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Research Article

Pomegranate-Based Polyherbal Beverage for Supportive Management of Hypertension

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ABSTRACT

Hypertension is a major global health concern and a leading risk factor for cardiovascular diseases, necessitating the development of safe and effective alternative approaches for its management. The present study aimed to formulate and evaluate a pomegranate-based polyherbal functional beverage for supportive management of hypertension. The formulation was prepared using pomegranate juice in combination with selected medicinal herbs, including tulsi, hibiscus, hawthorn, and arjuna, along with natural excipients such as mint, lemon, and honey. The developed beverage was evaluated for its physicochemical properties, antioxidant activity, sensory attributes, and stability. The physicochemical analysis revealed that the formulation possessed an acceptable pH, total soluble solids, viscosity, and titratable acidity, indicating good stability and suitability for consumption. The antioxidant activity, determined using the DPPH radical scavenging assay, demonstrated significant free radical inhibition, suggesting strong antioxidant potential of the formulation. Sensory evaluation using a 9-point hedonic scale indicated good acceptability in terms of taste, color, odor, and overall preference. Stability studies showed that the formulation remained stable under refrigerated conditions with minimal changes in physicochemical parameters, while slight variations were observed at room temperature. Microbial analysis confirmed that the formulation was safe for consumption within the study period. In conclusion, the developed polyherbal beverage exhibits promising physicochemical stability, antioxidant activity, and sensory acceptability, indicating its potential as a functional nutraceutical product for supportive management of hypertension. However, further clinical studies are required to establish its therapeutic efficacy.

INTRODUCTION

Hypertension, commonly referred to as high blood pressure, is one of the most prevalent non-communicable diseases globally and a leading risk factor for cardiovascular morbidity and mortality. It is characterized by a sustained increase in

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arterial blood pressure, which places excessive strain on blood vessels and vital organs. If left uncontrolled, hypertension can lead to serious complications such as coronary artery disease, stroke, heart failure, and chronic kidney disease. The increasing prevalence of hypertension is largely associated with modern lifestyle factors, including unhealthy dietary habits, physical inactivity, stress, obesity, and aging, making it a significant global public health challenge [1].

Despite the availability of a wide range of antihypertensive medications, effective long-term management of hypertension remains a challenge. Conventional pharmacological therapies, although efficacious, are often associated with limitations such as adverse effects, high treatment costs, and poor patient adherence. These drawbacks have encouraged the exploration of alternative and complementary approaches that are safer, more cost-effective, and suitable for long-term use [2].

Functional foods and beverages have emerged as an important category within the nutraceutical sector, offering health benefits beyond basic nutrition. Functional beverages, in particular, provide a convenient and acceptable means of delivering bioactive compounds such as antioxidants, polyphenols, vitamins, and minerals. Fruit-based beverages enriched with herbal extracts have gained popularity due to their dual advantages of nutritional value and therapeutic potential. These beverages can play a significant role in preventive healthcare by targeting oxidative stress, inflammation, and metabolic imbalances associated with hypertension [3].

Among various fruits, pomegranate (Punica granatum) has received considerable scientific attention due to its rich phytochemical composition. It contains high levels of polyphenols, including ellagitannins, flavonoids, and anthocyanins, which are known for their potent antioxidant activity. These bioactive constituents contribute to cardiovascular health by reducing oxidative stress, improving endothelial function, and inhibiting angiotensin-converting enzyme (ACE) activity, thereby aiding in blood pressure regulation [4,5].

In addition to fruit-based components, medicinal herbs have long been used in traditional systems of medicine such as Ayurveda for the management of cardiovascular disorders. Herbs such as holy basil (Ocimum sanctum), hibiscus (Hibiscus sabdariffa), hawthorn (Crataegus spp.), and arjuna (Terminalia arjuna) possess well-documented pharmacological activities relevant to hypertension management. These include antioxidant, anti-inflammatory, vasodilatory, diuretic, and cardiotonic effects. The presence of bioactive compounds such as flavonoids, tannins, and phenolic acids enables these herbs to act through multiple mechanisms, including enhancement of nitric oxide production, modulation of calcium channels, and reduction of vascular resistance [6–9].

