

Development of Pineapple Effervescent Beverage Powder with the Application of Foam-mat Drying Method

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ABSTRACT

Pineapple (*Ananas comosus*) – Jospine variety is a fruit-bearing plant and rich in nutrients that confer various benefits to the human body. However, its consumption is comparatively lower than that of other fruits due to the tingling effect or burning sensation in the mouth produced by the bromelain enzyme. Therefore, this study aimed to formulate pineapple effervescent beverage prepared from foam-mat dried pineapple powder and evaluate its physical properties, sensory acceptance, and ascorbic acid content in comparison with a commercial spray-dried pineapple effervescent beverage powder (CSPEBP) as control. Five formulations were developed by using simplex lattice mixture design (SLMD) with varying amounts of effervescent agents (citric acid and sodium bicarbonate). Formulations 1, 2, and 3 had acceptable effervescence times of 1 to 2 minutes and maintained a pH range of 5 to 7. The optimised formulated pineapple effervescent beverage powder (OFPEBP) comprised 19% citric acid and 21% sodium bicarbonate and demonstrated optimal effervescent time (1.57 min) and pH (5.17). Both OFPEBP and CSPEBP displayed medium density and excellent flow properties. Sensory evaluation revealed that panellists were able to accept OFPEBP except for the

aroma attribute due to the use of egg albumen as foaming agent ($p > 0.05$). OFPEBP also had an adequate amount of ascorbic acid content of 1.61 mg/100 mL, comparable with CSPEBP (1.32 g/100 mL). To conclude, OFPEBP prepared using foam-mat dried pineapple juice powder has a high potential to be commercialised in beverage and nutraceutical industries.

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INTRODUCTION

Pineapple (*Ananas comosus*), a member of the Bromeliaceae family, is a tropical fruit of economic importance that is widely consumed for its distinctive flavour and abundant nutrients. It has a diverse array of vitamins (A, B1, B2, B3, B6, B9, C, D, E, and K), minerals (calcium, copper, iron, magnesium, manganese, phosphorus, potassium, sodium, selenium, and zinc), and also dietary fibres (Assumi et al., 2021). Pineapple offers a spectrum of health benefits, including having antioxidant, anticancer, and anti-inflammatory properties, promoting digestive health, supporting energy metabolism, and contributing to the proper functioning of the nervous system (Ali et al., 2020; Danielly & Katia, 2019; Ferreira et al., 2016; Nor et al., 2015; Williams et al., 2017). Pineapples are extensively grown with several varieties and one of these is the Jospine variety. This variety is known for its juiciness, high sugar content, tangy flavour and low acidity, which makes it well-suited for fresh consumption and juice manufacturing (Assumi et al., 2021).

However, despite its numerous health advantages and appealing taste, utilisation of pineapple is relatively low which may be attributed in part to its acidic and sour taste (Kumar et al., 2016). Some peoples may find the tingling or burning sensation in the mouth to be an unpleasant side effects due to the presence of the enzyme bromelain (Assumi et al., 2021). In addition, pineapple has a limited shelf life that usually lasts for only 3 to 6 days after ripening and this poses challenges during the postharvest period (Pizato et al., 2019). These factors have prompted the exploration of alternative methods for pineapple preservation and consumption. One of them is the application of foam-mat drying method for developing shelf-stable pineapple-based products. The pineapple juice is whipped with foaming agents and foam stabilisers to give it a stable foam, which is then dried and ground into powder form. Foam-mat drying is simpler, cheaper, and less time-consuming compared to other drying methods like spray-drying and freeze-drying, besides being able to preserve its nutritional content (Hardy et al., 2015; Shaari et al., 2017).

Moreover, effervescent beverage is commonly known as fizzy drink or carbonated drink due to the production of carbon dioxide gas (CO₂). The release of CO₂ can act as a buffer to balance the acid and alkali that imparts the characteristic of fizzing sensation which have led to the increase demand on consumer preference (Salbi et al., 2022). Nowadays, effervescent beverages are accessible in various forms such as tablets, powders, and sachets (Gillani et al., 2022). This research highlighted the development of pineapple effervescent beverage powder with the application of foam-mat drying method where the effervescent agents was incorporated and mixed with the foam-mat dried pineapple powder. This new development able to attain a good quality of powder, appealing sensory, and adequate amount of ascorbic acid content which was comparable to the commercial spray-dried pineapple effervescent beverage powder (CSPEBP). Hence, this study aims to optimise formulations of pineapple effervescent beverage powder (OFPEBP) prepared from foam-mat dried pineapple powder

that has optimal effervescent time and pH value which dictate its effervescent quality. Besides that, the physical properties, sensory acceptance, and ascorbic acid content of the powder (OFPEBP) were determined and compared with a CSPEBP.

