

Formulation and Evaluation of Polyherbal ORS Enriched with Immunomodulatory and Anti-diarrheal Phytoconstituents

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Abstract:

Diarrheal diseases are among the leading causes of dehydration, electrolyte imbalance, and gastrointestinal complications, particularly in children and elderly individuals. Conventional Oral Rehydration Solution (ORS) effectively restores fluid and electrolyte balance but lacks antimicrobial, antioxidant, and immunomodulatory properties. The present study aimed to formulate and evaluate a polyherbal ORS enriched with medicinal plant extracts possessing anti-diarrheal and immune-enhancing activities. Herbal extracts of *Ocimum sanctum*, *Zingiber officinale*, *Phyllanthus emblica*, and *Mentha piperita* were incorporated into a WHO-based ORS formulation in different concentrations to prepare three formulations (F1, F2, and F3). The prepared formulations were evaluated for organoleptic characteristics, pH, phytochemical constituents, antimicrobial activity, and stability. Phytochemical screening confirmed the presence of alkaloids, flavonoids, tannins, and phenolic compounds. Antimicrobial activity was assessed against *Escherichia coli* using the agar well diffusion method. The formulations exhibited significant antibacterial activity with zones of inhibition of 10 mm, 15 mm, and 17 mm for F1, F2, and F3 respectively. Stability studies showed no significant changes in color, odor, precipitation, or pH during storage. Among all formulations, F2 containing 20 mL polyherbal extract demonstrated optimum pH, acceptable taste, good stability, and significant antimicrobial activity, making it the optimized formulation. The study concluded that the developed polyherbal ORS can serve as a safe, stable, economical, and multifunctional therapeutic formulation providing rehydration along with antimicrobial, antioxidant, digestive, and gut-protective benefits for the management of diarrhea-associated dehydration.

Keywords: Polyherbal, Immunomodulatory, ORS, Diarrhea, Dehydration.

Introduction

Oral Rehydration Solution (ORS) is widely used for the management of dehydration caused by diarrhea. However, conventional ORS mainly restores electrolyte balance and does not provide antimicrobial or immunomodulatory effects. The present research aimed to formulate and evaluate a polyherbal ORS enriched with medicinal plant extracts possessing anti-diarrheal, antimicrobial, antioxidant, and immunomodulatory properties. Herbal extracts of *Ocimum sanctum*, *Zingiber officinale*, *Phyllanthus emblica*, and *Mentha piperita* were incorporated into WHO-based ORS formulation. The prepared formulations were evaluated for physicochemical parameters, phytochemical screening, antimicrobial



activity, and stability studies. Among the prepared formulations, F2 containing 20 mL polyherbal extract showed optimum pH, acceptable taste, good stability, and significant antimicrobial activity against *Escherichia coli*. The study concluded that polyherbal ORS can serve as a multifunctional therapeutic formulation providing rehydration along with antimicrobial and gut-protective effects. [1-2]

Diarrheal diseases remain one of the major causes of morbidity and mortality worldwide, especially among children and elderly populations. Dehydration caused by diarrhea leads to severe electrolyte imbalance and fluid loss. Oral Rehydration Solution (ORS) is considered one of the most effective and economical therapies for treating dehydration. Diarrheal disorders are among the most common gastrointestinal diseases affecting people of all age groups, particularly children and elderly individuals. Continuous fluid and electrolyte loss during diarrhea can rapidly lead to dehydration, weakness, electrolyte imbalance, and in severe cases, life-threatening complications. Oral Rehydration Solution (ORS) has been recognized as one of the most effective therapies for restoring fluid and electrolyte balance and reducing mortality associated with diarrheal dehydration.

Although conventional ORS effectively replenishes lost fluids and electrolytes, it does not possess antimicrobial, anti-inflammatory, antioxidant, or immune-enhancing properties. Due to increasing interest in herbal medicine and natural therapeutics, incorporation of medicinal plant extracts into ORS formulations has gained significant importance. Herbal medicines are widely accepted because of their safety, affordability, minimal side effects, and therapeutic potential. Medicinal plants such as *Ocimum sanctum*, *Zingiber officinale*, *Phyllanthus emblica*, and *Mentha piperita* are rich sources of bioactive phytoconstituents including flavonoids, tannins, alkaloids, phenolics, and essential oils. These phytochemicals exhibit antimicrobial, antioxidant, digestive, anti-inflammatory, and immunomodulatory activities that may help in reducing the severity and duration of diarrheal conditions. Tulsi possesses strong antimicrobial and immune-boosting properties, while Ginger helps in relieving nausea, abdominal discomfort, and intestinal inflammation. Amla acts as a natural antioxidant and enhances immunity due to its high vitamin C content. Mint improves digestion, provides a soothing effect on the gastrointestinal tract, and enhances flavor acceptability of the formulation. [3-5]

