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Physical Quality of Tomato Powder (*Lycopersicum Esculentum* Mill.) Produced by Foam-Mat Drying Method Using Convection Oven

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ABSTRACT

Tomatoes (Lycopersicum esculentum Mill.*) have a fairly low shelf life, therefore further processing is needed to increase the shelf life and economic value of tomatoes, one of which is by processing it into tomato powder. The purpose of this study was to determine the physical quality of tomato powder produced from foam drying in a convection oven at different temperature variations and concentrations of Tween 80. This research method used a completely randomized design with two treatment variables, namely temperature and concentration of foaming agent Tween 80. The temperatures used were 60, 70, and 80°C while the concentration of Tween 80 used was 0.4; 0.7; and 1.0%. Data analysis used a two-way ANOVA test followed by the Duncan test and correlation test. The physical quality parameters of tomato powder showed values of the fineness modulus ranging from 1.19 – 1.77; the grain size value ranges from 0.0094 – 0.0141 mm; powder moisture content values range from 5.36 – 6.48%bb; L values range from 76.20 – 79.01; a value ranges from 12.51 – 14.81; b values range from 18.21 – 21.73; bulk density values range from 0.56 – 0.63 g/cm^3; oil absorption value ranges from 0.85 – 0.89 ml/g; angle of repose values range from 33.65 – 36.09°. The temperature difference affects the fineness modulus, grain size, and moisture content. While the difference in the concentration of Tween 80 affects the color parameters (L, a, b), bulk density, and angle of repose.*

1. INTRODUCTION

Tomato (*Lycopersicum esculentum Mill*.) is one of the horticultural plants with relatively high antioxidant content, making it a healthy plant widely consumed by society. Tomatoes belong to the berry fruit type with a thin, smooth outer layer, thick flesh, and juicy interior (Sugandi *et al*., 2016). Tomatoes are easily accessible in Indonesia due to their increasing production, which lowers prices during peak harvest seasons (Hariyadi, 2018). According to Astuti *et al*., (2021), tomatoes contain compounds beneficial for the body, such as lycopene, which acts as an antioxidant. Despite their high nutritional content, tomatoes are prone to damage if not properly stored, mainly due to their high water content, reaching up to 94%, making them susceptible to physical, chemical, and microbiological deterioration (Widyasanti *et al*., 2019).

One way to prevent tomato spoilage is through drying. Drying methods are useful for diversifying products, enhancing the utility or economic value of tomatoes, and extending their shelf life. Drying is a commonly used preservation method that involves removing or reducing the moisture content of food by evaporating the water using heat energy (Hariyadi, 2018). Convection oven drying is one method employed for drying tomatoes, utilizing the principle of natural convective heat transfer, where heat is transferred by air inside the oven, causing moisture in the wet material to evaporate and be carried away by the heating medium, either air or hot gas (Atika & Isnaini, 2019).

Drying processes can be expedited through the use of foam-mat drying method (Hariyadi, 2018). Foam-mat drying is a technique for drying liquid and heat-sensitive materials through foaming with the addition of foaming agents. The presence of foam accelerates the drying process because the addition of foaming agents creates a larger surface area, facilitating faster moisture removal (Kusumaningrum & Hartati, 2018). Foam drying can employ foaming agents for food products, one of which is Tween 80, categorized as a non-ionic surfactant and commonly recognized as a safe food additive (Prasetyo *et al*., 2005). The use of Tween 80 in foam drying has been extensively studied, as demonstrated in research by Kurniasari *et al*., (2019) on the application of foam-mat drying method in ginger powder production, resulting in optimal drying with ginger powder moisture content ranging from 0.07% to 0.08%.

The physical quality of food materials describes the physical characteristics of food. Physical quality relates to the characteristics of materials that do not involve changes in substance (Nurhadi & Nurhasanah, 2010). Physical quality of food materials, along with chemical and biochemical properties, is important, especially concerning analyses involving physical principles, food processing operations, and food product engineering (Wirakartakusumah *et al*., 1992). Therefore, this research aims to analyze the physical quality of tomato powder produced by foam drying with different temperatures and concentrations of Tween 80 to determine the quality of the resulting products.

