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Formulation of Instant Functional Collagen Drink with Date Seeds Coffee (*Phoenix dactylifera*) and Spices (Ginger, Cinnamon, Cardamom, Clove) Using The D-Optimal Mixture Design Method

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Abstract

The functional food trend has grown rapidly since the Covid-19 pandemic, including products made from natural ingredients like herbal collagen drinks. This research aims to develop an optimal collagen drink formulation by adding date seed coffee with ginger, cinnamon, cardamom, and cloves as antioxidants to optimize collagen function.Optimization was carried out using the Design Expert-13 device with the optimization response of antioxidant activity (mg TE/100g) and water content (%). The results showed that the optimal formulation consisted of date seed coffee 35.57%; hydrolyzed collagen 25%; and spice mixture (ginger, cinnamon, cardamom, cloves) of 39.432% with a desirability value of 0.741. The optimal product was then instantiated using the spray drying method and compared with commercial products without instantiation and collagen addition.The optimal product has an IC50 antioxidant activity of 743.86 ppm and total phenols of 187.23 mg GAE/100g, with a water content of 3.35%, hygroscopicity of 7.76%, bulk density of 0.488 g/mL, and a dissolution time of 23.32 seconds. The results of the hedonic test on the optimal sample as a whole from 100 panelists were “rather like” to “like” with an average value of 3.17 with the most preferred attributes being the consistency and aroma of spices.

Keywords: Functional drinks; Collagen; Date seed coffee; Spices.

INTRODUCTION

Indonesia has begun to increase food system innovation in the last decade to address food security and nutrition challenges triggered by global issues such as the COVID-19 pandemic. This has raised public awareness regarding the importance of functional foods, which provide additional health benefits and reduce the risk of disease without the side effects of chemical drugs. (Hariyadi, 2024). Based on (Indonesian Food and Drug Supervisory Agency, 2011) concerning Supervision of Claims in Processed Food Labels and Advertisements Article 1 paragraph 3, "Functional Food is Processed Food containing one or more food components which, based on scientific studies, have certain physiological functions beyond their basic functions, and are proven to be harmless and beneficial to health." Different from supplements, functional foods are foods or drinks that also fulfill basic needs such as hunger and thirst, so aspects of taste, texture, and color are considered to remain attractive and delicious to consume (Triandita et al., 2020).

One of the emerging functional food trends recently is the consumption of collagen drinks as beauty drinks. The collagen drink trend continues to grow and accounts for a total of 12.5% of the global market share (Bilek & Bayram, 2015). Collagen is the main protein in the body (25%) that helps regenerate skin, increase elasticity, prevent wrinkles, maintain hydration, and protect against free radicals (Wu et al., 2024). As a structural protein, collagen is composed of repeating combinations of the amino acids proline, glycine, and hydroxyproline that form a triple helix structure and work as cell adhesives, triggering regeneration, angiogenesis, morphogenesis, and tissue repair (Campos et al., 2023). Collagen consumption can be done orally through functional foods, or non-orally through topical creams or injections (Lee et al., 2022). However, based on the methods mentioned, the use of collagen through the oral system is considered the safest, cheapest and most effective (León-López et al., 2019). As the trend develops, collagen drinks are starting to be enriched with other supporting nutritional content such as antioxidants (Ghaffar, 2021).

As a rarely utilized byproduct, date seeds contain compounds such as antioxidants and fiber that have the potential to be processed into functional foods (Mrabet et al., 2020). According to (Maqsood et al., 2020), date seeds contain bioactive compounds such as flavonoids,

carotenoids, tocopherols, tocotrienols, and phytosterols, which in addition to functioning as antioxidants also have anticancer, anti-inflammatory, and antimicrobial effects. Date seeds tend to have a hard texture, making them difficult to grind and process for consumption. Therefore, a roasting process is carried out to facilitate grinding the date seeds into the final product, namely date seed coffee powder.

