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Optimization of Date Palm Extract (*Phoenix dactylifera* L.) Based Collagen Powder Beverage Formula with Spices (Tamarind and Cinnamon) Addition Using D-Optimal Mixture Design Method

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Abstract

The trend of collagen-based beauty functional drinks is predicted to increase. However, its use can potentially cause a fishy taste, so it is usually formulated together with fruit or spice extracts. Date fruit has the potential for high bioactive content, but its utilization as a powder drink in Indonesia is still relatively low. Tamarind and cinnamon are also Indonesian spice commodities that are rich in bioactive components and have a strong flavor that can cover the fishy taste of collagen. Thus, this study aimed to obtain the optimal formulation and the effect of the addition of date, tamarind, cinnamon, and hydrolase collagen powder on the physicochemical characteristics of the final product using the Design Expert program D-Optimal Mixture Design Method. The first stage of the research was determining the upper and lower limits of the independent variables and a fixed value. The optimal formula suggested by Design Expert consisted of 50% date powder, 24,91% tamarind powder, 20,09% cinnamon powder, and 5% hydrolase collagen powder with a desirability value of 0,805. The second stage of characterization testing in the form of chemical tests resulted in antioxidant activity (IC_{50}) of 263,25 ± 8,01 ppm and total phenol content of 101,71 ± 9,21 mg GAE / 100 g. Characterization in the form of physical tests resulted in a moisture content of 2,98 ± 0,01%, dissolving time of 20,52 ± 0,72 seconds, bulk density of 0,52 ± 0,14 g/ml, and hygroscopicity of 18,73 ± 0,04%.

Keywords: Collagen; dates; design expert; functional drinks; spices.

INTRODUCTION

Functional beverages can be defined as a type of non-alcoholic beverage that in addition to providing hydration effects can also provide other health benefits, mainly due to special additives containing minerals, vitamins, herbs, or other bioactive compounds (Li et al., 2019). According to global news wire in Kumar et al. (2022), the functional beverage market is expected to grow to $208.13 billion by 2024 with a compound annual growth rate of 7.5% from 2022 to 2027. One type of functional beverage that is quite popular is collagen-based beauty drinks (Dini, 2019). Collagen is the main protein that dominates as much as 30% of human connective tissue (Hashim et al., 2015). Consumption of hydrolase collagen-based beverages can increase the supply of collagen in the human body so as to maintain skin elasticity and prevent signs of aging (Asserin et al., 2015). However, the addition of too much collagen can cause a fishy flavor, so it is usually formulated with spices or fruit extracts.

Date fruit is one of the fruits that is rich in antioxidant content such as carotenoids (β-carotene, lycopene, lutein, neoxanthin, and zeaxanthin), phenols, flavonoids, flavonols, cinnamic acid (and its derivatives), and anthocyanins (Alhuzali et al., 2023). Date fruit in the khalas variety has a lower economic value than other varieties and its utilization as a powder drink is still very limited. Development of date powder has been carried out by foam matt drying method (Halede, 2024). However, no attempt has been made to increase antioxidant levels with spice substitution, or to increase collagen supply with the addition of hydrolase collagen.

Tamarind spices contain bioactive compounds such as flavonoids, tannins, alkaloids, saponins, sesquiterpenes (Silalahi, 2020). Tamarind has a distinctive and fresh sour taste that is expected to balance the sweetness of the date powder produced. In addition, cinnamon has chemical components such as cinnamic alcohol, coumarin, cinnamic acid, cinnamaldehyde, anthocyanins, essential oils, sugar, protein, simple fat, pectin and so on (Emilda, 2018). The fragrant, slightly sweet, and warm flavor of cinnamon is expected to balance the taste and

reduce the fishy taste and aroma of collagen from the formulated powder drink. The development of date juice-based functional beverages with the addition of spices has been carried out with a mixture of spices in the form of ginger, ginger, cinnamon, and meniran (Rosada, 2024). However, the product is ready to drink so that the shelf life is shorter than powdered drinks. In addition, efforts have not been made to increase collagen supply with the addition of hydrolase collagen.

Collagen powder drinks based on date juice and spices are still very limited in the market. Thus, optimization of the formula of collagen powder drink based on date juice and spices is needed to produce the appropriate quality. This research used the Mixture Design D-Optimal method in the Design Expert program for the formula optimization process. The research was then continued with the characterization stage based on chemical and physical tests.

