

ADVANCING HERBAL THERAPEUTICS THROUGH EFFERVESCENT FORMULATIONS: A COMPREHENSIVE REVIEW**Shubham Patel, Sunil Ahirwar*, Satkar Prasad and Shailesh Kumar Ghatuwar****RKDF School of Pharmaceutical Sciences, BHABHA University, Bhopal (M.P.)***Corresponding Author's E mail: sunilahirwar687@gmail.com

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ABSTRACT

The increasing preference for user-friendly and better-tasting alternatives to traditional herbal dosage forms has driven substantial interest in effervescent herbal formulations. These systems offer the dual advantage of rapid dissolution and improved bioavailability, while effectively masking the often bitter or astringent taste of herbal extracts. Despite these benefits, the development of herbal effervescent tablets involves notable formulation challenges such as accommodating the variable and often unstable physicochemical nature of herbal constituents, preserving their antioxidant potential, and achieving optimal sensory attributes without sacrificing therapeutic effectiveness. Several studies have investigated effervescent formulations using plant-based ingredients, incorporating various excipients including binders, sweeteners, and disintegrants. Additionally, formulation techniques such as wet and dry granulation, direct compression, and emerging technologies like 3D printing have been employed to enhance physical properties, stability, and dissolution behavior. Given the growing scope and complexity of this field, a thorough review is essential to consolidate current findings, identify key formulation strategies, and outline future research pathways toward developing robust, palatable, and efficacious herbal effervescent delivery systems.

Keywords: Effervescent granules; Taste masking; Herbal formulation; Solubility.

INTRODUCTION

The rising awareness around health and wellness has significantly contributed to the growing popularity of nutraceuticals and plant-based therapeutic products¹. Integrating herbal extracts into traditional oral dosage forms can be challenging, primarily because of their intense flavor, distinctive smell, and low bioavailability²⁻³. Effervescent tablets have gained attention as a favorable alternative to overcome these limitations and improve patient adherence⁴⁻⁶. These tablets are known for their rapid dissolution and ability to form a pleasant, fizzy solution, which may also facilitate better absorption of active compounds through carbon dioxide generation⁷. Typically, they are composed of acidic agents

for instance citric or tartaric acid and a basic agent like sodium bicarbonate, which react upon contact with water to produce effervescence, leading to the swift breakdown and dissolution of the tablet⁸.

Effervescent systems provide a user-friendly and effective platform for delivering herbal actives. Nonetheless, several formulation hurdles persist. Herbal extracts often exhibit chemical instability, moisture sensitivity, and potential incompatibility with formulation excipients⁹⁻¹⁰. Examples like *Moringa oleifera* and Kelakai root contain complex phytochemicals that pose challenges in terms of taste masking and ensuring long-term stability²⁻⁴. While sweeteners and flavoring agents are commonly used to improve palatability, achieving complete taste masking without affecting the formulation's performance requires strategic excipient selection⁴⁻⁵. Additionally, optimizing tablet attributes such as hardness, friability, and disintegration time, while maintaining antioxidant efficacy, involves a thorough understanding of how herbal constituents interact with gas-releasing agents and other excipients⁴⁻⁶.

Although interest in herbal effervescent formulations is expanding, there remains a lack of comprehensive literature summarizing key formulation parameters, associated challenges, and best practices for optimization. A deeper exploration of how various formulation components including acids, bases, binders, and sweeteners impact the overall quality, performance, and therapeutic potential of these dosage forms is crucial for future advancements⁹⁻¹¹. Therefore, a systematic review of the current knowledge base is essential to guide research and innovation in this area, ultimately supporting the development of stable, effective, and consumer-acceptable effervescent herbal products.

