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Formulation and quality evaluation of Tamarind (*Tamarindus indica* L.) based effervescent beverage powder

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Abstract
The study aimed to standardise an effervescent drink powder based on tamarind (*Tamarindus indica L.*) prepared from cabinet-dried tamarind pulp powder and to evaluate its sensory and physicochemical properties. The formulation containing 60 per cent tamarind pulp powder and 20 per cent sugar was found to be highly acceptable based on sensory evaluation. The developed beverage powder exhibited high solubility along with acceptable particle size, bulk density, and hygroscopicity. The pH of the formulation was found to be optimal for effervescence upon reconstitution with water. The product was nutritionally balanced, providing an energy value of 60 kcal per serving. The development of a low-cost, nutritious, and acceptable effervescent beverage powder from cabinet-dried tamarind pulp highlights a promising opportunity for value addition in the fruit processing industry. The study demonstrates that cabinet drying can be effectively utilized for producing fruit powders with high solubility when appropriate drying aids are used. Furthermore, tamarind-based effervescent beverage powder shows significant potential for commercial exploitation.

Keywords: Tamarind, pulp powder, cabinet drying, effervescent powder, sensory quality

Introduction
Tamarind (*Tamarindus indica* L.), a member of the Leguminosae family, is a multipurpose tropical fruit widely cultivated across Asia, Latin America, and the Caribbean (El-Siddig *et al.*, 2006) [14]. The pulp is valued for its rich composition of bioactive compounds such as tartaric acid, polyphenols, flavonoids, vitamins, and essential minerals, which contribute to its antioxidant, anti-inflammatory, and antimicrobial properties (Martinello *et al.*, 2006; Siddhuraju 2007; Havinga *et al.*, 2010) [18, 23, 36]. Despite its nutritional and functional potential, the utilisation of tamarind in value added functional food products remains limited compared to other tropical fruits.

The growing demand for functional beverages has led to increased interest in convenient and shelf-stable formats such as effervescent powders, which offer advantages including extended shelf life, ease of transportation, and rapid reconstitution (Oikonomopoulou *et al.*, 2011) [29]. Tamarind pulp, due to its high natural tartaric acid content, is particularly suitable for such applications, as it can enhance effervescence while contributing beneficial phytochemicals.

Drying plays a critical role in the production of fruit powders by reducing moisture content and improving storage stability. However, the choice of drying method significantly affects the retention of bioactive compounds and the functional properties of the powder (Ratti, 2001; Caparino *et al.*, 2012) [10, 33]. Cabinet drying offers a cost effective alternative for preserving colour and flavour of fruits due to controlled temperatures (Chegini and Ghobadian, 2005; Harish *et al.*, 2025) [11, 17].

Materials and methods
Collection of raw materials
Tamarind required for the study was procured from the fruit orchard of Department of Fruit Science, College of Agriculture, and Vellanikkara. The other ingredients needed for study were purchased from the local market.

Extraction of tamarind pulp
Mature tamarind fruits were deshelled, deseeded and soaked in hot water (50-60 °C) in a ratio of 1:2 for four hours to obtain maximum extraction of pulp from the fruit. The mixture was then homogenised and filtered through cheese cloth to obtain fine pulp (Pattar *et al.*, 2013) [4].

Preparation of tamarind pulp powder by cabinet drying
Tamarind pulp was dried in a cabinet dryer following the method of Manasa *et al.* (2018) [22] with slight modifications. Drying agent maltodextrin at 50% was added to tamarind pulp and the mixture was dried at 80 °C for 22 hours for better powder recovery.

Standardisation of tamarind fruit based effervescent beverage powder
The tamarind fruit based effervescent beverage powder was formulated by blending tamarind pulp powder with sugar at different levels, as detailed in Table 1. In all formulations

citric acid (10%) and sodium bicarbonate (10%) were used as effervescent agents, and gum arabic (0.2%) was added as the stabiliser. The prepared powders were packed in laminated aluminium pouches and assessed for their sensory properties to select the most acceptable combination.

Table 1: Treatments for standardisation of tamarind based effervescent beverage powder

Sl. No	Treatments	Combination
1	T_1	TPP 50 % + Sugar 30%
2	T_2	TPP 55% + Sugar 25%
3	T_3	TPP 60% + Sugar 20%
4	T_4	TPP 65% + Sugar 15%

(TPP- Tamarind pulp powder)

Organoleptic evaluation

The organoleptic evaluation of effervescent beverage powder was carried by mixing 10g of effervescent powder in 100 mL of chilled water. The score card of nine-point hedonic scale was used for evaluation with a panel of 20 judges. The sensory parameters such as appearance, colour, flavour, consistency, taste and overall acceptability were analysed. Based on the organoleptic qualities best treatment was selected for further studies.

