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Influence of Soaking Temperature and Concentration of Sugar Solution in the Process of Osmotic Dehydration of Curcuma (*Curcuma xanthorrhiza* Roxb.)

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ABSTRACT

Curcuma (Curcuma xanthorrhiza Roxb.) is a type of medicinal plant native to Indonesia that has a moisture content of around 80-90% when harvested. Osmotic dehydration is a technique for reducing water content that can be used to overcome this problem by immersing the material in a high concentration solution. The purpose of this study was to analyze the effect of temperature and concentration of sugar solution on final water content, weight reduction, solid gain, water loss, and analyze the temperature and concentration optimal for the observed variables in curcuma dehydration process. The method used in this study was to use a completely randomized design (CRD) which was arranged in a factorial manner with 2 factors namely sugar content 50°Brix, 60°Brix, 70°Brix and immersion temperature 30°C, 40°C, 50°C with 3 repetitions. The results of the curcuma osmotic dehydration process which produces the most optimal treatment combination is at an immersion temperature of 50°C and a solution concentration of 70°Brix. This treatment combination resulted in a water content of 63.44% wb, a weight reduction of 34.73%, a solid gain of 11.81%, a water loss of 46.54%, and a total color difference of 69.64.

1. INTRODUCTION

Temulawak or curcuma (*Curcuma xanthorrhiza* Roxb.) is one of the indigenous medicinal plants of Indonesia that is widely utilized by the community. It has a genus of curcuma and It is known as Javanese turmeric (Nurcholis *et al*., 2018). Temulawak grows wild in forests on the islands of Java, Madura, Maluku, Kalimantan, Bali, and Nusa Tenggara. The rhizome of this plant can be utilized for raw materials for medicine, traditional herbal drinks, and fresh beverages (Hatmi & Febrianty, 2014). Furthermore, *C. xanthorrhiza* is used in various food and beverage industries such as natural dyes, starch sources, and cosmetic dyes. *C. xanthorrhiza* is rich in essential oils and curcumin. Curcumin content in temulawak is 8.08% (g/g sample) (Sutarsi *et al*., 2024). Curcumin is a natural polyphenol. Curcumin has higher antioxidant properties than vitamin E and betacarotene (Rosidi, 2020). It also has bioactivity as a nitric oxide inhibitory, anti-inflammatory (Awin *et al*., 2019), and anticarcinogenic activities (Vernieri *et al*., 2018). Temulawak, as a medicinal plant, certainly has many benefits. According to Fauzi (2018), the widely known benefits of temulawak among the community include increasing appetite, treating constipation and muscle aches, and liver disorders.

Temulawak has a relatively high water content, ranging from 80% to 90% when harvested (Putra & Kuncoro, 2021). This can lead to increased growth of microorganisms such as bacteria and fungi. Moreover, the high water content in the plant can reduce its shelf life. Temulawak also has a distinctive aroma and taste even after being processed into beverages or simplicia, resulting in many people not being interested in consuming this healthy spice (Moehady, 2015).

To address this issue, the most commonly used method is drying. One of the methods for drying food materials is osmotic dehydration drying.

Osmotic dehydration is a technique used to remove some water by immersing the material in a hypertonic solution (Magdalena, 2014). In the process, osmotic dehydration is influenced by the type of solute, osmotic solution concentration, solution temperature, and soaking time. Osmotic dehydration is usually carried out in the pre-treatment stage of drying, which will later be combined with two or more other methods. Additionally, osmotic dehydration using sugar solutions can maintain the initial characteristics of the material (color, aroma, nutrition, and texture), save and improve energy efficiency, and preserve the material so that browning does not occur.

The objective of this study is to analyze the influence of temperature and sugar solution concentration on water content, weight reduction, solid gain, water loss, and color analysis in the osmotic dehydration process of temulawak. Additionally, to analyze the optimal operating conditions of temulawak osmotic dehydration (temperature and sugar solution concentration) based on water content, weight reduction, solid gain, water loss, and color analysis in the osmotic dehydration process of temulawak.