MATERIALS AND METHODS

Study Areas

This research was conducted at the Food Processing Technology Laboratory, Biochemistry and Food Analysis Laboratory, and Food Sensory Analysis Laboratory of FTP UB, Malang and online. This research started in October 2024 and continued until March 2025.

Materials

In this study, the tools used for the process of making date spice collagen drink include analytical scales (Ohaus), electric oven dryer, mixer (Philips HR-1538), 100 ml measuring cup (Pyrex), grinder (Ecentio Glass Dual-Cup Juicer), container, and spoon. Tools used for antioxidant activity response testing and moisture content included analytical balance (Ohaus), beaker glass (Pyrex), 100 ml volumetric flask, distilled water bottle, glass stirrer, 1 and 10 ml volume pipettes (Iwaki Pyrex), bulb, centrifuge (Hettich EBA 200), centrifuge tube, dark bottle, test tube, vortex (IKA 3 Z654779), cuvette, UV-Vis spectrophotometer (Shimadzu). Tools used for characterization of antioxidant activity, total phenolics, dissolving time, hygroscopicity, and bulk density included centrifuge (Hettich EBA 200), centrifuge tubes, test tubes (Iwaki), bulb, 1 and 10 ml volume pipettes (Iwaki Pyrex), vortex (IKA 3 Z654779), cuvette, UV-Vis spectrophotometer (Shimadzu), stopwatch, stirrer, oven, analytical balance (Ohaus), desiccator, and measuring cup (Pyrex).

The ingredients used for the process of making date spice collagen powder drink include khalas variety dates in the tamar (ripe) phase obtained from the "Raja Kurma" store in Malang City, pure tamarind powder (Cairo Food), pure cinnamon powder (Blantika), fish hydrolase collagen powder (Max Food), maltodextrin (EX Lihua DE 10-20 food grade), TBM (Koepoe Koepoe), stevia extract powder (Subur Kimia Jaya Store), and distilled water. The materials used in the antioxidant activity test were 2,2-diphenyl-1-picrylhydrazyl (DPPH) reagent, methanol PA (Smartlab), trolox reagent (Merck), and distilled water. The materials used in the total phenol test were folin-ciocalteu reagent (Smartlab), gallic acid (Merck), Na_2CO_3 (Smartlab), and distilled water.

Research Procedures

Determination of Upper and Lower Limits on Independent and Fixed Variables

The first stage is the determination of the upper and lower limits on the independent variables consisting of date pollen, tamarind powder, cinnamon powder, and hydrolase collagen powder. Fixed variables in the formulation were also determined in the form of 2% stevia extract powder as shown in the following table.

Table 1. Independent Variables in Date-Spice Collagen Powder Beverage Formula Optimization.

Ingredient Name	Lower Limit	Upper Limit
Dates Powder	40%	50%
Tamarind Powder	20%	25%
Cinnamon Powder	20%	25%
Hydrolase Collagen Powder	5%	10%

Table 2. Fixed Variables in Date-Spice Collagen Powder Beverage Formula Optimization.

Ingredient Name	Amount (%)
Stevia Extract Powder	2

Optimization Condition on Design Expert

The formulation design in Design Expert consists of 20 runs with 4 factors, namely date powder, tamarind powder, cinnamon powder and hydrolase collagen powder with a total mixture of 100 and two types of responses, namely antioxidant activity (mg TE/100 g) and moisture content (%). The antioxidant activity response will be set according to the desired optimization results, which is at the maximize level while the moisture content is set at the minimize level.

Raw Material Analysis and Design Expert Optimization Response

Extraction of Khalas Date Fruit Variety

The dates were cut into smaller sizes. Then, the extraction process was carried out using distilled water solvent with the ratio of date fruit and solvent 2:3. The maceration process was carried out for 3x24 hours at a temperature of 5-9^{o}C to obtain date fruit extract (modification of Liandhajani et al., 2024).

Drying Date Fruits by Foam Matt Drying Method
Drying by the foam mat drying method was carried out by mixing 20% b/v maltodextrin and 1% b/v TBM with date fruit extract liquid and then homogenising with a mixer. The foam was then dried in an electric oven at 70±5ºC for 32 hours. The powder was cooled in a refrigerator at 5-9ºC for 24 hours. After that, pulverization was carried out with a grinder to obtain date fruit pollen. The powder was then sieved with a 40 mesh sieve to obtain a uniform particle size (modified by Halede, 2024; Estiasih et al., 2024). Based on this procedure, it can be concluded that the 'date fruit pollen' component in the formulation contains as much as 20% maltodextrin.