Physicochemical qualities

The physicochemical qualities of the selected effervescent beverage powder such as particle size, bulk density, solubility, moisture, hygroscopicity, pH, titrable acidity, total sugar, total carbohydrate, protein, fat and energy were determined.

Particle size

The mean particle size of the samples was measured using a commercial dynamic light scattering instrument (Zetasizer Nano-ZS, Malvern Instruments, and Worcestershire, UK). The results were expressed as the surface volume mean particle diameter.

Bulk density

For determination of bulk density, the sample was poured from a height of 20 cm into a 50 mL beaker and levelled without applying pressure. The weight of the sample was recorded, after which it was removed and the beaker was filled with water to the same level. The weight of the beaker containing water was then measured, and density was calculated using the formula described by Okaka and Potter (1977) [30].

Solubility

The solubility of tamarind effervescent powders was determined using the Water Solubility Index (WSI) method as described by Anderson *et al.* (1969) [2]. A 2.5 g sample of powder was weighed and transferred into a 50 mL centrifuge tube, followed by the addition of 30 mL of distilled water. The mixture was stirred continuously for 30 minutes at room temperature to ensure complete dispersion. It was then centrifuged at 3000 rpm for 10 minutes, and the supernatant was carefully decanted into a pre-weighed evaporating dish. The collected supernatant was dried in a hot air oven at 105 °C until a constant weight was achieved, and the weight of the dried residue was recorded.

The WSI was calculated using the following formula:

$$\text{WSI (\%)} = \frac{\text{Weight of dissolved solids in supernatant}}{\text{Weight of dry sample}} \times 100$$

Moisture

The moisture content was determined using the AOAC (2023) method. Approximately 5 g of the sample was weighed into a petridish and dried in a hot air oven at 60–70°C. The sample was then cooled in a desiccator and weighed. This process of heating, cooling, and weighing was repeated until a constant weight was obtained. The moisture content was calculated based on the loss in weight during drying and expressed as a percentage.

$$\text{Moisture content (\%)} = \frac{\text{(Initial weight) - (Final weight)}}{\text{Weight of the sample}} \times 100$$

Hygroscopicity

The hygroscopicity of tamarind effervescent beverage powders was determined following the method described by Tonon *et al.* (2008) [38]. Approximately 2 g of the powder sample was placed in a desiccator maintained at room temperature (25°C) with a saturated sodium chloride solution providing 75.29% relative humidity. The samples were weighed after one week, and hygroscopicity was expressed as grams of moisture absorbed per 100 g of dry solids.

pH

The digital pH meter was calibrated against standard buffer solutions. The samples were mixed well to homogenise and the pH values were measured using the calibrated pH meter.

Acidity

The titratable acidity of tamarind pulp powders was determined following the AOAC (2023) method. Approximately 10 g of the sample was mixed with 50 mL of distilled water and titrated against 0.1 N NaOH using phenolphthalein as an indicator. The endpoint was indicated by the appearance of a persistent pale pink colour. The results were expressed as percentage of tartaric acid.

Total sugars

The total sugar content was estimated using the method described by Ranganna (2014) [32]. A 25 g sample was mixed with 100 mL of distilled water in a conical flask and neutralised using 1 N sodium hydroxide with phenolphthalein as an indicator. The neutralised solution was clarified by adding 2 mL of lead acetate. From the clarified extract, 50 mL was taken, treated with citric acid and water, and gently boiled. The solution was then re-neutralised with sodium hydroxide and the volume was made up to 250 mL. An aliquot of this solution was titrated against Fehling's solutions A and B. The total sugar content was calculated and expressed as a percentage.

$$\text{Total sugars (\%)} = \frac{\text{Fehling's factor x 250 x dilution}}{\text{Titre value x 50x weight of the sample}} \times 100$$

Total carbohydrate

The carbohydrate content was determined using the anthrone colorimetric method as described by Sadasivam and Manickam (2023) [34]. Approximately 0.1 g of pulp powder was hydrolysed with 5 mL of 2.5 N HCl. After cooling, the hydrolysate was neutralised with solid sodium carbonate, and the volume was made up to 100 mL in a standard flask, followed by centrifugation. An aliquot of 0.1 mL of the supernatant was taken, diluted with 1 mL of distilled water, and mixed with 4 mL of anthrone reagent. The mixture was heated for 8 minutes, then cooled, and the developed green to dark green color was measured at 630 nm using a spectrophotometer.