MATERIALS AND METHODS

Materials

Ripe pineapples (*Ananas comosus*) with Josapine variety were procured from a local supplier in Pagoh, Muar, Johor. The pineapple maturity was chosen based on its uniformity of green-yellow shade and firm surface (Shaari et al., 2017). Eggs and stevia powder (Equal, Thailand) were acquired from a local market in Pagoh and Muar, Johor. Maltodextrin (BisChem, Malaysia), iodine (Avondale Laboratories, United Kingdom), and starch (Merck, Germany) were acquired from the UTHM laboratory. Citric acid (USP EP BP FCC, China) and sodium bicarbonate (DChemie, Johor) were purchased from Take It Global Sdn. Bhd. (Penang, Malaysia). Commercial spray-dried pineapple powder (K&W, Malaysia) was purchased from K&W Drinks Supply Sdn. Bhd. (Selangor, Malaysia).

Pineapple Effervescent Beverage from Foam-mat Dried Pineapple Juice Powder

Foam-mat Dried Pineapple Juice Powder Preparation

Pineapple powder was prepared following a modified method from a previous study conducted by Shaari et al. (2017). Ripe Josapine pineapples were washed, peeled, and cut into 1 cm³ pieces. These pieces were blanched for 1 minute at 95 °C to deactivate the enzyme. Pineapple juice was then extracted using a juice extractor (Philips, HR 1871, China), mixed with 20% egg albumen, and whipped for 10 minutes using a kitchen mixer (KitchenAid, Model 5KPM50, USA) at a speed of 8×. Maltodextrin (5%) was added to stabilise the foam and serve as an encapsulation coating. The resulting foam juice was dried in a smoke house (YuanChang Food Mechanism, ZXL-250, China) at 60 °C for 4 hours until the moisture content of the sample fell below 8% (wet basis). The product was then ground into powder using a blender (Panasonic, MX-V310, Malaysia), sieved through a 500 µm mesh sieve (sieve no. 35, Test Sieve, ISO 3310-1, Germany) for uniformity, and stored in airtight containers at room temperature (23 to 25 °C) in a desiccator for further processing.

Formulation and Preparation of Pineapple Effervescent Beverage Powder

Simplex lattice mixture design (SLMD) in Design Expert software (Version 13.0.14, State Ease, Inc., Minneapolis, USA) was used to systematically express the influence of each factor on the response by generating response surface plots (Patel & Siddaiah, 2018). Five formulations were prepared with varying percentages of effervescent agents (citric acid and

sodium bicarbonate) as independent variables, as shown in Table 1. The dependent response variables included effervescent time and pH test to evaluate its effervescent powder quality. The amount of foam-mat dried pineapple powder and sweetener (stevia) were kept constant for each formulation. The sum of each formulation was 100%, constituting a total mass of 1 g for the pineapple effervescent powder in each formulation. This comprised approximately 0.1-0.3 g of citric acid, 0.1-0.3 g of sodium bicarbonate, 0.5 g of pineapple powder, and 0.1 g of stevia. The foam-mat dried pineapple powder, citric acid, sodium bicarbonate, and sweetener for each formulation were sieved using a stainless-steel sieve with a mesh size of 500 μm (no. 35) to ensure uniform particle size. The pineapple effervescent powders were then weighed by using an electronic balance (OHAUS, Ohaus Corporation, USA) and added into water to produce pineapple effervescent beverage. The optimised formulated pineapple effervescent beverage powder (OFPEBP) was shown in Figure 1(a) while commercial spray-dried pineapple effervescent beverage powder (CSPEBP) that served as control is shown in Figure 1(b).

Table 1

Formulations of the pineapple effervescent beverage from SLMD

Formulation (1 g)	Citric acid (%)	Sodium bicarbonate (%)	Pineapple powder (%)	Stevia (%)
1	10	30	50	10
2	15	25	50	10
3	20	20	50	10
4	25	15	50	10
5	30	10	50	10



(a)



(b)

Figure 1. Pineapple effervescent powder (a) formulated (OFPEBP) and (b) commercial (CSPEBP)

Evaluation of Effervescent Quality

Effervescent Time

An amount of 1 g of pineapple effervescent beverage powder was placed in a beaker containing 50 mL of distilled water and stirred with a homogeniser (IKA, RW20 digital, Germany) at 200 rpm until the powder completely dissolved and the bubbles around the container began to disappear (Fernanda et al., 2021).

pH Test

Approximately 1 g of powder was weighed and completely dissolved in distilled water (50 mL). A pH meter (Eutech Instrument, pH 700, Singapore) was employed to measure the pH value of the solution (Arisanty & Daswi, 2021). This process was repeated three times for accuracy.