As a beverage, date seed coffee is considered to have a high content of phenolic antioxidant compounds, a taste and aroma similar to coffee but caffeine-free, making it suitable as a healthier alternative to coffee (Ghnimi et al., 2017). However, the consumer sensory acceptance rate for date seed coffee drinks is still lower than conventional coffee because in terms of taste it is not 100% similar to coffee made from coffee beans (Fikry et al., 2019). The nutritional and sensory profile of date seed collagen coffee can be enhanced by the addition of spices such as ginger, cinnamon, cardamom, and cloves, which in addition to their strong aroma are also rich in antioxidants to support the health and effectiveness of collagen in the skin. In addition to being antioxidants, several bioactive compounds in the spice mixture also have other functional properties. Red ginger contains shogaol and gingerol which are effective as anti-cancer agents (Prasad & Tyagi, 2015), cinnamon with cinnamaldehyde compounds which act as antimicrobials and anti-inflammatories (Wang et al., 2022), cardamom contains catechins and epigallocatechins (EGC) which act as antimicrobials (Nasution et al., 2023), and cloves contain eugenol, eugenyl acetate, and caryophyllene compounds which have high antimicrobial activity (Gengatharan & Rahim, 2023).

To increase the sensory value of the final product, an instantaneous process is carried out using the spray drying method (spray dryingSpray drying is a drying method that uses heat and pressure to evaporate water, leaving behind a dry, powdery component (Joshi et al., 2022). Spray dryers work by vaporizing the solvent through contact with a sample that has been atomized using hot air to increase drying effectiveness (Anandharamakrishnan & Ishwarya, 2015).

METHOD

The research was conducted at the Nutrition and Food Laboratory of the Faculty of Agricultural Technology, Brawijaya University. A series of raw material selection and testing, composition optimization with Design Expert 13, and instantaneous processing with a spray dryer (spray drying), chemical and physical characterization of the final product. The study was conducted from November 2024 to January 2025. Composition optimization with Design Expert 13 was carried out using the antioxidant activity response (mg TE/100g).

Equipment

The equipment used in the study included an electric oven (Memmert™), analytical balance (Ohaus™), 100 mL measuring cylinder (Pyrex™), crucible, spoon, UV-Vis spectrophotometer (Genesys10™), analytical balance (Mettler Toledo™), test tube (Iwaki™), test tube rack, glass Erlenmeyer flask (Pyrex™), volumetric pipette (Iwaki™), bulb, volumetric flask (Pyrex™), vortex, cuvette, oven (Memmert™), desiccator, spray flask bottle, lab spray dryer (Labfreez™), color analyzer.

Material

The materials used in the study included date seed coffee powder, collagen powder, a spice powder mixture consisting of ginger powder, cinnamon powder, cardamom powder, and clove powder, and a commercial spiced date seed coffee product with the same spice content as a comparison.

The materials used in the analysis series consist of 2,2 Diphenyl-1-Picrylhydrazyl (DPPH) reagent, 6-hydroxy-2,5,7,8-tetramethylchromane-2-carboxylic acid (Trolox), methanol (CH_3OH) analytical grade, Folin & Ciocalteu Reagent, anhydrous sodium carbonate (Na_2CO_3), gallic acid ($C_7H_6O_5$), Sodium chloride (NaCl), and distilled water.

Research methods

The research stages consist of preliminary testing, including characterization of raw materials. The testing is followed by the main research, which includes optimization of the raw material formulation. The formulation optimization process is carried out using software-based software.*Design of Experiments* (DoE) is *Design Expert* 13 and continued with the instantaneous process using the spray drying method. After that, the chemical, physical, and sensory characterization of the final product was carried out.

Preliminary Research

The preliminary research was a characterization of the raw materials to be used, consisting of date palm coffee, a mixture of spices (ginger, cinnamon, cardamom, cloves). The characterization of the raw materials included (1) testing the antioxidant activity using the Trolox method (Plank et al., 2012) and (2) water content using the conventional method with an oven dryer (AOAC, 2005).

Further Research

Further research is a stage consisting of optimizing the composition of raw materials using the Design Expert 13 Mixture D-Optimal method. The selected formulation is then followed by an instantaneous process using spray drying (*spray drying*) using 30% maltodextrin filler, which produces a finished product in the form of instant coffee collagen drink powder with date seeds and spices.

Characterization

Characterization of finished products includes physical, chemical, and hedonic. Physical characterization includes testing (1) Water content (AOAC, 2005), (2) Dissolution time (Ridwan Taher Lubis et al., 2023) and (3) Hygroscopicity level (Huda, 2020). Chemical characterization includes IC50 antioxidant activity test (Plank et al., 2012) and total phenol test (Maramy et al., 2024). In addition, the product is also tested for its level of acceptance among consumers using a preference level test (Hedonic).

