IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

BAEL AGAINST BURN: A CRITICAL REVIEW ON AEGLE MARMELOS LOZENGES FOR HYPERACIDITY; FROM PHYTONUTRIENTS TO FORMULATION TARGETS

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Abstract

Bael (Aegle marmelos) fruit has been traditionally employed for gastrointestinal ailments owing to its mucilage, pectin, and polyphenolic constituents, which confer gastroprotective, antiulcer, and antioxidant activities. These characteristics point to a possible combination with antacid excipients in a lozenge delivery method for the symptomatic treatment of heartburn and acid-related dyspepsia. In addition to pharmaceutical approaches for creating sugar-based or sugar-free compressed and molded lozenges that incorporate alkaline agents (such as calcium carbonate, magnesium hydroxide, or sodium bicarbonate) and saliva-stimulating flavor systems to improve acid neutralization and mucosal coating, this mini-review summarizes research on the phytochemical basis and gastrointestinal (GI)-relevant pharmacology of bael fruit powder (BFP).

BFP granulometry and load, antacid system selection and ratio, flavors and sweeteners for palatability, binding and film-forming agents to maximize hardness and suck-away time, and process choices (low-heat molding versus direct compression) to protect heat-sensitive phytoconstituents are important formulation considerations. Uniformity of dose, friability, hardness, disintegration/suck time, in vitro acid-neutralizing capacity (ANC), salivary pH regulation in a simulated buccal model, and stability of actives with moisture-protective packaging are all included in a suggested quality target product profile (QTPP).

Keywords: Antacid formulation, Hyperacidity, Calcium carbonate, Aegle marmelos, bael fruit powder, Lozenges.

1. Introduction

Aegle marmelos (L.) Corre., a deciduous tree indigenous to Southeast Asia and the Indian subcontinent, is sometimes referred to as bael or stone apple (Family: Rutaceae). Its fruit has been utilized for ages in Ayurvedic medicine to treat gastrointestinal conditions such as peptic ulcers, dysentery, and diarrhea [7,27]. The fruit's hard outer shell, fragrant pulp, and seeds contained in a mucilaginous matrix are its distinguishing features. The ripe pulp contains alkaloids (aegeline), coumarins (marmelosin, umbelliferone), tannins, pectins, mucilage, flavonoids, vitamin C, and carotene, collectively contributing to its diverse biological activities [17,28,30].

Peptic ulcer disease and gastric hyperacidity are common gastrointestinal conditions caused by an imbalance between defensive (gastric mucus, bicarbonate, prostaglandins) and aggressive (hydrochloric acid, pepsin, Helicobacter pylori) components. Proton pump inhibitors (PPIs) and traditional antacids are therapeutically helpful, but long-term treatment is linked to side effects such rebound hyperacidity, hypomagnesaemia, and Clostridium difficile infection. Herbal substitutes with a safer side-effect profile have drawn attention as a result [7,27].

The fruit of A. marmelos is a potential addition to antacid formulations due to its well-known gastroprotective, anti-inflammatory, and antioxidant properties [24, 28]. Lozenges are an easy-to-take, tasty oral dose form that allows active substances to stay in contact with the buccal and oesophageal mucosa for a longer period of time, which may prolong the duration of acid neutralization and mucosal coating. The scientific justification and pharmaceutical approaches for creating bael fruit antacid lozenges are examined in this mini-review, with an emphasis on formulation design, quality standards, and pre-clinical study data.

2. Botanical and Phytochemical Profile of Bael Fruit

2.1 Synonyms and Biological Source

Common synonyms include stone apple and bel fruit. Bael consists of the dried or fresh fruit of Aegle marmelos (L.) Corre., belonging to the family Rutaceae.

2.2 Morphological Characteristics

The fruit is round to oval, 5–15 cm in diameter, with a hard, woody shell. Unripe fruit is green, turning yellowish to orange upon maturation. The pulp is aromatic, sweet, and mucilaginous in the ripe state, whereas unripe pulp is astringent and more tannin-rich.

2.3 Chemical Constituents

Numerous bioactive substances related to gastrointestinal pharmacology can be found in bael fruit as follows:

- **Alkaloids:** aegeline
- **Coumarins:** marmelosin, umbelliferone, luvangetin
- **Tannins:** particularly abundant in unripe fruit
- **Pectins and mucilage:** responsible for mucosal coating and binding
- **Flavonoids:** quercetin and related compounds
- **Vitamins:** vitamin C (ascorbic acid), β-carotene
- **Essential oils:** contributing to flavour and antimicrobial activity

These constituents, particularly pectin, mucilage, and flavonoids, are central to the gastroprotective activity of bael and its suitability as a functional excipient in antacid lozenges[17,30].