The concept of polyherbal formulation is based on the principle of synergism, where the combined effect of multiple herbal components is greater than the sum of their individual effects. Such formulations are widely used in traditional medicine and are increasingly being explored in modern research for their improved efficacy and safety profile [10].

In this context, the development of a pomegranate-based polyherbal functional beverage represents a promising strategy for supportive hypertension management. By combining the antioxidant-rich properties of pomegranate with the therapeutic potential of selected medicinal herbs, it is possible to develop a nutraceutical product that is both effective and acceptable to consumers. Moreover, such a beverage can serve as a natural, preventive

approach to cardiovascular health, aligning with the growing demand for plant-based and health-promoting products.

Therefore, the present study focuses on the formulation and evaluation of a pomegranate-based polyherbal functional beverage intended for supportive management of hypertension. The study includes the development of the formulation and its evaluation based on physicochemical properties, antioxidant activity, sensory characteristics, and stability, thereby assessing its potential as a functional nutraceutical beverage.

AIM

To formulate and evaluate a pomegranate-based polyherbal functional beverage for supportive management of hypertension.

OBJECTIVES

1. To develop a polyherbal functional beverage using pomegranate juice in combination with selected medicinal herbs.
2. To optimize the formulation for palatability, stability, and effective incorporation of bioactive constituents.
3. To evaluate the physicochemical properties of the formulated beverage, including pH, total soluble solids (TSS), viscosity, and titratable acidity.
4. To assess the antioxidant activity of the formulation using the DPPH radical scavenging method.
5. To perform sensory evaluation of the beverage using a 9-point hedonic scale for parameters such as taste, color, odor, and overall acceptability.
6. To study the stability of the developed formulation under different storage conditions.
7. To explore the potential of the formulated beverage as a nutraceutical product for supportive management of hypertension.

DRUG PROFILES

Profile 1: Pomegranate

Fig.1. Pomegranate

Description: Pomegranate is a fruit-bearing deciduous shrub or small tree. The fruit is technically a berry, known for its thick, reddish skin and hundreds of juicy, red seeds called arils. Its deep red color indicates a high concentration of bioactive compounds.

Taxonomy (Classification):

Table 1. Taxonomy of pomegranate

Taxonomical Rank	Scientific Name
Kingdom	Plantae
Division	Angiosperms
Class	Eudicots
Order	Mrytales
Family	Lytraceae
Genus	Punica
Species	Punica granatum L.
Common Name	Pomegranate

Phytochemical Properties: The primary phytochemicals in pomegranate relevant to

cardiovascular health are ellagitannins (like punicalagin and punicalin), gallic acid, and anthocyanins. These compounds are potent antioxidants.

Pharmacological Activities: Antioxidant, anti-inflammatory, cardioprotective [8, 10].

Role in Hypertension: Helps reduce blood pressure by inhibiting angiotensin-converting enzyme (ACE), improving endothelial function, and reducing oxidative stress.[10].

Profile 2: Hawthorn Berries

Fig.2. Hawthorn Berries

Description: Hawthorn consists of a large genus of shrubs and trees in the rose family. The primary medicinal parts are the berries, leaves, and flowers. It is widely used in Traditional Chinese Medicine and European phytotherapy as a cardiotonic herb.

Taxonomy (Classification):

Table 2. Taxonomy of Hawthorn Berries

Taxonomical Rank	Scientific Name
Kingdom	Plantae (Plants)
Division	Angiosperms (Flowering plants)
Class	Eudicots
Order	Rosales
Family	Rosaceae
Genus	Crataegus
Species	Crataegus spp. (e.g., C. oxyacantha)
Common name	Hawthorn

Phytochemical Properties: Hawthorn contains high concentrations of flavonoids, specifically vitexin, quercetin, and hyperoside, as well as oligomeric proanthocyanidins (OPCs).

Pharmacological Activities: Cardioprotective, vasodilatory, antioxidant [2].

Role in Hypertension: Improves coronary circulation and promotes vasodilation, leading to reduction in blood pressure [2,16].

Profile 3: Hibiscus

Fig. 3. Hibiscus

Description: Hibiscus, often consumed as "Sour Tea," refers to the species *H. sabdariffa*. The medicinal parts are the dark red, fleshy calyces that surround the fruit. It is native to Africa and cultivated widely in tropical and subtropical regions.

