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PREPARATION OF HERBAL-BASED MEDICINAL BEVERAGES AND DETERMINATION OF THEIR SAFETY INDICATORS.

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Abstract: This study investigates the preparation methods, chemical composition, and safety parameters of medicinal beverages produced from selected medicinal plants. Herbal extracts derived from Plantago major, Mentha piperita, and Matricaria chamomilla were used to formulate functional beverages. The analysis focused on identifying bioactive compounds, evaluating antioxidant capacity, and determining microbiological and toxicological safety indicators. The results demonstrate that beverages based on these medicinal plants possess significant therapeutic potential while meeting essential safety standards. The research highlights the importance of quality control in the production of herbal-based medicinal drinks and provides recommendations for ensuring their safe consumption.

Keywords: Herbal beverages; medicinal plants; Plantago major; Mentha piperita; Matricaria chamomilla; bioactive compounds; antioxidant activity; safety indicators; toxicological analysis; microbiological safety; functional drinks.

Introduction

The growing global interest in natural and plant-based products has intensified research on the development of herbal beverages with proven therapeutic value. Medicinal plants have long been used in traditional healthcare systems due to their rich composition of biologically active compounds such as flavonoids, phenolic acids, terpenoids, essential oils, and vitamins. These phytochemicals exhibit a wide range of pharmacological effects, including antioxidant, anti-inflammatory, antimicrobial, immunomodulatory, and detoxifying properties. As a result, beverages formulated from medicinal herbs are increasingly recognized not only as refreshing drinks but also as functional products capable of promoting human health. In recent years, the commercialization of herbal beverages has expanded rapidly; however, this growth has also raised concerns regarding their quality, safety, and standardization. The chemical composition of herbal drinks can vary significantly depending on plant species, ecological conditions, harvesting time, extraction techniques, and storage conditions. Moreover, contamination with heavy metals, pesticide residues, pathogenic

microorganisms, or excessive levels of biologically active compounds may pose potential health risks. Therefore, scientific evaluation of both the functional efficacy and safety parameters of plant-based beverages is essential.

This study focuses on three medicinal plants widely used in traditional and modern phytotherapy: Plantago major, Mentha piperita, and Matricaria chamomilla. These species were selected due to their well-documented therapeutic actions, availability, and suitability for beverage formulation. The research aims to develop standardized preparation methods for herbal beverages derived from these plants, analyze their bioactive composition, and assess key safety indicators—including microbiological purity, toxicological parameters, and antioxidant stability.By integrating phytochemical analysis with modern safety assessment methods, this study provides a comprehensive scientific foundation for the production of safe and effective herbal beverages. The findings are expected to contribute to improved quality control practices in the herbal drink industry and support the development of evidence-based functional products.

Materials and Methods

Plant Materials. Three medicinal plants commonly used in phytotherapy were selected for beverage formulation: Plantago major (greater plantain), Mentha piperita (peppermint), and Matricaria chamomilla (chamomile). Fresh aerial parts of these plants were collected during their optimal vegetation period from environmentally clean regions. Each plant species was taxonomically authenticated by a qualified botanist. The plant materials were washed, shade-dried at 25–28°C for 5–7 days, and ground into coarse powder for extraction.

Preparation of Herbal Extracts. Infusion-based extraction was chosen as the primary method due to its suitability for beverage preparation and ability to preserve thermolabile bioactive compounds. For each plant, 10 g of dried powder was infused in 200 mL of hot distilled water at 90–95°C for 20 minutes. The mixtures were then filtered through sterile Whatman No. 1 filter paper. The resulting extracts served as the base for the medicinal beverage formulations. Combined herbal beverages were prepared by mixing equal proportions of the three extracts to evaluate synergistic effects. Physicochemical Analysis. Physicochemical parameters of the beverages—including pH, total soluble solids (°Brix), titratable acidity, and conductivity—were measured using standard laboratory instruments. Total phenolic content (TPC) was determined using the Folin–Ciocalteu reagent and expressed as mg gallic acid equivalents (GAE) per liter. Total flavonoid content (TFC) was quantified using the aluminum chloride colorimetric method and expressed as mg quercetin equivalents (QE) per liter. Determination of Antioxidant Activity. Antioxidant capacity of the beverages was assessed using two complementary assays:

1. DPPH radical scavenging assay: The reduction of DPPH absorbance at 517 nm was measured after reaction with the extracts.
2. ABTS assay: ABTS•+ radical decolorization was used to quantify antioxidant potential at 734 nm. Results for both assays were expressed as Trolox equivalent antioxidant capacity (TEAC).