Herbal remedies

Herbal medicine, involves the therapeutic application of plant-derived materials¹². This practice is one of the oldest forms of healthcare, with evidence tracing its origins to the Paleolithic period and written records from ancient Sumerian civilizations¹³. Traditional herbals, which are Collections of descriptions of medicinal plants, have historically served as practical guides or pharmacopeias, focusing on usage and preparation rather than botanical classification or theoretical mechanisms¹⁴. Unlike pharmaceutical agents derived from plants that isolate specific active constituents, herbal medicines typically use complex mixtures found in whole plants or crude extracts. These may include dried or fresh plant materials and are commonly formulated into various dosage forms such as capsules, tablets, powders, tinctures, and decoctions¹⁵.

Effervescent formulations and their benefits in herbal products

Effervescent formulations are designed to undergo a chemical reaction upon dissolution in water, resulting in the release of carbon dioxide (CO₂). This effervescence facilitates rapid disintegration and can significantly enhance the solubility and subsequent bioavailability of the active constituents¹⁶. These formulations are available in multiple delivery formats, offering versatility in drug design and patient use.

The most widely used form is the effervescent tablet, which is formed through the compression of a formulation containing active ingredients and an acid. (such as citric or tartaric acid) and a base (commonly sodium bicarbonate or carbonate). Upon contact with water, the acid-base reaction generates CO₂, promoting immediate tablet breakdown and active ingredient dispersion. Effervescent granules function similarly but are provided in coarse or fine particle forms and are typically packaged in moisture-resistant sachets, offering improved storage stability and convenience. Effervescent powders, characterized by smaller particle size, allow for even faster dissolution and are commonly applied in the context of herbal supplements. Less commonly, effervescent capsules have reactive powders that require removal from the capsule prior to dissolution; this form is particularly useful for sensitive actives that degrade in compressed forms. Additionally, effervescent liquids, where active ingredients are pre-dissolved in a solution that fizzes upon dilution, are used in specialized pharmaceutical applications. The diversity of these formats enables tailored formulation strategies that account for both pharmacokinetic and pharmacodynamic considerations.

The increased adoption of effervescent dosage forms can be attributed in part to their streamlined manufacturing processes. Whether produced as powders, granules, or tablets, these formulations can be manufactured using conventional techniques such as direct compression, wet granulation, or dry granulation. Unlike traditional tablets or emulsified suspensions, effervescent products do not require advanced equipment for film coating, dispersion stabilization, or emulsification, reducing production complexity and cost.

A key benefit of effervescent systems lies in their capacity to improve the bioavailability of poorly soluble herbal compounds¹⁷. The CO₂-driven reaction leads to the creation of a uniform aqueous solution, promoting enhanced dissolution and gastrointestinal absorption¹⁸. This is especially advantageous for hydrophobic phytochemicals, such as flavonoids and polyphenols, which typically demonstrate limited oral bioavailability when administered in solid dosage forms.

Effervescent formulations are also especially advantageous for populations with swallowing difficulties, including pediatric, geriatric, or dysphagic patients¹⁹⁻²⁰. The liquid form of administration enhances ease of use and can be customized with flavoring agents and natural sweeteners to mask the often bitter or astringent taste of botanical ingredients, thereby improving palatability and patient adherence²¹.

Key considerations in formulating herbal effervescent products

The development of effervescent formulations incorporating herbal ingredients requires careful consideration of multiple formulation parameters. This section highlights specific, often underexplored, factors that can significantly influence the physicochemical characteristics and overall acceptability of herbal effervescent products, particularly in unique or challenging formulations. Well-established parameters, that are the impact of the acid-to-base ratio on disintegration time, are not addressed here, as they have been extensively studied in previous literature. Various herbal effervescent formulations have been shown in Table 1.

