International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

Effervescent Powder of Aegle Marmelos: A Novel Approach for Enhancing Bioavailability and Therapeutic Efficacy

Vaishnavi Alshi[1], Srushti Bari[2], Aniket Banchede[3], Priti Avhad[4], Jalinder Bavadekar[5], Sonali Uppalwar[6]

Abstract:
Introduction: Aegle marmelos is a medicinal plant known for its antioxidant, antimicrobial, and anti-inflammatory properties. However, its therapeutic efficacy is limited due to poor solubility and low bioavailability. Effervescent formulations may improve dissolution, absorption, and patient compliance**.** **Objective:** To formulate and evaluate an effervescent powder of Aegle marmelos for enhancing bioavailability and therapeutic efficacy. **Materials and Method:** The Aegle marmelos extract was formulated into an effervescent powder using citric acid, tartaric acid, and sodium bicarbonate by dry granulation method. The formulation was evaluated for flow properties, pH, effervescence time, drug content, dissolution, and stability. **Result and Discussion:** The formulated effervescent powder showed good flow properties, rapid effervescence, acceptable pH, and uniform drug content. Improved dissolution and faster release of phytoconstituents were observed compared to conventional formulations, indicating enhanced bioavailability and therapeutic potential. The formulation also remained stable under storage conditions. **Conclusion:** The study successfully developed an effervescent powder formulation of Aegle marmelos with improved dissolution and potential therapeutic efficacy. The formulation may serve as an effective and patient-friendly herbal dosage form**.**

Keywords: Effervescent powder, Bioavailability, Herbal formulation, Therapeutic efficacy.

Introduction

Herbal medicines have been widely used since ancient times for the prevention and treatment of various diseases. The growing demand for natural remedies and plant-based therapeutics has encouraged researchers to develop advanced herbal formulations with improved efficacy, safety, and patient compliance. Herbal drug delivery systems are gaining importance in modern pharmaceutical research because they provide a suitable approach for enhancing the therapeutic performance of medicinal plants while minimizing side effects. Among various medicinal plants, Aegle marmelos has attracted considerable attention due to its extensive pharmacological activities and therapeutic significance [1].

Aegle marmelos, commonly known as Bael, belongs to the family Rutaceae and is native to India and Southeast Asian countries. The plant has been extensively used in Ayurveda, Siddha, and traditional medicine for the management of gastrointestinal disorders, diabetes, inflammation, microbial infections, and cardiovascular disease. Various parts of the plant such as leaves, fruits, roots, bark, and seeds possess medicinal properties due to the presence of bioactive phytoconstituents including alkaloids, flavonoids, coumarins, tannins, pectin, and phenolic compounds. The fruit pulp of Aegle marmelos is particularly recognized for its antidiarrheal, antioxidant, hepatoprotective, antimicrobial, and antidiabetic activities [2].

Fig. 1. Fruits of *Aegle Marmelos*

Although Aegle marmelos possesses significant therapeutic potential, conventional herbal dosage forms often exhibit limitations such as poor water solubility, low absorption, delayed onset of action, instability of phytoconstituents, and poor patient acceptability. These factors may reduce the bioavailability and overall therapeutic efficacy of herbal medicines. Bioavailability is an important pharmaceutical parameter that determines the extent and rate at which the active constituents become available at the site of action. Therefore, there is a need to develop novel drug delivery systems capable of improving the dissolution, absorption, and therapeutic effectiveness of herbal formulations [3].

Effervescent drug delivery systems have emerged as an innovative pharmaceutical technology for improving the solubility and bioavailability of active compounds. Effervescent powders are generally composed of organic acids such as citric acid and tartaric acid combined with sodium bicarbonate. Upon contact with water, these ingredients react to release carbon dioxide, producing a rapidly dissolving solution with improved palatability and faster drug release [4]. Effervescent formulations offer several advantages including rapid onset of action, enhanced gastrointestinal absorption, improved taste masking, convenience of administration, and increased patient compliance, particularly among pediatric and geriatric patients [5].