Evaluation of Physical Properties of Pineapple Effervescent Powder

Angle of Repose

The prepared pineapple effervescent powder was passed through a funnel, and the height (h) and radius (r) were measured (Ashok et al., 2017). The angle of repose (θ) was calculated using Equation 1:

$$\text{Angle of repose } (\theta) = \tan^{-1} (h/r) \quad [1]$$

Bulk Density

An amount of 2g of pineapple effervescent powder was poured into a 10 mL measuring cylinder without compacting. The powder level was maintained and the volume it occupied in the cylinder was recorded (Devi & Das, 2019). The average value from three measurements for the optimised pineapple effervescent powder was reported. The bulk density was calculated Equation 2:

$$\text{Bulk density} = \frac{\text{Weight of the powder}}{\text{Volume occupied in the cylinder}} \quad [2]$$

Tapped Density

An amount of 2 g of pineapple effervescent powder was placed into a 10 mL measuring cylinder and homogenised using a vortex mixer (LabMart, LM-3000, South Korea) (Tan et al., 2015). The vortex was stopped after 1 minute and the powder was allowed to settle down. This volume of the settled powder was used to determine its tapped density and calculated by dividing the weight of the powder by the tapped volume in the cylinder. The

average value of three measurements for the optimised pineapple effervescent powder was reported. The tapped density was calculated Equation 3:

$$\text{Tapped density} = \frac{\text{Weight of the powder}}{\text{Tapped volume}} \quad [3]$$

Carr's Index

Carr's index was determined using bulk density and tapped density using Equation 4 (Laurent et al., 2023):

$$\text{Carr's index} = \frac{(\text{Tapped density} - \text{Bulk density})}{\text{Tapped density}} \times 100 \quad [4]$$

Hausner's Ratio

Hausner's ratio was calculated from bulk density and tapped density using Equation 5 (Laurent et al., 2023):

$$\text{Hausner's ratio} = \frac{\text{Tapped density}}{\text{Bulk density}} \quad [5]$$

Sensory Evaluation

A hedonic test was performed to evaluate overall acceptance of the optimised formulated pineapple effervescent beverage powder (OFPEBP) in comparison with the control, commercial spray-dried pineapple effervescent beverage powder (CSPEBP). An amount of 20 g of effervescent powder was added into 1 L of distilled water to make each sample. Next, 10 mL samples from both formulations were served in sensory cups to 50 trained panellists aged between 20 to 30 years old. The panellists evaluated sensory attributes using a 9-point hedonic scale for the colour, aroma, sourness, carbonation, mouthfeel, aftertaste, and overall acceptance. The panellists rinsed their mouths with water between samples to minimise residual flavour effects (Ain et al., 2016). The data collected for overall acceptance were analysed using an analysis of variance (ANOVA) in the Statistical Package for the Social Sciences (SPSS) software (IBM, Version 20.0, United Kingdom).

Ascorbic Acid Content

The ascorbic acid contents of OFPEBP and CSPEBP (control) were determined by redox titration using iodine (Silva et al., 2019). A 500 mL volume of 1% iodine solution in 2% potassium iodide was added to a 1 L volumetric flask and filled to the mark distilled water. To make the starch indicator solution, 0.25 g soluble starch was dissolved in 50 mL distilled water, heated to 79 °C for 5 minutes, and then cooled to room temperature (23–25 °C). For

the analysis of ascorbic acid in pineapple effervescent powders, 0.5 g of the powder was dissolved in 50 mL distilled water. Then, 20 mL of the solution was mixed with 150 mL distilled water and 1 mL starch indicator solution in a 250 mL conical flask. The solution was titrated using 0.005 mol/L iodine solution until the first permanent trace of a dark blue-black colour appeared, which indicated the titration endpoint. The titration process was repeated with further aliquots of the solution until consistent results were obtained.

The chemical reaction between ascorbic acid and iodine is represented by Equation 6:



The molar concentration of the standard iodine solution was 0.005 mol/L. The molar ratio between iodine and ascorbic acid is 1:1. First, the moles of iodine were calculated using Equation 7:

$$N = CV \quad [7]$$

where, $C = 0.005 \text{ mol/L}$; $V = \text{Mean volume of the concordant readings from burette}$

Then, the moles of ascorbic acid (AA) were calculated using Equation 8:

$$N_{AA} = N \quad [8]$$

Next, the moles of AA were converted to mass (g) using Equation 9.

$$M = N_{AA} \times M_{AA} \quad [9]$$

where, M_{AA} is the molecular mass of ascorbic acid.