The present study was therefore designed to formulate and evaluate a polyherbal ORS enriched with selected medicinal plant extracts in order to provide not only rehydration therapy but also additional therapeutic benefits such as antimicrobial protection, improved gut health, antioxidant support, and enhanced patient compliance. The developed formulation may serve as a novel and effective herbal therapeutic approach for the management of dehydration associated with diarrheal diseases. Conventional ORS mainly works by replacing electrolytes and improving intestinal absorption of water through sodium-glucose co-transport mechanisms. However, it lacks antimicrobial, antioxidant, and immunomodulatory activities. Medicinal plants have been traditionally used for gastrointestinal disorders due to their therapeutic phytoconstituents. Herbal ingredients such as Tulsi, Ginger, Amla, and Mint possess antimicrobial, anti-inflammatory, antioxidant, digestive, and immune-enhancing properties. Therefore, incorporation of herbal extracts into ORS may provide additional therapeutic benefits beyond rehydration.[6-8]

Aim & Objective



To formulate and evaluate a polyherbal Oral Rehydration Solution enriched with immunomodulatory and anti-diarrheal phytoconstituents.

To prepare aqueous extracts of selected medicinal plants.

To optimize the concentration of herbal extract in ORS.

To study antimicrobial activity against diarrheal pathogens.

To evaluate stability of the prepared formulation.

To develop and evaluate a stable and effective polyherbal Oral Rehydration Solution (ORS) containing medicinal plant extracts for enhanced rehydration, antimicrobial activity, and gastrointestinal protection.

To formulate a WHO-based polyherbal ORS using selected medicinal plants.

To prepare aqueous extracts of *Ocimum sanctum*, *Zingiber officinale*, *Phyllanthus emblica*, and *Mentha piperita*.

To optimize different concentrations of herbal extracts in the ORS formulation.

To evaluate organoleptic properties such as color, odor, taste, and clarity.

To determine physicochemical parameters including pH and stability of the formulation.

To assess the potential immunomodulatory and antioxidant benefits of the herbal ingredients.

To compare different formulations and select the optimized batch based on evaluation parameters.

To develop a safe, economical, and patient-friendly herbal ORS formulation with improved therapeutic efficacy. [1,2,9,10]

Plan of Work

The present research work was planned systematically to develop and evaluate a polyherbal Oral Rehydration Solution (ORS) enriched with immunomodulatory and anti-diarrheal phytoconstituents. Initially, an extensive literature review was carried out to collect scientific information regarding diarrheal diseases, dehydration management, conventional ORS therapy, and the therapeutic importance of medicinal plants. Based on reported antimicrobial, antioxidant, digestive, and immunomodulatory activities, medicinal plants such as *Ocimum sanctum*, *Zingiber officinale*, *Phyllanthus emblica*, and *Mentha piperita* were selected for formulation development.

Fresh plant materials were collected, washed thoroughly, shade dried, and powdered. The powdered materials were subjected to aqueous extraction using distilled water followed by filtration and concentration to obtain polyherbal extracts rich in bioactive phytoconstituents. Different concentrations of the prepared extract were incorporated into WHO-based ORS formulations to prepare three batches namely F1, F2, and F3.

The prepared formulations were evaluated for various organoleptic parameters including color, odor, taste, and clarity to assess patient acceptability. Physicochemical evaluation such as pH determination was performed using a digital pH meter to ensure compatibility for oral administration. Phytochemical screening was conducted to identify the presence of important constituents such as alkaloids, flavonoids, tannins, and phenolic compounds.

Antimicrobial activity of the prepared formulations was evaluated against *Escherichia coli* using the agar well diffusion method. The zones of inhibition were measured to determine antibacterial effectiveness of each formulation. Stability studies were carried out by storing the formulations at room temperature for 15 days and observing changes in color, odor, precipitation, and pH. Finally, all formulations were compared on the basis of evaluation parameters, and the optimized formulation was selected based on antimicrobial activity, stability, pH, taste acceptability, and overall therapeutic performance.

Methodology

ORS Components

Sr. No.	Ingredients	Quantity for F1	Quantity for F2	Quantity for F3
1	Sodium Chloride (Nacl)	2.6 g	2.6 g	2.6 g
2	Pottasium Chloride (kcl)	1.5 g	1.5 g	1.5 g
3	Trisodium citrate	2.9 g	2.9 g	2.9 g
4	Glucose (Dextrose)	13.5 g	13.5 g	13.5 g
5	Purified water	Up to 1 L	Up to 1 L	Up to 1 L
6	Herbal Extract	10 ml	20 ml	30 ml

Herbal Ingredients Used in Polyherbal ORS

1. Ocimum sanctum

Synonyms: Holy Basil , Sacred Basil, Tulasi

Biological Source : Tulsi consists of the fresh and dried leaves of *Ocimum sanctum* Linn.

