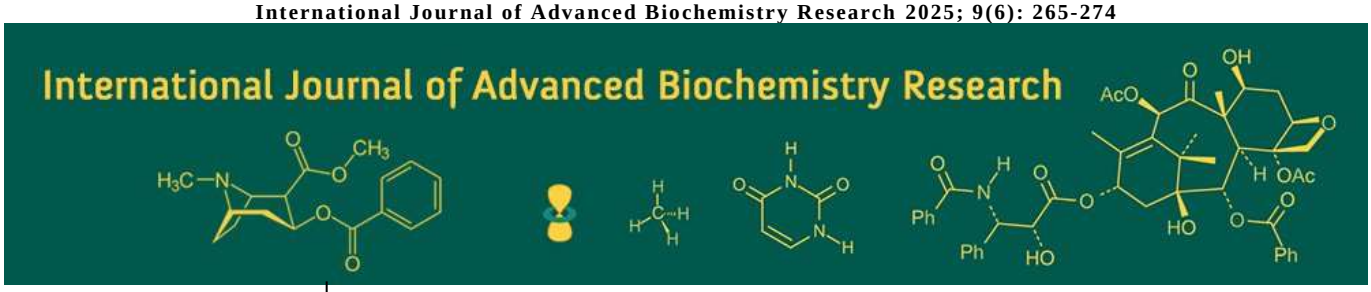

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Formulation and evaluation of herbal gummies from *Bacopa monnieri* and walnut oil for memory enhancing

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Abstract
The growing worldwide incidence of cognitive impairment and memory disorders has led to seeking safer and more effective natural substitutes for traditional nootropics. One such widely recognized Ayurvedic herb is *Bacopa monnieri*, also referred to as Brahmi. The herb is well-documented to possess memory-enhancing, neuroprotective, and adaptogenic activity. Its major active ingredients, the bacosides, have been identified to facilitate synaptic communication and enhance neuronal repair. Adding to this, walnut oil contains alpha-linolenic acid (ALA), an omega-3 fatty acid of plant origin, and polyphenols which contribute to brain function via anti-inflammatory and antioxidant effects.
The objective of this study was to develop a new herbal gummy supplement from *Bacopa monnieri* extract and walnut oil to provide a taste-friendly, user-friendly dose form that is ideal for children and the elderly. The *Bacopa monnieri* herbal extract was procured through Soxhlet extraction with ethanol as the solvent to ensure the retention of important phytoconstituents. Cold-pressed walnut oil was added as a lipid-based memory booster. Gelatin was chosen as the gelling agent owing to its thermos-reversible and biocompatible nature, and other excipients such as sweeteners, citric acid, and flavouring agents were optimized to enhance acceptability and stability.
The gummy product was prepared through the fusion process for homogenous blending and appropriate moulding. The outcome was a uniform, visually pleasing herbal gummy that may be used as a novel vehicle for cognitive health supplementation. This product is a promising avenue toward natural, safe, and non-invasive remedy for improving memory and brain function.

Keywords: Cognitive impairment, *Bacopa monnieri*, memory-enhancing, herbal gummy, walnut oil, cognitive health

Introduction
Learning and daily performance are very essential components of our existence, especially in the current fast-paced world. In recent years, the global interest in cognitive health has significantly increased due to the rising prevalence of neurodegenerative disorders, age-associated memory decline, and attention-deficit conditions in both paediatric and elderly populations (Prince *et al.*, 2015) [14]. As more academic and lifestyle pressures affect people, mostly students and working professionals, there is an increasing need for natural mental enhancers that are safe yet effective. The demand is also underscored by studies that show cognitive impairment can severely impair performance and quality of life (Stough *et al.*, 2001) [4]. The growing burden of diseases such as Alzheimer's disease, mild cognitive impairment (MCI), and attention-deficit/hyperactivity disorder (ADHD) has encouraged the search for safer, natural alternatives to synthetic nootropics (Salloway *et al.*, 2014) [16].
One of the hopeful solutions is *Bacopa monnieri*, also known as Brahmi, a traditionally proven medicinal plant used in Ayurvedic medicine. It has been used historically to improve cognitive abilities, especially memory retention and learning capacity (Russo &Borrelli, 2005) [3]. Several clinical and preclinical researches have revealed the neuropharmacological efficacies of *Bacopa monnieri*, featuring its antioxidant, neuroprotective, and memory-improving activities (Calabrese *et al.*, 2008) [2]. All these therapeutic effects can mainly be credited to its bioactive ingredients, particularly bacosides A and B, which are thought to improve synaptic transmission and help repair injured neurons (Aguiar &Borowski, 2013) [1].