Taxonomy (Classification):

Table 3. Taxonomy of Hibiscus

Taxonomic Rank	Scientific Name
Kingdom	Plantae (Plants)
Division	Angiosperms (Flowering plants)
Class	Eudicots

Order	Malvales
Family	Malvaceae
Genus	Hibiscus
Species	Hibiscus sabdariffa L.
Common Name	Hibiscus / Roselle

Phytochemical Properties: The calyces are rich in organic acids, such as hibiscus acid and hydroxycitric acid, and anthocyanins, specifically delphinidin-3-sambubioside and cyanidin-3-sambubioside [30].

Pharmacological Activities: Antioxidant, diuretic, antihypertensive [30]

Role in Hypertension: Helps lower blood pressure through ACE inhibition and diuretic action, reducing vascular resistance [31,32,33].

Profile 4: Arjuna Bark

Fig.4. Arjuna Bark

Description: Arjuna is a deciduous tree, typically growing near water. The primary medicinal part is its thick, grey bark. In Ayurvedic medicine, it is considered the premier cardiotonic herb.

Taxonomy (Classification):

Table 4. Taxonomy of Arjuna Bark

Taxonomic Classification	Scientific Name
Kingdom	Plantae (Plants)
Division	Angiosperms (Flowering plants)
Class	Eudicots
Order	Myrtales
Family	Combretacrae
Genus	*Terminalia*
Species	*Terminalia arjuna (Roxb.) Wight & ”rn.*
Common name	Arjuna Bark

Phytochemical Properties: The bark is rich in tannins (over 20%) and triterpenoid saponins, with the primary bioactive marker being arjunolic acid [34].

Pharmacological Activities: Cardiotonic, antioxidant, anti-ischemic

Role in Hypertension: Enhances cardiac function and reduces oxidative stress, thereby supporting blood pressure regulation [34].

Profile 5: Holy Basil (Tulsi)

Fig. 5. Holy Basil

Description: Holy Basil, or Tulsi, is an upright, many-branched, perennial medicinal herb. It is highly revered in Indian traditional medicine (Ayurveda) and is often linking with adaptogenic properties, meaning it helps the body cope with stress.

Taxonomy (Classification):

Table 5. Taxonomy of Holy Basil

Taxonomic Rank	Scientific Name
Kingdom	Plantae (Plants)
Division	Angiosperms (Flowering plants)
Class	Eudicots
Order	Lamiales
Family	Lamiaceae
Genus	*Ocimum*
Species	*Ocimum sanctum* L. or *Ocimum tenuiflorum*
Common Name	Holy Basil / Tulsi

Phytochemical Properties: The essential oil of Holy Basil contains a high concentration of eugenol, which is the key compound responsible for its vascular effects. Recent research has also identified novel bioactive antihypertensive peptides, such as Peptide 1 (Asp-Leu-Ser-Ser-Ala-Pro), in its leaves [21].

Pharmacological Activities: Adaptogenic, antioxidant, anti-inflammatory

Role in Hypertension: Exhibits antihypertensive activity by acting as a mild calcium channel blocker and reducing stress-induced elevation of blood pressure.

MATERIALS AND METHODS

Raw Materials and Reagents

Fresh pomegranates (Punica granatum) were procured from a local market to ensure freshness and high phytochemical content. Dried herbal materials including Ocimum sanctum (Tulsi), Hibiscus sabdariffa (Hibiscus), Crataegus spp. (Hawthorn), and Terminalia arjuna (Arjuna) were obtained from authenticated herbal suppliers.

Other ingredients such as fresh mint leaves (Mentha spicata), lemon (Citrus limon), and honey were sourced locally. Sodium benzoate was used as a preservative. All chemicals and reagents used in the study, including DPPH, methanol, sodium hydroxide, and phenolphthalein, were of analytical grade.

Formulation Development

The beverage was formulated based on a 100 mL batch scale, optimized for palatability, stability, and bioactive concentration. The composition (Table 5) was derived from therapeutic dosages identified in the literature review, scaled for a functional beverage format.

