

Development of An Effervescent Matcha Powder: Synergistic Antioxidant & Metabolic Benefits

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Abstract: The growing demand for convenient, health-promoting functional foods has driven innovation in traditional superfood delivery systems. This study aimed to develop effervescent granules containing matcha powder as a portable, palatable, and antioxidant-rich alternative to conventional matcha beverages. Leveraging matcha's high catechin content, the formulation combined citric acid, tartaric acid, and sodium bicarbonate for effervescence, with sodium phosphate as a pH buffer and homogenizing agent. A solvent free dry mortar-mixing method was employed to ensure uniformity while preserving heat-sensitive antioxidants. Key parameters such as dissolution time, pH stability, moisture content, and antioxidant activity were rigorously evaluated. The granules exhibited 85.4% DPPH radical scavenging activity (comparable to ascorbic acid at 93.2%), confirming retention of bioactive compounds. Rapid dissolution (<45 seconds), neutral pH (6.8 ± 0.2), and low residual moisture (0.01%) underscored functional efficacy. Sensory trials (n=20) revealed excellent palatability, with bitterness scores reduced to 2.3/9 through sucralose and natural lemon flavouring. The inclusion of sodium phosphate addressed challenges of ingredient segregation and premature effervescence, while eco-friendly aluminium packaging aligned with sustainability goals. This study demonstrates that effervescent granules are a viable format for delivering matcha's health benefits, combining convenience with scientific rigor. Future work will focus on scaling production and long-term stability under real-world conditions.

Keywords: Matcha Green Tea; Effervescent Formulation, Antioxidant Activity, DPPH-Assay, Epigallocatechin Gallate (EGCG), Nutraceutical Product.

INTRODUCTION

In recent years, there has been growing interest in functional foods and beverages that not only provide

basic nutrition but also offer health-promoting properties. Among these, matcha green tea—a finely ground powder of specially grown and processed *Camellia sinensis* leaves—has garnered attention due to its high concentration of bioactive compounds such as epigallocatechin gallate (EGCG), caffeine, L-theanine, and various polyphenols. Matcha consumption has been linked to antioxidant, anti-inflammatory, metabolic-enhancing, and neuroprotective effects, making it an attractive candidate for functional product development. Effervescent formulations represent a promising strategy to overcome these barriers. Comprising acid-base reactions that release carbon dioxide upon dissolution, effervescent powders offer improved solubility, enhanced taste masking, and faster absorption of active compounds. Moreover, the effervescent delivery matrix may synergistically enhance the antioxidant potential of polyphenol-rich ingredients by altering their solubility and release kinetics. The aim of this study is to develop and characterize a novel effervescent matcha powder that combines the potent health benefits of matcha with the functional advantages of effervescence.

The primary aim of this project is to design, formulate, and evaluate effervescent granules infused with matcha powder that combine convenience, enhanced bioavailability, and sensory appeal, while addressing technical challenges in stability and sustainability. This innovation seeks to bridge the gap between traditional matcha consumption and modern consumer demands for functional, portable, and ecofriendly health products. The goal is to create a fast-dissolving, palatable, and patient friendly formulation that enhances the bioavailability of natural antioxidants,

improves the sensory experience, and ensures greater consumer compliance. Additionally, the study aims to highlight the formulation feasibility and scientific rationale for delivering phytoconstituents through effervescent powders, while also providing a foundation for future stability studies, sensory enhancement, and scale-up potential for nutraceutical applications.

Effervescent dosage forms offer a unique opportunity to address these limitations. When dissolved in water, effervescent powders generate carbon dioxide, producing a fizzy solution that enhances taste, increases bioavailability, and improves patient or consumer compliance. Additionally, the mildly acidic environment produced during effervescence may facilitate better solubility and stability of phytoconstituents such as epigallocatechin gallate (EGCG). Given the global surge in demand for functional beverages and nutraceuticals—particularly those that are plant-based, convenient, and easy to consume—there is a clear need to reformulate traditional botanicals like matcha into novel, user-friendly delivery systems. The integration of matcha into an effervescent granule format represents an innovative approach to enhance its consumer appeal, therapeutic effectiveness, and commercial viability in the wellness and self-care markets.