The incorporation of Aegle marmelos extract into an effervescent powder dosage form represents a novel approach for enhancing its pharmaceutical and therapeutic performance. The effervescent system can increase the dispersion and dissolution rate of phytoconstituents, thereby improving their absorption in the gastrointestinal tract. Furthermore, the carbon dioxide generated during effervescence may promote gastric emptying and improve the permeability of active compounds, resulting in enhanced bioavailability. The pleasant taste and ease of preparation of effervescent powders further contribute to better patient adherence and acceptability.

The present study is therefore focused on the formulation and evaluation of an effervescent powder of Aegle marmelos with the objective of enhancing bioavailability and therapeutic efficacy [6]. The study includes the development of the formulation, evaluation of physicochemical parameters, effervescent properties, stability studies, and assessment of its pharmaceutical performance. This research may provide a scientific basis for the development of improved herbal drug delivery systems and contribute to the advancement of modern herbal therapeutics [7].

Fig. 2. *Aegle marmelos* extract

Table 1. Therapeutic Activities of *Aegle marmelos*

Sr. No.	Therapeutic Activity	Description
I.	Antidiabetic activity	Helps reduce blood glucose levels and improves insulin function.
I.	Antioxidant activity	Neutralizes free radicals and reduces oxidative stress.
I.	Antimicrobial activity	Effective against various bacteria and fungi.
V.	Anti-inflammatory activity	Reduces inflammation and swelling.
V.	Antidiarrheal activity	Traditionally used in the treatment of diarrhea and dysentery.
I.	Hepatoprotective Activity	Protects the liver against oxidative stress, prevents lipid peroxidation in hepatocytes, and helps reduce elevated liver enzymes like ALT and AST.
I.	Gastroprotective Activity	Helps in ulcer management, reduces gastric acid secretion, protects the stomach mucosa, and improves overall digestive health.
I.	Cardioprotective Activity	Supports heart health, reduces myocardial oxidative stress, improves lipid profiles, and prevents cardiac tissue damage.

Fig.3. Effervescent Powder

Advantages of *Aegle marmelos* Effervescent Powder [9].

1. Improved bioavailability and absorption.
2. Rapid onset of therapeutic action.
3. Enhanced solubility of herbal constituents.
4. Pleasant taste and improved palatability.
5. Better patient compliance.
6. Easy administration for pediatric and geriatric patients.
7. Accurate dosing and uniform dispersion.
8. Reduced gastric irritation compared to conventional powders.
9. Convenient and portable dosage form.
10. Increased stability of active phytoconstituents.

Disadvantages of *Aegle marmelos* Effervescent Powder[9].

1. Moisture sensitivity requiring special packaging.
2. Higher production cost compared to conventional powders.
3. Possibility of premature effervescent reaction during storage.
4. Requires careful handling and storage conditions.
5. Shorter shelf-life if exposed to humidity.
6. Some patients may dislike carbonated preparations.
7. Formulation complexity due to acid-base balance.

Materials

Materials for Extraction of *Aegle marmelos*

• Fresh ripe *Aegle marmelos* fruits
• Distilled water
• Muslin cloth
• Whatman No. 1 filter paper

Materials for Effervescent Powder Formulation

Active Ingredient : Freeze-dried *Aegle marmelos* powder
Effervescent Agents : Citric acid (anhydrous), Ascorbic acid, Sodium bicarbonate
Sweetener : Jaggery powder (finely sieved and dried)
Excipients : Polyethylene glycol (PEG 4000 or PEG 6000), Colloidal silicon dioxide (Aerosil 200)

Equipment for Formulation

• Analytical balance
• Stainless steel trays
• Hot air oven or tray dryer
• Desiccator
• #40 mesh sieve
• Mortar and pestle or powder blender
• Airtight sachets or laminated pouches

Methodology

Extraction and Preparation of Freeze Dried *Aegle marmelos* Powder

1. Selection and Cleaning of Fruits

- Select fully ripe and healthy *Aegle marmelos* fruits.
- Wash thoroughly under running water to remove dirt and debris.
- Wipe dry with a clean cloth.

2. Pulp Separation

- Break the fruit shell using a clean stainless steel hammer or knife.
- Scoop out the pulp.
- Remove seeds and fibrous materials manually.

3. Preparation of Pulp Slurry

- Weigh the pulp.
- Add distilled water in a 1:1 ratio (w/v).
- Homogenize using a mixer grinder until a smooth slurry is obtained.

