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Formula Optimization and Physicochemical Characteristics of Functional Instant Beverage from Beetroot (*Beta vulgaris* L.) and Cinnamon (*Cinnamomum* spp.)

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Abstract

Instant beverages are food products in the form of fine, dry granules with low moisture content, typically made from fruits, vegetables, and grains. This study aims to determine the optimal ratio of beet extract, cinnamon extract, and maltodextrin in a functional instant beverage and to evaluate its physicochemical characteristics. The extracts were processed via foam mat drying at 60°C, and the resulting dried sheets were ground into powder. Formulation optimization was performed using the Response Surface Method with a D-Optimal Mixing Design in Design Expert 13 software, considering beet extract, cinnamon extract, and maltodextrin as factors, and betalain content, nitrate content, and solubility as response variables. The optimal formulation obtained was 75% beet extract, 15% cinnamon extract, and 10% maltodextrin, with predicted values of 46.99 mg/100 g for betalain content, 2060.84 mg/kg for nitrate content, and 94.58% for solubility. Verification results showed a betalain content of 44.76 mg/100 g, a nitrate content of 2082.12 mg/kg, and a solubility of 94.68%, with a desirability value of 0.96, indicating no significant difference between the predicted and actual values. Physicochemical characterization of the optimal formula revealed a water solubility index (WSI) of 95.40%, color values of L = 42.37, a = 16.79, and b = 5.33, a moisture content of 4.30%, and a half-maximal inhibitory concentration (IC_{50}) of 943.74 mg/L. These results indicate that the optimal formulation produces an instant beverage that maintains stable bioactive compounds and exhibits good solubility, making it a promising candidate for a functional beverage.

Keywords: Beta vulgaris L.; Cinnamomum spp.; D-Optimal Mixture Design; Foam Mat Drying; Physicochemical Characteristics.

INTRODUCTION

Hypertension is a noncommunicable disease (NCD) that causes more than ten million deaths worldwide each year and is a major risk factor for heart disease and stroke (Shabrina and Koesyanto 2023). According to the world health organization (WHO 2024), approximately 1.4 billion adults aged 30–79 years have hypertension and are at risk of death from cardiovascular complications. the majority of people with hypertension live in low-to middle-income countries (Khafidoh and Sari 2024). The prevalence of hypertension in indonesia increased from 25.9% in 2013 to 30.8% in 2023 (Health Development Policy Agency 2023). Long-term use of synthetic drugs such as captopril and enalapril can cause side effects (Widyaningsih et al. 2018), prompting a shift toward functional, naturally derived treatments. beetroots (*beta vulgaris* l.) contain bioactive compounds such as betalains, nitrates, flavonoids, and phenols (Panghal et al. 2017). betalains exhibit high antioxidant activity that protects endothelial cells from oxidative stress (Milton-Laskibar et al. 2021), while inorganic nitrates contribute to nitric oxide (NO) production, which enhances vasodilation and lowers blood pressure (Baião et al. 2020). Beet juice supplementation containing 200–800 mg nitrate per day has been shown to effectively lower blood pressure in hypertensive patients (Ocampo et al. 2018). However, the high water content of beetroots makes them prone to spoilage, necessitating product forms with better stability and shelf life (Utami and Farida 2022).

Instant powdered beverages are food products characterized by low moisture content, ease of preparation, and long shelf life (Michella et al. 2020). Combining beetroots with cinnamon (*Cinnamomum verum*) can enhance aroma and increase bioactive compound content (Hajiaghaei and Sharifi 2022). Cinnamon contains cinnamaldehyde, eugenol, procyanidin, and flavonoids that act as antioxidants, anti-inflammatories, and antihypertensives agent (Mohammadabadi and Jain 2024). The combination of beetroots and cinnamon exerts a synergistic effect in

lowering blood pressure by increasing NO availability and improving endothelial function through antioxidant activity (Zhang et al. 2024). Instant beverages can be processed using drying methods such as foam mat drying, which preserves color, bioactive compounds, and physical quality at relatively low temperatures (Bahriye et al. 2023). The addition of maltodextrin as a filler and coating agent can further protect bioactive compounds during drying and improve solubility.