2. MATERIALS AND METHODS

2.1. Instruments and Materials

The instruments used in this research included a convection oven; Color Reader CR-10 Konica Minolta; Ohaus Pioneer digital balance with 0.01 g accuracy; 60-mesh sieve; blender; label paper; desiccator; Unit miller (mixer); centrifuge; knife; measuring glass; white HVS paper; sample cup; tray; smartphone camera; thermocouple; stirrer; plastic bag; clamps. The materials required for this research included fresh apple variety tomatoes approximately 10 cm in size, bright red in color, with firm texture and harvested at 80-90 days old obtained from Pasar Tanjung, Jember. Foaming agent Tween 80 was purchased from UD Aneka Kimia store, Jember; and food-grade maltodextrin was purchased online.

2.2. Research Procedures

Tomatoes were thoroughly washed, sliced into small chunks, and then blended for 3 minutes. The tomato puree was then mixed with 20% maltodextrin by weight. Additionally, Tween 80 foaming agent was added at 0.4; 0.7; and 1.0% by weight, and the mixture was blended using a mixer for 7 minutes. The mixture was then poured into a stainless steel tray and leveled to a thickness of approximately 5 mm, then dried in a convection oven at treatment temperatures of 60, 70, and 80°C for 15 hours until the moisture content reached below 12%. The dried material was then milled using a miller for 5 minutes followed by sieving using a standard 60-mesh sieve for 15 minutes. Tomato powder that passed through the 60-mesh sieve was then subjected to physical quality parameter measurements, including moisture content, fineness degree, average grain size, color, bulk density, oil absorption capacity, and angle of repose.

2.3. Analysis Methods

2.3.1. Moisture Content Analysis (AOAC, 2012)

The initial moisture content was measured by weighing a dried empty cup using an oven for approximately 15 minutes and then cooled in a desiccator for approximately 15 minutes (value *a*). Then, 5 grams of the sample were added to the cup (value *b*), and the cup + sample were dried for 3-6 hours, weighed again after cooling in a desiccator for approximately 15 min (value *c*). The wet basis moisture content was calculated using Equation 1.

$$Moisture\ Content\ (wet\ basis)\ (\%wb) = \frac{(b-a)-(c-a)}{(b-a)} \times 100\% \quad (1)$$

2.3.2 Particle Size Distribution Analysis (Purbasari & Putri, 2021a)

Particle size distribution measurement included the measurement of average grain size (D) and the measurement of powder fineness degree (FM). Eight sieves (10, 12, 16, 20, 50, 60, 80, and 100 mesh) were used and indicated as *a* to *h,* respectively. The tomato powder product used was the powder that passed through a 60-mesh sieve. The tomato powder was poured onto the top sieve, 100 g was used, and gently shaken for 15 min. Then, the weighed particles retained on each sieve were weighed. The tomato powder retained on each sieve was converted into mass fraction or mass percentage, and the fineness modulus (FM) and average grain size (D) were determined using Equations 2 and 3.

$$FM = \frac{(8a+7b+6c+5d+4e+3f+2g+1h+0)}{100} \quad (2)$$

$$D = 0.0041(2)^{FM}\ (mm) \quad (3)$$

2.3.3. Color Measurement Analysis (Hunter, 1958)

Color measurement of tomato powder was performed using the Color Reader CR-10 device. Prior to measurement, the device was calibrated by aiming it at white paper. Once calibrated, the device was aimed at the material at three different points to obtain color data. The observed color parameters were the L, a, and b values, calculated using Equations 4, 5, and 6, respectively.

$$\Delta L = L + L_s \quad (4)$$

$$\Delta a = a + a_s \quad (5)$$

$$\Delta b = b + b_s \quad (6)$$

where *L*, *a*, and *b* represent respectively the brightness, redness, and yellowness values of the sample.