Table 1: herbal effervescent formulations

Active Ingredient	Dosage Form	Application	Acid	Binder	Granulation	Reference
Josapine pineapple powder	Tablet	Vitamin	CA	-	Direct compression	(22)
<i>Hibiscus sabdariffa</i> L. water extract	Tablet	Anti-dental-microbe	CA	-	Direct compression	(7)
Red ginger crude extract	Granule	Antioxidant	CA and TA	Povidone	Wet granulation	(5)
<i>Phyllanthus niruri</i> , <i>Strobilanthes crispus</i> , and <i>Orthosiphon aristatus</i> water extract	Tablet	Antioxidant	CA and malic acid	-	Direct compression	(6)
Elderberry extract powder and vine tea powder	Tablet	Antioxidant	CA	Povidone	Wet granulation	(9)
Aloe vera gel powder	Tablet	Cytoprotective in peptic ulcer	CA	Avicel PH 102	Direct compression	(23)
Grape seed extract	Tablet	Antioxidant	CA and	Povidone	Wet	(1)

			TA		granulation	
<i>Robusta coffee</i> ethanol extract	Granules	Psychostimulant	CA and TA	Avicel PH 102	Wet granulation	(24)
<i>Moringa oleifera</i> ethanol extract	Tablet	Antianemia	CA and TA	PEG 600	Wet granulation	(2)
<i>Stenochlaenapalustri</i> root extract	Tablet	Antioxidant	CA and TA	Povidone	Wet granulation	(4)
<i>Bryophyllumpinnatum</i> leaves extract	Tablet	Antiuro lithiatic	CA and TA	Povidone	Wet granulation	(11)
<i>Azadirachta indica</i> and Curcumin powder Freeze-dried	Tablet	Anti-dental- microbe	CA and TA	-	-	(25)
<i>Chromolaena odorata</i> and <i>Glochidion</i> <i>arborescens</i> leaves juice	Granules	Antioxidant	CA	Povidone	Wet granulation	(26)
Monoammonium glycyrrhizin and aloe vera gel powder	Tablet	Cytoprotective in peptic ulcer	CA	Avicel PH 102	Wet granulation	(3)
<i>Brassica spp.</i> (seeds), <i>Blumea balsamifera</i> (<i>L.</i>) DC. (leaves), <i>Terminalia chebula</i> Retz. (fruit pulp), <i>Piper nigrum</i> L. (fruits), <i>Citrus hystrix</i> DC. (fruit peels), and <i>Coriandrum sativum</i> L. (fruits) powder	Tablet	Expectorant	Anhydrous CA and TA	Microcrystalline cellulose	Direct compression	(27)
<i>Pedaliu murex</i> and <i>Tribulus terrestris</i> fruit extracts	Tablet	Demulcent and diuretic	-	Microcrystalline cellulose	Direct compression	(28)

Palatability optimization and taste-masking strategies in herbal effervescent formulations

Herbal extracts frequently possess inherently bitter, astringent, or otherwise unappealing taste profiles, which can significantly affect patient adherence and therapeutic outcomes if not adequately addressed². The effervescent reaction, which produces carbon dioxide upon dissolution, can enhance mouth feel and improve the overall sensory experience. However, this fizzy sensation alone is often insufficient to fully mask strong or unpleasant flavors¹.

To improve the organoleptic properties of effervescent herbal formulations, the judicious selection and optimization of sweetening and flavoring agents is essential. For instance, Forestryana *et al.* (2021) demonstrated that even at 15.5% concentration, aspartame failed to fully suppress the bitterness of the roots of Kelakai (*Stenochlaena palustris*) in effervescent tablets⁴. Conversely, an additional investigation observed that a much lower concentration 3% aspartame effectively masked the bitter notes of *Coffea canephora* ethanolic extract²⁴, underscoring the importance of tailoring sweetener levels to the specific herbal matrix.

In some cases, conventional flavourings such as lemon or strawberry were inadequate for masking the bitterness of *Moringa oleifera* extracts, indicating the requirement for stronger or more effective combinations of taste-masking agents². Natural sweeteners like stevia have shown promise due to their strong sweetening power and plant-based origin, contributing both to sweetness and patient acceptability^{9,22}. For herbal materials with inherently milder taste profiles, such as ginger, sucrose may suffice both as a sweetener and filler⁵.