Complementing *Bacopa monnieri*, walnut oil (extracted from Juglans regia) is rich in omega-3 fatty acids (especially alpha-linolenic acid), polyunsaturated fats, vitamin E, and antioxidants, which play an important role in brain development and neuroprotection (Ros *et al.*, 2018). Omega-3 fatty acids are integral to neuronal membrane fluidity and neurotransmission and are known to support long-term memory and reduce inflammation associated with cognitive disorders (Gómez-Pinilla, 2008) [13]. Recent studies have indicated that dietary supplementation with walnuts or walnut oil improves working memory and cognitive flexibility, making it a valuable candidate for combination with *Bacopa monnieri* in cognitive health supplements (Pribis & Shukitt-Hale, 2014) [15].

Although both are well-documented in their uses as *Bacopa monnieri* and walnut oil, their reformulation into a patient-friendly dosage form is a challenge. Conventional dosage forms like powders, tablets, and syrups tend to have poor palatability, low patient compliance, and are associated with variable bioavailability (Morgan & Stevens, 2010) [9]. Swallowable solid dosage forms in particular for paediatric and geriatric patients are problematic in terms of administration, requiring alternative delivery formats.

Here, gummy-based nutraceuticals provide a new and promising alternative. Gummies are edible, tasty, and easy to swallow, enhancing patient compliance in addition to offering a platform for stable encapsulation of herbal actives and oils (Deshmukh & Gursale, 2020). The dosage form of the gummy also supports dosing accuracy, cover-up of bad taste, and increased consumer appeal, particularly with children.

The current research will design and test herbal gummies of *Bacopa monnieri* and walnut oil to create a synergistic, efficient, and enjoyable delivery system for enhancing memory. The formulation will be tested for physicochemical attributes, organoleptic features, drug content, *in vitro* dissolution, and stability, as per regulatory and scientific guidelines. This study is meant to fill the gap between conventional herbal knowledge and contemporary nutraceutical technology for better cognitive well-being.

Rationale

Cognitive decline, memory impairment, and neurodegenerative disorders such as Alzheimer's disease are increasingly prevalent in both aging populations and young individuals exposed to stress, poor diet, and sedentary lifestyles (Singh *et al.*, 2016) [12]. There is a growing demand for safe, effective, and natural interventions that can support brain health and enhance memory function without the side effects commonly associated with synthetic drugs.

The growing interest in natural nootropic agents has drawn attention to *Bacopa monnieri* (commonly known as Brahmi), a well-established Ayurvedic herb known for its memory-enhancing, neuroprotective, and antioxidant properties (Aguiar & Borowski, 2013; Singh & Dhawan, 1997) [1, 12]. Scientific studies have confirmed that *Bacopa monnieri* contains bioactive compounds such as bacosides, which enhance synaptic communication and support neuronal repair (Russo & Borrelli, 2005) [3]. Clinical trials have shown its effectiveness in improving cognitive performance, especially memory recall and retention (Pase *et al.*, 2012) [7].

Walnut oil, rich in omega-3 fatty acids (especially alpha-linolenic acid), polyphenols, and antioxidants, contributes to brain development and function (Poulose *et al.*, 2014). [26] It reduces neuroinflammation, supports neurotransmitter function, and combats oxidative stress—all of which are vital in preventing cognitive decline and enhancing memory (Holcomb *et al.*, 2014) [24].

Despite its proven efficacy, conventional forms of *Bacopa monnieri* such as powders, capsules, and syrups suffer from issues like poor palatability, patient non-compliance, and limited bioavailability (Morgan & Stevens, 2010) [9]. To overcome these challenges, gummy formulations offer a novel, convenient, and palatable dosage form, especially suitable for children and elderly individuals who may have difficulty swallowing traditional pills (Yadav *et al.*, 2024) [11]. Gummies also provide a stable matrix for delivering herbal actives while ensuring dose uniformity, ease of administration, and improved patient adherence. Gummy formulations also allow the inclusion of oil-based actives with improved bioavailability when paired with suitable carriers (Rajput & Haldankar, 2021) [27].