2.3.4. Bulk Density Analysis (Mustofa, 2019)

Bulk density measurement was conducted using a 25 ml measuring glass. Tomato powder was poured into the measuring glass until it reached the predetermined volume (*V*) of 25 ml without compaction. The total mass (m_b) of the tomato powder was then weighed to calculate the bulk density (ρ_b) value using Equation 7.

$$\rho_b = \frac{m_b}{V} \quad (7)$$

2.3.5. Oil Absorption Capacity Analysis (Saputra *et al*., 2017)

Oil absorption capacity measurement involved weighing the reaction tube to be used (*a*), adding 1 g of powder and 10 ml of oil into the reaction tube (*b*), shaking the powder and oil mixture in the reaction tube for 1 minute and allowing it to stand for 15 min at room temperature, centrifuging the reaction tube at 3000 rpm for 30 minutes to separate solid particulates from the liquid, then weighing the reaction tube+powder+oil (*c*). The oil absorption capacity (OAC) was calculated using Equation 8

$$Oil\ Absorption\ Capacity\ (OAC\ ) = \frac{(c-b-a)}{b} \quad (8)$$

2.3.6. Angle of Repose Analysis (Khalil, 1999)

The material was dropped from a height of 15 cm through a funnel onto a flat surface lined with paper. The distance from the bottom of the funnel to the flat surface was 3 cm. The dropping process was stopped when the peak of the pile touched the bottom of the funnel. Diameter measurement was performed on the same side in all observations using a ruler and a right-angled triangle. The angle of repose (δ) was calculated by measuring the base diameter (*d*) and the pile height (*t*) using Equation 9.

$$Angle\ of\ Repose\ (\delta) = Arctan\left(\frac{2t}{d}\right) \quad (9)$$

2.3.7 Data Analysis

The data obtained from the research were subjected to Analysis of Variance (ANOVA) to compare the mean differences among the physical quality of tomato powder at different temperature and Tween 80 concentration variations. Furthermore, a Duncan's Multiple Range Test (DMRT) was conducted for significant differences between treatment combinations. The relationship between the physical quality variables of tomato powder was then determined using correlation analysis.

3. RESULTS AND DISCUSSION

3.1. Moisture Content (*MC*)

The moisture content in food materials can determine the level of freshness and shelf life of the food. The water content in the material is closely related to the shelf life and resistance of a food material to deterioration (Priastuti *et al*., 2016). Based on Figure 1, it can be observed that higher drying temperatures result in lower moisture content. This is consistent with the opinion of Riansyah *et al*., (2013) that increasing drying temperature accelerates the evaporation process, resulting in lower moisture content in the material. The measurement results of the moisture content indicate that the moisture content values of tomato powder obtained ranged from 5.36% to 6.48% wet basis (wb). The highest moisture content value of 6.48% wb was obtained from the product with a combination of 60°C drying temperature and 0.4% Tween 80 concentration. Meanwhile, the lowest moisture content value of 5.36% wb was obtained from the product with a combination of 80°C drying temperature and 0.4% Tween 80 concentration.