Finally, the unit of mass was converted to mg/100 mL.

Statistical Analysis

The physical properties of pineapple effervescent powder were denoted as mean values with their corresponding standard deviations. For the sensory evaluation and ascorbic acid data, an analysis of variance (ANOVA) was performed using the SPSS software (IBM, Version 25.0, United Kingdom). One-way ANOVA was applied to determine the formulation with the highest level of sensory acceptance and the significant differences of ascorbic acid content between the two products (Silva et al., 2019). The statistical significance was set at a confidence level of 95% ($p < 0.05$) (Kwak, 2023).

RESULTS AND DISCUSSION

Evaluation of the Effervescent Quality

Effervescent quality analysis of effervescent beverage powder is crucial to ensure the powder is safe, appealing, and palatable. Table 2 shows the effervescent quality (disintegration or effervescent time and pH levels of the powder obtained after the dissolution) of five formulations of pineapple effervescent powder that were designed from Simplex Lattice Mixture Design (SLMD). In this study, the use of 20% egg albumen concentration in foam-mat drying process can affect the effervescent quality attributes. This is because an excessive or insufficient amount of foaming agent can affect the foam formation and stability. For instance, unstable foam formation led to an increase in foam pore size and reduce the effervescent quality (Shaari et al., 2017).

Table 2
Effervescent quality of pineapple effervescent beverage powder

Formulation	Citric acid (%)	Sodium bicarbonate (%)	Pineapple powder (%)	Stevia (%)	Effervescent time (min)	pH
1	10	30	50	10	1.87 ± 0.04 ^d	6.05 ± 0.03 ^c
2	15	25	50	10	1.75 ± 0.02 ^c	5.79 ± 0.01 ^d
3	20	20	50	10	1.35 ± 0.02 ^b	5.06 ± 0.01 ^c
4	25	15	50	10	1.31 ± 0.01 ^b	4.21 ± 0.01 ^b
5	30	10	50	10	1.12 ± 0.04 ^a	3.57 ± 0.02 ^a

Values are expressed as mean ± standard deviation (SD) of 3 replicates (n = 3). Values in the column with different superscripts are significantly different from one another ($p < 0.05$)

Effervescent time was quantified in minutes using a standard curve with the equation $y = -0.194x + 2.062$ with $R^2 = 0.94$, indicating an effective range of 1.12 ± 0.04 to 1.87 ± 0.04 minutes for pineapple effervescent beverages ($p < 0.05$). All formulations fell within the time range of 1 to 2 minutes, which aligns with previous studies on effervescent times of various effervescent powders (Arisanty & Daswi, 2021; Devi & Das, 2019; Laurent et al., 2023; Zhao et al., 2020). This duration is an acceptable range to ensure complete powder dissolution while retaining the fizzing characteristics of the beverage (Zhao et al., 2020). Formulation 5 displayed the shortest effervescent time (1.12 ± 0.04 minutes), while Formulation 1 demonstrated the longest time (1.87 ± 0.04 minutes) due to the concentration of effervescent agents ($p < 0.05$). Previous research has reported that effervescent agent composition significantly influences effervescent time; thus, a balanced concentration is needed to prevent excessive carbon dioxide release and acidic pH values, which would be detrimental to consumer acceptance (Azahar et al., 2023; Patel & Siddiah, 2018; Saifullah et al., 2016).

The pH values were determined quantitatively with the standard curve with the equation $y = -0.655x + 6.904$ with $R^2 = 0.97$. The pH values for the pineapple effervescent beverages were between pH 3.57 and 6.05 due to different citric acid proportions ($p < 0.05$). Formulation 4 and Formulation 5 deviated from the optimal pH 5 to 7 range. This pH range is essential for enhancing the absorption of effervescent powders (Herlina et al., 2020) and ensures compatibility with intestinal and stomach pH levels of 7.5 and 1.4 respectively for better absorption (Oliveira et al., 2020). Besides that, an optimal pH that is closer to neutral may preserve the bromelain compound in the pineapple, which can be sensitive to extreme pH condition (Mala & Anal, 2021). Therefore, Formulations 1, 2, and 3 met the criteria for effervescent powders based on their effervescent time (1 to 2 minutes) and pH range (5 to 7). These characteristics are necessary to indicate the safety and palatability of the beverage powder (Arisanty & Daswi, 2021).