Family : Lamiaceae



Uses in ORS :

Helps reduce microbial infection associated with diarrhea

Enhances immunity

Provides antioxidant protection

Helps in relieving gastrointestinal discomfort

Pharmacological Action :

Tulsi possesses antimicrobial, anti-inflammatory, antioxidant, immunomodulatory, and antidiarrheal activities due to the presence of flavonoids, tannins, and essential oils. It helps inhibit pathogenic microorganisms and supports immune defense during gastrointestinal infections. [9,11]

2. Zingiber officinale

Synonyms : Ginger, Adrak , Sunthi

Biological Source :

Ginger consists of the dried rhizomes of *Zingiber officinale* Roscoe.

Family : Zingiberaceae.



Uses in ORS :

Reduces nausea and vomiting
Improves digestion
Relieves stomach cramps
Provides soothing effect to gastrointestinal tract

Pharmacological Action :

Ginger exhibits antiemetic, anti-inflammatory, digestive, antioxidant, and antimicrobial properties due to constituents such as gingerol and shogaol. It helps reduce intestinal irritation and improves gastrointestinal motility during diarrhea. [9,12]

3. Phyllanthus emblica

Synonyms : Indian Gooseberry , Amlaki, Emblica

Biological Source :

Amla consists of the dried and fresh fruits of *Phyllanthus emblica* Linn.

Family : Phyllanthaceae

Uses in ORS :

Improves immunity
Acts as antioxidant
Helps in tissue repair
Enhances nutritional value of ORS



Pharmacological Action :

Amla possesses antioxidant, immunomodulatory, antimicrobial, and anti-inflammatory activities mainly due to vitamin C, tannins, and polyphenols. It protects body cells from oxidative stress and improves immune response during infection. [9,13,14]

4. Mentha piperita

Synonyms : Peppermint , Pudina, Mint

Biological Source :

Mint consists of the fresh and dried leaves of *Mentha piperita* Linn.

Family : Lamiaceae



Uses in ORS :

Improves taste and flavor

Helps digestion

Reduces stomach discomfort

Provides cooling and soothing effect

Pharmacological Action :

Mint shows carminative, digestive, antimicrobial, antispasmodic, and cooling properties due to menthol and volatile oils. It helps relieve abdominal cramps and improves patient acceptability of the ORS formulation.[15,9]

Method of Preparation

Preparation of Herbal Extracts

Step 1: Collection and Cleaning

Fresh plant materials were collected and washed thoroughly using distilled water to remove dirt and impurities.

Step 2: Drying

The plant materials were shade dried at room temperature for 2–3 days to preserve phytoconstituents.

Step 3: Powdering

The dried materials were powdered using a grinder and passed through sieve No. 40.

Step 4: Aqueous Extraction

10 g each of powdered Tulsi, Ginger, Amla, and Mint were mixed with 200 mL distilled water. The mixture was heated at 60–70°C for 30 minutes.

Step 5: Filtration

The extract was cooled and filtered through muslin cloth.

Step 6: Concentration

The filtrate was concentrated using a water bath until the volume reduced to approximately 50 ml. [16,17,18]



Preparation of Polyherbal ORS

Procedure

Step 1: Preparation of ORS Base

500 mL purified water was taken in a beaker and sodium chloride, potassium chloride, and trisodium citrate were dissolved completely.

Step 2: Addition of Glucose

13.5 g glucose was added and stirred continuously until complete dissolution.

Step 3: Incorporation of Herbal Extract

Concentrated polyherbal extract was added slowly with continuous stirring.

Step 4: Volume Adjustment

Purified water was added to make the final volume up to 1 L.

Step 5: Filtration

The prepared solution was filtered to remove insoluble particles.

Step 6: Flavor Adjustment

Mint extract was added for flavor enhancement.

Step 7: Packaging

The formulation was filled in clean amber-colored bottles and labeled properly.[19-21]

Evaluation Parameters

Organoleptic Evaluation

Color : Light brown to greenish

Odor : Characteristic herbal odor

Taste : Sweet and slightly pungent



Clarity : Clear

pH Determination :

The pH of the formulations was measured using a digital pH meter.

Phytochemical Screening :

The prepared extract was screened for phytoconstituents.