The acid–base components that drive effervescence (commonly citric acid and sodium bicarbonate) also influence taste perception. For example, sodium bicarbonate can help reduce the astringency of *Kaempferia galanga* extracts⁸. However, excessive use of these agents may result in overly alkaline or acidic pH, potentially causing gastrointestinal discomfort such as nausea^{9,11}. Therefore, careful balance is necessary not only for taste but also for safety and physiological compatibility.

Incorporating taste-enhancing co-ingredients such as fruit juices, tea extracts, or compatible aromas can further improve the sensory appeal of effervescent formulations⁹. Moreover, aligning flavour profiles with the visual colour of the dissolved extract can enhance consumer perception. For example, formulations exhibiting a purple coloration are typically complemented by grape flavouring, whereas yellow or orange shades are more suitably paired with citrus or pineapple Flavors to enhance sensory appeal¹.

Overall, developing a palatable herbal effervescent formulation requires an integrated approach involving taste-masking excipients, flavour optimization, and harmonization of sensory attributes with the chemical and physical properties of the active ingredients.

Stability enhancement strategies for herbal extracts in effervescent formulations

Herbal extracts are composed of a diverse range of bioactive phytochemicals that are highly susceptible to degradation when exposed to environmental factors such as moisture, temperature fluctuations, light, and chemical interactions with excipients²⁹. The instability of these constituents can result in diminished therapeutic efficacy, posing a major challenge in herbal product development. Converting herbal extracts into solid, dry effervescent formulations offers a practical approach to improving stability by significantly reducing water activity compared to liquid or semi-solid preparations.

However, components commonly used in effervescent formulations particularly organic acids like citric or tartaric acid tend to be hygroscopic, which can inadvertently increase moisture uptake and lead to Deterioration of susceptible herbal compounds^{4,8,10,27}. Therefore, effective moisture control strategies are critical during formulation and packaging.

One approach to enhancing the stability of herbal powders involves the use of cryoprotectants during freeze-drying. As demonstrated in a study by Xiangfang et al., this technique helps reduce the hygroscopic nature of the resulting powder and protects thermolabile constituents¹⁰. Moreover, encapsulating agents such as maltodextrin and Arabic gum are frequently incorporated during spray- or freeze-drying processes. These matrix-forming polymers act as stabilizers by creating a protective barrier around active compounds, shielding them from environmental stressors²².

The choice of polymer can influence both the physical and chemical properties of the final product. For example, maltodextrin, being highly water-soluble, facilitates reconstitution but may offer lower adsorption of phenolic compounds compared to Arabic gum, which has a higher binding affinity for antioxidants like anthocyanins—thereby enhancing their functional activity²⁹.

Nanoencapsulation has also been explored as an advanced method to protect herbal actives. This technology enables the encapsulation of bioactive compounds at the nanoscale, offering improved protection against oxidation, hydrolysis, and photo degradation. However, successful encapsulation requires careful consideration of the solubility and compatibility of both the core material and the encapsulating polymer to ensure optimal release and bioactivity.

In terms of excipient functionality, Aerosil (colloidal silicon dioxide) serves a dual role as a filler and moisture adsorbent. It is particularly useful in adsorbing excess moisture from hygroscopic extracts such as *Stenochlaena palustris* (Kelakai). However, its inclusion may also impact dissolution kinetics, potentially prolonging disintegration time by retaining water⁴.

Emerging technologies like 3D printing of effervescent tablets present novel opportunities for personalized and precise herbal dosage forms. In these applications, the concentration and type of cryoprotectant used during extract drying significantly influence powder characteristics such as flowability, rehydration rate, hygroscopicity, and the viscosity of the printable paste. Butar-Butar *et al.* (2025) found that incorporating 50% w/w mannitol into the freeze-dried extract matrix yielded optimal results in terms of physical form, moisture handling, and paste rheology. Conversely, excessively high concentrations (e.g., 150%) led to overly viscous mixtures that were unsuitable for printing¹⁰.

In conclusion, enhancing the stability of herbal constituents in effervescent formulations requires a comprehensive formulation strategy, including moisture control, protective carriers, encapsulation techniques, and tailored excipient selection. These measures not only safeguard bioactivity during storage and handling but also ensure consistent therapeutic performance.