Optimisation of Pineapple Effervescent Beverage Powder

Table 3 shows the ANOVA results for the model, indicating significant mixture model coefficients validated to linear models for the effervescent time and pH responses. The high F -values of 46.97 and 95.12 for the effervescent time and pH respectively, suggested the model's significance, with a low probability of occurrence due to noise (0.64% and 0.23% respectively) (Salbi et al., 2022). The linear models for effervescent time and pH displayed R^2 values of 0.94 and 0.97 respectively, showcasing strong variance explanation in their relationship (Chicco et al., 2021). These findings indicate the model's excellent fit to the actual data, supported by a low coefficient of variation (CV) of 6.05 and 5.71 for effervescent time and pH, respectively (Azahar et al., 2017). Adequate precision, measured by signal-to-noise ratio at 13.707 and 19.506 for effervescent time and pH respectively, demonstrates the accuracy of the linear model in optimising the pineapple effervescent beverage. The absence of a lack of fit analysis in this study was attributed to the utilisation of only two factors, rendering the experimental design less complex to analyse (Feng et al., 2023).

Table 3
ANOVA result of effervescent time and pH

Responses	Model	F value	p value	R ²	CV	Adequate precision
Effervescent time	Linear	46.97	0.0064	0.94	6.05	13.707
pH	Linear	95.12	0.0023	0.97	5.71	19.506

Analysis using the SLMD identified that the linear model was the best model to be selected in this study. Figure 2 shows the empirical regression of the linear model for effervescent time and pH test. Empirical regression for effervescent time demonstrated

a synergistic effect between citric acid and sodium bicarbonate, resulting in rapid effervescence, aligning with previous studies (Azahar et al., 2017; Eghbaliferiz & Iranshahi, 2016). Similarly, the pH test showed a positive correlation between citric acid and sodium bicarbonate, influencing the pH of the pineapple effervescent beverage, which is consistent with studies by Arisanty and Daswi (2021), Laurent et al. (2023), and Salbi et al. (2022). Therefore, citric acid and sodium bicarbonate have a greater influence on effervescent time and pH test with a synergistic effect.

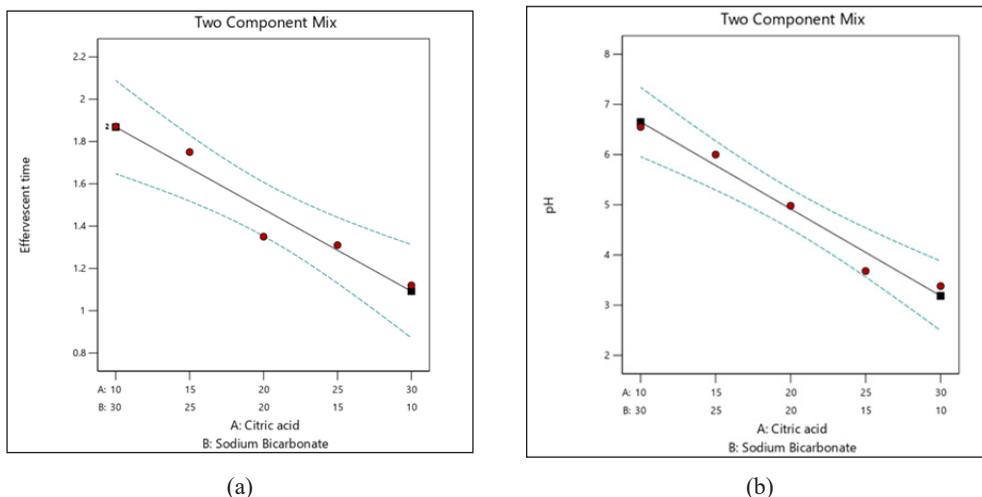


Figure 2. Empirical regression of the linear model for (a) effervescent time, and (b) pH test

Validation of Pineapple Effervescent Beverage Powder

For validation process of pineapple effervescent beverage, three formulations with the highest desirability derived from Design Expert software were chosen (Table 4). For validation of the regression models, the experimental data and predicted values were compared and bias percentage was calculated for each response (Kasim et al., 2023). However, Validation Formula 1 (V1) and Validation Formula 2 (V2) did not meet the acceptable bias percentages in the validation process as the bias percentage exceeded 4% which were unacceptable (Moon et al., 2017; Sopyan et al., 2022). Therefore, Validation Formula 3 (V3) was selected, which demonstrated a bias of 3.29% for effervescent time and 1.57% for pH, deemed acceptable for model validation. This validated the mixture model into a linear model, highlighting the optimal ratio of 19% citric acid to 21% sodium bicarbonate. This ratio is in accordance with a previous study conducted by Salbi et al. (2022) on Quranic mixed food (QMF). Therefore, the optimised formulated pineapple effervescent beverage powder (OFPEBP) comprising 19% citric acid, 21% sodium bicarbonate, 50% pineapple powder, and 10% stevia demonstrated the optimal effervescent