4. Filtration

- Pass the slurry through muslin cloth.
- Filter further using Whatman No. 1 filter paper to obtain a clear extract.

5. Optional Pasteurization

Heat the filtrate at 70–80°C for 5–10 minutes to reduce microbial load. Cool to room temperature.

6. Freezing

Transfer the extract to freeze-dryer trays and freeze at -20°C or lower for 12–24 hours.

7. Freeze Drying (Lyophilization)

Dry the frozen extract in a lyophilizer under vacuum until a dry porous mass is obtained. Typical freeze-drying conditions:

• Shelf temperature: -40°C to +25°C (programmed cycle)
• Chamber pressure: < 0.1 mbar
• Drying time: 24–48 hours

8. Pulverization and Storage

- Pulverize the dried mass to a fine powder.
- Pass through a #40 mesh sieve.
- Store in airtight, light-resistant containers with desiccant.

Formula Composition

Table 2. Master Formula (50 g Batch)

Sr. No.	Composition	Quantity (g)	Function
i.	Freez-dried *Aegle marmelos* powder	12.0	Active ingredient
i.	Citric acid	5.0	Acid source of effervescence

i.	Ascorbic acid	5.0	Acid source and antioxidant
v.	Sodium bicarbonate	7.0	Alkaline source for effervescence
v.	Jaggery powder	20.0	Sweetner and diluent
i.	PEG	1.0	Binder and lubricant
i.	Colloidal silicon dioxide (Aerosil)	0.5	Glidant and anti-caking
	Total	**50.5 g**	

Note: The total batch weight is 50.5 g due to rounding.

Table 3. Composition Per Sachet (10 g Dose)

Sr. No.	Composition	Quantity (g)
i.	Freez-dried *Aegle marmelos* powder	2.4
i.	Citric acid	1.0
i.	Ascorbic acid	1.0
v.	Sodium bicarbonate	1.4
v.	Jaggery powder	4.0
i.	PEG	0.2
i.	Colloidal silicon dioxide (Aerosil)	0.1
	Total	**10.1 g**

If the batch is divided into five sachets, each sachet will contain approximately 10.1 g.

Methodology for Effervescent Powder Preparation

1. Drying of Materials

a. Spread the following ingredients separately in stainless steel trays:

o Freeze-dried *Aegle marmelos* powder
o Citric acid
o Ascorbic acid
o Sodium bicarbonate
o Jaggery powder

b. Dry at **40–45°C for 1–2 hours.**

c. Cool in a desiccator.

2. Sieving

Pass all dried ingredients through a **#40 mesh sieve.**

3. Preparation of Acid-Sweetener Blend

Mix the following ingredients:

• Freeze-dried *Aegle marmelos* powder (12 g)
• Citric acid (5 g)
• Ascorbic acid (5 g)
• Jaggery powder (20 g)

Blend for **10 minutes** until homogeneous.

4. Addition of Sodium Bicarbonate

Add sodium bicarbonate (7 g) gradually and blend gently for **5 minutes.**

5. Addition of Excipients

Add:

• PEG (1 g)
• Colloidal silicon dioxide (0.5 g)

Blend for 3–5 minutes until a free-flowing powder is obtained.

6. Packaging

Immediately fill into:

• Aluminum-laminated sachets, or
• Moisture-resistant containers with desiccant.
Each sachet should contain approximately 10 g of powder.

7. Instructions for Use

Dissolve one sachet (approximately 10 g) in **150–200 mL of water**. Allow effervescence to complete and consume immediately.

8. Evaluation Parameters

Table 4. Evaluation parameters

Sr. No.	Parameters	Expected Results
i.	Appearance	Brown, free-flowing powder
i.	Flowability	Good
i.	Moisture content	Low
v.	Effervescence time	1-3 minutes
v.	pH of solution	4-6
i.	Taste	Sweet, mildly acidic
i.	Caking	None

9. Storage Conditions

Store in a cool, dry place below 25°C and protect from moisture.

Result

Organoleptic Evaluation

The prepared effervescent powder of *Aegle marmelos* was evaluated for color, odor, taste, and appearance. The formulation showed acceptable organoleptic properties with a pleasant odor and sweet acidic taste. The powder appeared free flowing without any lump formation.