Furthermore, there is a research gap in the standardized development and scientific evaluation of *Bacopa monnieri* gummies, particularly in terms of physicochemical characteristics, drug content, organoleptic acceptability, and *in vitro* drug release. Addressing this gap is essential to substantiate the therapeutic value of Bacopa-based nutraceutical gummies and to facilitate their integration into modern preventive and therapeutic healthcare systems.

This study aims to formulate and evaluate a herbal gummy supplement combining *Bacopa monnieri* extract and walnut oil for memory enhancement. The innovation lies in the dual-herb approach and its delivery via a patient-compliant dosage form, which may improve adherence and therapeutic outcomes. The formulation will be assessed for its physicochemical properties, acceptability, and cognitive benefits, potentially offering a natural, safe, and effective alternative to synthetic nootropics.

Aim

To formulate and evaluate herbal gummies incorporating *Bacopa monnieri* extract and walnut oil for potential memory-enhancing effects.

Objectives

- To extract and standardize the bioactive constituents of *Bacopa monnieri* (primarily bacosides) for use in gummy formulation.
- To evaluate the nutritional and neuroprotective properties of walnut oil, particularly its omega-3 fatty acid and antioxidant content, relevant to memory enhancement.
- To develop a stable and palatable gummy formulation using suitable gelling agents and excipients that can encapsulate both aqueous and oil-based actives effectively.
- To assess the physicochemical properties of the formulated gummies, including texture, pH, moisture content, drug content uniformity, and stability.
- To assess organoleptic acceptability and patient compliance potential, especially in paediatric and geriatric populations.
- To compare the memory-enhancing efficacy of the combination formulation against individual extracts to determine synergistic benefits.

Plant Profile

A. Brahmi

1. Scientific Name: *Bacopa monnieri* (L.) Wettst.

2. Common Names: Some commonly used names of *Bacopa monnieri* are-

- Brahmi
- Water Hyssop
- Herb of Grace
- Indian Pennyort
- Thyme-leaved gratiola

3. Family: Plantaginaceae

Fig 1: *Bacopa monnieri*plant

4. Other Names: Other names include-

- Jalneem (Hindi)
- Sambranichettu (Telugu)
- Neer Brahmi (Tamil)

5. Taxonomy

Table 1: Taxonomy of *Bacopa monnieri*

Taxonomic Rank	Name
Kingdom	Plantae
Division	Magnoliophyta
Class	Magnoliopsida
Order	Lamiales
Family	Plantaginaceae
Genus	*Bacopa*
Species	*B. monnieri*

6. Botanical Description

- **Growth Habit:** Creeping, mat-forming, succulent perennial herb.
- **Height:** Up to 15-30 cm tall.
- **Leaves:** Oblong, sessile, thick, and fleshy with a smooth margin; arranged oppositely.
- **Flowers:** Small, actinomorphic, pale blue to violet (sometimes white); axillary with five petals.
- **Roots:** Fibrous root system; spreads via stolons.
- **Stem:** Soft, green, branched, and glabrous.
- **Fruits:** Oval capsules containing numerous minute seeds.

7. Habitat and Distribution

- **Geographical Distribution:** Native to India, Nepal, China, Taiwan, Vietnam, and Sri Lanka; also found in Australia, the Americas, and Africa.
- **Habitat:** Prefers marshy, wet, and humid environments; commonly found near ponds, wetlands, and rice fields.
- **Cultivation:** Grows well in sandy loam or clay soil with good moisture retention; often propagated via stem cuttings in wet environment.

8. Phytochemical Constituents: *Bacopa monnieri* contains a wide variety of bioactive compounds

- **Saponins (Bacosides):** Bacoside A, B, C, D (major nootropic components)
- **Alkaloids:** Brahmine, herpestine
- **Flavonoids:** Luteolin, apigenin
- **Sterols:** β-sitosterol, stigmasterol
- **Phenols:** Quercetin
- **Other Compounds:** D-mannitol, betulic acid, cucurbitacins
- Bacoside A is the most studied component and is associated with enhanced synaptic transmission and neuroprotection.