2. MATERIALS AND METHODS

This research was conducted at the Agricultural Product Engineering Laboratory, Department of Agricultural Engineering, Faculty of Agricultural Technology, Universitas Jember from January 2023 to April 2023. The equipment used in this research included a water bath, electric stove, Daeyang oven, desiccator, refractometer, CS-10 colorimeter, 1 L beaker glass, spoon, digital scale (Ohaus pioner PA2102C), plastic containers, thermometer, knife, cup, and cutting board. The materials in this research included sugar, distilled water, plastic wrap, tissue roll, embroidery thread, label paper, and fresh temulawak obtained from the Gumukmas District, Jember Regency.

2.1. Research Design

This study employed a Completely Randomized Factorial Design consisting of 2 factors. Each factor consisted of 3 levels with 3 replications. The first factor was soaking temperature, consisting of T1: 30 °C; T2: 40 °C; and T3: 50 °C. The second factor was the sugar solution concentration, consisting of S1: 50°Brix; S2: 60°Brix; and S3: 70°Brix.

2.2. Research Implementation

1. Preparation of Osmosis Solution (Rum *et al*., 2019)

Preparation began with gathering the necessary equipment and materials. Then, sugar was weighed as much as 500 g, 600 g, and 700 g and added 500 ml, 400 ml, and 300 ml of distilled water respectively, or alternatively used a ratio of 1:2 or 1:3 for optimal ratio in the osmotic dehydration process (Chavan, 2012). Next, the sugar was put into a pan and cook at 80 °C for 4 min, stirred the mixture until all the sugar was completely dissolved. The concentration of the solution must be correct (50°Brix, 60°Brix, 70°Brix) by using a refractometer. Afterwards, the solution was transferred into a container and let it cool for at least one hour at room temperature.

2. Sample Preparation (Rum *et al*., 2019)

The steps in preparing the samples began with washing and cutting the temulawak into pieces with dimensions of approximately 2 cm in length and width, ±0.5 cm in thickness, and weighing approximately ±2 g.

3. Osmosis Dehydration Process (Rum *et al*., 2019)

The osmosis dehydration process was started by pouring the sugar solution into a beaker glass. Then, 24 pieces of samples were immersed into the sugar solution. Next, the beaker glass containing the solution and samples was placed into a water bath maintained at the predetermined temperature. Subsequently, the samples was immerse for the specified duration, weighed, and recorded the data.

2.3. Research Variables

1. Moisture Content

The calculation of initial and final moisture content was carried out using gravimetric or oven methods, which involve weighing the sample before soaking (A0) and after soaking (At). Subsequently, the samples were placed in an oven until a constant weight was achieved at 105 °C (S0) and (St). The data obtained was then processed using the formula for initial and final moisture content (Magdalena *et al*., 2014).

$$W0 = \frac{A0-S0}{A0} \text{ x } 100\% \tag{1}$$

$$Wt = \frac{At-St}{At} \text{ x } 100\% \tag{2}$$

where $W0$ is initial moisture content on a wet basis (%), $A0$ is weight of the temulawak sample before soaking (g), and $S0$ is weight of the dried temulawak sample before soaking (g), Wt is final moisture content on a wet basis (%), At is weight of the temulawak sample after soaking at time t (g), and St is weight of the dried temulawak sample after soaking at time t (g).

2. Weight Reduction

The weight reduction (WR) was calculated using the following formula (Givari *et al*., 2022).

$$WR = \frac{A0-At}{A0} \times 100\% \tag{3}$$

3. Solid Gain

Solid gain (SG, in %) was calculated according to the following formula (Givari *et al*., 2022).

$$SG = \frac{St-S0}{A0} \times 100\% \tag{4}$$

4. Water Loss

The water loss (WL, in %) was subsequently calculated using the water loss formula (Givari *et al*., 2022).

$$WL = \frac{(A0-S0)-(At-St)}{A0} \times 100\% \tag{5}$$

5. Color Analysis (Hunter & Harold, 1987)

Color analysis of temulawak was performed using the Colorimeter CS-10 device. Measurements with this device produce L, a, and b values. The L represents brightness parameter (0 = black to 100 = white). The chromatic color of red-green was indicated by the a value (a+ = 0 to 100 for red, a = 0 to -80 for green. The chromatic color of blue-yellow mixture was indicated by the b value (b+ = 0 to 70 for yellow, b = 0 to (-70) for blue color.

$$\Delta E^*_{ab} = \sqrt{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2} \tag{6}$$

where ΔE^*_{ab} is total color difference, ΔL = (L* sample – L* standard), Δa = (a* sample – a* standard), and Δb = (b* sample – b* standard). Positive ΔL indicated brighter, and negative ΔL meant darker. Positive Δa indicated red, and negative Δa meant green. Positive Δb indicated yellow, and negative Δb meant blue.