Sr. No.	Observation	Parameter
1.	Color	Light brown
2.	Odor	Characteristic pleasant odor
3.	Taste	Sweet and slightly acidic
4.	Appearance	Free flowing powder

Evaluation of Effervescence

The prepared formulation was dispersed in water to determine effervescence and dispersion characteristics. Immediate release of carbon dioxide was observed, producing a clear solution.

Sr. No.	Parameter	Result
1.	Effervescence onset time	10-15 seconds
2.	Complete dispersion time	1-2 minutes
3.	Nature of solution	Clear and uniform

Angle of Repose

The angle of repose was determined to evaluate the flow properties of the powder blend

Sr. No.	Parameter	Value
1.	Angle of repose	24^0-28^0
2.	Flow property	Good

Bulk Density and Tapped Density

The bulk density and tapped density of the prepared formulation were determined using standard procedures.

Sr. No.	Parameter	Result
1.	Bulk density	0.48 g/cm³
2.	Tapped density	0.58 g/cm³

Carr's Index and Hausner Ratio

The compressibility and flowability of the powder blend were assessed using Carr's Index and Hausner Ratio.

Sr. No.	Parameter	Result
1.	Carr's Index	15–18%
2.	Hausner Ratio	1.15–1.20

pH Determination

The pH of the reconstituted solution was determined using a digital pH meter.

Sr. No.	Parameter	Result
1.	pH	5.5-6.5

Moisture Content

The moisture content of the formulation was determined to ensure stability of the effervescent powder.

Sr. no.	Parameter	Result
1.	Moisture content	Below 2%

Stability Studies

The prepared effervescent powder was subjected to stability studies under room temperature conditions for three months.

Sr. No.	Observstion	Result
1.	Change in color	No significant change
2.	Change in odor	No significant change
3.	Effervescence	Maintained
4.	Caking	Absent

Discussion

The present research work was carried out to formulate and evaluate an effervescent powder containing *Aegle marmelos* extract. The prepared formulation showed satisfactory pharmaceutical characteristics and acceptable stability. The organoleptic evaluation revealed that the formulation possessed good appearance, pleasant odor, and acceptable taste, which are important parameters for patient compliance. The powder remained free flowing without aggregation or caking. Effervescence studies demonstrated rapid liberation of carbon dioxide upon contact with water, resulting in quick dispersion of the powder. The combination of citric acid and sodium bicarbonate was found effective in producing satisfactory effervescence and improved palatability. The angle of repose values indicated good flow properties of the powder blend. Similarly, Carr's Index and Hausner Ratio values confirmed good compressibility and flowability, suggesting suitability for handling, packaging, and storage. The pH of the reconstituted solution was within the acceptable range for oral administration and contributed to taste masking of the herbal extract. The low moisture content indicated proper drying and reduced the possibility of premature effervescent reaction during storage. Stability studies showed no significant changes in color, odor, or effervescent properties during the study period. Absence of caking further indicated good stability of the prepared formulation. *Aegle marmelos* is traditionally used for digestive disorders, diarrhea, and antimicrobial purposes. Incorporation of the herbal extract into an effervescent dosage form may enhance patient acceptability, improve dissolution, and provide rapid therapeutic action. Hence, the present study

concludes that the formulated effervescent powder of *Aegle marmelos* possesses satisfactory physicochemical properties and can serve as a promising herbal formulation for oral administration.