Test	Result
Alkaloids	Present
Flavonoids	Present
Tannins	Present
Phenolics	Present

Antimicrobial Activity

Agar well diffusion method was used to evaluate antimicrobial activity against Escherichia coli.

Procedure :

Nutrient agar plates were prepared.

Bacterial culture was spread uniformly.

Wells were created using sterile borer.

Formulations were added into wells.

Plates were incubated at 37°C for 24 hours.

Zone of inhibition was measured. [22-24]

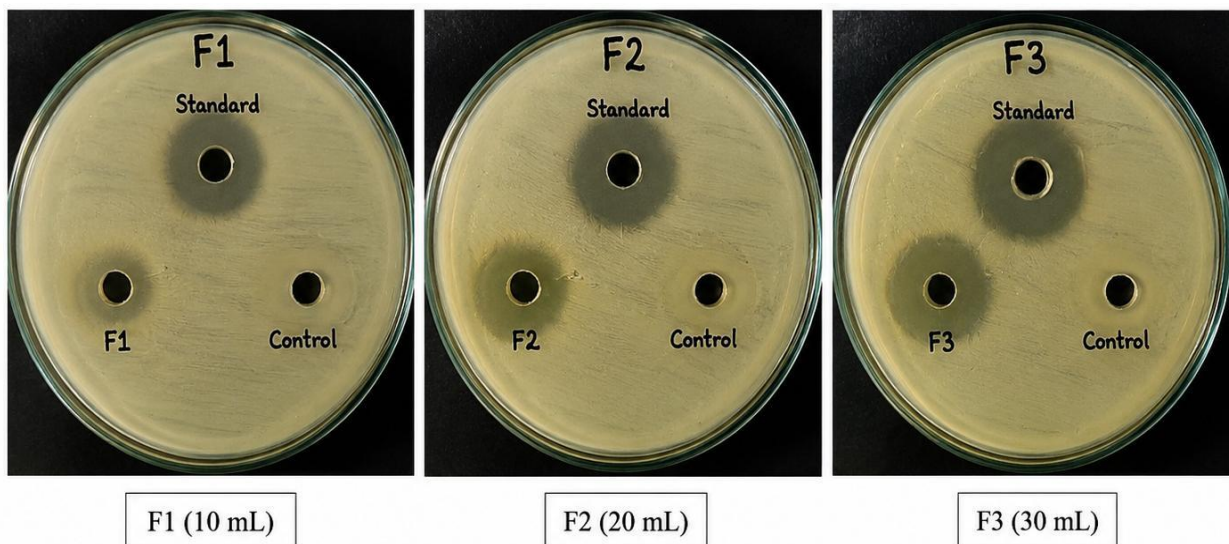
The antimicrobial activity of the prepared polyherbal ORS formulations was evaluated using the agar well diffusion method against Escherichia coli. The effectiveness of each formulation was determined by

measuring the zone of inhibition surrounding the wells after incubation. The zone of inhibition represents the clear area around the well where bacterial growth was prevented due to the antimicrobial action of the formulation.

The results demonstrated that all formulations exhibited antibacterial activity against *Escherichia coli*. Formulation F1 showed a zone of inhibition of 10 mm, indicating moderate antimicrobial activity. Formulation F2 produced a 15 mm zone of inhibition, showing improved antibacterial effectiveness due to the increased concentration of herbal extract. Formulation F3 exhibited the highest zone of inhibition of 17 mm, indicating maximum antimicrobial activity among all batches.

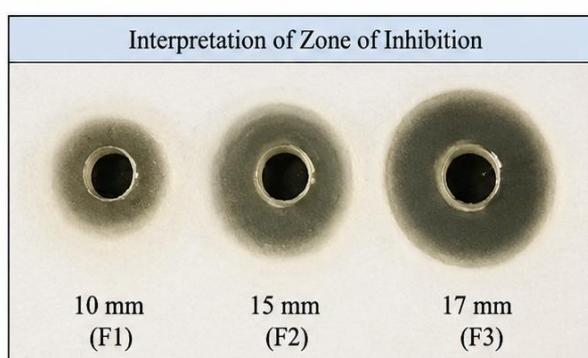
The increase in zone diameter from F1 to F3 suggests that antimicrobial activity increased with increasing concentration of polyherbal extract. The antibacterial effect may be attributed to the presence of phytoconstituents such as flavonoids, tannins, phenolics, and essential oils present in *Ocimum sanctum*, *Zingiber officinale*, *Phyllanthus emblica*, and *Mentha piperita*.

Although F3 showed the highest antimicrobial activity, F2 was considered the optimized formulation because it provided a good balance between antimicrobial efficacy, taste, stability, and patient acceptability.