2.4. Data Analysis

The data obtained from the testing were processed using Microsoft Excel and SPSS version 24 software. The analyses conducted in this research include two-way Analysis of Variance (ANOVA). If there was a significant difference in the ANOVA test, the analysis was continued by Duncan's Multiple Range Test (DMRT) at a significance level of $p \leq 0.05$.

After the Duncan's test, correlation was examined using the bivariate two-way Pearson method. Data analysis was used to determine the optimal treatment combinations for each observation variable was done using scoring methods. Subsequently, the data is presented in tabular form to facilitate data interpretation.

3. RESULTS AND DISCUSSION

3.1. Changes in Moisture Content during Osmotic Dehydration Process

Measurement of moisture content in the temulawak samples is conducted before and after the osmotic dehydration process. This measurement is carried out to determine the initial moisture content of temulawak before treatment and the final moisture content after treatment. The measurement of initial moisture content is performed using fresh temulawak samples, while the measurement of final moisture content is conducted using temulawak samples that have undergone the osmotic dehydration process. The results of the initial moisture content measurement in this study ranged from 90.09%. This is consistent with the statement by Putra & Kuncoro (2021) which states that temulawak has a relatively high water content, ranging from 80% to 90% when harvested. The difference in moisture content in temulawak is influenced by the age of the temulawak plants. Young temulawak tends to have higher moisture content than older temulawak. In addition, the length of storage also affects this difference in moisture content. The longer it is stored in an open space, the lower its moisture content. The results of the final moisture content measurement in this study can be seen in the following figure.

Based on Figure 1, it can be observed that the higher the soaking temperature and the higher the concentration of the sugar solution used, the lower the resulting final moisture content. The decrease in moisture content is caused by the difference in solute concentration between the sample and the sugar solution, resulting in a difference in osmotic pressure between the water in the sample tissue and the sugar solution, causing water to exit the sample tissue into the sugar solution (Aras *et al*., 2019). This is consistent with the statement by Magdalena (2014), which suggests that moisture content decreases as the temperature and concentration of the solution increase. The moisture content obtained in this study is 53.13%. This moisture content is still insufficient for regular storage. Therefore, further drying is necessary to remove moisture to a safe level for long-term storage.

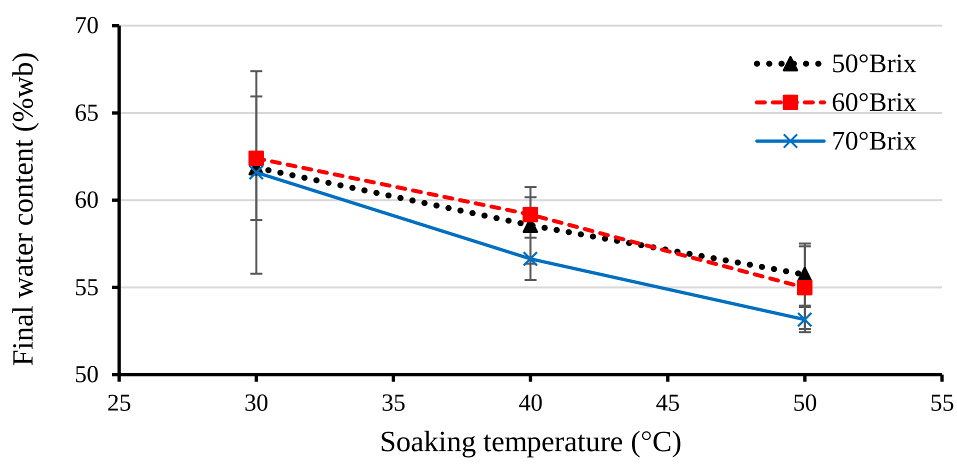

Figure 1. Effect of soaking temperature and solution concentration on the final moisture content (%wb) at soaking time of 160 min.