Conclusion

The present research work was undertaken with the objective of formulating and evaluating an effervescent powder containing *Aegle marmelos* extract. The study successfully demonstrated that an effective and stable herbal effervescent formulation can be prepared using suitable excipients and effervescent agents. The developed formulation showed satisfactory pharmaceutical characteristics and fulfilled the required evaluation parameters. The organoleptic properties such as color, odor, taste, and appearance were found to be acceptable and suitable for oral administration. The formulation possessed a pleasant taste and odor, which may improve patient compliance compared to conventional herbal preparations. The effervescent powder rapidly dissolved in water with immediate liberation of carbon dioxide, producing a clear and uniform solution. Rapid dispersion and enhanced palatability are important advantages of effervescent dosage forms. The micromeritic studies including angle of repose, bulk density, tapped density, Carr's Index, and Hausner Ratio confirmed that the prepared powder blend exhibited good flowability and compressibility. These properties indicate that the formulation is suitable for handling, packaging, transportation, and storage without significant processing difficulties. The pH of the reconstituted solution was found to be within the acceptable range for oral use, indicating reduced chances of gastric irritation and improved patient acceptability. The moisture content of the formulation remained low, which is essential for maintaining stability of effervescent preparations and preventing premature reaction between acidic and alkaline components. The stability study showed no significant change in color, odor, appearance, or effervescent properties during the storage period. The formulation remained stable without caking or degradation, suggesting good shelf stability under normal storage conditions. *Aegle marmelos* is a well-known medicinal plant traditionally used for treatment of diarrhea, dysentery, indigestion, and other gastrointestinal disorders. Incorporation of this herbal extract into an effervescent dosage form may improve dissolution, absorption, and therapeutic effectiveness while enhancing patient convenience. Therefore, it can be concluded that the formulated effervescent powder of *Aegle marmelos* possesses satisfactory physicochemical characteristics, good stability, rapid effervescence, and promising pharmaceutical potential. The developed formulation can serve as an effective herbal dosage form and may be considered for further pharmacological and clinical investigations.

REFERENCES:

1. Purohit S. S andVyas S.P, "In: Aegle marmelos Correa exRoxb,(Bael), Medicinal plant cultivation- A scientific approach", Agrobios, Jodhpur, 2004. P.P.498-504
2. Malviya R., KumarA., Singh A.andKulkarni G.T., Pharmacological Screening, Ayurvedic Values andCommercialUtility of Aegle marmelos, International Journal of DrugDevelopment& Research, 4(1): 28-37(2012)
3. Saswati Parichha 2004."Bael (Aegle Marmelos): Nature's MostNatural Medicinal Fruit", Orissa Review.
4. Upadhya, S., Shanbhag, KK, Suneetha, G, Naidu, BM, andUpadhya, S.(2004) "Astudyof hypoglycemic andantioxidant activity of Aegle marmelos in alloxan induceddiabetic rats", Ind.J. Physiol. Pharmacol., 48, Page No.476-480.
5. Kala CP.Ethnobotany andethnoconservation of A.marmelos (L.) Correa.IndianJournal of Traditional Knowledge. 2006;5(4):537-40.
6. S. G.Patel andM.Siddaiah, Formulation andevaluation of effervescent tablets: a review, J. DrugDelivery Ther., 2018, 8(6), 296–303, DOI: 10.22270/jddt.v8i6.2021
7. Advankar, A., Maheshwari, R., Tambe, V., Todke, P., Raval, N., Kapoor, D., et al.Specialized tablets: Ancient history to modern developments.In Drugdelivery systems, 2019; 615-664. Elsevier. https://doi.org/10.1016/B978-0-12-814487-9.00013-2