Gas-generating agents

Effervescence in pharmaceutical dosage forms arises from an acid–base reaction, typically involving organic acids such as citric, tartaric, or malic acid and alkaline compounds like sodium bicarbonate/carbonate. This reaction produces CO₂, leading to the distinctive effervescent effect^{4,8,27}. The selection and proportion of these reactants play a critical role in modulating the effervescence kinetics, influencing not only the reaction rate and intensity²² but also the organoleptic properties and the final pH of the reconstituted solution^{1,8}.

Utilizing citric and tartaric acid in combination, is frequently more beneficial than relying on a single acid source. For instance, citric acid alone may increase stickiness, while tartaric acid alone may produce weak granules^{1,24}. An optimal acid-to-base ratio ensures complete reaction without leaving residual components that could influence taste or pH negatively.

The study involving Kelakai root demonstrated that increasing citric and tartaric acid levels elevated the moisture content and cohesive forces in granules, thereby increasing their angle of repose⁴. These cohesive forces also improved the tablets' mechanical strength and resistance to handling stresses⁸.

Moreover, acidic agents impact the phytochemical profile of herbal formulations. Higher levels of acidic components have been shown to enhance total phenolic content, flavonoid content, and antioxidant activities such as free radical scavenging and ferric-reducing antioxidant power⁶. These effects may result from improved solubility and extraction efficiency of phenolic compounds in acidic environments, which disrupt plant cell walls and release bound bioactive compounds. Acidic media also stabilize phenolic compounds and enhance their redox activity, making them more effective antioxidants. Furthermore, acid hydrolysis can cleave glycosidic bonds in polyphenols, releasing more bioavailable and potent antioxidant molecules. Acids like citric and ascorbic acid contribute directly to antioxidant capacity due to their inherent properties.

Interestingly, in floating tablet formulations, sodium bicarbonate alone can act as the effervescent agent by reacting with gastric acid (0.1 N HCl), generating CO₂ and reducing tablet density to enhance gastric retention, negating the need for formulation-based acidic agents²⁸.

Binder selection

In effervescent tablets, binders play a crucial role in ensuring mechanical strength while maintaining rapid disintegration and solubility. Since these formulations are typically hygroscopic and fragile, binders must enhance compressibility without compromising moisture sensitivity or flow properties.

Polyvinylpyrrolidone (PVP) is a common binder that improves solubility, particularly for poorly water-soluble drugs. It also contributes to more uniform granule size and shape, resulting in consistent tablet weight across batches. Higher PVP concentrations can enhance tablet hardness⁴. However, gummy-textured herbal extracts may require adjustments in binder selection and concentration to avoid overly hard or sticky tablets¹¹.

In floating effervescent tablets, the binder also acts as a matrix-forming polymer to trap CO₂ gas and prolong buoyancy. Hydroxypropyl methylcellulose (HPMC), especially the higher viscosity K-series, can form robust gels in gastric fluid, increasing floating time but potentially slowing drug release³. Conversely, HPMC E5 (a lower viscosity grade) was Demonstrated to achieve an optimal equilibrium between buoyancy and drug release. When appropriately formulated. An imbalanced ratio of sodium bicarbonate and HPMC may lead to rapid erosion rather than sustained buoyancy^{3,23}.

Formulation techniques

The method of preparation significantly affects the quality of effervescent formulations. Techniques such as wet granulation, dry granulation, direct compression, and 3D printing each offer distinct advantages and limitations based on formulation requirements.

Wet granulation involves using a liquid binder, which poses a risk of premature acid-base reactions if components are not adequately isolated. Proper mixing prior to granulation is critical to ensure uniform drug content and performance¹¹. Dry granulation avoids liquid solvents but requires good powder flow and compressibility. Direct compression is a straightforward manufacturing technique; however, it may be unsuitable for herbal extracts that exhibit poor flowability or elevated moisture content. The sieving stage during these processes is crucial, as uniform particle size improves drug content homogeneity and dissolution^{1,7,2}.