RESULTS AND DISCUSSION

Analysis of raw material characteristics

The raw materials used as components of the spiced date seed collagen coffee drink consist of roasted date seed coffee, hydrolyzed collagen powder, and a mixture of spices (ginger (5%), cinnamon (8%), cardamom (4%), and cloves (1%). Each ingredient is characterized physically and chemically as shown in Table 1.

Table 1. Results of Raw Material Characteristics Tests.

Test Variables	Roasted date seed powder	Hydrolyzed Collagen Powder	Spice mix powder
Antioxidant Activity (mg TE/ 100 g)	44.46 ± 3.39	-	121.69 ± 0.28
Inhibition (%)	31,36 ± 1,73	-	70,81 ± 0,14
Total Phenol (mg GAE/ 100 g)	59.39 ± 8.44		215.97 ± 50.12
Water Level (%)	2.62 ± 0.00	7.86 ± 0.00	2.78 ± 0.00

The spice mix powder had the highest antioxidant activity (121.69 mg TE/100 g), followed by roasted date seed powder (44.46 mg TE/100 g). Meanwhile, collagen hydrolysate powder did not show any antioxidant content, although previous research (Yanti et al., 2022) recorded that the antioxidant activity of fish collagen hydrolyzed with bromelain reached 20.45 $FeSO_4$/g (FRAP method). Free radical inhibition analysis showed that spice raw materials had the highest inhibition ratio (70.81%), followed by date seed powder (31.36%).

Total phenol as one of the most abundant antioxidant components and the main indicator of antioxidant activity was also tested, with the highest results in spice powder (215.97 mg GAE/100 g) and roasted date seed coffee powder (59.39 mg GAE/100 g). Physical testing of water content showed that collagen hydrolysate powder had the highest water content (7.86%), followed by spice mixture powder (2.78%) and roasted date seed powder (2.62%). The high water content in collagen hydrolysate powder is caused by the use of hygroscopic maltodextrin as a mixture in making powder in collagen hydrolysate (Ramadhani et al., 2024).

Composition optimization with Design Expert 13 Mixture D-Optimal method.

The experimental design to be carried out by Design Expert 13 using the D-Optimal Mixture method is based on determining the upper and lower limits of each component. The determination of the limits refers to the results of trial and error of the raw material formulation based on the results of characterization and previous research, as shown in Table 2.

Table 2. Upper and lower limits of independent variables.

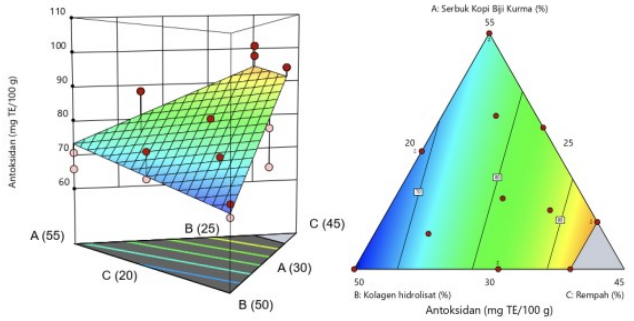
Material Name	Lower Limit	Upper Limit
Date Seed Coffee	30%	55%
Hydrolyzed collagen	25%	50%
Spice mix (ginger, cinnamon, cardamom, cloves)	20%	40%

In this study, the total number of independent variables was 100% of the total base. Using water content (%) and antioxidant activity (mg TE/100g Trolox) as the responses, a 16-item experimental design was obtained. the results are shown in Table 3.

Table 3. Results of the Design Expert-13 recommendation experiment on response.