Previous studies have shown that beetroots and cinnamon hold potential as functional foods, but research on optimizing instant beverage formulations combining the two remains limited and has largely focused on extracts or juices without addressing the physical and chemical stability of the final product (Mousavi et al. 2020; Das et al. 2022; Amelia et al. 2024). Therefore, this study developed a beetroot and cinnamon instant beverage using foam mat drying, with the formulation optimized through D-Optimal Mixture Design in Design Expert 13 software to determine the best combination of beetroot extract, cinnamon extract, and maltodextrin. The resulting optimal formulation was verified through physicochemical characterization. The objective of this study was to determine the optimal formulation of beetroot and cinnamon instant beverage and to evaluate its physicochemical characteristics.

MATERIALS AND METHODS

Procedures

The research was conducted at Food and Agricultural Products Processing Technology Laboratory, Food Nutrition Laboratory, Food Chemistry and Biochemistry Laboratory Faculty of Agricultural Technology, Universitas Brawijaya; and the Analysis and Experimental Animal Laboratory, Satwa Sehat Indonesia.

The equipment used in the production of instant beverages includes a cabinet dryer, mixer, juicer, blender, stove, glass stirrer, spatula, 60-mesh sieve, analytical balance, and strainer. The ingredients used in the production of instant beverages are beetroots, cinnamon, maltodextrin, and egg whites.

The analysis used equipment including beakers (Pyrex), magnetic stirrer, centrifuge (Hettich Eba 200), measuring pipette (Pyrex), dark bottles, vortex (LW Scientific), spectrophotometer (Shimadzu), water bath (Memmert), vacuum filter (Faithful), erlenmeyer flask (Pyrex), 100 mL measuring flask (Pyrex), aluminum foil, test tubes (Pyrex, Iwaki), test tube caps, foil cups, oven (Memmert), analytical balance (Kern), spatula, color reader (Konica Minolta), and plastic seals. The materials used including distilled water, 0.05 M phosphate buffer solution, KNO_3, chloroform, 1 N HCl, methanol, 0.1 mM DPPH.

Extraction of Beetroot and Cinnamon

Beetroot of the F1 Hybrid Ayumi 04 variety were obtained from Batu, Malang, East Java, with each beet weighing 200–300 g. Cinnamon was obtained in the form of Nutrifarm brand ground cinnamon. Beetroots were peeled, washed thoroughly, cut into small pieces, and processed using a juicer without added water to obtain Beetroot extract (Hajiaghaei and Sharifi 2022). Cinnamon extract was prepared by mixing 20 g of cinnamon powder with 500 mL of water (1:25 w/v), heating and stirring the mixture for 4–5 minutes, and filtering it through a filter cloth to obtain the cinnamon extract.

Preliminary Study

A preliminary study was conducted to determine the lower and upper limits of beetroot extract, cinnamon extract, and maltodextrin proportions, as well as the temperature, duration, and foaming agent concentration for the foam mat drying process. The lower and upper limits were established at 55–75% for Beetroot extract, 10–15% for cinnamon extract, and 10–30% for maltodextrin. The optimal foam mat drying conditions were determined to be 10% egg white as the foaming agent, a drying temperature of 60°C, and a drying duration of 6 hours.

Formula Optimization

Formula optimization was performed using a D-Optimal Mixture Design under the Response Surface Method (RSM), with beetroot extract, cinnamon extract, and maltodextrin as factors. The response variables analyzed were betalain content, nitrate content, and solubility. The experimental design generated by Design Expert 13 software is presented in Table 1.

Table 1. Experimental design and response data for the beetroot and cinnamon instant beverage formulations.

Run	Beetroot	Cinnamon	Maltodexstrin	Betalain (mg/g)	Nitrate (mg/L)	Solubitily (%)
1	60	10	30			
2	60.6	13.8	25.6			
3	60	10	30			
4	75	15	10			
5	70.6	11.25	18.1			
6	66.3	12.5	21.3			
7	75	15	10			
8	55	15	30			
9	63.1	11.3	25.6			
10	57.5	12.5	30			
11	55	15	30			
12	65	15	20			
13	75	12.5	12.5			
14	75	10	15			