9. Pharmacological Activities

- **Nootropic:** Enhances memory, learning, and cognitive function.
- **Neuroprotective:** Protects against neurotoxicity, oxidative stress, and degeneration (especially relevant in Alzheimer's and Parkinson's models).
- **Anxiolytic & Antidepressant:** Reduces anxiety and improves mood; shown to increase serotonin levels.
- **Antioxidant:** Scavenges free radicals and inhibits lipid peroxidation in brain tissues.
- **Anti-inflammatory:** Inhibits pro-inflammatory cytokines.
- **Hepatoprotective:** Protects the liver from damage induced by toxins.
- **Anti-epileptic:** Suppresses convulsions and seizures in animal models.
- **Adaptogenic:** Enhances resistance to stress and restores physiological balance.
- **Cardioprotective:** Shown to reduce blood pressure and improve lipid profiles in some models.

10. Traditional Uses

- **Ayurveda:** Used for improving intellect, memory, concentration, and longevity and for treating anxiety, epilepsy, and cognitive disorders.
- **Unani and Siddha Systems:** Used as a nervine tonic and in the treatment of insomnia, headaches, and nervous disorders.
- **Folk Medicine:** Applied as a poultice for ulcers, inflammation, and skin diseases.

B. WALNUT

1. Scientific Name: *Juglans regia* L.

2. Common Names: Some commonly used names *Juglans regia* are-

- Walnut
- English walnut
- Persian walnut
- Akhrot (Hindi)

3. Family: Juglandaceae
4. Plant Type: Deciduous tree

5. Botanical Description
- **Plant Type:** Large, Deciduous tree (It has a broad crown with a short trunk)
- **Height:** 25-35 meters
- **Leaves:** Widespread, pinnately compound leaves measuring 20-40 cm, comprising 5-9 leaflets
- **Bark:** Light grey in colour and becomes deeply furrowed with age
- **Fruit:** The fruit is a drupe, commonly referred to as a "nut." It consists of a green outer husk (exocarp), a hard-lignified shell (endocarp), and a deeply lobed, edible seed (kernel). The kernel is rich in oils and has a distinctive brain-like morphology.

6. Geographical Distribution: Native to Central Asia and the Balkans, *Juglans regia* is widely cultivated in temperate regions across the world, including the United States, China, Iran, Turkey, and parts of Europe and South Asia. The tree prefers deep, fertile, well-drained soils and grows best in areas with long summers and cold winters.

7. Phytochemical Composition: Walnuts are nutritionally dense and phytochemically rich. Their major bioactive components include-
- **Fatty acids:** High in polyunsaturated fatty acids (PUFAs), especially alpha-linolenic acid (ALA) and linoleic acid
- **Proteins:** Contain all essential amino acids
- **Polyphenols:** Ellagic acid, gallic acid, catechins, juglone, and tannins
- **Phytosterols:** β-sitosterol
- **Vitamins:** E (as γ-tocopherol), B-complex (B1, B6, folate)
- **Minerals:** Magnesium, phosphorus, copper, zinc, and manganese
- **Melatonin:** Found in appreciable amounts in the kernel
- Juglone: A naphthoquinone found in leaves and husk with antimicrobial properties

8. Pharmacological Properties
- **Antioxidant:** Polyphenols and tocopherols scavenge free radicals, preventing oxidative stress-related damage (Fukuda *et al.*, 2004).
- **Neuroprotective:** ALA and polyphenols enhance brain plasticity, reduce neuroinflammation, and support cognitive function (Gómez-Pinilla, 2008) [13].
- **Anti-inflammatory:** Walnut oil suppresses pro-inflammatory cytokines and reduces CRP levels.
- **Cardioprotective:** Regular walnut consumption reduces LDL cholesterol and improves endothelial function (Ros, 2010).
- **Anti-cancer:** Ellagic acid and juglone exhibit antiproliferative effects against certain cancer cell lines.
- **Antimicrobial:** Walnut hulls and leaves possess antimicrobial and antifungal activities due to juglone and phenolic compounds.

9. Traditional Uses
- Kernels are used as a brain tonic and for sexual health.
- Oil is used for skin nourishment and to treat eczema.
- Leaves and bark are used topically for wounds, inflammations, and fungal infections.
- Decoctions from green husks are employed as astringents and vermifuges.