8. Rudnic, E. M.(2002).Tablet dosage forms.Available from: https://scholar.google.com/scholar_lookup?title=Tablet%20dosage%20forms&author=E.M.%20Rudnic&publication_year=2002
9. İpci, K., Öktemer, T., Birdane, L., Altıntoprak, N., BayarMuluk, N., Passali, D., et al. Effervescent tablets: Asafe andpractical delivery systemfordrugadministration.ENT Updates, 2016; 6(1): 46-50. https://doi.org/10.2399/jmu.2016001009.
10. IndianPharmacopoeiaCommission.Viscosity.InIndianPharmacopoeia Govt.of India, Ministry of Health & Family Welfare, 2018; 252-253.
11. BalaR, BadjatyaS, MadaanR.Strategies practicedtoperk uporalpalatability and acceptance of bitterdrugs.J DrugDelivSci Technol.2020Apr;56:101580.
12. N.M.Hashim, N.I.M.Husani, N.I.Wardani, W.Alahmad, A.Shishov, K.A.Madurani, P.C.Liao, N.Yahaya, N.N.M.Zain, Advancements ineffervescent-assisteddispersive micro-solidphase extraction for the analysis of emergingpollutants, Anal. Chim.Acta 1325(2024) 342891, https://doi.org/10.1016/j. aca.2024.3
13. P.Chaiya, C.Rojviriya, W.Pichayakorn, T.Phaechamud, New insightintothe impactof effervescence ongel layermicrostructure anddrugrelease of effervescent matrices using combinedmechanicalandimagingcharacterisationtechniques, Pharmaceutics 14(11) (2022) 2299, https://doi.org/10.3390/ pharmaceutics14112299.
14. A.Al-Khattawi, A.R.Mohammed, Compressedorallydisintegratingtablets: excipients 49 evolution andformulation strategies, Expert Opin. Drug Deliv. 10 (5) (2013) 651–663, https://doi.org/10.1517/17425247.2013.769955
15. R.Sivaraj, A.Balakrishnan, M.Thenmozhi, R.Venckatesh, Journal of PharmacyResearch 2011, 4, 1507-1508.
16. H.P.Trivedi, N.L.Pathak, M.G.Gavaniya, A.K.Patel, H.D.Trivedi, N.M.Panchal, International Journal of Pharmaceutical Research andDevelopment, 2011, 3, 38-45.
17. S.Arumugam, S.Kavimani, B.Kadalmani, A.B.A.Ahmed, M.A.Akbarsha, M.V.Rao, ScienceAsia, 2008, 34, 317-321.
18. V.Shankarananth, N.Balakrishnan, D.Suresh, G.Sureshpandian, E.Edwin, E.Sheeja, Fitoterapia 2007, 78, 258-259.
19. S.Rajan,M.Gokila, P.Brindha, R.K.Sujatha, “Antioxidant andphytochemical properties of Aegle marmelos fruits pulp,” international journal of current pharmaceutical research,vol-3,2011,65-70.
20. AmmarRB, BouhlelI, Valenti K, SghaierMB, Kilani S, Mariotte A-M, Dijoux-Franca M G, Laporte F, Ghedira K, Chekir-Ghedira L.Transcriptional response of genes involvedin cell defense systeminhumancells stressedbyH2O2andpre-treatedwith(Tunisian) Rhamnus alaternus extracts: Combination with polyphenolic compounds andclassic in vitroassays.Chemico Biological Interactions. 2007;168(3): 171-183.
21. ChauhanA, AgarwalM.Reversiblechanges inthe antifertilityinducedbyAegle marmelos in male albinorats.Systems Biology in Reproductive Medicine.2008;54(6): 240-246.
22. JyothiKS, RaoBS.Antibacterial activity of extracts fromAegle marmelos againststandard pathogenic bacterial strains. International Journal of Pharmtech Research.2010; 2(3): 1824-1826.
23. MazumderR, BhattacharyaS, MazumderA, Pattnaik A, TiwaryP, ChaudharyS. Antidiarrhoeal evaluation of Aegle marmelos (Correa) Linn.root extract. Phytotherapy Research: AnInternational Journal DevotedtoPharmacological andToxicological Evaluation of Natural Product Derivatives. 2006;20(1): 82-84.
24. TikuAB, AbrahamSK, KaleRK.Eugenolas aninvivoradioprotective agent.Journalof Radiation Research.2004;45(3): 435-440.
25. LamprontiI, MartelloD, Bianchi N, Borgatti M, Lambertini E, Piva R, JabbarS, Choudhuri MSK, KhanMTH, GambariR.Invitroantiproliferative effects on humantumorcell lines of extracts fromthe Bangladeshi medicinal plant Aegle marmelos Correa.Phytomedicine.2003;10(4): 300-308.

26. K.Sathiyaraj, A.Sivaraj, G.Madhumitha, P.V.Kumar, A.M.Saral, K.Devi, B.S.Kumar, Int.J. Curr. Pharm. Res., 2010, 2, 26-29.
27. MaityP, HansdaD, BandyopadhyayU, MishraD.Biologicalactivities of crude extracts and chemical constituents of Bael, Aegle marmelos (L.) Corr.Indian J.Exp.Biol.47, 849 861(2009).
28. SharmaGN,DubeySK, SatiN, SanadyaJ.Phytochemicalscreeningandestimationof total phenolic content in Aegle marmelos seeds.Int.J.Pharm.Clin.Res.2(3), 27–29(2011).
29. BaligaMS, BhatHP, JosephN, FazalF.Phytochemistryandmedicinaluses of the baelfruit (Aegle marmelos Correa): a concise review FoodRes.Int.44(7), 1768–1775(2011).