Antioxidant Activity Analysis DPPH Method
The antioxidant activity analysis began with the preparation of a standard curve of trolox at dilutions of 0, 10, 20, 30, 40, and 50 ppm. A total of 0.5 ml of trolox solution was put into a test tube, 3 ml of 40 ppm DPPH reagent was added, vortexed, and incubated in a dark room for 30 minutes. Then, the absorbance was measured by UV-Vis spectrophotometer at λ 517 nm. The absorbance results at each trolox concentration were plotted on the linear equation y = ax + b (modification of Thaipong et al., 2006; Plank et al., 2012).

In the sample test, 0.5 ml of sample solution was taken into a test tube and added with 3.5 ml of methanol and 3 ml of 40 ppm DPPH. Homogenized with a vortex and incubated in a dark room for 30 minutes. The absorbance was calculated by UV-Vis spectrophotometer at λ 517 nm. The absorbance results were plotted on the linear equation of the trolox standard curve to obtain concentration data (Maramy et al., 2024).

Moisture Content Analysis
The cup is dried in an oven at 105ºC for 1 hour before weighing the cup. The test sample is placed on the cup and the initial weight of the cup containing the sample is weighed. Drying in an oven at 105ºC for 1 hour and put in a desiccator for 10-15 minutes. Weighing the final weight of the cup containing the sample until it reaches a constant weight (difference of 0.002 grams) (AOAC, 2005). The percentage of moisture content was calculated using the following formula.

$$\text{Moisture content (\%)} = \frac{a-b}{b} \times 100$$

Notes:
a : Initial mass before drying (g)
b : Final mass after drying (g)

Total Phenol Analysis *Folin-ciocalteu* Method
The analysis of total phenolics began with the preparation of a gallic acid standard curve at dilutions of 0, 20, 40, 60, 80, and 100 ppm. A total of 0.5 ml of trolox solution was put into a test tube, added 10% folin-ciocalteu reagent was added up to 5 ml, vortexed, and incubated in a dark room for 5 minutes. Added 7.5% Na2CO3 solution as much as 4 ml, vortexed, and incubated in a dark room for 60 minutes. Then, the absorbance was measured by UV-Vis spectrophotometer at λ 756 nm. The absorbance results at each trolox concentration were plotted on the linear equation y = ax + b (modification of Singleton et al., 1999; Kupina et al., 2018).

In the sample test, 0.5 ml of the sample solution was taken into a test tube, 5 ml of 10% folin-ciocalteu reagent was added, vortexed, and incubated in a dark room for 5 minutes. 4 ml of 7.5% Na2CO3 solution was added, vortexed, and incubated in a dark room for 60 minutes. The absorbance was calculated by UV-Vis spectrophotometer at λ 756 nm. The absorbance results were plotted on the linear equation of the gallic acid standard curve to obtain concentration data (Maramy et al., 2024).

Characterization Test of Optimal Formula Solution
The second stage is the final product characterization stage. The final product consists of 98% independent variables that have been optimized using the Mixture Design D-Optimal method on Design Expert and 2% fixed variables. Before going through the characterization stage, the final product of optimization with the addition of 2% stevia extract powder will go through a re-drying process with an electric oven at 60ºC for 4 hours to meet the product requirements stated in SNI. No-01-4320-1996 on 'traditional powder drink', which has a maximum moisture content of 3%.

Dissolving Time Analysis
The test sample was weighed at 5 g and put into a glass beaker. Added 50 ml of room temperature water and homogenized with stirring. The dissolution time was recorded using a stopwatch until the sample solution was perfectly homogenized (Lubis et al., 2023).

Bulk Density Analysis
The test sample was weighed as much as 2 grams and a 10 ml measuring cup was prepared. Put the test sample into the measuring cup and stomped until the sample solidified and did not drop. The mass ratio of the test sample to the volume occupied in the measuring cup is recorded to determine the bulk density value in units of g/ml (Wulandari et al., 2020).