Drug Profile

A. Bacoside A: [Aguiar *et al.*, 2013 [1]; Kongkeaw *et al.*, 2014] [5]

1. **Overview:** Bacoside A is a major active compound derived from the leaves and stems OF *Bacopa monnieri*.
2. **IUPAC Name:** (5R,8R,9S,10S,13R,14R,17S)-3-[(2R,3R,4R,5S,6R)-3,4-dihydroxy-6-(hydroxymethyl)-5-[(2S,3R,4S,5S)-3,4,5-trihydroxyoxan-2-yl]oxyoxan-2-yl]oxy-10-(hydroxymethyl)-17-[(2S)-2-hydroxy-6-methylhept-5-en-2-yl]-4,4,8,14-tetramethyl-1,2,3,5,6,7,9,11,12,13,15,17-dodecahydrocyclopenta[a]phenanthren-16-one

- **Molecular Formula:** $C_{41}H_{68}O_{13}$
- **Molecular Weight:** 769.0 g/mol
- **Categorisation:** Triterpenoid saponins

Structure: It consists of a dammarane-type triterpenoid aglycone (known as bacogenin) attached to a sugar moiety.

Pharmacological Effects
- **Neuroprotective:** Protects neurons against oxidative stress and amyloid toxicity
- **Nootropic:** Enhances learning, memory consolidation, and cognitive processing
- **Antioxidant:** Increases levels of endogenous antioxidants (SOD, catalase, glutathione)
- **Cholinergic:** Enhances acetylcholine synthesis and inhibits acetylcholinesterase (AChE)
- **Anti-inflammatory:** Reduces expression of pro-inflammatory cytokines (TNF-α, IL-6)
- **Anxiolytic and Antidepressant:** Modulates GABAergic and serotonergic pathways
- **Adaptogenic:** Improves resistance to stress and fatigue

8. Mechanism of Action
- **Cholinergic Modulation:** Bacosides increase choline acetyltransferase activity, thereby enhancing acetylcholine synthesis, a key neurotransmitter involved in memory and learning.
- **AChE Inhibition:** They inhibit acetylcholinesterase, slowing acetylcholine breakdown and increasing its availability at synapses.
- **Neuroprotection:** Bacosides scavenge reactive oxygen species (ROS), upregulate antioxidant enzymes, and inhibit lipid peroxidation, protecting neuronal integrity.
- **Synaptogenesis:** Promote neurite outgrowth and synaptic repair, as evidenced in *in vitro* and animal studies.
- **Anti-amyloid:** Prevent aggregation of β-amyloid peptides, relevant in Alzheimer's pathology.
- **Modulation of kinases:** Regulate protein kinases involved in memory signaling pathways, like ERK1/2 and CREB.

B. Alpha-Linolenic Acid: [Goyens *et al.*, 2006; Simopoulos *et al.*, 2002; Burdge *et al.*, 2005] [40, 41, 42]

1. **Overview:** Alpha-linolenic acid (ALA) is an essential omega-3 polyunsaturated fatty acid predominantly found in plant sources such as flaxseed, chia seeds, walnuts, and their oils. It cannot be synthesized by the human body and must be obtained from the diet.

IUPAC Name: (9Z,12Z,15Z)-Octadeca-9,12,15-trienoic acid

- **Molecular Formula:** $C_{18}H_{30}O_2$
- **Molecular Weight:** 278.43 g/mol
- **Categorisation**
- **Class:** Polyunsaturated fatty acid (PUFA)
- **Subclass:** Omega-3 fatty acid

2. **Structure:** Alpha-linolenic acid has an 18-carbon chain with three cis double bonds at the 9th, 12th, and 15th positions from the carboxylic acid end, corresponding to the omega-3, omega-6, and omega-9 positions respectively.

3. **Pharmacological Effects**

- **Cardioprotective:** Reduces serum triglycerides and LDL cholesterol; increases HDL cholesterol; improves endothelial function
- **Anti-inflammatory:** Inhibits production of pro-inflammatory cytokines (e.g., TNF-α, IL-6)
- **Neuroprotective:** Supports brain development and may improve cognitive function
- **Antioxidant:** Reduces oxidative stress by modulating redox pathways
- **Lipid-modulating:** Alters lipid metabolism and fatty acid profiles in cell membranes

4. **Mechanism of Action**

- **Conversion Pathway:** ALA is desaturated and elongated to produce EPA and DHA via delta-6 and delta-5 desaturase enzymes, though this conversion is limited in humans.
- **Modulation of Gene Expression:** ALA and its metabolites influence transcription factors like PPAR-α (Peroxisome proliferator-activated receptor-alpha), which regulate lipid metabolism and inflammation.
- **Membrane Fluidity and Signalling:** ALA integrates into phospholipid bilayers, influencing membrane fluidity and cellular signalling processes.
- **Inhibition of Arachidonic Acid Pathway:** ALA competitively inhibits the omega-6 arachidonic acid pathway, reducing the synthesis of inflammatory eicosanoids (e.g., prostaglandins, leukotrienes).
- **Neurotransmission Modulation:** Its derivatives, including DHA, play roles in neuronal membrane integrity, neurotransmitter release, and synaptic plasticity.