Analysis of Betalain Content

Betalain content was determined using UV-Vis spectrophotometry, which measures betalain pigment concentration based on light absorbance at specific wavelengths. Then, 0.1 g sample was extracted with 10 mL distilled water and homogenized using a vortex mixer. The mixture was centrifuged for 10 minutes at 3300 rpm to separate the supernatant from the residue. The remaining residue was re-extracted twice with 10 mL distilled water, centrifuged, and the supernatants from the first and second extractions were combined to a total volume of 50 mL. The extracted sample was dissolved in 0.05 M phosphate buffer solution (pH 6.5) to maintain pigment stability. Sample absorbance was measure at three main wavelengths: 476 nm (betaxanthin absorbance), 538 nm (betanin absorbance), and 600 nm (correction for color interference caused by impurities) (Kerr and Varner 2020; Kumar et al. 2023).

Analysis of Nitrate Content

Nitrate content was measured for the response variables, the verified optimal formula, and the single beetroot instant beverage. Then, 1 mL sample was placed in an Erlenmeyer flask and mixed with 50 mL distilled water. The mixture was heated in a water bath at 80°C for 20 minutes, cooled, and diluted to 100 mL. An aliquot of 1 mL was then taken and diluted to 50 mL in an Erlenmeyer flask, followed by the addition of 1 mL of 1 N HCl. Sample absorbance was measured at wavelengths of 220 nm and 275 nm using UV-Vis spectrophotometry. The difference in absorbance between the two wavelengths was compared against a potassium nitrate (KNO_3) standard curve to obtain a linear regression equation used to determine the nitrate content of the samples (Yumaitelia 2018).

Analysis of Solubility

Solubility, as a response variable for formula optimization of the beetroot-cinnamon instant beverage, was determined using the gravimetric method, which measures the amount of dissolved solids relative to the total sample weight. Then, 2 g sample of the instant beverage powder was dissolved in 100 mL distilled water and stirred for 30 minutes. Whatman filter paper was dried in an oven at 105°C for 30 minutes and then weighed. The sample was then filtered using the pre-dried Whatman filter paper, after which the filter paper and residue were dried in an oven at 105°C for 3 hours, cooled for 15 minutes, and weighed (Adhayanti and Ahmad 2019).

Analysis of Physicochemical Characteristics

Water Solubility Index (WSI)

WSI was measured as a characterization parameter to support the gravimetric solubility results, as it measures the dissolved solids (supernatant) remaining after centrifugation, representing the dissolved components and colloidal dispersion of the sample. Then, 2 g sample of the instant beverage powder was dissolved in 100 mL distilled water and stirred for 30 minutes. The mixture was then centrifuged at 3000 rpm for 15 minutes. The supernatant was separated from the precipitate, and the remaining precipitate was dried in an oven at 105°C until a constant weight was achieved (Hossain et al. 2024).

Color Analysis (L, a, b)

Color was measured using a FRU-brand chromameter, expressed as L*, a*, and b* values. Measurements were performed on the optimal formula and the single beetroot instant beverage. Each sample was placed in a small clip plastic bag with a white paper base. The color reader was switched on, and the lens tip was placed on the surface of the plastic bag containing the sample before the reading button was pressed to obtain the L* (lightness), a* (chromatic red-green), and b* (chromatic yellow-blue) values, which were automatically displayed on the screen. Measurements were performed in triplicate for each sample. The L* value represents lightness, ranging from 0 (black) to 100 (white). The a* value represents the red-green chromatic axis (red: 0–100, green: 0–80), while the b* value represents the yellow-blue chromatic axis (yellow: 0–70, blue: 0–70) (Utami et al. 2023).

Analysis of Antioxidant Activity (IC 50)

Antioxidant activity was measured using the DPPH method, in which a higher antioxidant activity corresponds to a more intense purple color reduction. Sample extraction followed a modified method of Natta et al. (2022). Then, 0.1 g sample was diluted in methanol to 10 mL and macerated for 24 hours under refrigeration. Samples of 2, 4, 6, and 8 mL were taken, and methanol was added to each until the volume reached 10 mL. This resulted in samples with concentrations of 2,000, 4,000, 6,000, 8,000, and 10,000 ppm. Then, 2 mL sample was placed in a test tube and mixed with 2 mL of 0.1 mM DPPH reagent. The mixture was vortexed and incubated in the dark for 30 minutes. Sample absorbance was measured using a spectrophotometer at a wavelength of 517 nm and IC_{50} value were then calculated.