Zone of Inhibition against *Escherichia coli*

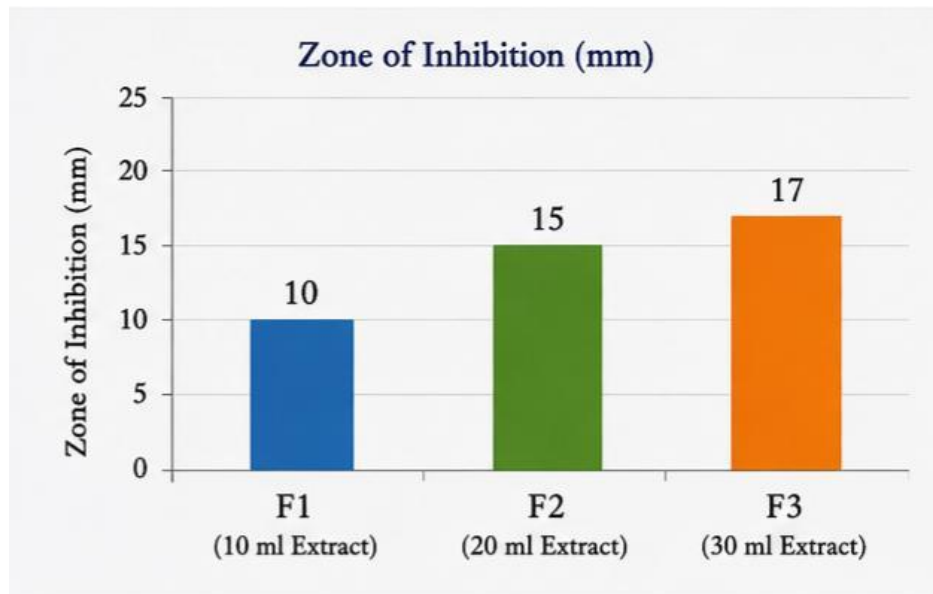
Formulation	Zone of Inhibition (mm)
F1	10 mm
F2	15 mm
F3	17 mm



Stability Study

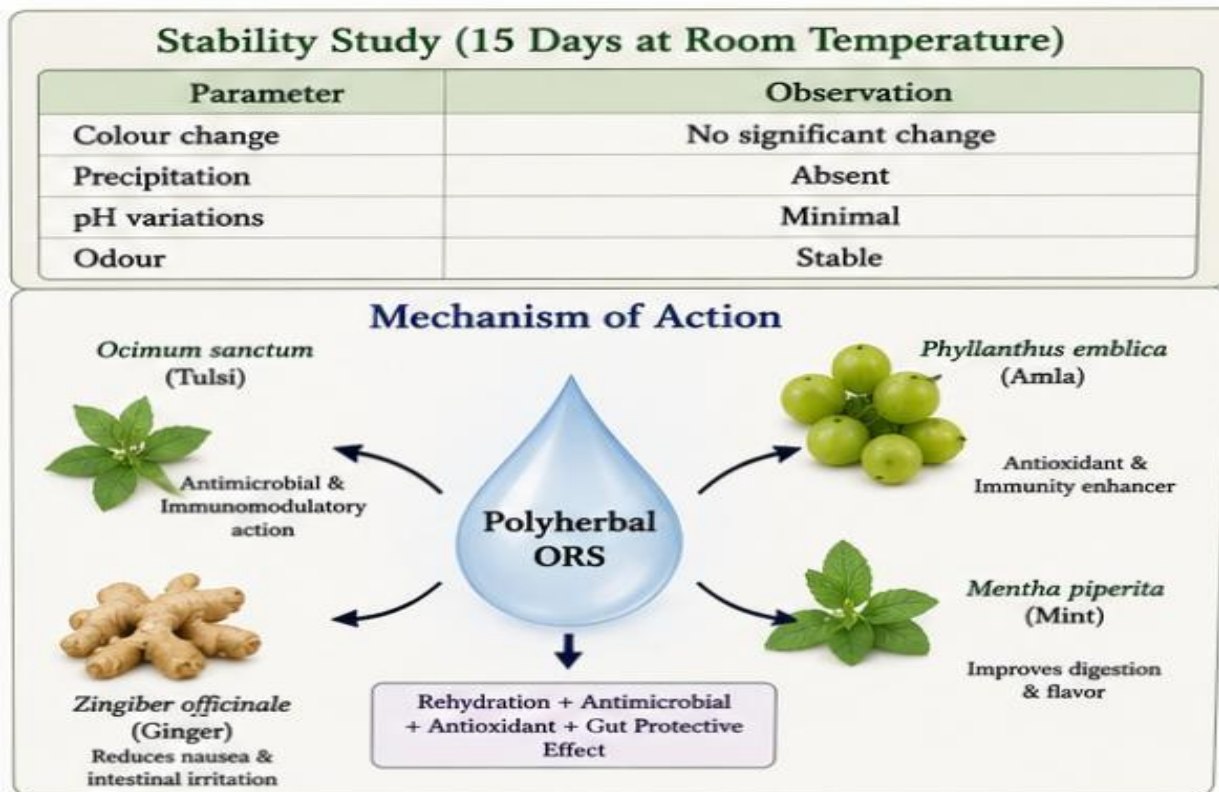
The prepared formulations were stored at room temperature for 15 days and evaluated periodically.