Table 4

Comparison of predicted and experimental values for pineapple effervescent beverage powder

Formulation	Citric acid (%)	Sodium bicarbonate (%)	Effervescent time (min)				pH testing			
			Predicted	Experimental	Residuals	Prediction error (%)	Predicted	Experimental	Residuals	Prediction error (%)
1	10	30	1.87	2.11	0.24	12.83	6.65	7.12	0.47	7.07
2	16	24	1.64	1.77	0.13	7.93	5.61	5.95	0.34	6.06
3	19	21	1.52	1.57	0.05	3.29	5.09	5.17	0.08	1.57

time (1.57 min) and pH (5.17). The used of foam-mat drying process in OFPEBP has re-emerge other drying techniques that commonly applied in food industry such as freeze drying and spray drying that could influence the end-product quality due to high temperature usage and also time-consuming. Therefore, the use of low temperature and short drying time in foam-mat drying can be beneficial to the food industry (Hardy et al., 2015; Shaari et al., 2017).

Evaluation of Physical Properties of Pineapple Effervescent Beverage Powder

Table 5 shows the physical properties of the optimised formulated pineapple effervescent beverage powder (OFPEBP) and commercial spray-dried pineapple effervescent beverage powder (CSPEBP) which differed significantly ($p < 0.05$), except for the angle of repose and Hausner's ratio, which exhibited similar values. The angle of repose portrays the flow behaviour of powders. Arisanty and Daswi (2021) suggested that an angle of repose within 25–30° indicates excellent flow properties. Shenoy et al. (2015) emphasised that the angle of repose is influenced by particle size. The powders were sieved using a stainless-steel test sieve with a mesh size of 500 µm to ensure uniform particle size in this study. Smaller particles tend to pack more efficiently, resulting in lower angle of repose (Shenoy et al., 2015). In addition, both powders exhibited excellent flow properties due to their low moisture content: 5.72% for OFPEBP and 5.92% for CSPEBP. Moisture content affects particle cohesion and reduced moisture can decrease cohesion, affecting the angle of repose (Fitzpatrick, 2013). These findings are consistent with previous studies (Devi & Das, 2019; Laurent et al., 2023).

Bulk and tapped density are the main factors used to evaluate the flow properties of powders. The bulk density of OFPEBP was measured at 0.71 g/cm^3 , whereas the CSPEBP showed a lower bulk density of 0.56 g/cm^3 ($p < 0.05$). In addition, the tapped density for OFPEBP was 0.83 g/cm^3 , higher than the tapped density of CSPEBP which was 0.59 g/cm^3 . Both OFPEBP and CSPEBP fell within the medium-density powder range between 0.5 and 1.2 g/cm^3 (Fitzpatrick, 2013; Saifullah et al., 2016). These density characteristics are influenced by the ingredients used in the formulation. Maltodextrin, known for its water solubility and low viscosity, was incorporated into both powders and contributed toward their density (Chranioti et al., 2015). This is in accordance with a previous study conducted by Salbi et al. (2022). In contrast, the lower bulk and tapped densities of CSPEBP resulted from the presence of carboxymethyl cellulose (CMC), which acted as a binder, enhancing particle cohesion and reducing the overall density (Rahman et al., 2021).

Hausner's ratio is also necessary to determine the flowability of powdered substances. The OFPEBP exhibited a Hausner's ratio of 1.17 ± 0.00 , while for CSPEBP it was 1.05 ± 0.00 ($p < 0.05$). According to Laurent et al. (2023), Hausner's ratio below 1.25 signifies excellent flow properties, suggesting that both powders demonstrated excellent flow properties. Meanwhile, compressibility index, also known as Carr's index, is used as an indication of the powder compressibility. The OFPEBP retained a higher Carr's index value of 14.40 ± 0.09 compared to the CSPEBP with 5.09 ± 0.00 . Laurent et al. (2023) described that a Carr's index ranging below or equal to 10 indicates excellent compressibility, and 11 to 15 denotes good compressibility. Hence, OFPEBP displayed good compressibility, whereas CSPEBP exhibited excellent compressibility due to the presence of an anticaking agent. Anticaking agents prevent clumping or aggregation in powders, enhancing flowability by forming barriers between particles and competing with moisture (Pui et al., 2024). To summarise, both OFPEBP and CSPEBP were classified as medium density powders which possessed excellent flow properties. OFPEBP displayed good compressibility, whereas CSPEBP (control) exhibited excellent compressibility.