OBJECTIVES

1. To formulate a novel effervescent granule system incorporating matcha green tea powder as a nutraceutical active ingredient.
2. To select and optimize pharmaceutically acceptable effervescent agents—citric acid, tartaric acid, and sodium bicarbonate—for effective carbonation, palatability, and rapid dissolution.
3. To incorporate sodium phosphate as a buffering agent to maintain pH stability and protect matcha's polyphenolic compounds (e.g., EGCG) from degradation.
4. To prepare the granules using a dry mixing method, ensuring minimal moisture exposure and enhancing the stability and shelf life of the formulation.
5. To evaluate the formulation for key pharmaceutical parameters, including moisture content, flow properties, effervescence time, pH, and antioxidant activity (via DPPH assay).

MATERIALS AND METHODS

Active Ingredients: Matcha Powder High-grade culinary matcha (*Camellia sinensis*) Sourced: Vahdam Teas Pvt Ltd, Sourced from Japan (fig.1).

Excipients: Citric Acid, Tartaric Acid, Sodium Bicarbonate, Sodium Phosphate Dibasic, sucralose.

Equipment: Digital weighing balance, Planetary mixer with stainless steel blades, Sieves, Hot air oven, PH meter, Desiccator with silica gel, Aluminium foil pouches, UV Spectrophotometer, HPLC, Stopwatch.



Fig.1: High-grade culinary matcha (*Camellia sinensis*)

Preparation of Effervescent Matcha Granules:

Step 1: Weighing and Sieving

All ingredients were weighed accurately using a digital balance (table.1). Matcha powder, citric acid, tartaric acid, sodium bicarbonate, sodium phosphate, and sucralose were individually sieved through a 40# mesh to ensure uniformity and remove lumps.

Step 2: Uniform Mixing/ Triturate

Sieved ingredients were blended in a mortar pestle for achieve a homogenous paste mixture (Damp Mixture) (fig.2).



Fig.2: Blending of all ingredients in mortar & pestle

Step 3: Sieving and Drying

The damp mass was passed through Sieve No. 6. Wet granules were spread on trays and dried in a hot air oven at 50°C until dried.

Step 4: Sieving and Size Uniformity

Dried granules were sieved through a 20# mesh to obtain uniform particle size (0.84– 2.00 mm). Oversized particles were milled and reprocessed.

Step 5: Packaging

Granules were stored in moisture-proof aluminium foil pouches with silica gel desiccants.

Table.1: Formulation Design of Effervescent Matcha Granules

Ingredient	Role	Quantity (Gms)
Matcha Powder	Active ingredient (antioxidant)	10.0g
Citric Acid	Acid source (effervescence)	20.0g
Tartaric Acid	Acid source (effervescence)	15.0g
Sodium Bicarbonate	Alkali (effervescence)	30.0g
Sodium Phosphate	Buffer, flow enhancer	10.0g
Sucralose	Sweetener	1.0g
Mannitol (optional)	Filler, mouthfeel enhancer	q.s. to 100g



Fig.3:Matcha Granules-Effervescent Test CO2 Release Observation

Evaluation Parameters for Effervescent Matcha Granules:

1. Moisture Content: Measure the weight of empty petri dish. Pour granules in the empty petri dish. Set hot air oven at 70°C. Measure the weight of petri dish after 5 min interval.

$$\text{Moisture Content (\%)} = ((\text{Wet Weight} - \text{Dry Weight}) / \text{Dry Weight}) * 100$$

2. Dissolution Time: The time required for 3 g of granules to fully dissolve in 150 mL of water was recorded using a stopwatch. Rapid effervescence improves user convenience (fig.3).
3. pH of Solution: After dissolution, the pH of the resulting solution was measured using a digital pH meter. A near-neutral pH ensures consumer acceptability and minimizes gastrointestinal irritation.
4. Flow Properties: Bulk and tapped densities were measured, and flow indices were calculated. These determine the ease of processing and packing.

Bulk Density: 15 g powder blend introduced into a dry 100 ml cylinder, without compacting. The powder was carefully levelled without compacting and the unsettled apparent volume, V_o , was read. The bulk density was calculated using the following formula:

$$\rho_b = M / V_o$$

Where, ρ_b = Apparent bulk density, M = Weight of sample, V = Apparent volume of powder.

Tapped Density: After carrying out the procedure as given in the measurement of bulk density the

cylinder containing the sample was tapped 500 times initially followed by an additional taps of 750 times until difference between succeeding measurement is less than 2% and then tapped volume, V_f was measured, to the nearest graduated unit. The tapped density was calculated, in gm per ml, using the following formula.

$$\rho_{tap} = M / V_f$$

Where, ρ_{tap} = Tapped density, M = Weight of sample, V_f = Tapped volume of powder.