Run	A: Date Coffee Powder (%)	B: Hydrolyzed collagen (%)	C: Spices (%)	Response	
				Antioxidant activity (mg TE/100g)	Water content (%)
1	46.25	28.75	25.00	8.98	6.33
2	42.50	37.50	20.00	11.72	6.3
3	30.00	36.67	33.33	11.46	6.81
4	35.00	25.00	40.00	7.81	6.65
5	30.00	50.00	20.00	15.63	6.93
6	55.00	25.00	20.00	7.81	6.34
7	42.50	37.50	20.00	11.72	6.29
8	30.00	30.00	40.00	9.38	7
9	36.25	28.75	35.00	8.98	6.63
10	45.00	25.00	30.00	7.81	6.4
11	35.00	25.00	40.00	7.81	6.95
12	33.75	41.25	25.00	12.89	6.64
13	55.00	25.00	20.00	7.81	6.37
14	30.00	36.67	33.33	11.46	6.76
15	30.00	50.00	20.00	15.63	6.87
16	37.50	32.50	30.00	10.16	6.55

Based on the test data, the modeling results for the antioxidant activity response optimization experiment showed that the appropriate statistical analysis model was a linear model.

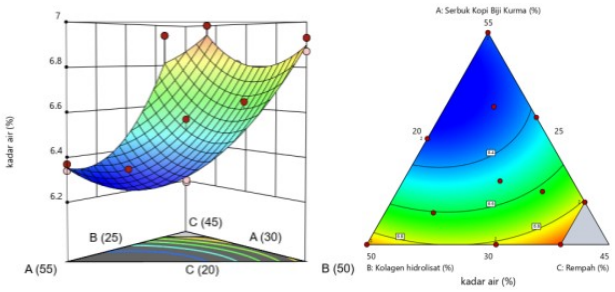


(A) (B)

Figure 1. 3D graph of linear model (A) & Contour graph of antioxidant activity response (B).

The graph shows a linear model with a straight surface at a specific slope. The red dots in the graph represent experimental points combining the three components (Sabariman et al., 2021). The 3D graph model shows that the addition of spice powders significantly increased antioxidant activity, while coffee powder and date seeds had a smaller effect. Conversely, the addition of collagen hydrolysate up to 50% actually decreased antioxidant activity to the lowest point. This response is visualized in a color gradient, with yellow-orange indicating the highest activity and dark blue the lowest (Mugendiran et al., 2014).

The water content response shows that the appropriate statistical analysis model is quadratic, as shown in the 3D graph in Figure 2.



(A) (B)

Figure 2. 3D graph of the quadratic model (A) & Contour graph of the water content response (B).

The 3D quadratic model graph shows that the water content increases to its highest point with the addition of 50% hydrolyzed collagen or 40% spices. Meanwhile, the date seed coffee powder produces the lowest water content, even with its highest composition reaching 55% of the total components. The characterization test results support this finding, with the highest water content in the hydrolyzed collagen powder (7.8%), followed by the spice mixture (2.78%) and the roasted date seed coffee powder (2.62%).

Optimization results *Design Expert*-13 and verification

Optimization is carried out by setting criteria for each variable to achieve the antioxidant response and water content according to the target, as in Table 4.

Table 4. Optimization criteria based on desired response.

Parameter	Criteria	Minimum Point	Maximum Point
Roasted date seed powder	*Is in range*	30	55
Hydrolyzed Collagen Powder	*Is in range*	25	50
Spice mix	*Is in range*	20	40
Antioxidant activity	*Maximize*	63.13	100.9
Water level	*Minimize*	6.29	7.00

The recommended optimal response prediction resulted in a formulation with 35.56% roasted date seeds, 25% collagen powder, and 39.43% spice mix. The desirability value of the formulation was 0.741. The results were then verified to determine the significance of the difference between the prediction and the actual results table 5.

Table 5. Verification of optimal formulation.

Response	Results		*P-value*
	Design expert predictions	Actual value	
Antioxidant Activity	94.29	93.40	0.176
Water level	6.78	6.63	0.251

Verification of the formulation prediction results by Design Expert 13 software was carried out through a Paired T-test with a significance value of 0.05. If the P-value <0.05, there is a significant difference between the prediction and the actual results, whereas if the P-value >0.05, the two are not significantly different (Apriliyanti et al., 2017). Based on the table, the P-value for antioxidant activity is 0.176 and water content is 0.251. This shows that the actual experimental results are accurate with the predictions analyzed by Design Expert 13.

Optimal results are then instantiated through a spray-drying method. The purpose of the instantaneous process is to improve the physical and sensory profile of the product while maintaining quality (García-Carrasco et al., 2023). A 30% maltodextrin is used as a filler and coating for the active ingredient (Ramadhani et al., 2024).