Hygroscopicity Analysis
Prepare a desiccator with a controlled RH of about 75%. Weighed the initial weight of the cup and the test sample as much as 0.5 g. Put the cup containing the sample into the desiccator for 24 hours. Weighed the final weight until it reached a constant weight (Huda, 2020). Calculated the level of hygroscopicity (Hg) using the following formula.

$$\text{Hg}\ (\%) = \frac{(\%\text{Wi} + \%\text{FW})}{100 + \%\text{Wi}} x100$$

Notes:
%Wi : (Weight of absorbed water/weight of material) x 100%
%FW : Initial moisture content of the ingredient

RESULTS AND DISCUSSION

Results

Raw Materials Analysis Results

The raw materials analyzed included date pollen, tamarind powder, cinnamon powder, and hydrolase collagen powder. The parameters tested included antioxidant activity (mg TE/100 g) DPPH method, moisture content (%), and total phenols (mg GAE/100 g) folin-ciocalteu method. The results of the analysis can be seen in Table 3 below.

Table 3. Raw Materials Analysis Results.

Test Variables	DTP	TMP	CNP	CLP
Antioxidant Activity (mg TE/ 100 g)	34,01±0,92	36,72±5,21	177,19±0,82	-
Moisture Content (%)	2,81±0,53	8,45±0,11	9,13±1,04	7,10±1,11
Total Phenol (mg GAE/ 100 g)	26,12±4,60	23,23±0,77	46,38±0,51	-

Notes: DTP = dates powder; TMP = tamarind powder; CNP = cinnamon powder; CLP = hydrolase collagen powder.

Formulation of Date Spice Based Collagen Powder Drink with Mixture Design

In using the D-Optimal Mixture Design method, the optimal formulation can be determined based on the desired target response. In this study, the antioxidant activity response will be set at the maximize level while the moisture content is set at the minimize level. The results of laboratory analysis of 20 formulations can be seen in Table 4 below.

Table 4. Response Analysis Result of Date Spice Based Collagen Powder Drink Formulation with Mixture Design.

	Independent Variables				Responses	
Run	Dates Powder (%)	Tamarind Powder (%)	Cinnamon Powder (%)	Hydrolase Collagen Powder (%)	Antioxidant Activity (mg TE/ 100 g)	Moisture Content (%)
1	40	25	25	10	66,79	6,54
2	50	20	20	10	31,29	6,27
3	47,5	20	25	7,5	53,41	6,26
4	45	20	25	10	53,99	6,17
5	40	25	25	10	52,24	6,46
6	46,43	22,86	22,86	7,86	69,12	6,34
7	50	20	25	5	73,59	6,10
8	43,21	23,93	23,93	8,93	33,23	6,29
9	50	20	20	10	31,10	6,24
10	47,5	25	20	7,5	77,66	6,28
11	45	25	25	5	109,67	6,17
12	45	25	20	10	72,03	6,38
13	50	25	20	5	108,12	6,37
14	45	25	25	5	94,93	6,48
15	47,5	22,5	25	5	70,09	6,22
16	50	22,5	20	7,5	53,80	6,05
17	50	22,5	22,5	5	78,63	5,99
18	50	20	22,5	7,5	30,32	6,03
19	45	20	25	10	58,84	6,48
20	45	25	20	10	60,97	6,32

Modelling and Analysis of DPPH Antioxidant Activity Response

Based on the analysis of the Design Expert program, it is known that the suggested model which considered to explain the interaction between variables on antioxidant activity response is a quadratic model. Analysis based on ANOVA for quadratic model of antioxidant activity response can be seen in Table 5.

Table 5. ANOVA of Quadratic Model on Antioxidant Activity Response.

	Antioxidant Activity	
	P-Value	
Model	0,0017	*significant*
Lack of Fit	0,0995	*not significant*

The relationship between each component of the independent variable and the antioxidant activity response in the form of an actual equation is as follows.

$$Y = -2{,}5068\ A + 74{,}8289\ B + 56{,}3700\ C + 152{,}5313\ D - 0{,}5992\ AB - 0{,}5266\ AC - 1{,}6243\ AD - 2{,}4384\ BC - 3{,}3473\ BD - 2{,}0472\ CD$$

Notes: A = dates powder; B = tamarind powder; C = cinnamon powder; D = hydrolase collagen powder

The 3D Surface graph shows the effect of the proportion between components on the tested response. The inter-component 3D surface graph of the antioxidant activity response can be seen in Figure 1 below.