Table 5
Physical properties of OFPEBP and CSPEBP

Physical properties	OFPEBP	CSPEBP
Angle of repose ($^{\circ}$)	25.78 ± 0.05^a	25.33 ± 0.03^a
Bulk density (g/cm^3)	0.71 ± 0.01^a	0.56 ± 0.00^b
Tapped density (g/cm^3)	0.83 ± 0.01^a	0.59 ± 0.00^b
Carr's index	14.40 ± 0.09^a	5.09 ± 0.00^b
Hausner's ratio	1.17 ± 0.00^a	1.05 ± 0.00^a

Values are expressed as mean \pm standard deviation (SD) of 3 replicates ($n = 3$). Values in the row with different superscripts are significantly different from one another ($p < 0.05$). OFPEBP: optimised formulated pineapple effervescent beverage powder, CSPEBP: commercial spray-dried pineapple effervescent beverage powder

Sensory Evaluation of Pineapple Effervescent Beverage

Sensory evaluation for OFPEBP and CSPEBP was conducted and compared to assess market acceptability. Sensory attributes namely colour, aroma, sourness, carbonation level, mouthfeel, aftertaste, and overall acceptance were evaluated by panellists, who rated them between 4.76 and 7.12 as shown in Table 6. The ratings for sensory attributes of colour and aroma differed significantly between OFPEBP and CSPEBP ($p < 0.05$). However, no significant differences were found in the ratings for sourness, carbonation level, mouthfeel, aftertaste, and overall acceptance ($p > 0.05$).

CSPEBP scored highest in aroma attribute (7.12 ± 1.66), which may be due to the addition of pineapple flavouring. As previously reported, flavouring agents can enhance aroma and taste in food products (Zhu & Yu 2020). This is in agreement with a previous study conducted by Azahar et al. (2023), which stated that strawberry flavour was used in radish effervescent tablet. Conversely, OFPEBP obtained a lower aroma score (4.76 ± 1.99) due to the inclusion of egg albumen, known for its fishy aroma influenced by nitrogen and hydrogen content in proteins (Milawati et al., 2020). The decomposition of these compounds contributed to an unpleasant aroma in OFPEBP.

Besides that, there were significant differences in the panellists' rating for the colour attributes between OFPEBP and CSPEBP due to permitted food colouring used in the control. OFPEBP displayed a pale-yellow colour, while CSPEBP exhibited a fresh yellow colour. This is supported by Silva et al. (2019), who reported that food producers often use food colouring to enhance or achieve the desired appearance of food products. According to the Food and Drug Administration (FDA), colouring agents play a crucial role in improving the visual appeal of food items, correcting colour variations that may occur during processing or storage. This is in line with colouring agents used in other beverages including soft drinks like Coca-Cola (Silva et al., 2019). Moreover, prior research highlighted the use of carotenoids as natural colourants to enhance the colour characteristics of reduced-fat mayonnaise by increasing yellowness (b^* value) in the samples (Santipanichwong & Suphantharika, 2007).

For the remaining attributes of sourness, carbonation level, mouthfeel, aftertaste, and overall acceptance, there were no significant differences in the panellists' rating between

Table 6
Consumer acceptability on the sensory attributes of OFPEBP and CSPEBP

Attribute	OFPEBP	CSPEBP
Colour	5.18 ± 1.88^a	6.64 ± 1.80^b
Aroma	4.76 ± 1.9^a	7.12 ± 1.66^b
Sourness	5.02 ± 1.97^a	5.24 ± 1.80^a
Carbonated	5.22 ± 2.03^a	5.08 ± 1.83^a
Mouthfeel	5.18 ± 1.96^a	5.62 ± 1.83^a
Aftertaste	5.06 ± 2.11^a	5.34 ± 2.10^a
Overall acceptance	5.24 ± 1.91^a	5.74 ± 1.39^a

Values are expressed as mean \pm standard deviation (SD). Values in the row with different superscripts are significantly different from one another ($p < 0.05$). OFPEBP: optimised formulated pineapple effervescent beverage powder, CSPEBP: commercial spray-dried pineapple effervescent beverage powder