Microbiological Safety Assessment .Microbial contamination was evaluated following standard food safety protocols. Total viable count (TVC), yeast and mold counts, and the presence of pathogenic bacteria (Escherichia coli, Salmonella spp., Staphylococcus aureus) were assessed using selective culture media. Incubation conditions were maintained at 35–37°C for bacteria and 25–28°C for fungi. Acceptable limits followed WHO and Codex Alimentarius guidelines for non-alcoholic beverages. Toxicological and Heavy Metal Analysis.To ensure safety, the levels of potentially toxic heavy metals—including lead (Pb), cadmium (Cd), arsenic (As), and mercury (Hg)—were analyzed

using atomic absorption spectroscopy (AAS). Samples were digested with nitric acid prior to measurement. Values were compared with permissible limits established by international food safety regulations. Statistical Analysis. All measurements were conducted in triplicate. Results were expressed as mean ± standard deviation (SD). Statistical significance between samples was assessed using one-way ANOVA followed by Tukey's post-hoc test ($p < 0.05$). Analytical processing was performed using SPSS software version 26.0.

Results and Discussion

The antioxidant capacity measured by DPPH and ABTS assays showed strong radical-scavenging activity across all samples. Chamomile and peppermint extracts exhibited higher inhibition percentages in both assays, supporting previous reports on their potent antioxidant properties. The mixed herbal beverage showed the highest Trolox equivalent antioxidant capacity, likely due to complementary interactions among phenolics, flavonoids, and volatile oils present in the three plants. The correlation analysis revealed a strong positive relationship between total phenolic content and antioxidant activity ($r > 0.85$), confirming that phenolic compounds act as primary contributors to antioxidant potential in herbal beverages. Microbiological analysis demonstrated that all beverage samples met international acceptability standards. Total viable counts were below the threshold limit for ready-to-drink herbal products, and no pathogenic bacteria—including E. coli, Salmonella spp., or Staphylococcus aureus—were detected. Yeast and mold counts were also minimal, indicating effective extraction conditions and good hygienic handling during preparation. These findings confirm the microbiological safety of the beverages for human consumption.

The concentrations of heavy metals such as Pb, Cd, As, and Hg were found to be significantly lower than maximum permissible limits set by Codex Alimentarius and WHO. This suggests that the medicinal plants used in the study were collected from uncontaminated environments and that the extraction process did not introduce additional toxic elements. The absence of heavy-metal accumulation is a critical factor for consumer safety, particularly in herbal products consumed regularly. The combined results demonstrate that beverages prepared from Plantago major, Mentha piperita, and Matricaria chamomilla possess strong functional characteristics—including high antioxidant activity and rich phytochemical composition—while fully complying with safety standards. The synergistic interactions in the blended formulation further enhance its therapeutic value and stability. These findings support the suitability of medicinal-plant-based beverages as promising functional drinks capable of contributing to preventive healthcare. The study underscores the importance of standardized preparation, regular safety assessments, and quality control in the development of herbal beverages intended for commercial or therapeutic use.

Conclusion

The present study demonstrates that beverages formulated from Plantago major, Mentha piperita, and Matricaria chamomilla possess substantial functional and safety attributes, making them suitable candidates for the development of natural health-promoting drinks. The phytochemical analyses confirmed that the beverages contain considerable amounts of phenolic and flavonoid compounds, which are strongly associated with their antioxidant capacity. Among the individual extracts, chamomile and peppermint showed particularly high levels of bioactive constituents, while the blended formulation exhibited synergistically enhanced antioxidant activity. Microbiological and toxicological assessments confirmed that all beverage samples met international safety standards, with negligible contamination and heavy-metal levels far below established limits. These findings

indicate that the selected medicinal plants, when processed under appropriate hygienic and controlled conditions, can yield beverages that are both safe and therapeutically valuable. Overall, this research highlights the importance of integrating phytochemical profiling with safety assessments to ensure the quality of herbal beverages. The results provide a scientific basis for further product development, optimization of extraction techniques, and potential commercialization of functional drinks derived from medicinal plants. Future studies may expand on sensory evaluation, shelf-life stability, and clinical assessment to better understand the health benefits of such beverages.

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