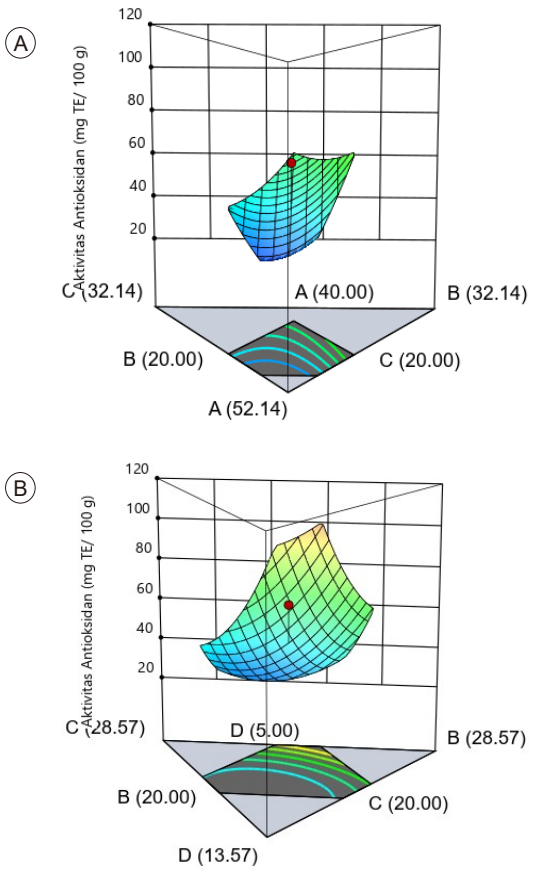

Figure 1. 3D Surface Graph of Date Powder (A), Tamarind Powder (B), Cinnamon Powder (C), and Hydrolyzed Collagen Powder (D) for Antioxidant Activity Response.

Modelling and Analysis of Moisture Content Response

Based on the analysis of the Design Expert program, it is known that the suggested model and considered to explain the interaction between variables on the antioxidant activity response is a linear model. Analysis based on ANOVA for the linear model of moisture content response can be seen in Table 6 below.

Table 6. ANOVA Linear Model on Moisture Content Response.

	Moisture Content	
	P-Value	
Model	0,0070	*significant*
Lack of Fit	0,8169	*not significant*

The relationship between each component of the independent variable and the moisture content response in the form of an actual equation is as follows.

$$Y = 0{,}0454\ A + 0{,}0847\ B + 0{,}0687\ C + 0{,}0846\ D$$

Notes: A = dates powder; B = tamarind powder; C = cinnamon powder; D = hydrolase collagen powder

The 3D Surface graph shows the effect of the proportion between components on the tested response The 3D Surface graph between components of the moisture content response can be seen in Figure 2. below.

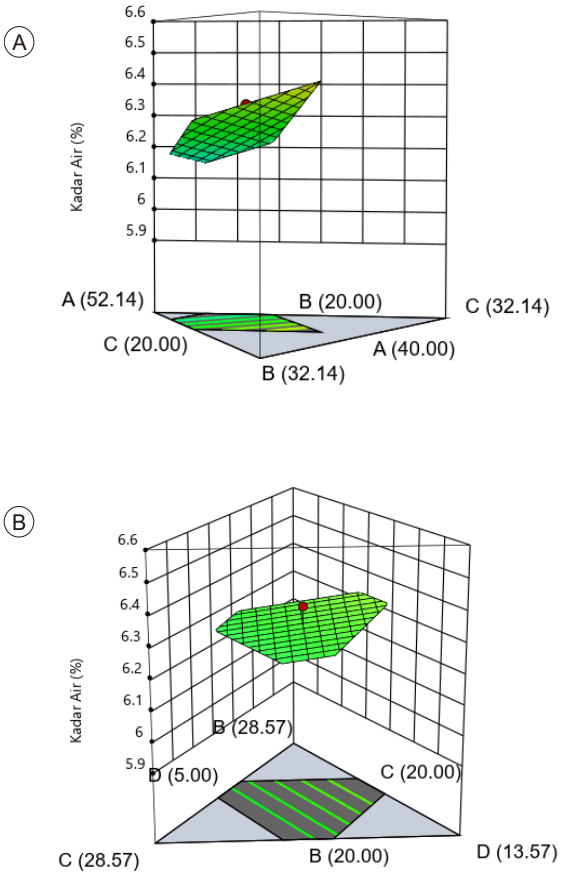

Figure 2. 3D Surface Graph of Date Powder (A), Tamarind Powder (B), Cinnamon Powder (C), and Hydrolyzed Collagen Powder (D) for Moisture content Response.