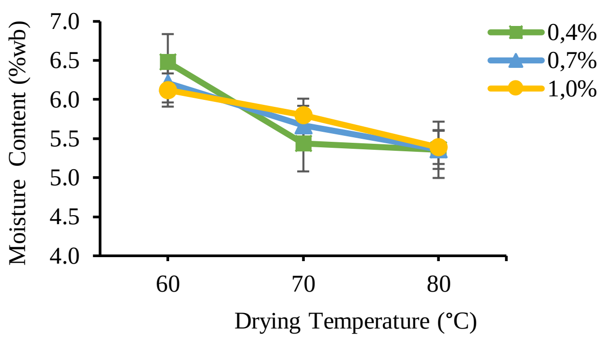

Figure 1. Effect of treatment on moisture content of tomato powder

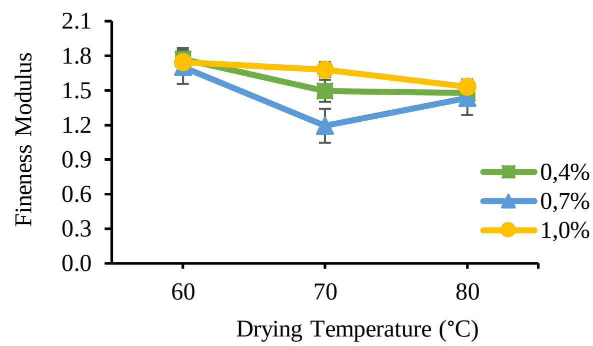

Figure 2. Effect of treatment on fineness modulus of tomato powder

3.2. Fineness Modulus (*FM*)

Fineness modulus represents a number that represents the average particle size of the ground material (Priastuti *et al*., 2016). The fineness modulus value is one of the variables indicating the particle fineness level (Susanti *et al*., 2014). Based on Figure 2, it can be observed that higher drying temperatures result in lower fineness modulus values. The fineness modulus values of tomato powder ranged from 1.19 to 1.77. The highest fineness modulus value of 1.77 was obtained from the product with a combination of drying temperature of 60°C and Tween 80 concentration of 0.4%. Meanwhile, the lowest fineness modulus value of 1.19 was obtained from the product with a combination of drying temperature of 70°C and Tween 80 concentration of 0.7%. According to Purbasari & Putri (2021a), the drying process makes the material harden quickly and become easily breakable, resulting in fine powder when milling is performed. A lower fineness modulus value indicates a finer powder produced (Rangkuti *et al*., 2012). The fineness modulus of tomato powder in this study refers to the Indonesian National Standard (SNI) 01-3709-1995, which requires minimum passing through sieve number 40.

3.3. Average Particle Size (*D*)

The average particle size (*D*) value can be determined after obtaining the FM value. The quality of the powder can be determined by the particle size expressed in particle uniformity (uniformity index) as well as the fineness modulus (*FM*) (Purwantara *et al*., 2008). Based on Figure 3, it can be observed that higher drying temperatures result in lower average particle size (*D*) values. The average particle size (*D*) values of tomato powder ranged from 0.0094 to 0.0141 mm. The highest average particle size (*D*) value of 0.0141 mm was obtained from the product at a combination of

60°C drying temperature and 0.4% Tween 80 concentration. Meanwhile, the lowest average particle size (*D*) value of 0.0094 mm was obtained from the product at a combination of 70°C drying temperature and 0.7% Tween 80 concentration. According to Purbasari & Putri (2021b), a smaller fineness modulus value indicates finer particle size.

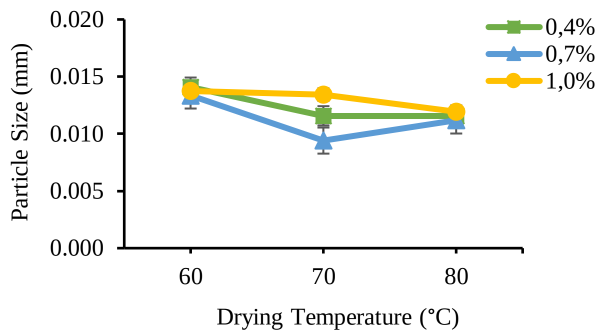

Figure 3. Effect of treatment on particle size of tomato powder

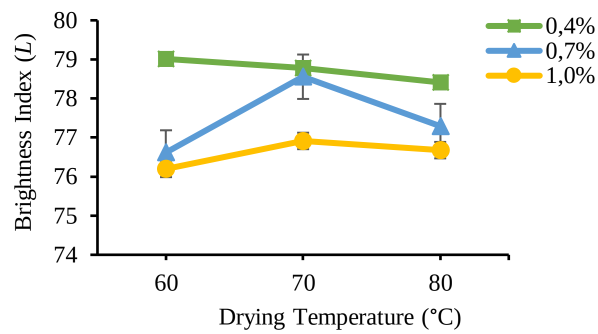

Figure 4. Effect of treatment on brightness of tomato powder

3.4. Brightness (*L*)

Color parameters are divided into three: brightness (*L*), redness (*a*), and yellowness (*b*). Color parameters can be observed directly and are important aspects in selecting food products (Lestari *et al*., 2023). Brightness (*L*) is a variable indicating the brightness of the food product. Brightness level has values ranging from 0 to 100, where 0 is equivalent to black and 100 is equivalent to white. Based on Figure 4, it can be observed that the brightness index (*L*) can be influenced by the concentration of Tween 80. Drying becomes faster due to the addition of Tween 80, which creates a larger surface area, resulting in faster water removal (Kusumaningrum & Hartati, 2018). Additionally, the foam produced by Tween 80 can strengthen the protective layer present in the foam system, preventing the color of the powder from fading or deteriorating due to the drying process (Isabella *et al*., 2022). The measurement results indicate that the brightness index (*L*) of tomato powder ranged from 76.20 to 79.01. The highest *L* value of 79.01 was obtained from the combination of 60°C drying temperature with 0.4% Tween 80 concentration. Meanwhile, the lowest *L* value of 76.20 was obtained from the combination of 60°C drying temperature with 1.0% Tween 80 concentration.