A standard calibration curve was prepared using serial dilutions of glucose, and the total carbohydrate content of the sample was calculated from the curve and expressed as a percentage.

Protein

The protein content was determined using the AOAC (2023) method. A 0.2 g sample was digested with 6 mL of concentrated H_2SO_4 in the presence of 0.4 g $CuSO_4$ and 3.5 g K_2SO_4 in a digestion flask until the solution turned green, indicating complete digestion. The digest was then diluted with water, followed by the addition of 25 mL of 40% NaOH. The released ammonia was distilled and absorbed in a 2% boric acid solution containing mixed indicators. The collected distillate was titrated against 0.2 N HCl to determine the nitrogen content. The crude protein content was calculated by multiplying the nitrogen value by a conversion factor of 6.25.

Fat

The fat content was estimated using the modified batch solvent extraction method described by Sadasivam and Manickam (2023) [34]. One gram of sample was mixed with 20 mL of hexane in a separating funnel and shaken vigorously to facilitate the extraction of fat into the organic solvent. The aqueous phase was then discarded. The solvent was subsequently evaporated, and the remaining fat residue was weighed to determine the fat content.

Energy

The gross energy content of tamarind pulp powders was calculated based on the amounts of total carbohydrate, protein, and fat present in the samples. The values of carbohydrate, protein, and fat per 100 g of product were multiplied by conversion factors of 4, 4, and 9, respectively, to estimate the energy contribution from each component. These values were then summed to obtain the total energy content, which was expressed in kilocalories (kcal).

$$\text{Energy (Kcal)} = (\text{Carbohydrate} \times 4) + (\text{Protein} \times 4) + (\text{Fat} \times 9)$$

Statistical analysis

The data on the physicochemical attributes of tamarind based effervescent beverage powders were statistically analysed using standard deviation. The results of the organoleptic evaluation were assessed using Kendall's coefficient of concordance (W).

Results and Discussion

The organoleptic scores of reconstituted tamarind effervescent beverages are summarised in Table 2. The Kendall coefficient of concordance (W) ranged from 0.706 to 0.865 across all attributes, indicating a high degree of agreement among panellists and confirming the reliability and internal consistency of the sensory data. Among the four formulations, Treatment T_3 (60% CDP+20% sugar+10% citric acid and 10% sodium bicarbonate) attained the highest score across all organoleptic parameters with highest total mean score of 8.66.

The mean appearance scores of the four formulations ranged from 7.75 (T_2) to 8.85 (T_3). Treatment T_3, containing 60% tamarind pulp powder, received the highest appearance score of 8.85, followed by T_4 (8.10), T_1 (7.80), and T_2 (7.75). The superior appearance of T_3 may be attributed to the optimal level of tamarind pulp powder, which contributed to a uniform, well structured powder with visually characteristic attributes of tamarind. Tamarind pulp acquires a characteristic brown to reddish-brown coloration upon maturity, and this natural pigmentation, when present in a balanced proportion, contributes to an attractive and consistent appearance in the reconstituted beverage (Adeola and Aworh, 2014) [1].

The colour scores for the four formulations ranged between 7.48 (T_1) and 8.48 (T_3). Treatment T_3 recorded the highest colour score (8.48), followed by T_4 (8.06), T_2 (7.53), and T_1 (7.48). The characteristic reddish-brown colour imparted by tamarind pulp is primarily attributable to its polyphenolic pigments, tartaric acid content, and the Maillard-type browning reactions occurring during powder processing (Tumpa *et al.*, 2021) [39].

Maximum score for flavour, consistency and taste was recorded for T_3. Indicating a well-balanced and pleasant characteristic tamarind flavour and taste. At 60% pulp concentration, T_3 maintained the characteristic sweet-sour tamarind flavour at an intensity that was neither too mild, nor overpowering. Similar findings were noted by Naji-Tabasi *et al.* (2021) [28] where effervescent beverage tablets formulated with 60% barberry juice powder attained the highest sensory scores. Minh (2022) [24] developed effervescent tablets with 65% jambolan pulp powder with highest overall acceptability of 8.81. Kei *et al.* (2026) [20] prepared effervescent tablets from pineapple juice powder of 50%.

The addition of effervescent agent's mainly citric acid imparted the desirable flavour to the powder. Lambros *et al.* (2022) [21] reported that citric acid is most widely used in effervescent formulations because it imparts a pleasant citrus-type flavour and acts as a flavour enhancer. Furthermore, the effervescent reaction between citric acid and sodium bicarbonate upon dissolution generates carbon dioxide, which is known to enhance flavour release and improve aroma perception (Delompré *et al.*, 2025) [13].