Table 5. Optimized Composition of Polyherbal Antihypertensive Beverage (per 100 mL)

Ingredient	Quantity	Pharmacological Role	Bioactive Marker
Pomegranate Juice	50 mL (50% v/v)	Base vehicle, ACE inhibition	Punicalagins
Hawthorn Extract	1 mL (1% v/v)	Vasodilation	Hyperoside/Vitexin
Hibiscus Extract	1 mL (1% v/v)	Diuretic, ACE inhibition	Anthocyanins
Arjuna Bark Extract	1 mL (1% v/v)	Cardiotonic, Antioxidant	Arjunolic Acid
Holy Basil Extract	1 mL (1% v/v)	Ca++ Channel Blocker	Eugenol
Fresh Mint Infusion	0.5–1 mL	Digestive aid, Flavor	Menthol
Lemon Juice + Zest	3–4 mL + Zest	pH adjuster, Stabilizer	Citric Acid, Limonene
Honey	8–12 g	Sweetener, Antimicrobial	Glucose/Fructose
Sodium Benzoate	0.1 g (0.1%)	Preservative (Class II)	Benzoic Acid
Purified Water	q.s. to 100 mL	Vehicle	-

Preparation Protocol (Standard Operating Procedure)

Pomegranate Juice Extraction: Fresh arils were separated manually to avoid tannin contamination from the rind. Juice was extracted using a low-speed masticating juicer to minimize oxidation, filtered through a muslin cloth (mesh size 40), and immediately chilled to 4°C.

Herbal Decoction and Infusion:

- **Hard Parts (Arjuna, Hawthorn):** A decoction method was employed. 10 g of dried bark/berries were boiled in 100 mL purified water for 30 minutes to ensure extraction of hydrophilic tannins and triterpenoids. The extract was filtered and concentrated.
- **Soft Parts (Hibiscus, Holy Basil, Mint):** An infusion method was used to prevent thermal degradation of anthocyanins and volatilization of eugenol. 10 g of plant material was steeped in water at 85°C for 15 minutes.

Blending and pH Adjustment: Pomegranate juice was placed in a glass beaker under magnetic stirring (200 rpm). Herbal extracts were added sequentially. Lemon juice and zest were added to acidify the medium. The pH was monitored using a calibrated digital pH meter and adjusted to the target range of **3.5–4.0** using Citric Acid. This acidic pH is critical for the hyperchromic effect of anthocyanins (maintaining the red flavylium cation structure) and for preservative efficacy.

Preservation and Pasteurization: Honey and Sodium Benzoate (0.1% w/v) were dissolved in the mixture. The beverage underwent thermal pasteurization at 65°C for 15 minutes. High-temperature short-time (HTST) conditions were avoided to prevent the thermal degradation of heat-sensitive bioactives like vitamin C and anthocyanins.

Bottling: The formulation was hot-filled into sterilized amber PET bottles to protect against photodegradation and sealed immediately.

Evaluation of Formulation

Physicochemical Analysis

- **pH:** Measured using a calibrated digital pH meter (Eutech Instruments) at 25°C.
- **Total Soluble Solids (TSS):** Determined using a handheld refractometer (0–32 °Brix) and expressed in degrees Brix. Corrections were applied for temperature variations.
- **Viscosity:** Measured using an Ostwald viscometer. The flow time of the beverage was compared to distilled water, and dynamic viscosity.
- **Titratable Acidity:** Analyzed according to **AOAC Official Method 942.15**. A 10 mL sample was titrated against 0.1 N NaOH using phenolphthalein as an indicator. Results were expressed as % Citric Acid equivalent.

Antioxidant Activity (DPPH Assay)

The radical scavenging activity was evaluated using the AOAC Official Method 2012.04 adapted for beverages.

- **Principle:** The stable purple radical DPPH (2,2-diphenyl-1-picrylhydrazyl) is reduced to the yellow hydrazine form by hydrogen-donating antioxidants.
- **Protocol:** 1 mL of the beverage (diluted 1:10) was mixed with 3 mL of 0.1 mM methanolic DPPH solution. The mixture was incubated in the dark at room temperature for 30 minutes. Absorbance was measured at 517 nm using a

UVVis spectrophotometer (Shimadzu UV-1800).