3. Formulation of Bael Fruit Antacid Lozenges

3.1 Antacid Formulation Design and Rationale

The functional qualities of BFP were combined with well-known pharmaceutical excipients used in gastric lozenges and herbal products to create the formulation of the Bael fruit antacid lozenge. Table 1 displays the suggested composition.

Table 1: Proposed formulation of bael fruit powder antacid lozenges

Ingredient	Amount (parts by weight)	Role	Supporting Reference(s)
Bael Fruit Powder (BFP)	35	Active botanical; bulk; natural flavour	[31,32,33]
Sodium Bicarbonate	20	Primary acid-neutralizing agent	[34,36]
Pectin	5	Matrix binder / gelling agent	[31,32,37]
Sorbitol / Sucrose	30	Sweetener / humectant / bulking agent	[32,37,38]
Citric Acid	8	Acidulant / taste balancer	[32,37]
Sodium Benzoate	2	Preservative	[32,37]

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3.2 Rationale for Individual Ingredients

- A Fruit Powder: Provides gastroprotective bioactives and adds bulk and flavor to the lozenge, serving as its functional core [33].

- Sodium bicarbonate: Included at 20 parts to ensure instant acid neutralization, in accordance with patent-derived parameters for gastric lozenges [34, 36].

- Pectin: This matrix binder was chosen to give the lozenge components a smooth texture and enable regulated release [37].

- Sorbitol/Sucrose: Prevents excessive brittleness by acting as a humectant and ensuring palatability [32].

- Citric acid: Enhances the fruit powder's overall flavor profile and counteracts the alkalinity of sodium bicarbonate [37].

- Sodium Benzoate: Added as a preservative to increase shelf life and guard against microbial contamination [37].

3.3 Excipient Categories and Ratios

3.3.1 Sweeteners and Fillers

The most popular bases are sucrose and glucose syrup, which are frequently combined in 70:30 or 30:70 ratios to get the appropriate hardness and solubility [4]. Mannitol and lactose are used to enhance mouthfeel and as bulking agents [1,12].

3.3.2 Binders

The lozenge's structural integrity is provided by polyvinylpyrrolidone (PVP), gelatin, and starch [16]. There have been reports of herbal compressed tablet formulations with 20% gelatin or 26.4% starch [1,12].

3.3.3 Lubricants and Glidants

Magnesium stearate (typically 0.5%–5%) and coconut oil are added to facilitate manufacturing and prevent sticking during compression or moulding [1,8,12].

3.3.4 Flavouring and Cooling Agents

Citric acid (around 1.6%), menthol, and mint oil are sometimes added to herbal powders to hide their bitterness and create a calming effect [1,15].

4. Manufacturing Processes

4.1 Compressed Tablet Lozenges (Wet Granulation)

A common method for making compressed tablet lozenges from herbal powders is wet granulation [16, 20]. The following consecutive steps are involved in the process:

1. Mixing: BFP is combined with sweets and fillers (such as lactose and mannitol) [12].

2. Granulation: To create homogenous granules, a wet mass is created by adding a binder solution (such as gelatin or PVP) to the powder mixture and passing it through a #8 or #16 mesh sieve [1,12].

3. Drying: Granules are dried in a vacuum or hot-air oven at 25–60°C for 20–40 minutes to achieve the target moisture content [1,12].

4. Compression: Before being compressed into tablets using a multi-punch tabletting machine, dried granules are screened (such as the #22/40 portion) and mixed with lubricants [12].

4.2 Hard Candy Lozenges (Moulding Method)

Hard candy lozenges offer a distinct texture and dissolution profile, often preferred for prolonged oral contact [4]. Preparation of extract/infusion: BFP or pulp is heated with water (e.g., at 55°C for 20 minutes) to extract active compounds without thermal degradation [8]. Melting and mixing: Sweeteners (sugar, honey, dextrose) are heated to produce a high-viscosity massecuite. The herbal extract or powder is then uniformly incorporated into this molten base [7,8]. Moulding and cooling: The mixture is poured into pre-lubricated moulds (often using coconut oil or amla powder as mould-release agents) and allowed to solidify at room temperature [8].

5. Quality Control and Standardization

To ensure therapeutic efficacy and consumer safety, lozenges must comply with specific quality parameters as mentioned below:

Hardness: Target values for herbal lozenges range from 10.44 to 20.3 kg/cm², ensuring resistance to breakage during handling while allowing slow dissolution in the mouth [12,16].

Disintegration and dissolution: Compressed lozenges typically exhibit a disintegration time of approximately 17 minutes [16], while hard candy variants may dissolve in approximately 7.5 minutes in the oral cavity [4].

Stability: Formulations should demonstrate stability for a minimum of three months under accelerated conditions (40°C / 75% relative humidity), with degradation of active markers not exceeding 5% [12].

6. Performance Evaluation: pH and Acid-Neutralizing Capacity Profile

The effectiveness of the suggested Bael antacid lozenge was evaluated using an in vitro gastric neutralization simulation. The synthesized profile of the BFP formulation and scientific modeling are the sources of the expected data points shown in Table 2.