Data analysis

Data analysis was conducted in three stages: the sequential model sum of squares, lack of fit, and summary of statistics. Subsequently, each response was analyzed using ANOVA based on the model's p-value and lack of fit according to the recommended model. The analysis used Design Expert 13 software. The verification stage used the 95% low-high PI in Design Expert 13 and the %error value to assess the validity of the verification results.

RESULTS AND DISCUSSION

The results of the instant beverage formula design using the D-Optimal Mixture Design method with Design Expert 13 software, with lower and upper limit ratios for beetroot extract at 55–75%, cinnamon extract at 10–15%, and maltodextrin at 10–30%. The response data, including betaine content, nitrate content, and solubility, are presented in Table 2.

Table 2. Experimental design and response data for the Beetroot and cinnamon instant beverage formulations.

Run	Beetroots	Cinnamon	Maltodexstrin	Betalain (mg/g)	Nitrate (mg/L)	Solubitily (%)
1	60	10	30	22.1	774.3	95.7
2	60.6	13.8	25.6	22	959.9	95.8
3	60	10	30	21.3	765.2	94.9
4	75	15	10	47.9	2024.3	94
5	70.6	11.25	18.1	22.8	1556	93.9
6	66.3	12.5	21.3	20.2	1297.4	95.2
7	75	15	10	47.4	2057.4	94.9
8	55	15	30	11.8	649.6	96
9	63.1	11.3	25.6	17.7	1008.5	93.9
10	57.5	12.5	30	16.7	850.4	93.93
11	55	15	30	14.6	692.4	95.5
12	65	15	20	27.9	1552.9	93.7
13	75	12.5	12.5	29.9	2197.7	91.8
14	75	10	15	27.6	1884.4	93.9

Betalain Content Response

Based on Table 3, the highest betalain content response was observed in the formula with a 75% beetroot extract, 15% cinnamon extract, and 10% maltodextrin. The lowest betalain content was found in the formula with a 55% Beetroot extract, 15% cinnamon extract, and 30% maltodextrin. The beetroot extract factor is denoted as A, the cinnamon extract as B, and the maltodextrin as C. Based on the ANOVA results, all components had a significant effect on betalain content.

Table 3. ANOVA of betalain content response.

Source	F-value	p-value	
Model	110.52	<0.0001	Significant
AB	0.4493	0.5324	
AC	0.3234	0.5941	
BC	0.77	0.4204	
A^2BC	0.0152	0.9068	
AB^2C	0.0093	0.9269	
ABC^2	0.2979	0.6087	

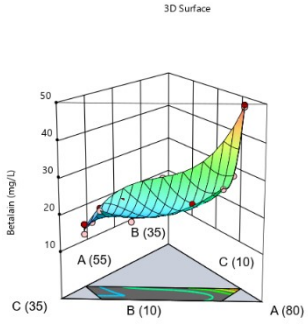


Figure 1. 3D Graph Model of Betalain Concentration Response.

Nitrate Concentration Response

The response of nitrate levels in the beetroot and cinnamon instant beverage formula, as shown in Table 4, indicates a p-value <0.05, indicating that beetroot extract, cinnamon extract, and maltodextrin have a significant effect on nitrate levels. The factors are denoted as

follows: beetroot extract (A), cinnamon extract (B), and maltodextrin (C).

Table 4. ANOVA of nitrate content response.

Source	F-value	p-value	
Model	8.33	0.0282	Significant
AB	21.46	0.0098	
AC	29.70	0.0055	
BC	21.39	0.0098	
ABC	22.76	0.0088	
AB(A-B)	22.12	0.0093	
AC(A-C)	2.31	0.2032	

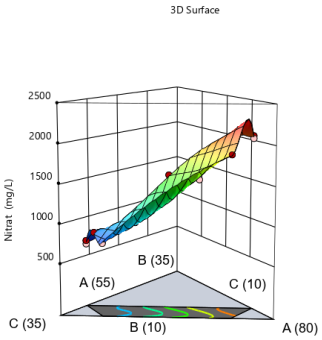


Figure 2. 3D Graph Model of Nitrate Concentration Response.