Parameter	Observation
Colour change	No significant change
Precipitation	Absent
PH variations	Minimal
Odour	Stable



Mechanism of Action

The polyherbal ORS formulation acts by combining the rehydration effect of conventional ORS with the therapeutic benefits of medicinal herbs. Glucose present in ORS enhances sodium absorption through the sodium-glucose co-transport mechanism in the intestine, which promotes water uptake and restores electrolyte balance, thereby preventing dehydration. *Ocimum sanctum* provides antimicrobial and immunomodulatory activity that helps control intestinal infections and improve immune response. *Zingiber officinale* reduces nausea, vomiting, and intestinal irritation due to its anti-inflammatory and digestive stimulant properties. *Phyllanthus emblica* acts as a potent antioxidant and immunity enhancer that protects intestinal cells from oxidative stress and supports recovery, while *Mentha piperita* improves digestion, relieves abdominal discomfort, and enhances the flavor and palatability of the formulation. [25-29]



Ocimum sanctum → Antimicrobial and immunomodulatory action

Zingiber officinale → Reduces nausea and intestinal irritation

Phyllanthus emblica → Antioxidant and immunity enhancer

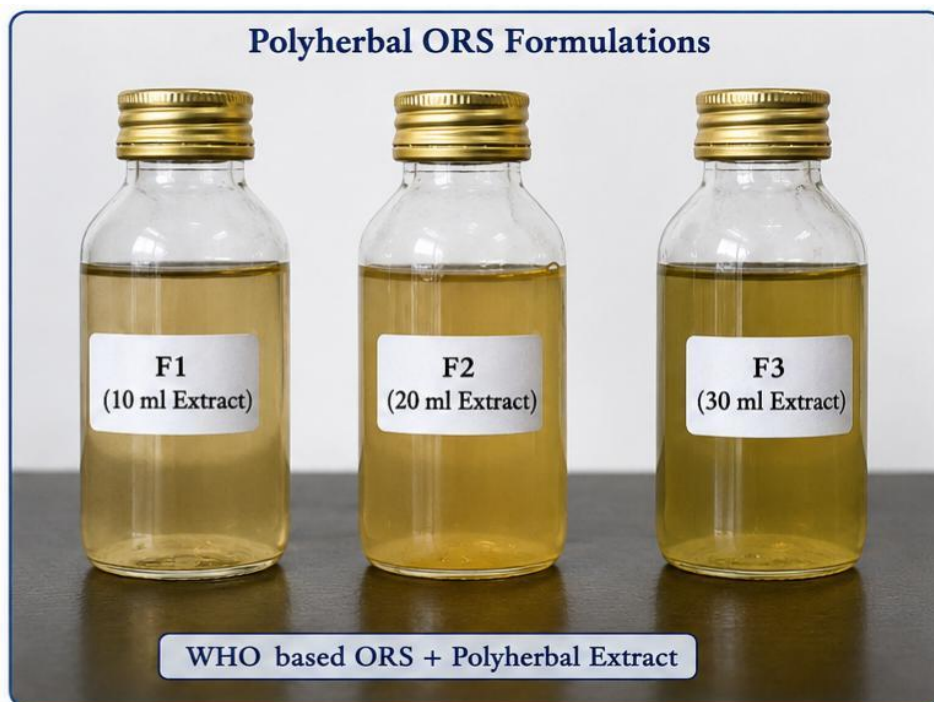
Mentha piperita → Improves digestion and flavor

Results and Discussion

Parameter	F1	F2	F3
Taste Acceptability	Good	Excellent	Moderate
pH Suitability	Acceptable	Optimum	Slightly alkaline
pH	6.5	6.8	7.1
Antimicrobial Activity	Moderate	Significant	Highest
Stability	Stable	Stable	Stable
Overall Evaluation	Satisfactory	Optimized Batch	Less acceptable taste
Zone of inhibition	10 mm	15 mm	17 mm

The present study was carried out to formulate and evaluate a polyherbal Oral Rehydration Solution (ORS) enriched with immunomodulatory and anti-diarrheal phytoconstituents. Three formulations (F1, F2, and

F3) containing different concentrations of polyherbal extract were prepared and evaluated for organoleptic properties, physicochemical parameters, phytochemical constituents, antimicrobial activity, and stability. All formulations showed acceptable organoleptic characteristics. The prepared ORS solutions were clear in appearance with a light brown to greenish color and characteristic herbal odor. The taste was sweet with slight pungency due to the presence of ginger and mint extracts, which improved palatability and patient acceptability. No visible particulate matter or precipitation was observed, indicating good



clarity and proper formulation compatibility.