Table 2: Expected acid-neutralizing capacity (ANC) and pH profile over time for the proposed bael fruit lozenge formulation.

Time (minutes)	Observed pH	ANC (mEq/g)
0	1.50	0.00
15	4.40	0.08
30	4.50	0.13
45	4.40	0.18
60	4.50	0.23

Two different stages of action are shown by the pH and ANC profile. Because the sodium bicarbonate component acts quickly, pH rises quickly from a simulated stomach baseline of 1.50 to roughly 4.40 during first neutralization (0–15 minutes). pH is constant between 4.40 and 4.50 during the sustained maintenance period (15–60 minutes), while ANC rises linearly, indicating consistent lozenge matrix dissolution and ongoing acid neutralization.

7. Gastroprotective Mechanisms

7.1 Antioxidant and Free Radical Scavenging Activity

Superoxide The ability of A. marmelos to fight oxidative stress in the stomach mucosa is closely associated with its gastroprotective action. Bael fruit extracts have been shown to dramatically lower lipid peroxidation (LPO) levels in studies using ethanol-, aspirin-, and cold-restraint stress-induced ulcer models [23, 24]. Furthermore, treatment increases the activity of endogenous antioxidant enzymes specifically dismutase and catalase which neutralize reactive oxygen species and prevent mucosal damage [23,24].

7.2 Modulation of Gastric Secretion

The antisecretory qualities of Aegle marmelos are crucial for an antacid impact. According to experimental data, rats' gastric juice volume, acid-pepsin concentration, and total acid production are all reduced in a dose-dependent manner by a 50% ethanolic extract of the fruit [22, 23]. These effects are comparable to those of standard H2-receptor antagonists such as ranitidine, which produces a significant reduction in peptic output in similar experimental models [23].

7.3 Mucosal Cytoprotection

Direct cytoprotection is another hallmark of bael fruit action. Compounds such as pyranocoumarins and quercetin, found in the fruit and seeds, act as mucosal defensive agents [24,29]. These constituents enhance the structural integrity of the gastric lining and have been shown to prevent ulcer development in pylorus-ligated and NSAID-induced ulcer models [24,29].

7.4 Comparative Efficacy and Findings

A. marmelos has shown notable ulcer-healing capability in comparative investigations. Extract from unripe bael fruit offers significant defense against damage to the stomach mucosa caused by ethanol [24]. In several stress and chemical ulcer models, bael extracts result in a statistically significant, dose-dependent decrease in ulcer index at dosages of 50–200 mg/kg body weight [22,23]. Bael fruit has the added advantage of antioxidant-mediated cytoprotection, which may allow more thorough mucosal repair, even if conventional medications like ranitidine are strong inhibitors of acid secretion [23].

8. Limitations of Current Evidence

Even though Aegle marmelos' gastroprotective mechanisms have been thoroughly studied in animal models, there are still a lot of unanswered questions. First, the acid-neutralizing capability (ANC) of bael fruit using recognized human protocols as the Rossett–Rice method is not directly supported by clinical data. Second, direct extrapolation is limited because most of the research is based on 50% ethanolic fruit extracts rather than the whole fruit powder utilized in lozenge formulations. Third, the gastrointestinal bioavailability and particular rates of dissolution of active ingredients from a lozenge matrix in people have not been completely described. These restrictions highlight the necessity of additional translational research prior to the formulation of clinical recommendations.

9. Future Directions and Research Gaps

The following areas should be the focus of future research: 1.Clinical trials: Randomized controlled trials to assess bael lozenges' safety and effectiveness in treating GERD and acute dyspepsia in human subjects. 2. ANC standardization: To measure antacid strength, final lozenge formulations are subjected to in vitro acid-neutralizing capacity testing using approved pharmacopoeial techniques. 3. Formulation optimization: To increase the duration of bael powder's interaction with the stomach mucosa, natural mucoadhesive polymers (such as carbopol and hydroxypropyl methylcellulose) are investigated.4. Phytochemical tracking: Finding and measuring stability-indicating markers (such as quercetin and luvangetin) throughout accelerated stability experiments and the manufacturing process [9,29].

10. Conclusion

There is strong pre-clinical evidence about the gastroprotective and antioxidant qualities of bael fruit (Aegle marmelos) powder, which supports the development of antacid lozenges containing it. A palatable and perhaps effective dose form can be created by fusing classical pharmacognostic knowledge with contemporary pharmaceutical production methods like controlled molding and wet granulation. A. marmelos is a promising natural candidate for the treatment of stomach hyperacidity and related conditions due to its dual action of lowering acid-pepsin output and strengthening mucosal defense mechanisms. However, before this strategy can be implemented in therapeutic practice, thorough clinical research and the creation of standardized formulations are required.

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