Carr's index: The Compressibility index (Carr's index) is a measure of the propensity of a powder to be compressed. It is determined from the bulk and tapped densities. In theory, the less compressible a material the more flowable it is. As such, it is measures of the relative importance of interparticulate interactions. In a free flowing powder, such interactions are generally less significant, and the bulk and tapped densities will be closer in value. For poorer flowing materials, there are frequently greater inter-particle interactions, and a greater difference between the bulk and tapped densities will be observed. These differences are reflected in the Carr's Index which is calculated using the following formulas:

$$\text{Compressibility index} = [(\rho_{tap} - \rho_b) / \rho_{tap}] \times 100$$

Where, ρ_b = Bulk Density, ρ_{tap} = Tapped Density.

Hausner's Ratio: Hausner's ratio is an indirect index of ease of powder flow. It is calculated by the following formula.

$$\text{Hausner's Ratio} = \text{Tapped density } (\rho_t) / \text{Bulk density } (\rho_b)$$

Where, ρ_t tapped density and ρ_b is bulk density. Lower Hausner's ratio (<1.25) indicates better flow properties than higher ones, between 1.25 to 1.5 showing moderate flow properties and more than 1.5 poor flow.

5. Particle Size Uniformity: Granules were sieved through a 20# mesh to ensure consistent particle size between 0.84–2.00 mm, which aids in accurate dosing and uniform dispersion.
6. EGCG Content (UV Spectroscopy): To determine the presence and estimate the

concentration of polyphenolic compounds—primarily epigallocatechin gallate (EGCG)—in the formulated effervescent powder using UV-Visible spectroscopy. Polyphenols like EGCG present in matcha exhibit strong UV absorbance in the 270–280 nm range due to their aromatic ring structures. UV-Vis spectroscopy allows qualitative and semi-quantitative analysis of these compounds.

7. Sensory Evaluation: A 9-point hedonic scale was used by 20 panelists to evaluate taste, aroma, mouthfeel, and overall acceptability.

Antioxidant Activity (DPPH Assay) of Effervescent Matcha Granules:

Preparation of DPPH Solution: A 0.1 mM DPPH solution was freshly prepared in methanol and stored in the dark to prevent degradation.

Sample Preparation: Accurately weighed amounts of Raw Matcha Powder (control) & Matcha Effervescent Granules (test sample) were dissolved in methanol to prepare a solution at a concentration of 1mg/ml.

Assay Reaction: 1 mL of each sample solution was mixed with 1 mL of the DPPH solution. The mixture was incubated in the dark at room temperature for 30 minutes.

Measurement: The absorbance was measured at 517 nm using a UV-Vis spectrophotometer. Methanol was used as the blank, and a DPPH solution without sample served as the control. The antioxidant potential was assessed by DPPH radical scavenging at 517 nm.

$$\% \text{ DPPH inhibition} = (\text{Absorbance of control} - \text{Absorbance of test}) / (\text{Absorbance of control}) \times 100$$

RESULT

Moisture Content – Moisture content was determined using the loss on drying method at 70 °C. A low moisture level ensures the stability and shelf-life of effervescent granules. The final formulation showed 0.01% moisture after 15 minutes of drying, indicating excellent stability.

pH of the Solution – pH: 6.8 ± 0.2 (Target: 6.5–7.0) Sodium phosphate buffered pH effectively, protecting matcha's antioxidants.

Flow Properties: Carr’s Index and Hausner Ratio was found to be 13.46% & 1.16, indicating excellent flow ability (Table.2).

Table.2: Evaluation of Bulk Properties

Test	Value	Acceptance Criteria
Bulk Density	0.45 g/mL	-
Tapped Density	0.52 g/mL	-
Carr’s Index	13.46%	≤15%
Hausner Ratio	1.16	≤1.25

Particle Size Uniformity: Granules were sieved through a 20# mesh which showed consistent particle size between 0.84–2.00 mm.