The pH of the prepared formulations ranged from 6.5 to 7.1, which is considered suitable for oral administration and gastrointestinal compatibility. Formulation F1 showed a pH of 6.5, F2 showed 6.8, and F3 showed 7.1. Among all batches, F2 demonstrated optimum pH close to neutral, making it more acceptable and stable compared to other formulations. Phytochemical screening of the prepared polyherbal extract confirmed the presence of important bioactive constituents such as alkaloids, flavonoids, tannins, and phenolic compounds. These phytoconstituents are known to possess antimicrobial, antioxidant, anti-inflammatory, and immunomodulatory properties, which may contribute to the therapeutic effectiveness of the formulation during diarrheal conditions.

The antimicrobial activity of the formulations was evaluated against *Escherichia coli* using the agar well diffusion method. All formulations exhibited antibacterial activity with varying zones of inhibition. Formulation F1 showed a 10 mm zone of inhibition indicating moderate antimicrobial activity. Formulation F2 exhibited a 15 mm zone of inhibition, demonstrating significant antibacterial effectiveness. Formulation F3 showed the highest zone of inhibition of 17 mm due to the higher concentration of herbal extract. The increase in antimicrobial activity from F1 to F3 suggests that antibacterial effectiveness increased proportionally with the concentration of polyherbal extract. The antimicrobial action may be attributed to phytoconstituents such as flavonoids, tannins, phenolics, and volatile oils present in *Ocimum sanctum*, *Zingiber officinale*, *Phyllanthus emblica*, and *Mentha piperita*. Although F3 demonstrated maximum antimicrobial activity, it showed comparatively stronger herbal taste

and reduced patient acceptability. Formulation F2 was therefore considered the optimized batch because it provided the best balance between antimicrobial activity, taste, pH, stability, and overall acceptability. The stability study conducted for 15 days at room temperature showed no significant changes in color, odor, pH, or precipitation in any formulation. The formulations remained physically stable throughout the study period, indicating good compatibility of herbal extracts with the ORS base and suitability for short-term storage. The mechanism of action of the prepared polyherbal ORS involves both rehydration and therapeutic herbal benefits. Glucose present in ORS enhances sodium and water absorption through the sodium-glucose co-transport mechanism in the intestine, thereby restoring electrolyte balance and preventing dehydration. ♦ Ocimum sanctum contributes antimicrobial and immunomodulatory effects, Zingiber officinale helps reduce nausea and intestinal irritation, Phyllanthus emblica provides antioxidant and immune-enhancing activity, and Mentha piperita improves digestion and flavor acceptability. These combined actions make the formulation more effective than conventional ORS by providing additional antimicrobial, antioxidant, digestive, and gut-protective benefits.

Overall, the study concluded that the developed polyherbal ORS formulation can serve as a safe, stable, economical, and multifunctional therapeutic preparation for the management of dehydration associated with diarrhea. Among the prepared batches, formulation F2 was found to be the optimized formulation due to its balanced physicochemical properties, good stability, acceptable taste, and significant antimicrobial activity.

Summary & Conclusion

The present study was carried out to formulate and evaluate a polyherbal Oral Rehydration Solution (ORS) enriched with medicinal plant extracts possessing antimicrobial, antioxidant, digestive, and immunomodulatory activities. Conventional ORS mainly helps in restoring fluid and electrolyte balance during diarrheal dehydration but does not provide additional therapeutic benefits. Therefore, herbal extracts of Ocimum sanctum, Zingiber officinale, Phyllanthus emblica, and Mentha piperita were incorporated into a WHO-based ORS formulation to enhance its effectiveness. Three formulations namely F1, F2, and F3 were prepared using different concentrations of polyherbal extract and evaluated for organoleptic properties, pH, phytochemical screening, antimicrobial activity, and stability studies. All formulations showed acceptable appearance, clarity, odor, and taste. Phytochemical screening confirmed the presence of alkaloids, flavonoids, tannins, and phenolic compounds which are responsible for various therapeutic activities such as antimicrobial, antioxidant, and anti-inflammatory effects.