- **Calculation:**

% Inhibition = (Acontrol − Asample / Acontrol) × 100

$\% \ Inhibition = \frac{A_{control} - A_{sample}}{A_{control}} \times 100$

Sensory Evaluation

The formulated beverage was evaluated by a panel of 10 semi-trained judges using a 9-point hedonic scale for:

- Taste
- Color
- Odor
- Mouthfeel
- Overall acceptability

Stability and Microbial Testing

- **Stability:** Samples were stored at 4°C and 25°C for 4 weeks. Parameters (pH, TSS, Color) were recorded weekly.
- **Microbial Load:** The Total Plate Count (TPC) method was used. Samples were plated on Nutrient Agar and incubated at 37°C for 48 hours. The limit for safe consumption was set at $< 10^3$ CFU/mL.

RESULTS AND DISCUSSION

Physicochemical Characterization

The physicochemical properties of the formulated beverage are summarized in Table 6.

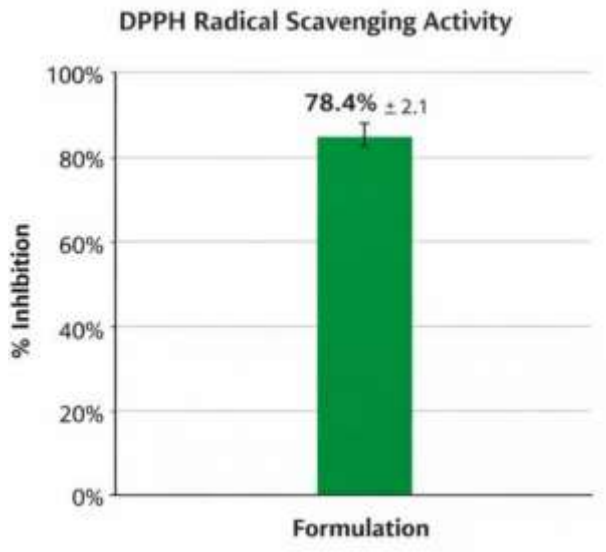
Table 6. Physicochemical Parameters of the Polyherbal Formulation

Parameter	Observed Value (Mean ± SD)	Standard Limit	Interpretation
pH	3.82 ± 0.05	3.5 – 4.5	Optimal for anthocyanin stability and microbial inhibition.
TSS (°Brix)	12.5 ± 0.2	10 – 15	Palatable sweetness; balanced by natural sugars and honey.
Titratable Acidity (%)	0.65 ± 0.03	0.3 – 1.0	Provides tartness and freshness; consistent with fruit juice blends.
Viscosity (cP)	1.85 ± 0.15	1.5 – 5.0	Fluid consistency, slightly higher than water due to pectin/honey.
Specific Gravity	1.048 ± 0.002	1.030 – 1.060	Indicates adequate dissolved solids content.

Antioxidant Activity

The antioxidant potential of the formulated beverage was evaluated using the DPPH radical scavenging method.

- % Inhibition: 78.4 ± 2.1%
- The formulation exhibited high free radical scavenging activity, indicating strong antioxidant potential.



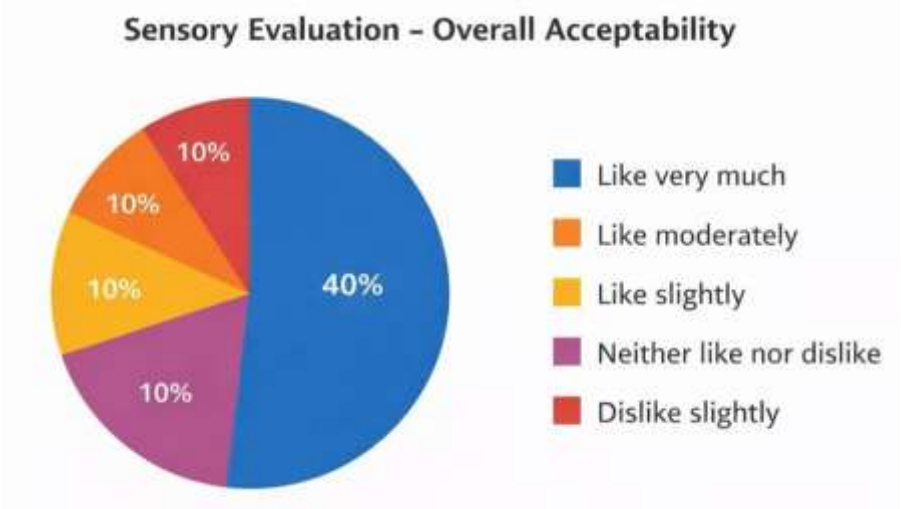
Graph 1. DPPH Radical Scavenging Activity of the Formulated Polyherbal Beverage