OFPEBP and CSPEBP ($p > 0.05$). This similarity is due to the consistent use of 19% citric acid and 21% sodium bicarbonate in both formulations. The uniformity in the concentrations of these effervescent agents resulted in similar sensory characteristics. Citric acid mainly contributes to sourness, while its reaction with sodium bicarbonate generates carbonation, mouthfeel, and aftertaste sensations (Lambros et al., 2022; Salbi et al., 2022). The resulting sensory attributes remained similar and the panellists did not find notable differences due to the identical amounts of effervescent agents used in both formulations. To summarise, there were significant differences in the ratings for sensory attributes of colour and aroma between OFPEBP and CSPEBP but not in the ratings for sourness, carbonation level, mouthfeel, aftertaste, and overall acceptance. Overall, the panellists were able to accept both OFPEBP and CSPEBP.

Analysis of Ascorbic Acid Content

Ascorbic acid content serves as an indicator for preserved nutrients in dried food due to its extreme sensitivity to heat and its tendency to evaporate easily. Table 7 shows the ascorbic acid concentration per 100 mL for OFPEBP and CSPEBP, showing no significant difference between the samples ($p > 0.05$). OFPEBP exhibited an ascorbic acid concentration of 1.61 mg per 100 mL, which may have been influenced by the application of foam-mat drying technique that applied a medium temperature of 60 °C and the addition of egg white with 4 h of drying time. This is in line with studies by Hossain et al. (2021) and Kadam et al. (2011), which revealed that foam-mat drying with similar parameters resulted in ascorbic acid contents of 2.86 mg/100 mL for tomato powder and 2.89 mg/100 mL for mandarin powder. Another study revealed that foam-mat dried pineapple powder contained 4.05 mg/100 mL of ascorbic acid (Kadam et al., 2012). Similarly, another study reported a low amount of ascorbic acid content (3.87 mg/100 mL) in commercial mango juices due to long shelf life, exposure to high temperatures, and self-oxidation (Siriangkhawut, 2014).

Meanwhile, CSPEBP was prepared using spray drying, a method known to cause ascorbic acid degradation due to high temperatures, leading to oxidation and heat sensitivity (Yin et al., 2022). Lee et al. (2016) and Pua et al. (2010) highlighted that the ascorbic acid loss in spray-dried powder is due to the high drying temperature with short duration. These studies show that ascorbic acid is a heat-sensitive pigment that easily evaporates at high temperatures. This is supported by Lee et al. (2016) and

Table 7
Ascorbic acid contents of OFPEBP and CSPEBP

Sample	Mean \pm SD (mL)	Ascorbic acid (mg/100 mL)
CSPEBP	0.30 \pm 0.00 ^a	1.32 \pm 0.00 ^a
OFPEBP	0.37 \pm 0.05 ^a	1.61 \pm 0.25 ^a

Values are expressed as mean \pm standard deviation (SD). Values in the row with different superscripts are significantly different from one another ($p < 0.05$). OFPEBP: optimised formulated pineapple effervescent beverage powder, CSPEBP: commercial spray-dried pineapple effervescent beverage powder

Pui et al. (2022), who found low ascorbic acid content in spray-dried tomato powder and Bintangor orange powder, respectively. The findings reveal the impact of drying temperature and drying time on the degradation of ascorbic acid in both samples. This is due to the high temperature and long drying time in the spray drying method, as opposed to the low temperature and long drying time used in the foam-mat drying method. The equilibrium between drying temperature and drying time in both methods is reflected in the consistently low ascorbic acid content observed in this study.

CONCLUSION

The effervescent qualities of Formulation 1, 2, and 3 were acceptable as effervescent powders because their effervescent time were in the range of 1 to 2 minutes while maintaining the range of pH 5 to 7. The OFPEBP prepared from Validation Formula 3 comprising 19% citric acid, 21% sodium bicarbonate, 50% pineapple powder, and 10% stevia exhibited optimal effervescent time (1.57 min) and pH (5.17). The OFPEBP demonstrated medium density, excellent flow properties, and good compressibility ($p < 0.05$). The panellists generally accepted OFPEBP with the exception of the aroma attribute, which was adversely affected by the inclusion of egg albumen ($p > 0.05$). The low ascorbic acid content highlighted the significant influence of drying temperature and drying time on ascorbic acid degradation. Therefore, pineapple effervescent beverage prepared from foam-mat dried pineapple juice powder has a high potential to be commercialised in beverage and nutraceutical industries. In the future, the development of fast-dissolving pineapple effervescent beverage with high ascorbic acid content can be commercialised in the market.

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