25130/tjas.19.1.7
35. Ali, D.S., Khalaf, D.S. (2023). Chemical composition, radical scavenging, rheological and sensory properties of local soft cheese (*Paneeri Salik*) supplemented with some natural anti-oxidant extracts, *Tikrit Journal for Agricultural Sciences*, 23(4), 43–57. https://doi.org/10.25130/tjas.23.4.5
36. de la Luz Cádiz-Gurrea, M., Zengin, G., Leyva-Jiménez, F. J., Fernández-Ochoa, A., Sinan, K. I., Cakilcioglu, U. et al. (2020). A comparative assessment of biological activities of *Gundelia dersim* Miller and *Gundelia glabra* Vitek, Yüce

and Ergin extracts and their chemical characterization *via* HPLC-ESI-TOF-MS. *Process Biochemistry,* 94(4), 143–151. https://doi.org/10.1016/j.procbio.2020.04.002
37. Tarhan, A., Firat, M. Topal, G. (2023). Comprehensive study of all *Gundelia L. taxa* exists in the globe: An insight on LC–MS/MS based phytochemical investigation and bioactivity potential of 22 species. *Journal of Biochemical Systematics and Ecology,* 109(26), Article 104672. https://doi.org/10.1016/j.bse.2023.104672
38. Baron, E.J., Peterson, L.R., Fingold, S.E. (1994). Bailey and Scott's Diagnostic Microbiology. Mosby Company, Baltimore, 1994.
39. Forbes, B.E., Sahm, D.F., Weissfeld, A. S. (2002). Bailey and Scott's Diagnostic Microbiology. St. Louis, MO: Mosby, USA, 2002.
40. Brown, D. F. J., Edwards, D.I., Hawkey, P.M., Morrison, D., Ridgway, G.L., Towner, K.J. et al. (2005). Guidelines for the laboratory diagnosis and susceptibility testing of methicillinresistant *Staphylococcus aureus* (MRSA). *Journal of Antimicrobial Chemotherapy*, 56(6), 1000–1018. https://doi.org/10.1093/jac/dki372
41. Atlas, R. M., Parks, L.C., Brown, A.E. (1995). Laboratory manual of experimental microbiology. Retrieved from https://www.scienceopen.com/document?vid = 1b85b53d-0653–4ada-b301-d05905da16c9 Accessed January 17, 2025.
42. Collee, J. G., Fraser, A.G., Marmino, B.P., Simmons, A. (1996). Practical medical microbiology. Churchill Livingstone Inc., New York, 1996.
43. Benson, H. J. (2001). Microbiological applications: Laboratory manual in general microbiology. McGraw-Hill companies, Inc. New York, 2001.
44. Grimont, P.A.D., Weill, F.-X. (2007). Antigenic Formulas of the *Salmonella* Serovars. WHO Collaborating Center for Reference Research on Salmonella. Pasteur Institute, Paris, France, 2007.
45. Brenner, F., McWhorter-Murlin, A. (1998). Supplement 1997 (no. 41) to the Kauffmann — White scheme. *Research in Microbiology,* 149(8), 601–604. https://doi.org/10.1016/s0923-2508(99)80008-4
46. Popoff, M.Y., Bockemühl, J., Gheesling, L.L. (2004). Supplement 2002 (no. 46) to the KauffMann — White scheme. *Research in Microbiology*, 155(7), 568–570. https://doi.org/10.1016/j.resmic.2004.04.005
47. Davis, P.H. (1967). Geranium L. Chapter in a book: Flora of Turkey. Edinburgh University press, 1967.
48. Hernández-Pérez, M., López-García, R.E., Rabanal, R.M., Darias, V., Arias, A. (1994). Antimicrobial activity of *Visnea mocanera* leaf extract. *Journal of Ethnopharmacology*, 41(1–2), 115–119. https://doi.org/10.1016/0378-8741(94)90065-5
49. Messora M. R., Pereira L. J., Foureaux R., Oliveira L. F. F., Sordi C. G., Alves A. J. N. et al. (2016). Favourable effects of *Bacillus subtilis* and *Bacillus licheniformis* on experimental periodontitis in rats. *Archives of Oral Biology*, 66, 108–119. https://doi.org/10.1016/j.archoralbio.2016.02.014
50. Burtis, C.A., Ashwood, E.R., Bruns, D.E. (2006). Textbook of Clinical Chemistry and Molecular Diagnostics. Elsevier Health Sciences, 2006.
51. SAS (2001). SAS User's guide: Statistics. SAS Institute, 2001.
52. Duncan, D. (1955). Multiple range and multiple F-Test. *Biometrics*, 11(1), 1–42. https://doi.org/10.2307/3001478
53. Carr, F.J., Chill, D., Maida, N. (2002). The lactic acid bacteria: A literature survey. *Critical Reviews in Microbiology*, 28(4), 281–370. https://doi.org/10.1080/1040-840291046759
54. Abd Elhalim, S.A., Sharada, H.M., Abulyazid, I., Aboulthana, W.M., Abd Elhalim, S.T. (2017). Ameliorative effect of carob pods extract (*Ceratonia siliqua L.)* against cyclophosphamide induced alterations in bone marrow and spleen of rats. *Journal of Applied Pharmaceutical Science*, 7(10), 168–181. https://doi.org/10.7324/japs.2017.71025