Design Expert Optimization Solution Prediction

The optimized solution from Design Expert shows the optimal formulation that matches the desired response target. The predicted response is subjected to a triplo verification test with the results in Table 7 and Table 8 below.

Table 7. Design Expert Optimization Solution Prediction.

Variables				Response Prediction		Desirability
Dates Powder (%)	Tamarind Powder (%)	Cinnamon Powder (%)	Hydrolase Collagen Powder (%)	Antioxidant Activity (mg TE/ 100 g)	Moisture Content (%)	
50,00	24,91	20,09	5,00	109,67	6,18	0,805

Table 8. Optimal Design Expert Formula Verification Result Data.

	Variables				Response Prediction	
	Dates Powder (%)	Tamarind Powder (%)	Cinnamon Powder (%)	Hydrolase Collagen Powder (%)	Antioxidant Activity (mg TE/ 100 g)	Moisture Content (%)
Prediction					**109,67**	**6,18**
Verification	50,00	24,91	20,09	5,00	105,34±6,61	6,03±0,23
Paired-T Test Results (*p-value*)					**0,374**	**0,364**

Characterization Stage: Chemical and Physical Test

The final formulation of collagen powder beverage product consists of 98% independent variables that have been optimized using Mixture Design D-Optimal method on Design Expert and 2% fixed variables. Before going through the characterization stage, the final optimized product with the addition of 2% stevia extract powder will go through a re-drying process with an electric oven at 60^{o}C for 4 hours. The results of chemical and physical characterization tests can be seen in Table 9 below.

Table 9. Chemical and Physical Test Characterization Results.

Test Variables	Characterization Results
Antioxidant Activity (IC_{50})(ppm)	263,25±8,01
Total Phenol (mg GAE/ 100 g)	101,71±9,21
Moisture Content (%)	2,98±0,01
Dissolving Time (seconds)	20,52±0,72
Bulk Density (g/ml)	0,52±0,14
Hygroscopicity (%)	18,73±0,04

Discussion

Raw Material Analysis Results

The raw materials analyzed included date pollen, tamarind powder, cinnamon powder, and hydrolase collagen powder. The parameters tested included antioxidant activity (mg TE/100 g) DPPH method, moisture content (%), and total phenols (mg GAE/100 g) folin-ciocalteu method.

Date powder was found to have antioxidant activity, moisture content, and total phenols of 34.01±0.92 mg TE/100 g, 2.81±0.53%, and 26.12±4.60 mg GAE/100 g, respectively. According to the literature, date powder contains antioxidant activity with percent inhibition up to 49.59 ± 0.27%, moisture content of 4.71 ± 0.11%, and total phenols of 27.9 ± 0.004 mg GAE / 100 g (Assous et al., 2021). These differences may occur due to differences in concentration and type of fillers as well as drying temperature and time. Date fruit itself naturally contains antioxidant compounds such as simple phenols, flavonoids (including flavones, anthocyanidins, flavonols, and isoflavones), cinnamic acid (along with derivatives such as ferulic acid, caffeic acid, p-coumaric acid, and others), and anthocyanins (flavonoid pigments) (Elisya et al., 2017).

Tamarind powder is known to have antioxidant activity, moisture content, and total phenols of 36.72±5.21 mg TE/100 g, 8.45±0.11%, and 23.23±0.77 mg GAE/100 g, respectively. According to the literature, tamarind powder contains antioxidant activity with percent inhibition of up to 49.27%, moisture content of 6.56±0.38%, and total phenols of 59.45-131.33 mg GAE/100 g (Muzaffar et al., 2016; Prasasti et al., 2023; Bhusari & Pradyuman, 2014). The difference may occur due to differences in drying methods, the addition of fillers, time, and drying temperature. Tamarind fruit itself naturally contains antioxidant compounds such as tannins and flavonoids (including catechin, epicatechin, proanthocyanidin, procyanidin, taxifolin, and apigenin) (Silalahi, 2020).

Cinnamon powder is known to have antioxidant activity, moisture content, and total phenols of 177.19±0.82 mg TE/100 g, 9.13±1.04%, and 46.38±0.51 mg GAE/100 g, respectively. According to the literature, tamarind powder contains antioxidant activity with a percent inhibition of up to 85.97%, moisture content of 8%, and total phenols of 13.85 mg GAE/g (Shoqairan et al., 2023; Nurminabari et al., 2019; Rakasivi & Koo, 2022). These differences may occur due to differences in drying methods, addition of fillers, time, and drying temperature. The antioxidant activity of cinnamon is

known to come from compounds such as eugenol, safrole, sinamaldehyde, tannins, and calcium oxalate (Dirpan et al., 2019).