3.2. Weight Reduction in Osmotic Dehydration Process

Measurement of weight reduction is conducted during the osmotic dehydration process. This measurement is carried out to determine the weight loss of the sample after the osmotic dehydration process. The following are the results of the weight reduction measurement in the osmotic dehydration process of temulawak. Based on Figure 2, it can be observed that the higher the temperature and concentration of the solution used, the higher the value of weight reduction

(*WR*) in temulawak. This is consistent with the statement by Rum *et al*., (2019), which states that a soaking temperature of 50°C and a solution concentration of 70°Brix have the highest WR value. The increase in *WR* value occurs because the soaking temperature or osmosis solution temperature and solution concentration can influence the *WR* value in the material. According to Magdalena *et al*., (2014), an increase in osmosis solution concentration results in increased water loss in the material, leading to an increase in weight reduction. Additionally, the osmosis solution temperature can affect the cell wall structure and cell density, thereby affecting mass transfer processes or permeability. If the soaking temperature is high, the cell wall and density will decrease, accelerating mass transfer and permeability in the osmotic dehydration process (Aras *et al*., 2019). This results in weight reduction in temulawak.

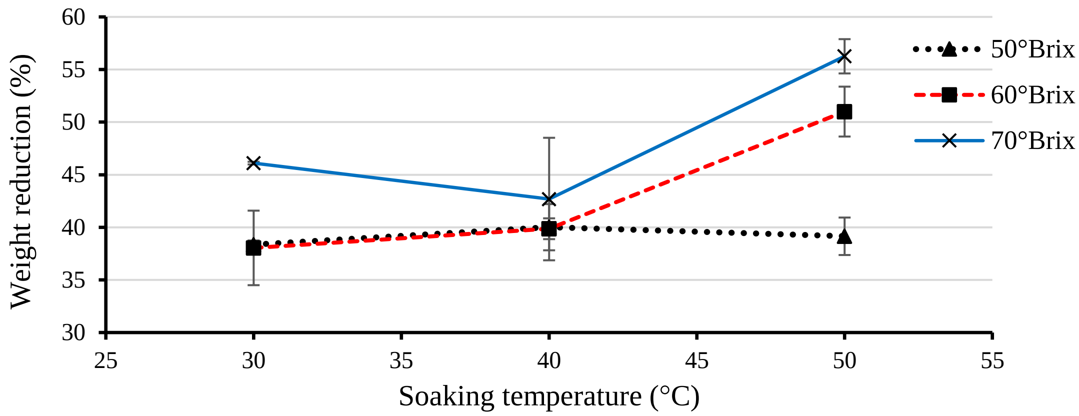

Figure 2. Effect of soaking temperature and solution concentration on weight reduction (%) at soaking time of 160 min.

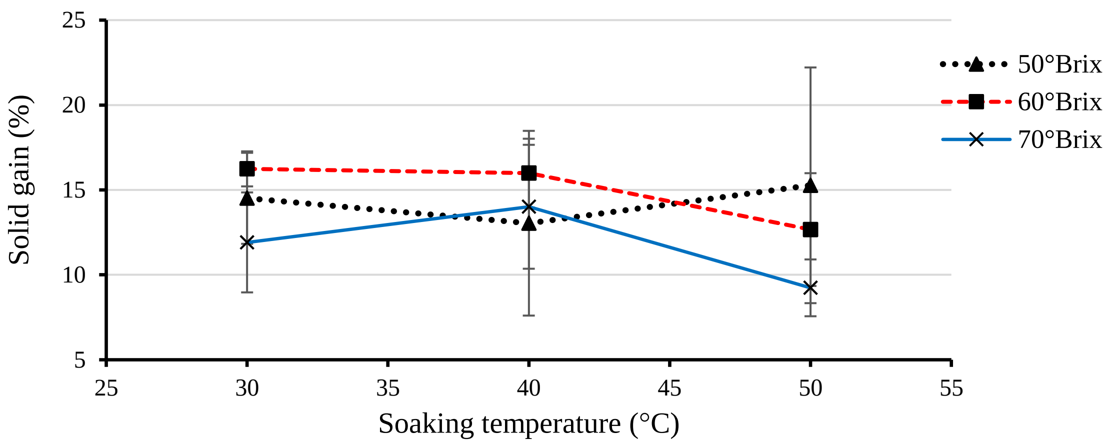

Figure 3. Effect of soaking temperature and solution concentration on solid gain (%) at soaking time of 160 min.