55. Werdi, C. M., Al-Hadidy, Y. I. (2023). Effectiveness of *Bacillus clausii* and *Bacillus megaterium* on some physiological and biochemical parameters in rats that induced diarrhea. IOP Conference Series: Earth and Environmental Science, 1158(11), Article 112012. https://doi.org/10.1088/1755-1315/1158/11/112012
56. Hanna, S.J., Al-Salhie, K.C.K. (2024). Evaluate the impact of the alcoholic extract of eruca sativa seeds on the physiological and productive responses of broiler chickens exposed to lead acetate-induced oxidative stress. *Tikrit Journal for Agricultural Sciences*, 24(3), 284–295. https://doi.org/10.25130/tjas.24.3.22
57. Martins, V., Dias, C., Caldeira, J., Duarte, L.C., Reis, A. da Silva, T.L. (2018). Carob Pulp Syrup: A potential mediterranean carbon source for carotenoids production by *Rhodosporidium toruloides* NCYC921. *Bioresource Technology Rep*orts, 3, 177–184. https://doi.org/10.1016/j.biteb.2018.07.008
58. Alaobady, F.A.H., Thalj, K. M. (2024). Evaluation of the antioxidant and inhibitory activity of Aloe vera plant extract (Fermented by Lactobacillus plantarum bacteria) against the pathogenic bacteria isolated from diarrhea infections. *Tikrit Journal for Agricultural Sciences*, 24(1), 246–262. https://doi.org/10.25130/tjas.24.1.20
59. Sultan, L. J., Fadhil, W. G., Hamid, M. M., Hadi, S. T. (2024). A comparative study of the effect of extracts extracted from Ocimum basilicum leaves using organic extract and essential oil. *Functional Foods in Health and Disease*, 14(6), 380–387. https://doi.org/10.31989/ffhd.v14i6.1304
60. Iranloye, B. O. (2002). Effect of chronic garlic feeding on some haematological parameters. *African Journal of Biomedical Research*, 5(1–2), 81–82.
61. AL-Kadhi, N. A., Ibrahim, E.K., Khalaf, R. N., Abass, K. S., Abass, Q. S. (2020). Antioxidant effect of gundelia tournefortii extract on some physiological, biochemical and histopathological changes in male rats. *The Journal of Research on the Lepidoptera,* 51(1), 479–495.
62. Amer, J., Salhab, A., Jaradat, N., Abdallah, S., Aburas, H., Hattab, S. et al. (2022). G*undelia tournefortii* inhibits hepatocellular carcinoma progression by lowering gene expression of the cell cycle and hepatocyte proliferation in immunodeficient mice. *Journal Biomedicine and Pharmacotherapy*, 156, Article 113885. https://doi.org/10.1016/j.biopha.2022.113885
63. Saleh, A.A., Salman, W.A., Abdullah, S.M. (2022). Effect of *Gundelia tournefortii* extract in some physiological and biochemical parameters changes induced by Pseudomonas aeruginosa. *Journal of the College of Basic Education,* 23(99), 69–84. https://doi.org/10.35950/cbej.v23i99.6606
64. Sarhan, I. G.h., Al-Hadidy, Y. I., Weshah, Sh. F. (2023). Effect of gundelia tournefortii l. extract on lipid profile and flora balance in rats exposed to experimental pseudomonas aeruginosa infection. *Anbar Journal of Agricultural Sciences,* 12(2), 366–376. https://doi.org/10.32649/ajas.2023.181867
65. Anraku, M., Takeuchi, K., Watanabe, H., Kadowaki D., Kitamura, K., Tomita, K. et al. (2011). Quantitative analysis of Cysteine-34 on the anitioxidative properties of human serum albumin in hemodialysis patients. *Journal of Pharmaceutical Sciences*, 100(9), 3968–3976. https://doi.org/10.1002/jps.22571
66. Ahmed, M.N. (2012). Using body mass index to find the effect of obesity and overweight on the recurrence of kidney stones in the western region of Iraq. *Anbar University Journal of Pure Sciences*, 6(1), 32–39.
67. Werdi, C. M., Al-Hadidy, Y. I. (2023). *The effectiveness of the Probiotic bacillus spp in induced infection with Staphylococcus*

aureus and the study of its effect on liver enzymes, kidney function and microbial balance of the gut in male rats. IOP Conference Series: Earth and Environmental Science, 1158(11), Article 112013. https://doi.org/10.1088/1755-1315/1158/11/112013

68. Rabizadeh, F. Mirian, M.S. (2024). The Classification of medicinal plants used in traditional Persian medicine for the treatment of liver disease based on phytochemical properties. *Journal of Medicinal Plants and By-products*, 13(2), 257–284.

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