Solubility Response

The solubility response for the beetroot-cinnamon instant beverage formula, as shown in Table 5, indicates a p-value <0.05, indicating that beetroot extract, cinnamon extract, and maltodextrin have a significant effect on solubility. The beetroot extract is denoted as A, cinnamon extract as B, and maltodextrin as C.

Table 5. ANOVA of solubility response.

Source	F-value	p-value	
Model	373.21	<0.0001	Significant
AB	3.31	0.1286	
AC	0.1705	0.6968	
BC	3.4	0.1243	
A^2BC	1.19	0.3244	
AB^2C	4.8	0.0799	
ABC^2	2.86	0.1516	

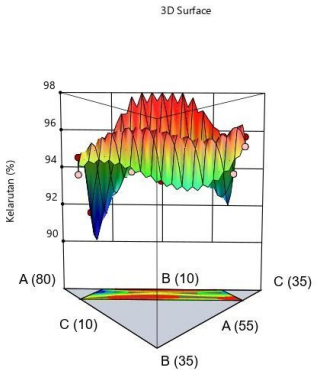


Figure 3. 3D Solubility Response Graph Model

Verification of the Optimal Formula

All response data were analyzed using ANOVA, followed by the determination of criteria for the responses to yield an optimal formula. The criteria set for optimizing the beetroot and cinnamon instant beverage formula aimed to produce a functional product that retains bioactive compounds while exhibiting good solubility. For the betalain, antioxidant activity, and nitrate responses, the criteria were set to maximize so that the optimal formula would contain the highest levels of bioactive compounds, thereby is functional. The solubility response is set within a specific range so that the resulting optimal formula has the physical characteristic of being easily soluble in the formulation. After determining the criteria for the optimal formula, Design Expert 13 will generate several optimal formulas with varying desirability values. The selected optimal formula has a desirability value closest to 1. The selected optimal formula is with a composition of 75% beetroot extract, 15% cinnamon, and 10% maltodextrin, yielding a desirability value of 0.96. The results of the optimal formula verification are presented in Table 6.

Table 6. Verification of the Optimal Formula Results for Beetroot and Cinnamon Instant Beverages.

Response	Predicted Value	95% PI low	95% PI high	Verification Value	% Error
Betalain (mg/100g)	46.99	43.94	50.03	44.76	4.75
Nitrate (mg/kg)	2060.84	1974.56	2147.13	2082.12	1.03
Solubility (%)	94.58	93.42	95.74	94.68	0.11

Physicochemical Characterization of the Optimal Formula for Beetroot and Cinnamon Instant Beverage

The formula verification process yielded an optimal formula that met the objectives. It followed by physicochemical characterization of the optimal formula for the Beetroot and cinnamon instant beverage. The physical characteristics analyzed were WSI and color. The chemical characteristic analyzed was IC_{50} antioxidant activity are presented in Table 7.

Table 7. Physicochemical Characterization of the Optimal Formula for Beetroot and Cinnamon Instant Beverages.

Test Variable	Results
WSI (%)	95.40 ± 0.44
L Value	42.37 ± 0.74
a* Value	16.79 ± 0.56
B* Value	5.33 ± 0.15
Antioxidant IC_{50} (mg/g)	943.74 ± 10.45