3.3. Solid Gain in Osmotic Dehydration Process

Measurement of dissolved solids entering the material, or solid gain, is conducted during the osmotic dehydration process. This measurement is carried out to determine the amount of solids entering the temulawak during the osmotic dehydration process, expressed as a percentage. The following are the results of solid gain measurement in the osmotic dehydration process of temulawak. Based on Figure 3, the solid gain measurement graph appears fluctuating. However, according to the research conducted by Arlita *et al*., (2013), this parameter should indicate that the higher the soaking temperature and osmosis solution concentration, the higher the SG value. This inconsistency may be due to the use of different temulawak samples for each measurement during the osmotic dehydration process, resulting in inconsistent SG values at each minute. Additionally, another possible factor affecting this inconsistency could be the varying cell density in each sample. According to Wirawan & Anasta (2013), the soaking temperature can affect cell wall thickness and density between cells. Materials with low porosity show higher absorption of solutes compared to materials with high porosity. This is because the air in the tissue pores can act as a barrier to mass transfer, thus the material's porosity can affect water loss and solid gain (González-Pérez *et al*., 2021).

3.4 Water Loss from the Material in the Osmotic Dehydration Process

Measurement of the amount of water exiting the material, or water loss, is conducted during the osmotic dehydration process. This measurement is carried out to determine the reduction in the amount of water present in the temulawak after osmotic dehydration occurs. The following are the results of water loss measurement in the osmotic dehydration process of temulawak. Based on Figure 4, it can be observed that the higher the temperature and concentration of the solution used, the higher the water loss value in temulawak. This is consistent with the statement by Magdalena *et al*., (2014), which suggests that the water loss value tends to increase as the temperature and concentration of the sugar solution used increase. This is due to the greater osmotic pressure difference between the sugar solution and the water in the material. This pressure difference acts as the driving force causing water mass in the material to flow out towards the osmosis solution (Aras *et al*., 2019). Additionally, according to Wirawan & Anasta (2013), the solution concentration provides a different potential influence in the osmotic dehydration system. The higher this potential difference, the faster the water exits the material.

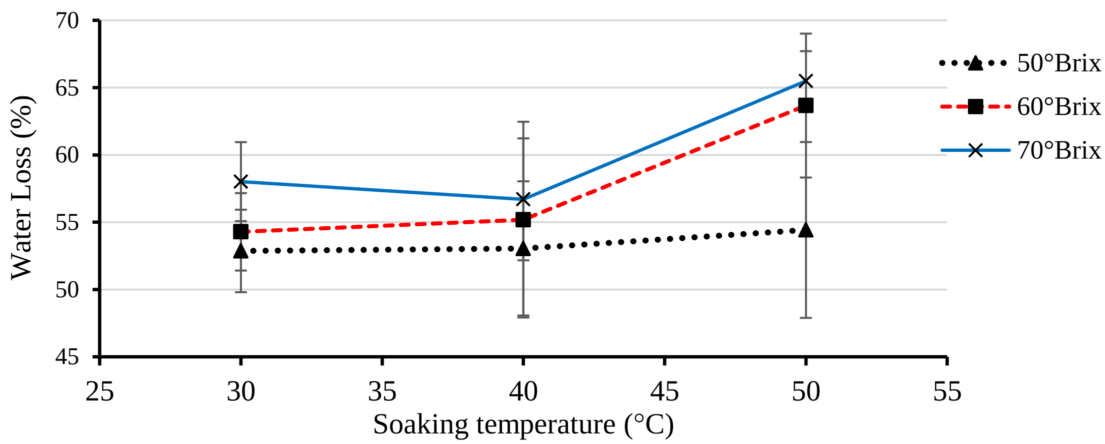

Figure 4. Effect of soaking temperature and solution concentration on water loss (%) at soaking time of 160 min.