Characterization of the final product

The optimal product that has gone through the instantaneous process is then characterized physically, chemically, and sensorily.

(A) (B)

Figure 3. Actual sample before spray drying (A) Optimal sample powder resulting from spray drying (B).

Visually, the optimal sample powder from spray drying produced a yellowish white powder with a lightness (L) value of 40.90, which was much brighter than the commercial product (82.17). The optimal sample also had a lower redness (a*) level (3.90 compared to 6.23) and a higher yellowness (b*) level (15.80 compared to 9.57). Previous research showed that the addition of maltodextrin above 10% can increase the brightness (L) and yellowness (b*) because the maltodextrin component affects the final color of the powder, following the basic color of maltodextrin which is yellowish white (Romulo & Aurellia, 2024).

The final powder product resulting from instantaneous processing was characterized physically and chemically and compared with the commercial product as shown in Table 6.

Table 6. Characterization of the optimal formulation resulting from spray drying compared to commercial samples.

Test variables	Collagen coffee seeds dates spices (spray dry powder)	Commercial spice date seed coffee
Antioxidant activity IC50 (ppm) GAE/100g)	743,864	275,443
Total phenols (mg GAE/100 g)	187,23	273,30
Water content (%)	3.35 ± 0,04	3.40 ± 0,55
Hygroscopicity (%)	7,76 ± 0.05	4,46 ± 0.48
Bulk density (g/mL)	0.488 ± 0.008	0.521 ± 0.016
Dissolve time (seconds)	23.32 ± 0.92	(Insoluble)
Color:		
L	82,17 ± 0,49	40,90 ± 0,26
a*	3,90 ± 0,35	6,23 ± 0,12
b*	15,80 ± 0,17	9,57 ± 2,83

The spiced date seed coffee collagen drink sample had a lower IC50 antioxidant activity (743.864 ppm) compared to the Commercial sample (275.443 ppm). According to Jumina et al. (2019), antioxidant activity in the IC50 range is considered strong in the 50-100 ppm range, while values above 200 ppm are categorized as "fatty."

The decrease in antioxidant activity in spray-dried samples compared to commercial samples can be caused by the degradation of phenolic compounds due to high temperatures in the spray-drying process. Spray drying in this study was carried out at an inlet temperature of 180°C with a feed rate of 10% (4.5 mL/min), which also contributed to the decrease in antioxidant activity. Gawałek (2022) showed that phenolic compounds encapsulated by maltodextrin (MD) of 25-35% can survive up to an inlet temperature of 150°C, but will decrease by 2.5% with increasing temperature. To reduce the process of damage to heat-resistant compounds, maltodextrin was added as an encapsulant as much as 30% (Ramadhani et al., 2024). However, based on research by Romulo & Aurellia (2024), it was stated that the addition of maltodextrin above 10% can reduce the antioxidant concentration because the total mass of solids increases, replacing the antioxidant mass in the spray-dried particles.

Spray drying treatment with 30% maltodextrin at an inlet temperature of 180°C did not significantly affect the product's water content, but increased hygroscopicity and decreased bulk density compared to the commercial product. The water content of the spray-dried powder (3.35%) was slightly lower than that of the commercial product (3.40%), but the difference was not significant (P-Value 0.44>0.05). The hygroscopicity of the spray-dried sample increased significantly, from 4.46% in the commercial product to 7.76%, although both were still classified as non-hygroscopic (Huda, 2020). The use of a relatively high inlet temperature of 165°C to 225°C can increase the hygroscopicity of the spray-dried powder because products with low water content resulting from rapid drying at high temperatures tend to absorb water more easily (Wijayanti et al., 2024).

The addition of 25% collagen hydrolysate to the optimal sample significantly increased the amount of maltodextrin. Therefore, the addition of maltodextrin from collagen hydrolysate and encapsulating agents to instant drinks causes the solid structure to be dominated by the hygroscopic starch component. This property makes maltodextrin more easily bind water, thereby increasing the hygroscopicity of the final spray-dried product (Lee et al., 2018). Therefore, the use of 30% maltodextrin can increase the hygroscopicity of the powder compared to commercial products without an instantaneous process due to its water-binding properties (Ramadhani et al., 2024).