Discussion

The optimization results showed that beet extract, cinnamon extract, and maltodextrin interacted synergistically; however, there were some opposing effects on the betaine content, nitrate content, and solubility of the instant beverage formula. The concentrations of betalains and nitrates are determined by the high proportion of beet extract; this is consistent with the fact that beets are the primary source of these two compounds compared to other vegetables (Milton-Laskibar et al. 2021). Cinnamon extract contributes differently to each response; its phenolic compounds help stabilize betalaín pigments, preventing them from oxidizing easily (Omoarukhe and Harbourne 2023), but through redox reactions, they can also act as reducing agents that lower nitrate levels if present in excess; thus, when balanced with other components, they can help maintain nitrate levels (Rocha et al. 2014). Phenolic compounds are hydrophobic, and cinnamon essential oil can reduce solubility by limiting interactions between powder particles and water molecules (Latifi et al. 2020); consequently, formulations containing bioactive compounds from cinnamon tend to be less soluble. Maltodextrin can consistently improve solubility by preventing particle agglomeration and protecting bioactive compounds from thermal degradation during the drying process (Hajiaghaei and Sharifi 2022); however, at high concentrations, it can dilute the proportions of betalains and nitrates in powdered products. This inverse relationship between maltodextrin concentration and the content of these bioactive compounds explains why the highest levels of betalains and nitrates are observed at low to moderate maltodextrin proportions, while the highest solubility requires a moderate maltodextrin proportion. Overall, the interaction between red beet extract, cinnamon extract, and maltodextrin requires an optimal balance that prioritizes a high proportion of beet extract, a low to moderate proportion of cinnamon extract, and a moderate proportion of maltodextrin. This balance forms the basis for selecting the optimal formula in the subsequent verification stage.

All response data were analyzed using ANOVA, followed by the establishment of criteria for these responses to derive an optimal formula. The criteria established for the beetroot and cinnamon instant beverage formula aimed to produce a functional optimal formula that preserves the content of bioactive compounds and exhibits good solubility. For the betalain and nitrate responses, the criteria were set to maximum values so that the optimal formula would contain the highest levels of bioactive compounds. The solubility response was set within a specific range so that the resulting optimal formula would have the physical characteristics of being easily soluble. After determining the criteria for the optimal formula, Design Expert 13 will generate several optimal formulas with varying feasibility scores.

The selected optimal formula has a desirability value closest to 1. The selected optimal formula consists of 75% beet extract, 15% cinnamon, and 10% maltodextrin, resulting in a desirability value of 0.96. Based on Table 4, it can be seen that the verified actual values for betaine content, nitrate content, and solubility fall within the 95% prediction interval, indicating that there is no deviation between the actual values of the optimal formula and the predicted values of the optimal formula, meaning that the actual response values fall within the 95% confidence interval of the predicted values. The percentage error of the predicted results compared to the verified results ranged from 4.66% to 10.58%; with an error percentage <15%, this model is valid for the optimal formula in accordance with the response characteristics (Nurcholis et al., 2023; Duraisamy et al., 2024). This is consistent with the study by Kristianto et al. (2021), which showed that the verified response values in the optimization of yellow pumpkin freezing fell within the 95% Prediction Interval (PI), indicating that the RSM model can explain the data well. The formula with a composition of 75% beet extract, 15% cinnamon extract, and 10% maltodextrin yielded actual response values that fell within the 95% Prediction Interval (PI) and resulted in an error percentage of <15%; thus, the interaction between the ingredients and the response demonstrates good predictive capability.

The verified optimal formula was then subjected to physicochemical characterization, which included the water solubility index (WSI), color, and antioxidant activity. Physicochemical characterization aims to produce a product with good physical and functional quality. The WSI (Water Solubility Index) serves as an indicator of the stability of instant beverage powders; a WSI value >90% indicates that the instant beverage powder has high porosity. The WSI value of the instant Merha beet and cinnamon beverage was high; this is consistent with the study by Hossain et al. (2024), which showed that the optimal WSI value in tomato powder beverages processed using foam mat drying—which exhibits good foam stability—can enhance solubility. Furthermore, the use of egg white as a foaming agent and maltodextrin as a carrier during the foam-mat drying process at 60°C creates a synergistic interaction among these ingredients. A similar effect was reported by Bahriye et al. (2023), who found that egg white combined with carboxymethyl cellulose (CMC) as a

carrier agent could increase the WSI of beet powder dried using the foam mat method by 11.72%. Powdered beverages made from beets, cinnamon, and quince—dried using the foam mat method and containing maltodextrin—exhibit high solubility and the shortest rehydration time (Hajiaghaei and Sharifi 2022). Maltodextrin can form an amorphous matrix, thereby enhancing powder rehydration (Eadmusik et al. 2024).