Polymer Profile

A. Gelatin: [Schrieber *et al.*, 2007; Gómez-Guillén *et al.*, 2011] [13, 43]

1. **Overview**: Gelatin is a natural, water-soluble, biodegradable polymer obtained by the partial hydrolysis of collagen, a structural protein abundant in the connective tissues, skin, and bones of animals (commonly pigs, cattle, or fish).

2. **Chemical Structure**: Gelatin is a mixture of peptides and proteins composed of repeating sequences of amino acids-mainly glycine (approx. 33%), proline, and hydroxyproline-forming triple-helical structures similar to those in native collagen.

- General Repeat Unit: Gly-X-Y (where X and Y are often proline and hydroxyproline)

3. **Physical Properties**

- **Appearance:** Pale yellow to light amber flakes, sheets, or powder
- **Solubility:** Insoluble in cold water, but swells; dissolves in warm water
- **Gelling Temperature:** 20-30 °C (depending on bloom strength and concentration)
- **Bloom Strength:** A measure of gel firmness (ranges from 50 to 300 g)
- **Viscosity:** Dependent on concentration, molecular weight, and extraction method

Material and Methods

A. Materials: [Kale *et al.*, 2021; Patil *et al.*, 2018] [19, 45]

Table 2: Formulation Composition Table

Ingredient	Quantity (per 100 g batch)	Purpose
Bacopa monnieri extract	2 g	Active nootropic agent
Walnut oil	1 g	Source of alpha-linolenic acid (brain support)
Gelatin	10 g	Gelling agent
Glycerin	5 g	Humectant and plasticizer
Honey	10 g	Natural sweetener
Lemon juice	2 ml	Flavouring agent
Sodium benzoate	0.2 g	Preservative
Citric acid	0.5 g	pH modifier and preservative
Purified water	q.s. to 100 g	Solvent
Calcium lactate	0.2 g	Calcium supplement

1. Source

- ***Bacopa monnieri*leaves:** Procured fromherbal garden of DBUU campus.
- **Walnut oil:** Cold-pressed oil from *Juglans regia* seeds, purchased from a GMP-certified nutraceutical supplier.
- **Gelatin (Type B, Food-grade):** Procured from laboratory of SOPR, DBUU.
- **All other ingredients (Analytical or food grade):** Procured from laboratory of SOPR, DBUU or purchased from reliablesupplier.

B. Methodology

1. Collection and Drying: Fresh leaves of *Bacopa monnieri* were collected from University's campus. The leaves were

washed with tap water followed by distilled water to remove dirt and other contaminants. The cleaned leaves were shade-dried for one week at room temperature to prevent degradation of heat-sensitive constituents.

2. Preparation of Plant Extract: [Phrompittayarat *et al.*, 2007] [46]

- Process: Soxhlet Extraction
- Materials Required
- Dried *Bacopa monnieri* powder (100 g)
- Ethanol (95%) - 400 mL
- Soxhlet apparatus and Condenser
- Heating mantle
- Whatman No.1 filter paper
- Water bath
- Weighing balance

Procedure

1. **Preparation of Plant Material**
   Dried aerial parts of *Bacopa monnieri* are coarsely powdered using a mechanical grinder and sieved through mesh size 40 to ensure uniformity.
2. **Packing**
   Place 100 g of powdered material in a thimble made from filter paper and insert it into the Soxhlet extractor.
3. **Extraction**
   Fill the distillation flask with 400-500 mL of ethanol or methanol. Attach the Soxhlet extractor and condenser. Heat gently using a heating mantle so the solvent refluxes and siphons through the plant material repeatedly for 6-8 hours (about 10-15 cycles) until the extract becomes colourless.