The hydrolase collagen powder was not chemically tested due to the turbidity of the solution caused by the remaining non-collagen content due to incomplete extraction and hydrolysis process (Pebrianti et al., 2023) thus interfering with the absorption reading by UV-Vis spectrophotometer. However, some literature mentioned the antioxidant activity of hydrolase collagen powder varies depending on the content of hydrophobic amino acids such as histidine, methionine, valine, asparagine, glycine, proline, and glutamine that can react with free radicals (Yanti et al., 2022). In addition, the moisture content of the collagen powder was found to be 7.10±1.11%. According to Walin et al. (2024), the moisture content of tilapia collagen hydrolysate hydrolyzed with papain enzyme ranged from 4.78 - 8.30%.

Modeling and Analysis of DPPH Antioxidant Activity Response

Based on Table 4, it is known that the tested powder drink formulations have antioxidant activity in the range of 30.32 - 109.67 mg TE/100g. Based on the analysis of the Design Expert program, it is known that the suggested model and considered to explain the interaction between variables on the antioxidant activity response is a quadratic model. In Table 5, it can be seen that based on the sequential model sum of squares shows a p-value of 0.0017 (<0.05) for the quadratic model so that the model can be said to be significant. In addition, the value of lack of it or model imprecision shows a p-value of 0.0995 (> 0.05) so it is not significant. It can be concluded that the inaccuracy of the model has a real effect and the model is considered to be able to explain the effect of the independent variables used and can estimate the optimum formula to get the desired response (Widyaningsih et al., 2022).

In the actual equation of the selected quadratic model, it is known that the date powder variable (A) individually causes a negative response to antioxidant activity. This could be due to the content of maltodextrin in date powder, which is 20% maltodextrin as filler. The more fillers used, the proportion of ingredients with antioxidant compounds will also be less because basically fillers such as maltodextrin do not contain antioxidant compounds as the main component (Framida et al., 2022). In addition, other variables showed a positive response to antioxidant activity due to the pure powder content that naturally contains various bioactive compounds. In addition, it is also known that all interactions between the two factors indicate a decrease in the antioxidant activity of the formula product. This is related to the antagonism that occurs when several antioxidant compounds are formulated together.

In Figure 1, regarding the 3D surface graph between components and antioxidant activity response, it can be seen that increasing the proportion of tamarind powder, cinnamon, and hydrolase collagen can increase the antioxidant activity of the powder drink formula. In addition, the decrease was caused by the increase in the proportion of date powder and the negative interaction between ingredients.

Modeling and Analysis of Moisture Content Response

Based on Table 4, it is known that the powder drink formulations that have been tested have a moisture content in the range of 5.99 - 6.54%. Based on the analysis of the Design Expert program, it is known that the suggested model and is considered to explain the interaction between variables on the antioxidant activity response is a linear model. Based on Table 6, it can be seen that the sequential model sum of squares shows a p-value of 0.0070 (<0.05) for the linear model so that the model can be said to be significant. In addition, the value of lack of it or model imprecision shows a p-value of 0.8169 (> 0.05) so that it is not significant.

In the actual equation of the selected quadratic model, it is known that each variable individually shows a response to the increase in moisture content in the powder drink formulation. This is in accordance with the results of the analysis of raw materials that have been carried out that each variable contains varying moisture content. Those are date powder of 2.81 ± 0.53%, tamarind powder of 8.45 ± 0.11%, cinnamon powder of 9.13 ± 1.04% and hydrolase collagen powder of 7.10 ± 1.11%.

In Figure 2, related to the 3D surface graph between components with the response of moisture content, it is known that the increase in the proportion of date powder, tamarind powder, cinnamon, and hydrolase collagen can each increase the moisture content of the powder drink formula.

Design Expert Optimization Solution Prediction

The optimized solution from Design Expert shows the optimal formulation that matches the desired response target. The predicted response will go through a triplo verification test with the results in **Table 8**. In **Table 7**, it is known that the optimal formulation suggested by Design Expert is 50% date powder, 24.91% tamarind powder, 20.09% cinnamon powder, and 5% hydrolase collagen powder. The predicted responses to the optimization results are antioxidant activity of 109.67 mg TE/100 g and moisture content of 6.18%. In addition, the resulting desirability value is 0.805 where the desirability value which is closer to 1 indicates the better the suggested formulation solution because it is considered capable of producing the predicted optimal response (Hidayat et al., 2021).