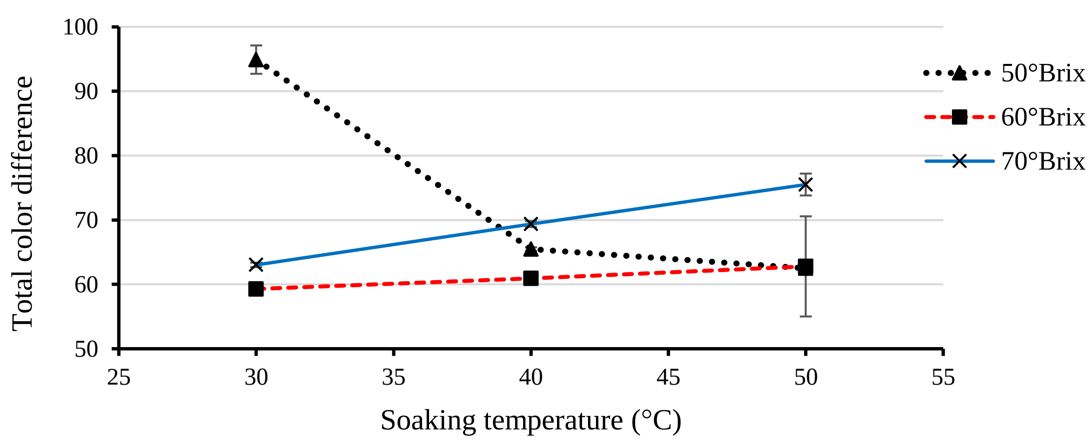

Figure 5. Effect of soaking temperature and solution concentration on total color difference (ΔE) at soaking time of 160 min.

3.5 Color Analysis in the Osmotic Dehydration Process

Color analysis is conducted before and after the dehydration process. This color testing is performed to understand the effect of osmotic dehydration on the color of temulawak. The following are the results of the total color difference measurement in the osmotic dehydration process of temulawak. In the color analysis, the graph appears fluctuating. However, based on the research conducted by Givari *et al*., (2022), the color analysis observations should indicate that the higher the soaking temperature and osmosis solution concentration, the higher the total color difference value. This inconsistency is attributed to the use of different temulawak samples for each measurement during the osmotic dehydration process, resulting in inconsistent ΔE values for each minute. According to Givari *et al*., (2019), the total color difference can be influenced by the amount of sugar molecules entering the material (solid gain).

3.6. Analysis of Variance of the Treatment Effect on Observation Variables

The data obtained during the research were further analyzed using a two-way ANOVA test aimed at determining the differences in means between soaking temperature and sugar solution concentration on various observation variables. The analysis of the two-way ANOVA test data was conducted using Microsoft Excel, and each observation variable used a significance level of 0.05. If the calculated F-value is greater than the tabulated F-value, it indicates a significant difference, meaning that the variables of temperature and sugar solution concentration have an influence on the observation variables of moisture content, weight reduction, solid gain, water loss, and color analysis. The following are the results of the ANOVA test that have been conducted.

Table 1. Results of two-way ANOVA test for each observation variable

Observation Variables	Source of Variation	Sum of Squares (SS)	Degrees of Freedom (df)	Mean Sum of Squares (MSS)	F-count	F-table	Explanation
Final Moisture Content	T	241.80	2	120.90	17.27	3.55	Significant
	S	16.61	2	8.30	1.19	3.55	Not significant
	Interaction T × S	5.49	4	1.37	0.20	2.93	
	Error	126.08	18	7.00			
	Total	389.97	26				
Weight Reduction	T	379.85	2	189.93	3.22	3.55	Not significant
	S	382.71	2	191.36	3.56	3.55	Significant
	Interaction T × S	218.21	4	54.55	0.92	2.93	
	Error	1063.45	18	59.08			
	Total	2044.22	26				
Solid Gain	T	21.53	2	10.77	0.77	3.55	Not significant
	S	52.66	2	26.33	1.88	3.55	Not significant
	Interaction T × S	44.43	4	11.11	0.79	2.93	
	Error	251.73	18	13.99			
	Total	370.36	26				
Water Loss	T	229.01	2	114.51	5.13	3.55	Significant
	S	202.85	2	101.42	4.55	3.55	Significant
	Interaction T × S	71.08	4	17.77	0.80	2.93	
	Error	401.69	18	22.32			
	Total	904.63	26				