Fig 2: Soxhlet extraction of *Bacopa monnieri*

Filtration
Filter the extract using Whatman filter paper to remove plant or powder debris from it before concentrating it.

Solvent Recovery: After completion, concentrate the extract using water bath to remove the solvent.

Fig 3: Filtration of the extract

Fig 4: Concentrating the extract in water bath

Drying and Storage
Dry the concentrated extract in a vacuum desiccator or water bath at 40-50°C. Store the dried extract in an airtight amber-coloured container in a cool, dry place until use

Formulation of Herbal Gummies
[Kale *et al.*, 2021; Patil *et al.*, 2018] [19, 45]

Hydration of Gelatin
1. Weigh 10 g of gelatin and soak it in 30 mL of purified water.
2. Allow it to bloom for 30 minutes at room temperature.

Preparation of Aqueous Phase
Dissolve 10 g honey, 5 g glycerin, 0.5 g citric acid, and 2 g *Bacopa monnieri* extract in 40 mL of warm water (45-50°C) under constant stirring.

Incorporation of Walnut Oil
1. Warm 1 g walnut oil gently to 35°C.
2. Add it slowly into the aqueous mixture with continuous stirring to form a stable emulsion.

Gelling Process
1. Melt the bloomed gelatin by heating the mixture in a water bath at 60°C.
2. Combine it with the preparedemulsion while stirring continuously.

Flavour and Preservative Addition
Add 2 mL lemon juice and 0.2 g Sodium benzoate at ~40°C before moulding.

Moulding and Setting
1. Pour the warm gummy mixture into silicone molds.
2. Allow to set at room temperature for 2 hours, then refrigerate (4°C) for 12 hours.

Fig 5: Moulding

Demoulding and Storage: Demould the gummies and store in airtight containers and zip bags.

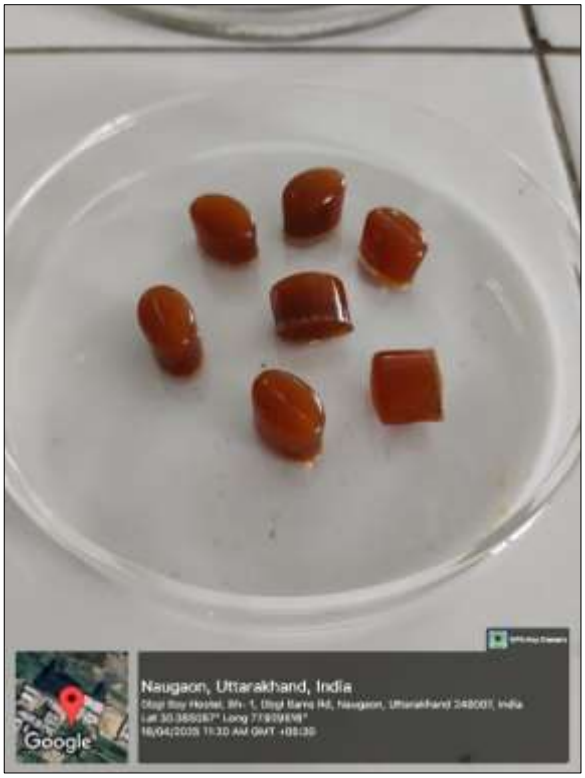

Fig 6: Demoulded gummies

Evaluation: Organoleptic Evaluation: [Kale *et al.*, 2021] [19] Organoleptic characteristics of the formulated gummies were evaluated using a panel of 5 semi-trained volunteers. Parameters like appearance, colour, odour, taste and texture were assessed.

Physicochemical evaluation
pH Measurement: [Kumar *et al.*, 2020] [10]

Method: 1 g of gummy was dissolved in 10 mL distilled water. pH was measured using a digital pH meter.

Result: pH = **4.82±0.05**
- **Significance**: This pH is within the acceptable range (3.5-5.5) for gummies, ensuring product stability and palatability.
- **Viscosity:** [Patil *et al.*, 2019] [45]
- **Method**: Viscosity of the melted gummy formulation (before molding) was measured using a Brookfield viscometer at 25°C.
- **Result**: Viscosity = **3450±50 cP**
- **Significance**: Indicates suitable flow and moldability for uniform gummy formation.