Color as an indicator of pigment content and the stability of bioactive compounds during the drying process. The relatively low lightness (L) value in the optimal formula is due to the natural yellowish-brown pigments in cinnamon, which absorb light and make the product darker; the higher the cinnamon concentration, the lower the lightness (L) value, resulting in a darker color for the instant rose drink (Saati et al., 2021). The cinnamaldehyde, tannins, and phenolic compounds—which are natural pigments in cinnamon—absorb light, thereby reducing lightness (Tan et al., 2011). At the same time, the redness value (a*) remains at a relatively high level, indicating that betacyanin pigments, although sensitive to light, heat, and oxygen, are protected from degradation. The protection provided by cinnamon's phenolic compounds stabilizes betalains through a copigmentation mechanism (Khan 2016). This is also influenced by the formation of an amorphous matrix by maltodextrin, which protects betalains from oxidative and thermal damage (Islam et al. 2024). The yellowness value (b*) shows a relatively higher value, reflecting the oxidation of cinnamon's flavonoids and polyphenols into melanoidin and quinone pigments (Rahayu et al. 2022), which occurs during the Maillard reaction between maltodextrin and cinnamon compounds during the drying process (Hajiaghaei and Sharifi 2022).

The antioxidant activity (IC_{50}) of the optimal formulation showed a high value; this is because the addition of cinnamon can enhance the product's overall free radical scavenging capacity. This increase is consistent with the rise in betalaín content, indicating a synergistic relationship between pigment stability and antioxidant activity. Phenolic and flavonoid compounds derived from cinnamon, including cinnamaldehyde, catechins, procyanidins, cinnamic acid, and eugenol, act as electron and hydrogen atom donors that neutralize free radicals generated during thermal processing while inhibiting the oxidative degradation of betacyanin pigments (Rahayu et al. 2022; Culas et al. 2024). This is consistent with the 30.9% increase in DPPH antioxidant activity reported for a beet-quince beverage combined with cinnamon (Hajiaghaei and Sharifi 2022). A relatively low drying temperature of 60°C can influence antioxidant activity, as beet powder dried at that temperature retains higher levels of betalains, phenolics, and flavonoids compared to powder dried at higher temperatures (Ng and Sulaiman 2018). Hydrogen bonds between cinnamon polyphenols and the foaming agents in egg whites can inhibit phenolic oxidation during the drying process (Islam et al. 2024). The combination of maltodextrin and cinnamon can increase the glass transition temperature (Tg), resulting in a more stable foam structure that protects bioactive compounds from oxidation (Shahidi and Mohammad 2020). This is consistent with the findings of Yanti et al. (2022), who reported that adding 10–15% cinnamon and maltodextrin to foam mats used for drying instant beverages can increase antioxidant activity and stabilize phenolic compound content. In conclusion, the optimal formulation consisting of 75 percent beet extract, 15 percent cinnamon extract, and 10 percent maltodextrin demonstrated a valid predictive model, accompanied by good solubility, stable pigmentation, and high antioxidant activity, indicating that these physicochemical and functional properties result from the synergistic interaction between beets and cinnamon during the foam mat drying process.

CONCLUSIONS

The optimization results showed that beet extract, cinnamon extract, and maltodextrin interacted synergistically with regard to betalain content, nitrate content, and solubility, although there were conflicting effects on each of these parameters. A high proportion of beet extract increased betalein and nitrate levels. Cinnamon extract plays a role in stabilizing betalein pigments, but an excessive proportion can reduce nitrate levels and solubility. Maltodextrin increases solubility, but at high concentrations it reduces the proportion of bioactive compounds. The optimal formula was obtained with a composition of 75% beet extract, 15% cinnamon extract, and 10% maltodextrin, yielding a desirability value of 0.96. Verification results showed that the actual values of all responses fell within the 95% prediction interval with an error percentage of 4.66–10.58% (<15%), thus validating the model. Physicochemical characterization of the optimal formula revealed high solubility, a relatively low lightness (L) value with a consistently high redness (a*) value, and high antioxidant activity, indicating good pigment stability during the foam mat drying process. This study contributes to the development of a functional instant beverage formula based on beets and cinnamon with favorable physical and functional characteristics through the use of response surface methodology. However, this study has limitations, namely that it examined only one drying condition (60°C) and did not include sensory evaluation or stability testing during storage. Therefore, future research is recommended to test the effects of varying temperatures, evaluate sensory acceptance using trained panelists, and test the shelf life of products with the potential for industrial-scale production.

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