Sensory Evaluation

The organoleptic properties of the formulation were evaluated using a 9-point hedonic scale by 10 panelists.

Table 2: Sensory Evaluation Results

Parameter	Score (Mean)	Interpretation
Colour	8.5	Highly acceptable
Taste	7.8	Pleasant, balanced flavor
Odor	8.0	Acceptable herbal aroma
Mouth feel	7.9	Smooth consistency
Overall acceptibility	8.1	Liked very much

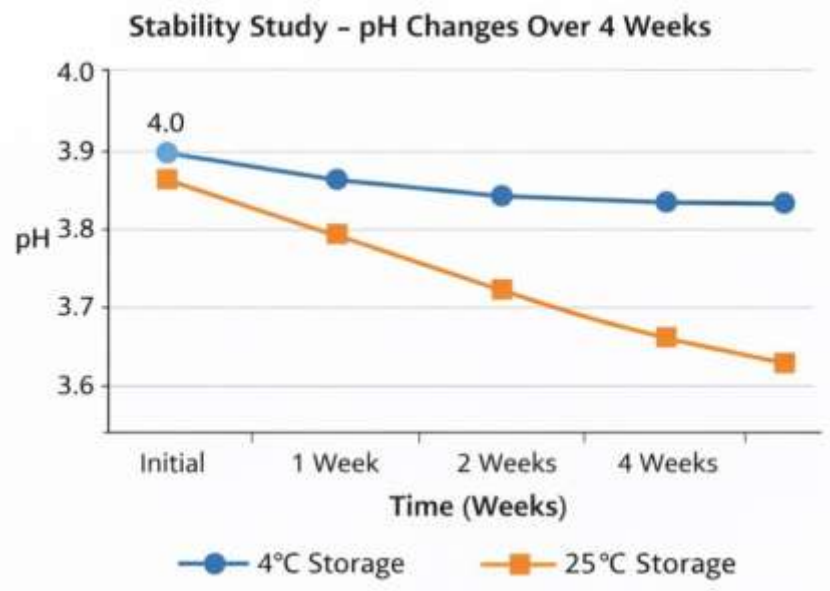


Graph 2. Sensory Evaluation of the Formulated Beverage Using 9-Point Hedonic Scale

Stability Analysis

The stability of the formulation was evaluated over a period of 4 weeks under different storage conditions.

Parameter	Initial	4°C (4 weeks)	25°C (4 weeks)
pH	3.82	3.80	3.75
TSS. (°Brix)	12.5	12.4	12.3
Color	Stable	No change	Slight Change



Graph 3. Effect of Storage Conditions on pH of the Formulated Beverage Over 4 Weeks

Microbial Analysis

The microbial quality of the formulation was assessed using the Total Plate Count method.

- Observed Count: < 100 CFU/mL
- The results indicate that the formulation is microbiologically safe for consumption.

DISCUSSIONS

The present study successfully developed a pomegranate-based polyherbal functional beverage intended for supportive management of hypertension. The formulation exhibited suitable physicochemical characteristics, including an acidic pH, acceptable total soluble solids, and appropriate viscosity, indicating good stability and palatability.

The antioxidant activity of the formulation was found to be high, as evidenced by significant DPPH radical scavenging activity. This can be attributed to the presence of polyphenols, flavonoids, and anthocyanins in pomegranate and herbal components such as hibiscus and tulsi. These compounds are known to reduce oxidative stress, which plays a key role in the development of hypertension.

The sensory evaluation results indicated good acceptability of the formulation, with favorable scores for taste, color, and overall acceptability. The addition of honey, lemon, and mint improved the flavor profile and masked the bitterness of herbal ingredients, making the beverage more suitable for regular consumption.