The antimicrobial study against Escherichia coli demonstrated that all formulations possessed antibacterial activity, with increasing activity observed as the concentration of herbal extract increased. Formulation F3 showed the highest zone of inhibition, while F2 exhibited optimum antimicrobial activity along with better taste, stability, and patient acceptability. Stability studies revealed that the formulations remained stable without significant changes in color, odor, pH, or precipitation during storage. The combined action of ORS electrolytes and medicinal plant extracts provided both rehydration and supportive therapeutic benefits. The herbal ingredients helped improve digestion, reduce intestinal irritation, enhance immunity, and provide antimicrobial protection during diarrheal conditions. Overall, the study concluded that the developed polyherbal ORS formulation can serve as a safe, stable, economical, and multifunctional therapeutic preparation for the management of dehydration associated with diarrhea. Among all the batches, formulation F2 was selected as the optimized formulation due to its balanced physicochemical properties, significant antimicrobial activity, stability, and improved palatability.

Future Scope

The developed polyherbal Oral Rehydration Solution (ORS) showed promising physicochemical stability, antimicrobial activity, and improved therapeutic potential compared to conventional ORS. However, further research and advanced studies are required to establish its wider pharmaceutical and clinical applications. The following future prospects may be considered for further development of the formulation:

1. Clinical Evaluation in Diarrheal Patients

The present study was carried out under laboratory conditions; therefore, clinical trials on human subjects are necessary to evaluate the actual therapeutic effectiveness of the formulation in diarrheal patients. Clinical studies can help determine the safety, efficacy, dosage regimen, patient compliance, recovery rate, and reduction in severity and duration of diarrhea. Evaluation in pediatric and geriatric populations may provide additional information regarding its suitability for vulnerable patient groups.

2. Advanced Stability Studies

Long-term and accelerated stability studies should be performed according to ICH guidelines to determine the shelf life and storage conditions of the formulation. Parameters such as pH, color, odor, microbial load, precipitation, and phytochemical stability should be monitored under different temperature and humidity conditions. These studies will help establish product stability during transportation and commercial storage.

3. Development of Flavored Pediatric Formulations

Since children are the major sufferers of diarrheal diseases, development of flavored pediatric formulations such as orange, lemon, mint, or fruit-flavored ORS may improve palatability and patient compliance. Sugar-free or low-sugar variants can also be developed for diabetic or special patient populations.

4. Large-Scale Industrial Production

The formulation may be further optimized for industrial-scale manufacturing using suitable pharmaceutical processing equipment and standardized extraction techniques. Scale-up studies can help improve production efficiency, formulation consistency, packaging, and cost-effectiveness for commercial marketing.

5. Evaluation Against Additional Microbial Strains

Further antimicrobial studies may be conducted against a wider range of diarrhea-causing microorganisms such as *Salmonella*, *Shigella*, *Vibrio cholerae*, and fungal pathogens to confirm broad-spectrum antimicrobial activity of the formulation.

6. Standardization of Herbal Extracts

Future studies can focus on standardization of the herbal extracts by identifying and quantifying active phytoconstituents responsible for therapeutic activity. Advanced analytical techniques such as HPLC, GC-MS, and spectroscopic analysis may be used for quality control and batch consistency.

7. Evaluation of Antioxidant and Immunomodulatory Activity

Detailed *in vitro* and *in vivo* studies may be conducted to evaluate antioxidant potential, immune-enhancing activity, and anti-inflammatory effects of the formulation. These studies can provide scientific validation for the multifunctional therapeutic benefits of the herbal ingredients.

8. Development of Ready-to-Use Dosage Forms

The formulation can be modified into different pharmaceutical dosage forms such as sachets, powders, effervescent granules, instant dissolving tablets, or ready-to-drink bottles for better convenience, portability, and patient acceptance.

9. Toxicological and Safety Studies

Acute and chronic toxicity studies should be performed to confirm the long-term safety of the formulation. Evaluation of any possible herbal-drug interactions and allergic reactions will help ensure safe therapeutic use.

10. Comparative Study with Marketed ORS Products

Future research may involve comparative studies between the developed polyherbal ORS and marketed ORS formulations to evaluate differences in antimicrobial activity, patient compliance, therapeutic efficacy, and overall clinical performance.

11. Nutritional Enhancement of ORS

Additional nutrients such as zinc, vitamins, probiotics, and natural electrolytes may be incorporated into the formulation to further improve nutritional support and intestinal recovery during diarrhea.

12. Patent and Commercial Development

The formulation may be explored for patent registration and commercial product development as a novel herbal therapeutic ORS with multifunctional benefits. Proper regulatory approval and industrial collaboration may support commercialization and public healthcare application.

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