The bulk density of the spray-dried sample was lower than that of the commercial sample, which was 0.488 g/mL compared to 0.521 g/mL in the commercial product, although both were not significantly different (P-Value 0.091>0.05). The lower bulk density in the spray-dried product was due to the rapid evaporation process at high temperatures causing a "Ballooning" effect, where the powder had cavities inside the dried wall particles. The addition of maltodextrin contributed to a decrease in bulk density by increasing the number of coating particles. The higher the concentration, the more coating particles were formed, preventing the sample particles from sticking together and increasing the number and volume of bubbles due to air desorption in the atomization process. As a result, a hollow structure was formed when dried at high temperatures due to the use of more maltodextrin (Kwapińska and Zbiciński, 2006). Research by Kodous (2020) showed that adding maltodextrin to dried animal collagen can produce a bulk density of up to 0.45–0.51 g/mL in the mixture. Meanwhile, commercial samples that did not undergo heating or maltodextrin addition retained their original chemical characteristics and had a denser, coarser powder texture with a higher specific gravity.

Spray-dried powder containing 30% maltodextrin filler has a fine texture, tends to stick together, and easily clumps (cakes), which affects product rehydration. Tests show that the powder dissolves within 23 seconds until completely dissolved. The size of the powder particles affects the permeability of water to penetrate the surface tension and wet the entire powder (Wijayanti et al., 2024). Larger particles have cavities between particles that allow water to penetrate more easily, while very fine maltodextrin particles make it more difficult for water to dissolve the powder. This factor is influenced by the Dextrose Equivalent (DE) value of the maltodextrin, where DE 10-12 indicates a moderate number of simple sugar chains, while the highest value reaches 20 (Caballero et al., 2015). The higher the DE, the larger the surface area and the stronger the cohesion between particles, thus slowing the dissolution of the powder (Fathoni & Hafidz, 2023).

The solubility of spray-dried powder can be improved by combining maltodextrin with other encapsulant agents such as whey protein or cellulose to increase particle size and reduce interparticle cohesion (Faldt et al., 1993). Spray-dried products improved solubility compared to commercial samples without instantization, which leave a significant amount of coffee grounds. Spray-dried products dissolved completely with low water content without solid residue, while retaining their characteristic flavor and aroma, which were subsequently tested hedonically.

Hedonic Test

The optimal product of the spray-dried spiced collagen date seed drink was tested for sensory acceptability through a hedonic test. This test was conducted using a preference rating method using a 1-5 scale (1 = dislike, 2

= dislike somewhat, 3 = like somewhat, 4 = like, 5 = like very much) (Meilgaard, 2016). A total of 100 panelists were used to obtain more representative data, considering that the hedonic test involved untrained panelists who could potentially provide subjective sensory responses (Stone et al., 2021). In addition to measuring preference, the hedonic test also serves as a*consumer sensory test* to assess the acceptance of new products in the market, because the selection of panelists is based on general consumer groups, not their sensory expertise (Rogers, 2018).

Table 7. Results of hedonic testing of optimal samples with commercial samples.

Response	Sample		*P-value*
	Spiced date seed collagen drink	Commercial spice date seed coffee	
Color	2.34 ± 0.89	3.49 ± 0.83	0.000
Consistency	3.81 ± 1.08	2.51 ± 0.98	0.000
Aroma Friends	3.76 ± 1.24	3.71 ± 1.20	0.728
The aroma of coffee	2.48 ± 0.86	3.38 ± 0.92	0.000
Aroma of spices	3.68 ± 0.92	3.51 ± 1.11	0.142
Overall Aroma	3.57 ± 0.88	3.55 ± 0.93	0.851
Coffee taste	2.61 ± 0.97	3.18 ± 1.05	0.000
Taste the spices	3.35 ± 0.98	2.94 ± 1.15	0.001
Rasa friends	3.58 ± 1.24	3.47 ± 1.21	0.351
Overall taste	2.97 ± 0.95	2.87 ± 1.04	0.347
Overall	3.17 ± 0.91	3.06 ± 0.98	0.251