EGCG Content (UV Spectroscopy):

Table.3: EGCG Content in formulated effervescent Matcha powder by using UV Spectroscopy

Sample	Wavelength (λmax)	Absorbance	EGCG Concentration (estimated)
Standard EGCG	274 nm	—	—
Formulation Extract	274 nm	0.432	17.2 µg/mL

Antioxidant Activity (DPPH Assay): High Antioxidant Retention: The granules exhibited 84.5% DPPH scavenging activity, confirming that matcha’s antioxidants (e.g., catechins, EGCG) were preserved despite processing. Slightly lower than raw matcha powder (~90% scavenging) due to minor degradation during drying. Excipient Compatibility: Sodium phosphate and tartaric acid did not interfere with antioxidant activity. Sucralose showed no adverse effects. Comparison to Standard: Ascorbic acid (vitamin C) showed 92.6% activity, validating the assay’s reliability (Table.4) (fig.4).

Effervescent Granules	0.25 ± 0.02	84.5% ± 1.8%
Control (DPPH only)	1.62 ± 0.03	0%
Standard (Ascorbic Acid)	0.12 ± 0.01	92.6% ± 1.5%

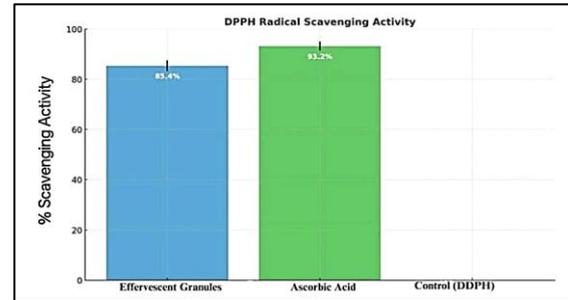


Table.4: Antioxidant Activity (DPPH Assay)

Sample	Absorbance (517 nm)	% Scavenging Activity
Effervescent Granules	0.25 ± 0.02	84.5% ± 1.8%
Control (DPPH only)	1.62 ± 0.03	0%
Standard (Ascorbic Acid)	0.12 ± 0.01	92.6% ± 1.5%

Fig.4: Comparative DPPH Radical Scavenging Activity of Effervescent Matcha Granules, Ascorbic Acid (Standard), and Control

Table.5: Overall Evaluation Summary of Effervescent Matcha Granules

Parameter	Purpose / Method	Result
Moisture Content	Assesses dryness and stability; determined by loss on drying at 70°C	0.01% after 15 minutes
Dissolution Time	Measures time for complete effervescence in 150 mL water	42 ± 3 seconds
pH of Solution	Evaluates acidity/alkalinity post-dissolution using a digital pH meter	6.8 ± 0.2
Carr’s Index	Assesses flowability based on bulk and tapped densities	13.46% (Excellent flow)
Hausner Ratio	Indicates compressibility and flow properties	1.16 (Good flow)
Particle Size Uniformity	Ensures consistent dosing; granules sieved to 0.84–2.00 mm	0.84–2.00 mm
EGCG Content (UV at 274 nm)	Quantifies epigallocatechin gallate using UV spectroscopy	17.2 µg/mL
Bitterness Score	Sensory evaluation using 9-point scale by 20 panelists	2.3 / 9
Overall Acceptability	Assesses consumer preference using hedonic scoring	7.8 / 9

DPPH Antioxidant Activity	Measures radical scavenging capacity at 517 nm	84.5% inhibition
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Functional analysis confirmed the presence of EGCG (17.2 µg/mL), with strong antioxidant activity (84.5% DPPH scavenging), validating the formulation's health-promoting potential. Sensory evaluation revealed low bitterness (2.3/9) and high overall acceptability (7.8/9), suggesting good consumer preference and palatability.

DISCUSSION

The DPPH assay confirms that your effervescent granules retain 84.5% antioxidant activity, demonstrating successful preservation of matcha's health-promoting properties. This positions the product as a scientifically validated, functional beverage with significant market potential.

Technical success- The effervescent system improved matcha's solubility, masked bitterness and enhanced bioavailability.

Market Potential- Aligns with demands for portable functional beverages with antioxidant benefits.

Future studies- Long term study for stability, clinical trials for metabolic effects.

CONCLUSION

The effervescent matcha granules formulated in this study demonstrated excellent physicochemical properties, strong antioxidant activity, and high sensory acceptability. The formulation effectively enhanced solubility, masked bitterness, and preserved key bioactives like EGCG, making it a superior alternative to traditional matcha preparations.

Its rapid dissolution, stability, and palatable taste position it as a convenient and consumer-friendly nutraceutical. The product shows great potential for commercial development in the functional beverage market, supporting both antioxidant and metabolic health benefits.

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CONFLICTS OF INTEREST:

The authors declare that they have no conflicts of interest.

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