Note: T is soaking temperature, and S is sugar solution concentration

Based on Table 1, soaking temperature treatment has an effect on the variables of moisture content and water loss. Meanwhile, sugar solution concentration treatment has an effect on the variables of weight reduction and water loss. However, there is no significant effect on the observation variables for the interaction between soaking temperature and sugar solution concentration. The strength of the relationship between the observation variables and treatment variables can be seen in the following Table 2. The positive correlation values indicate that there is a direct relationship between the observation variables and treatment variables. Negative values indicate an inverse correlation relationship. According to Supardi (2012), the coefficient intervals indicate the strength of the relationship: a coefficient in the range of 0.00 – 0.199 indicates a very low level of relationship, 0.20 – 0.399 indicates a low level of relationship, 0.40 – 0.599 indicates a moderate level of relationship, 0.60 – 0.799 indicates a strong level of relationship, and 0.80 – 1.000 indicates a very strong level of relationship.

Table 2. Results of correlation test between treatment variables and observation variables

Observation Variables	Value			Treatment Factors	
	Minimum	Maximum	Mean	Soaking Temperature	Solution Concentration
Moisture content (%wb)	52.64	68.04	58.23	-0.787**	-0.171
Weight reduction (%)	23.62	58	43.50	0.374	0.431*
Solid gain (%)	8.21	23.28	13.65	-0.201	-0.282
Water loss (%)	46.83	67.17	57.08	0.433*	0.467*

* There is a significant correlation at the level of ≤ 0.05; ** There is a significant correlation at the level of ≤ 0.01

Table 3. Total scores of treatment combinations for each observation variable

Treatment Combination	Mean Values					Score					Total Score
	MC (%wb)	WR (%)	SG (%)	WL (%)	ΔE	*MC*	*WR*	*SG*	*WL*	Δ*E*	
T1S1	61.86	38.36	14.51	52.86	94.92	2	2	6	1	1	12
T1S2	62.4	38.04	16.24	54.28	59.29	1	1	9	3	9	23
T1S3	61.59	46.1	11.91	58.01	63.03	3	7	2	7	5	24
T2S1	58.55	40.01	13.04	53.05	65.48	5	5	4	2	4	20
T2S2	59.17	39.87	15.99	55.19	60.91	4	4	8	5	8	29
T2S3	56.63	42.69	14.01	56.7	69.38	6	6	5	6	3	26
T3S1	55.73	39.15	15.27	54.42	62.5	7	3	7	4	7	28
T3S2	54.98	51	12.67	63.67	62.8	8	8	3	8	2	29
T3S3	53.15	56.26	9.24	65.49	75.51	9	9	1	9	6	34

Note: T = soaking temperature; S = sugar solution concentration; MC = moisture content; WR = weight reduction; SG = solid gain; WL = water loss; and ΔE = total color difference.

3.7. Optimal Soaking Temperature and Sugar Solution Concentration

The analysis to determine the most optimal combination of soaking temperature and sugar solution concentration for moisture content, weight reduction, solid gain, water loss, and color analysis is conducted using scoring method. Below are the scores obtained for each treatment combination for each observation variable. Based on Table 3. it can be observed that there are nine treatment combinations. resulting in a score range from 1 to 9. A score of 1 is given to the least desirable treatment combination, while a score of 9 is given to the most desirable one. The highest total score is obtained at a soaking temperature of 50 °C and a sugar solution concentration of 70°Brix. with a total score of 34. Therefore. the most optimal treatment combination based on the total score obtained for all observation variables is a soaking temperature of 50°C and a sugar solution concentration of 70°Brix.

4. CONCLUSIONS

1. The results of the two-way ANOVA and correlation analysis indicate that there is an effect on the variables of water content and water loss in the soaking temperature treatment. In the sugar solution concentration treatment. there is an effect on the variables of weight reduction and water loss. However, in the interaction between soaking temperature and sugar solution concentration, there is no effect on the observation variables.
2. The analysis of the most optimal soaking temperature and sugar solution concentration based on the observation variables in the osmotic dehydration process of temulawak indicates that the optimal treatment combination is soaking temperature of 50°C and sugar solution concentration of 70°Brix.

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