Advanced techniques like 3D printing facilitate spatial separation of reactive components, offering precise control over effervescence and tablet properties. However, inappropriate selection of acidic agents can adversely affect paste viscosity and moisture uptake¹⁰. Moreover, infill distance significantly impacts mechanical strength and disintegration, with a 1.0 mm spacing reported to yield an optimal balance between the two.

Pharmacokinetic advantages

Effervescent drug delivery systems provide several pharmacokinetic benefits over traditional oral solid dosage forms. One major advantage is the pre-dissolved state of the drug, which bypasses disintegration and promotes rapid absorption⁴. The effervescent reaction between acid and base, such as citric/tartaric acid and sodium bicarbonate, produces CO₂ that aids in rapid dispersion and solution clarity^{1,8}. This reaction enhances drug availability and contributes to quicker onset of therapeutic effects, particularly beneficial for drugs requiring rapid action¹⁰.

For poorly water-soluble drugs, wet granulation with hydrophilic binders like PVP facilitates better water penetration and enhances dissolution⁸. Moreover, combining effervescence with gastric-floating mechanisms can improve drug residence time in the stomach, which is particularly useful for drugs with localized gastric absorption^{3,23,28}.

Palatability is another key advantage of effervescent formulations. The fresh taste and ease of administration encourage patient adherence, especially for paediatric and geriatric populations².

Critical effervescent characterizations

Effervescence performance

Key performance indicators include onset time and duration of effervescence, which influence user experience and dosing reliability. Controlled CO₂ release ensures consistent dissolution without excessive foaming or gas loss.

pH stability and buffering

Maintaining an appropriate pH is essential for both API stability and bioavailability. The buffering capacity provided by components like citric acid and sodium bicarbonate ensures the pH remains within an acceptable range for absorption and drug integrity.

Wettability and dispersion

Efficient wetting and uniform dispersion prevent floating or sedimentation, especially in formulations containing poorly soluble APIs. These attributes are vital for dose uniformity and user acceptability.

Carbonation and sensory properties

Carbonation affects mouth feel and taste. While it can enhance palatability and mask bitterness, excessive foaming may lead to discomfort or dosage inconsistencies. A well-calibrated CO₂ level supports both compliance and therapeutic effectiveness.

Stability and moisture sensitivity

Effervescent formulations are highly prone to moisture. Packaging must protect against humidity-induced premature reactions. Desiccants foil blisters, and airtight containers are typically employed. Additionally, chemical stability post-dissolution must be ensured.

Gas pressure management

Managing gas pressure both inside packaging and during dissolution is critical. Excess internal pressure can compromise product integrity, while rapid CO₂ buildup during administration may cause gastrointestinal discomfort.

Conclusion and future perspectives

Effervescent formulations provide a promising platform for delivering herbal medicines, offering advantages in taste masking, absorption, and patient compliance. Formulations using herbal extracts such as Kelakai root, Kaempferia galanga, red ginger, green coffee, and elderberry vine have demonstrated satisfactory physical and antioxidant properties.

However, challenges remain. The complex nature of herbal constituents, bitter taste of phenolics and tannins, potential excipient interactions, and stability during manufacturing require ongoing optimization. Retaining biological activity post-effervescence is also critical.

Future directions should focus on advanced taste-masking strategies tailored for herbal flavour profiles, novel excipients to improve solubility and stability, and application of cutting-edge manufacturing like 3D printing to spatially separate acid-base components. Additionally, *in vivo* and clinical studies are needed to fully understand how effervescent formulations influence bioavailability and therapeutic outcomes.

Techniques like Design of Experiments (DOE) will continue to guide formulation optimization, enabling targeted improvements in disintegration, hardness, and sensory properties. With these developments, effervescent herbal products can become more effective, stable, and patient-friendly, supporting broader use in modern therapeutics.

Conflict of interest

Authors declare no conflict of interest between them.

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