Table 2: Mean scores for organoleptic qualities of tamarind based effervescent beverage powders

Treatments	Appearance	Colour	Flavour	Consistency	Taste	Overall acceptability	Total mean score
T_1	7.80 (1.48)	7.48 (3.30)	7.41 (1.38)	7.26 (1.14)	7.26 (1.10)	7.40 (1.40)	7.43
T_2	7.75 (1.10)	7.53 (1.10)	7.76 (1.10)	7.42 (1.10)	7.53 (1.15)	7.71 (1.43)	7.61
T_3	8.85 (3.60)	8.48 (3.40)	8.78 (3.53)	8.52 (3.40)	8.88 (3.75)	8.46 (3.55)	8.66
T_4	8.10 (3.20)	8.06 (3.10)	7.56 (1.14)	7.46 (1.40)	7.02 (1.10)	7.22 (1.14)	7.57
Kendall's W	0.827^{**}	0.715^{**}	0.786^{**}	0.715^{**}	0.865^{**}	0.706^{**}	-

Gum arabic, incorporated uniformly at 0.2% across all formulations as a stabiliser, contributed significantly to the consistency of the reconstituted beverage. Gum arabic is a natural hydrocolloid with excellent solubility, acid stability across a pH range of 2 to 10, and well-established emulsifying and suspension properties that prevent sedimentation and maintain a smooth, stable product consistency (Bhusari *et al.*, 2014) [7].

The superior taste performance of T_3 reflects the optimal sweet-sour balance achieved through the combination of 60% tamarind pulp powder and 20% sugar, complemented by 10% each of citric acid and sodium bicarbonate. The optimal formulation of effervescent powder prepared from *Solanum betaceum* consisted of lyophilised fruit (30%), along with maltodextrin (22.8%), citric acid (20%), sucrose (15%), sodium carbonate (12%), and tricalcium phosphate (0.2%) (Arevalo *et al.*, 2021).

Soluble sugars and organic acids are among the most critical taste-active molecules in fruit-based products, as they are directly responsible for the sweet, sour, and harmonious flavour sensations (Fabela-Morón, 2024) [15]. The highest acceptability score was noted in T_3, reflecting an optimal balance between the sourness of tamarind organic acids and the sweetness imparted by sugar, which together create the characteristic sweet-sour profile expected for a tamarind based beverage.

Physicochemical properties of tamarind based effervescent beverage powder

The physicochemical properties of tamarind based effervescent beverage powder were given in Table 3.

Table 3: Physicochemical properties of tamarind based effervescent beverage powder

Parameters	Mean ± SD
Particle size (µm)	320.4 ± 1.15
Bulk density (g/cm^3)	0.42 ± 0.02
Solubility (%)	89.8 ± 1.05
Moisture (%)	5.82 ± 0.15
Hygroscopicity (%)	24.2 ± 0.50
pH	2.4 ± 0.65
Acidity (%)	8.62 ± 0.16
Total sugars (%)	60.3 ±0.75
Total carbohydrate (%)	74.0 ±0.95
Protein (%)	0.89 ±0.02
Fat (%)	0.39 ± 0.02
Energy (Kcal/100g)	303.1 ± 1.21

The tamarind based effervescent beverage powder exhibited a mean particle size of 320.4 ± 1.15 µm. Aslani and Fattahi (2013) [6] reported mean particle size diameters ranging from 299.54 to 392.79 µm for effervescent powder formulations containing citric acid and sodium bicarbonate prepared by the direct compression method, which is in close agreement with the findings of the present study.

The bulk density of tamarind effervescent powders was found to be 0.42 ± 0.02 g/cm^3. Naji-Tabasi *et al.* (2021) [28] reported bulk density values for spray dried barberry juice powder effervescent tablets in the range of 0.29-0.32g/cm^3, which is comparable to the findings of the present study considering differences in composition. Similar results were found for tray dried banana powder. The bulk density of tray dried banana powder was 0.57 ± 0.06 g/cm^3 (Kabeer *et al.*, 2023). Mundhe *et al.* (2023) [19, 25] reported the bulk density of Ghol leaf powder prepared from cabinet drying method as 0.52 g/cm^3.