Based on Table 7, the optimal spray-dried spiced collagen date seed drink product showed significant differences compared to the commercial product in several aspects. In terms of color, the optimal sample had a higher lightness (L) value (33.9 compared to 26.4) and increased a* and b* values, indicating reddish and yellowish intensity. This difference was caused by the material composition and the spray-drying process with the addition of maltodextrin above 10%, which affected the final color following the original color of the maltodextrin (Kardas et al., 2024). Panelists preferred the consistency of the optimal product because it produced a homogeneous solution without pulp and received a hedonic score of 3.81 compared to 2.51 for the commercial product. The perfect solubility of the optimal product supported the absorption of the hydrolyzed collagen so that it could be consumed entirely without any residue remaining in the beverage pulp (Pudziuvelyte et al., 2019).

Fish collagen hydrolysate has a characteristic sensory aroma that tends to be fishy (Dewantoro et al., 2019). The fishy aroma of fish collagen hydrolysate showed almost the same preference value (3.76 compared to 3.71), indicating that the panelists "quite liked" it, with no difference in preference between the two samples. However, the coffee aroma in the commercial sample was preferred more than in the optimal sample, as seen from the lower panelist preference value in the optimal sample (2.48 compared to 3.38). The date seed coffee in the optimal mixture had a lower proportion of coffee (35.56%) than the commercial product, which is almost 80% composed of date seed coffee. With a low proportion that is then dissolved into feed for spray drying, it will reduce the concentration of date seed coffee in the mixture (Romulo & Aurellia, 2024). Fewer coffee components and supported by the degradation of volatile compounds during the spray drying process such as pyrazines, aldehydes, ketones, pyrroles, pyridines, and esters leaving more stable furans create a coffee aroma that is not too strong, so that panelists who like coffee tend to prefer commercial samples.

The impact of spray drying on aroma is also based on research by (Chindapan & Puangngoen, 2024), where the spray drying process only leaves 43.94% of the total volatile compounds in the optimal sample. However, the impact of damage to volatile compounds due to spray drying occurs a lot in spices (Suhendar & Sogandi, 2019) in the optimal sample, which is actually preferred by panelists in the spice aroma attribute with a higher hedonic value than the commercial sample (3.68 compared to 3.51). So for the overall aroma, the optimal sample is close to equality with the commercial sample (3.57 compared to 3.55). For the taste attribute, the optimal sample shows a lower level of panelists' preference for the coffee taste (2.61 compared to 3.18) compared to the commercial sample. However, the optimal sample is superior in spice flavor (3.35 compared to 2.94) and there is no significant difference in the fishy taste (3.58 compared to 3.47).

These results provide nearly comparable overall scores between the optimal sample and the commercial sample (2.97 versus 2.87), and a slightly higher overall acceptance rate for the optimal sample compared to the commercial sample (3.17 versus 3.06). Overall, the spray-drying process reduced the intensity of the coffee aroma and flavor, thus decreasing panelists' preference. However, improving consistency characteristics through an instantaneous process that removes dissolved solids and increases the homogeneity of the optimal sample can increase panelists' overall preference for the product

(Chen et al., 2020). The heat process in spray-drying, which can reduce the presence of volatile compounds (Rogers, 2018), also appears to improve the balance of aroma and spice flavors to reduce overpowering and successfully increase product acceptance, as reflected in consumer hedonic tests.

CONCLUSION

The optimal formulation consisted of roasted date palm seeds (35.56%), hydrolyzed collagen powder (25%), and spice mixture (39.43%) with a predicted antioxidant activity of 94.29 mg TE/100 g and a moisture content of 6.78%. Verification results showed an actual antioxidant activity of 93.40 mg TE/100 g and a moisture content of 6.63%, which was in accordance with the prediction. The characterization results of the spray-dried product had lower IC50 and total phenol antioxidant activity than the commercial product (743.864 ppm and 187.23 mg GAE/100 g). However, they were superior in moisture content and dissolution time (23.32 seconds) compared to the commercial sample, despite having higher hygroscopicity (7.76%) and a lower bulk density of 0.488 g/mL. The hedonic test showed that the optimal product was preferred in consistency and spice flavor, while the commercial product was superior in aroma and coffee flavor. The spray-dried product produced a fine powder with a pale bright yellow color.

Competing Interests: The authors declare that there are no competing interests.

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