Weight Variation: [USP, 2020]
- **Method**: 20 gummies were randomly selected and weighed individually using an analytical balance.
- **Result**: Average weight = **3.02 g±0.04 g**
- **Limit**: Within ±7.5% variation (as per pharmacopeial guidelines for dosage forms below 5 g).

Moisture Content: [AOAC, 2000] [51]

- **Method**: Determined by drying 1 g gummy in a hot air oven at 105°C for 4 hours.
- **Result**: Moisture content = **14.2%±0.5%**
- **Significance**: Ensures product chewiness and shelf stability.

Texture Profile Analysis (TPA)

- **Method**: Texture analyser measured hardness, elasticity, and chewiness.
- **Result**:
- **Hardness: 1.8 N**
- **Elasticity: 72%**
- **Chewiness: 0.9 N**
- **Significance**: Results confirm suitable sensory and mechanical properties for a paediatric-friendly gummy.

Results and discussion

Results

Table 3: Organoleptic Parameters Observed

Parameter	Observation
Appearance	Smooth, glossy, uniformly shaped
Colour	Brown (due to *Bacopa* extract and walnut oil)
Odour	Mild herbal aroma
Taste	Pleasant, slightly sweet with herbal undertone
Texture	Chewy, soft, elastic

Table 4: Physicochemical Parameters Observed

Parameter	Method	Result (Mean ±SD)	Significance
pH	pH meter (1 g in 10 mL water)	4.82±0.05	Within acceptable range (3.5-5.5) for stability and taste
Viscosity	Brookfield viscometer at 25°C	3450±50 cP	Ideal flow for moulding
Weight variation	Analytical weighing of 20 units	3.02±0.04 g	Within ±7.5% limit as per pharmacopeial standard
Moisture content	Hot air oven at 105°C for 4 hours	14.2%±0.5%	Maintains chewiness and shelf life
Hardness	Texture analyser	1.8 N	Appropriate for chewable dosage
Elasticity	Texture analyser	72%	Ensures flexibility during mastication
Chewiness	Texture analyser	0.9 N	Suitable for paediatric and geriatric users

Discussion

The formulated herbal gummies exhibited favourable organoleptic and physicochemical characteristics, supporting their suitability as a paediatric-friendly memory-enhancing supplement. The appearance was smooth and uniform, with abrown colour and pleasant herbal aroma and taste, which are critical for patient compliance, especially in children.

The pH value of 4.82 falls within the ideal range for oral gummies, ensuring product stability and minimizing microbial growth. The viscosity (3450±50 cP) confirmed proper flow for effective moulding without compromising uniformity. The gummies also showed acceptable weight variation and moisture content (14.2%), indicating good consistency and stability.

Texture analysis showed optimal hardness (1.8 N), elasticity (72%), and chewiness (0.9 N), suggesting they are easy to chew and palatable. Overall, these results confirm that the formulation meets standard quality attributes for herbal chewable dosage forms and holds potential as a natural cognitive enhancer.

Conclusion

The current research was able to develop and test herbal gummies containing *Bacopa monnieri* extract and walnut oil for delivering a tasty and effective natural memory-enhancing supplement. The optimal composition of the product was achieved with appropriate excipients like gelatin, sweeteners, and plasticizers for achieving optimal organoleptic and physicochemical attributes. The final product exhibited good physical properties, such as a smooth appearance, sweet taste, suitable hardness, chewiness, and elasticity. These characteristics are important for patient compliance, particularly with paediatric and elderly groups of patients.

pH value (4.82±0.05) and moisture level (14.2%) were in acceptable limits, providing microbial stability as well as shelf life. Texture profiling ensured proper chewability without loss of structural integrity. These characteristics reflect the stability and acceptability of the formulation as a new delivery system for herbal neuroenhancers.

Pharmacologically, *Bacopa monnieri* is well-characterized for its nootropic, antioxidant, and neuroprotective effects (Stough *et al.*, 2001 [4]; Aguiar & Borowski, 2013) [1], whereas walnut oil is a source of alpha-linolenic acid and polyunsaturated fatty acids, which sustain neuronal activity and memory (Gómez-Pinilla, 2008) [13]. The combination of these agents together in gummy form represents a novel and distinct way of supporting cognition.

This research provides a foundation for the creation of herbal memory-enhancing gummies as a consumer-friendly, effective, and safe supplement. *In vivo* studies and clinical trials are needed further to validate the formulation's therapeutic efficacy in target populations.

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