The solubility of the effervescent powder was found to be 89.8 ± 1.05%, which indicates excellent reconstitution ability. Muzaffar *et al.* (2017) [27] reported a solubility of 71.95% for spray dried tamarind pulp powder, which is considerably lower than the value obtained in the present study. The significantly higher solubility of 89.8% in the present formulation can be attributed to the effervescent action of citric acid and sodium bicarbonate, which upon contact with water produces carbon dioxide (CO_2), that accelerates powder disintegration and dissolution. This is consistent with the findings of Saifullah *et al.* (2016) [35], who demonstrated that dissolution rates of fruit powder tablets containing effervescent agents were significantly higher than those without effervescent agents in both water and simulated saliva fluid. The solubility of barberry juice powder effervescent tablets is ranged from 92.65% to 97.99% (Naji-Tabasi *et al.*, 2021) [28].

The Moisture content of effervescent beverage powder was found to be 5.82 ± 0.15, which is in agreement with the study conducted by Bisht (2022) [8], tamarind based effervescent tablets have moisture content of 6.07%. Poovai *et al.* (2023) [31] reported moisture content of fig fruit powder as 6.65 per cent. Harish *et al.* (2025) [17] reported the moisture content of dragon fruit powder prepared from cabinet drying as 4.47 % which is slightly lower than the present study. The higher moisture content of tamarind effervescent powder might be due to the high hygroscopic nature of tamarind pulp.

The hygroscopicity of the effervescent powder was 24.2 ± 0.50%, indicating a moderate tendency to absorb atmospheric moisture. According to the classification proposed by CAI and Corke (2000) [9], powders with hygroscopicity values between 20–25% are considered moderately hygroscopic. The moderate hygroscopicity may be attributed to the presence of organic acids (particularly tartaric acid) and sugars in tamarind, along with the effervescent salts. Similar hygroscopicity values (21–27%) have been reported for tamarind fruit powder (Muzaffar and Kumar, 2016) [26].

The pH of effervescent powder was 2.4 ± 0.65, and the titratable acidity was 8.62 ± 0.16%. The low pH is characteristic of tamarind based products, which are naturally rich in tartaric acid (Hamacek *et al.*, 2013[16]). Sulieman *et al.* (2015) [37] documented pH values as low as 2.14 for raw tamarind pulp, corroborating the acidic nature of tamarind based products. The high titratable acidity of 8.62% reflects the combined contribution of tamarind's natural organic acids and the citric acid added as part of the effervescent system. De Caluwe *et al.* (2010) [12] reported titratable acidity values of 7.5–10% for tamarind pulp products, consistent with the present findings.

The total sugar content was 60.3 ± 0.75% and the total carbohydrate content was 74.0 ± 0.95%. The high sugar and carbohydrate content was due to the addition of maltodextrin for preparation of tamarind pulp powder and addition of sugar in formulation of effervescent powder. The total carbohydrate content of 74.0% reflects the energy dense nature of the product and aligns with values reported by Saifullah *et al.* (2016) [35], the carbohydrate content of effervescent tablets of Pitaya powder, Pineapple powder, Mango powder and Guava powder is found to be 83.50 ± 0.15%, 88.10 ± 0.16%, 87.00 ± 0.09% and 79.50 ± 0.2%

respectively. Kabeer *et al.* (2023) [19] reported the carbohydrate content of banana powder made from cabinet drying method is 62.63% attributed due to the addition of maltodextrin.

The protein content was 0.89 ± 0.02% and fat content was 0.39 ± 0.02%, both of which are relatively low values expected in a fruit pulp-based powder. Tamarind is not a significant source of protein or fat. However, trace amounts contribute to the nutritional profile of the product. El-Siddig *et al.* (2006) [14] reported protein values of 0.8–1.2% and fat values of 0.2–0.6% in dried tamarind pulp, which correspond well with the present findings.

The energy content of the effervescent powder was 303.1 ± 1.21 Kcal/100g. This value reflects the significant contribution of carbohydrates and, to a lesser extent, proteins and fats to the overall energy density of the product.

Conclusion

The study successfully formulated an effervescent beverage powder using cabinet dried tamarind pulp powder (60%), combined with sugar (20%), citric acid (10%), and sodium bicarbonate (10%), which was identified as the most acceptable formulation. The product demonstrated a good balance of acidity and pH, while its moisture content and hygroscopicity remained within desirable limits. In addition, the particle size distribution contributed positively to improved solubility and bulk density of the powder.

The tamarind based effervescent beverage powder was found to be rich in carbohydrates and energy, making it an energy dense and refreshing drink option. Overall, the developed product showed favourable physicochemical and sensory properties, resulting in a nutritious, low fat, palatable, and functional beverage with strong potential for consumer acceptance and commercial application.

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