In Table 8, it is known that the p-value of paired t-test shows a value of 0.374 for the antioxidant activity response and 0.364 for the moisture content response. This shows that the results of verification in the laboratory are not significantly different from the

predicted response from Design Expert because it has a p-value > 0.05 (Niariska, 2024).

Characterization Stage: Chemical and Physical Test

Based on Table 9, related to the results of chemical and physical test-based characterization tests, it is known that the formulated product has an IC_{50} antioxidant activity value of 263.25 ± 8.01 ppm. IC_{50} is a value that states the concentration of an extract (ppm) needed to inhibit the oxidation of radical compounds by 50% so that the smaller the IC_{50} value of an extract the higher the antioxidant activity of the extract (Widyaningsih et al., 2015). IC_{50} values in the range of 250-500 ppm indicate the activity of antioxidant compounds at the 'weak' level (Asmin et al., 2021).

The formulated product has a total phenol of 101.71 ± 9.21 mg GAE / 100 g. In the analysis of raw materials conducted, it is known that each independent variable has varying levels of total phenols. The highest total phenol content was in cinnamon powder and the lowest was in date powder. So, it can be said that the total phenols of the final product may be dominated by the content of eugenol, safrole, cinnamaldehyde, tannins, and calcium oxalate in cinnamon powder (Dirpan et al., 2019).

The formulated product has a moisture content of 2.98 ± 0.01%. The moisture content is influenced by the initial moisture content of the raw materials, temperature, and drying time. Basically, this figure has met the product requirements stated in SNI. No-01-4320-1996 on 'traditional powdered beverages', which has a maximum moisture content of 3%.

The formulated product has a dissolving time of 20.52 ± 0.72 seconds. Basically, the powder drink cannot dissolve completely due to the presence of sediment from large enough powder molecules. However, the measurement of dissolving time is done only until the beverage solution looks unsuspended. The powder drink product still meets the criteria for the dissolving time of powder drinks which is classified as good because it has a dissolving time of less than 5 minutes (Yuliastuti, 2020).

The formulated product has a bulk density value of 0.52 ± 0.14 g/ml. The high bulk density can be caused by the high moisture content which causes the powder particles to stick together and the cavities between particles will be smaller so that when weighed in the same volume, the powder will be heavier (Hartati, 2023). A large slurry density indicates that the product can be stored in large quantities in small packages so that it is more economical and practical, especially on an industrial scale (Wulandari et al., 2020).

The formulated product has a hygroscopicity level of 18.73 ± 0.04%. The product is included in the category of hygroscopic products or easily absorbs water because it has a hygroscopicity value in the range of 15.1 - 20.0% (Nurlaela et al., 2024). Therefore, it is necessary to use airtight packaging or add anti-caking agents during storage. The high hygroscopicity value of the product can be caused by the natural sugar content in date powder such as fructose and glucose which are hygroscopic due to the presence of hydroxyl groups (-OH) that easily bind to water (Assalam et al., 2022).

CONCLUSIONS

The optimal date spice collagen powder beverage formula suggested by Design Expert software consists of 50% date powder, 24.91% tamarind powder, 20.09% cinnamon powder, and 5% hydrolase collagen powder. The predictions generated from the formula were antioxidant activity of 109.67 mg TE/100 g and moisture content of 6.18%. The verification test showed no significant difference between the laboratory test and the prediction of the optimal formula response.

In the antioxidant activity response, it was known that increasing the proportion of date powder caused a decrease in antioxidant activity while increasing the proportion of tamarind powder, cinnamon powder, and hydrolase collagen powder caused an increase in antioxidant activity. In addition, in the moisture content response, it is known that increasing the proportion of each variable causes an increase in moisture content.

The results of chemical test-based characterization on the optimal date spice collagen powder formula with the addition of stevia powder resulted in antioxidant activity (IC_{50}) of 263.25 ± 8.01 ppm and total phenol content of 101.71 ± 9.21 mg GAE / 100 g). In addition, the physical test-based characterization results resulted in a moisture content of 2.98 ± 0.01%, a dissolving time of 20.52 ± 0.72 seconds, a bulk density of 0.52 ± 0.14 g/ml, and a hygroscopicity of 18.73 ± 0.04%.

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