The stability study showed that the formulation remained stable under refrigerated conditions with minimal changes in physicochemical parameters, whereas slight variations were observed at room temperature. This suggests that storage at lower temperatures is preferable to maintain product quality.

Microbial analysis confirmed that the formulation was microbiologically safe, with low total plate count values. The acidic pH and use of sodium benzoate contributed to inhibiting microbial growth.

Overall, the results indicate that the developed polyherbal beverage possesses good physicochemical stability, significant antioxidant activity, acceptable sensory properties, and microbial safety. The combination of pomegranate and medicinal herbs may provide synergistic benefits, supporting its potential use as a functional beverage for hypertension management.

FSSAI REGULATORY CONSIDERATION

The formulated polyherbal beverage falls under the category of functional foods or nutraceuticals and is subject to regulations under the Food Safety and Standards Authority of India (FSSAI). As per FSSAI guidelines, the ingredients used in the formulation must be safe for consumption and comply with prescribed limits. The use of preservatives such as sodium benzoate should be within permissible limits as specified by FSSAI standards. Proper labeling, including ingredient list, nutritional information, and storage conditions, is required for commercialization. Additionally, any health claims related to antihypertensive activity must be scientifically substantiated and approved by regulatory authorities. Therefore, adherence to FSSAI regulations is essential for ensuring the safety, quality, and marketability of the formulated beverage.

PRODUCT LABEL DESIGN

The label for the formulated pomegranate-based polyherbal beverage was designed to provide essential product information and enhance visual appeal. The label includes details such as product name, list of ingredients, net quantity, storage instructions, and manufacturer information. The design emphasizes a natural and health-oriented theme, highlighting the presence of pomegranate and herbal ingredients.

Key elements incorporated in the label include:

- Product name reflecting its functional benefits
- Ingredient list in descending order
- Storage conditions (refrigerated)
- Expiry information
- Natural and herbal theme for consumer appeal

The label was developed in accordance with general food labeling guidelines to ensure clarity, readability, and consumer awareness.

Fig. 5. Label of the Drink

CONCLUSION

The present study successfully formulated and evaluated a pomegranate-based polyherbal functional beverage for supportive management of hypertension. The developed formulation exhibited desirable physicochemical properties, including appropriate pH, total soluble solids, and viscosity, indicating good stability and suitability as a beverage.

The formulation demonstrated significant antioxidant activity, which can be attributed to the presence of polyphenols and other bioactive compounds in pomegranate and selected herbal ingredients. The sensory evaluation indicated good acceptability, suggesting that the formulation is palatable and suitable for regular consumption.

Stability studies revealed that the beverage remains stable under refrigerated conditions, while minor changes were observed at room temperature, indicating the importance of proper storage. Microbial analysis confirmed that the formulation is safe for consumption within the studied period.

Overall, the findings suggest that the developed polyherbal beverage has potential as a functional nutraceutical product for supportive management of hypertension. However, further studies, including clinical evaluation, are required to establish its therapeutic efficacy.

This formulation represents a promising approach toward integrating traditional herbal knowledge with modern functional food development.

LIMITATIONS

The present study has certain limitations that should be considered. The formulation was evaluated only at a laboratory scale, and large-scale production feasibility was not assessed. The antioxidant activity was determined using an in vitro method (DPPH assay), which may not fully represent in vivo biological activity. Additionally, the study did not include clinical trials to directly evaluate the antihypertensive efficacy of the formulation in human subjects. The sensory evaluation was conducted with a limited number of panelists, which may not reflect broader consumer preferences. Furthermore, the stability study was carried out for a short duration, which may not accurately predict long-term shelf life.

FUTURE SCOPE

The developed formulation offers promising potential for further research and development. Future studies can focus on conducting in vivo and clinical trials to validate the antihypertensive efficacy of the beverage. Shelf-life studies over an extended period can be performed to determine long-term stability and storage conditions. The formulation can be optimized further for large-scale production and commercialization. Advanced analytical techniques may be employed to quantify specific bioactive compounds responsible for the therapeutic effects. Additionally, variations of the formulation can be explored by incorporating other medicinal plants or modifying ingredient concentrations to enhance efficacy and consumer acceptability.

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