3.5. Redness (*a*)

The *a* value, which ranges from 0 to -80, indicates greener color of the material, while if the *a* value ranges from 0 to +80, it indicates redder color of the material. Based on Figure 5, it can be observed that higher concentrations of Tween 80 result in higher redness index values. According to research by Isabella *et al*., (2022), the addition of Tween 80 can thicken the protective layer present in the foam, preventing the color of the powder from fading or deteriorating due to the drying process. The measurement results indicate that the redness index (*a*) of tomato powder ranged from 12.51 to 14.81. The highest *a* value of 14.81 was obtained from the product with a combination of 60°C drying temperature and 1.0% Tween 80 concentration. Meanwhile, the lowest *a* value of 12.51 was obtained from the combination of 70°C drying temperature with 0.4% Tween 80 concentration.

3.6. Yellowing Level (*b*)

The b value, ranging from 0 to +70, indicates the increasing yellowness of the material, while if the *b* value ranges from 0 to -70, it indicates a bluer material color. Based on Figure 6, it can be observed that higher concentrations of tween 80 result in higher levels of yellowness (*b*) in tomato powder. The addition of high concentrations of tween 80 can also affect the color level of the material to yellow, as stated by Rowe *et al*., (2012), where Tween 80 is a yellow-colored oily liquid. The measurement results show that the yellowness index (*b*) of tomato powder ranges from 18.21 to 21.73. The highest b value, 21.73, was obtained from the combination of 80°C temperature and 1.0% Tween 80 concentration. Meanwhile, the lowest *b* value, 18.21, was obtained from the combination of 70°C temperature and 0.4% tween 80 concentration.

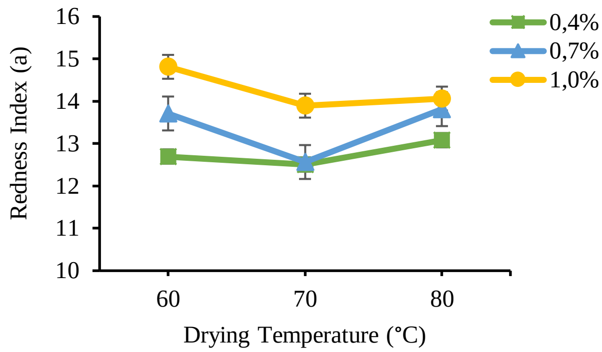

Figure 5. Effect of treatment on redness index (*a*) of tomato powder

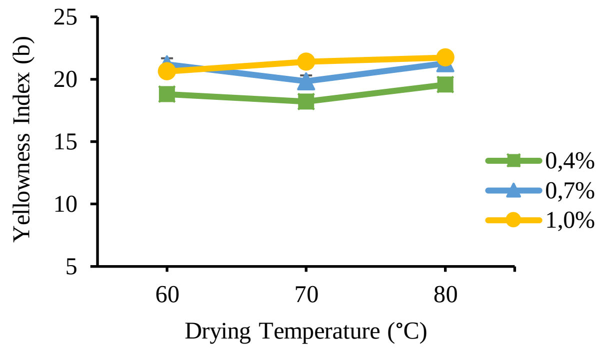

Figure 6. Effect of treatment on yellowness index (*b*) of tomato powder

3.7. Bulk Density

The density value indicates the material's density level; the higher the material density, the higher its compactness level (Yani & Juliana, 2012). According to Purbasari & Putri (2021a), bulk density is one of the physical qualities of powder closely related to the storage of a material. Based on Figure 7, it can be observed that higher concentrations of tween 80 result in lower bulk density values of tomato powder. Tween 80's ability to form foam expands the material's surface area and facilitates water evaporation, thus accelerating drying (Isabella *et al*., 2022). As the moisture content of tomato powder decreases, the mass of tomato powder will also decrease at the same volume, resulting in decreased bulk density (Widyasanti *et al*., 2019). The bulk density values of tomato powder range from 0.56 to 0.63 g/cm^3. The highest bulk density value, 0.63 g/cm^3, was obtained from the combination of 60°C temperature and 0.4% tween 80 concentration. Meanwhile, the lowest bulk density value, 0.56 g/cm^3, was obtained from the combination of 80°C temperature and 1.0% tween 80 concentration.

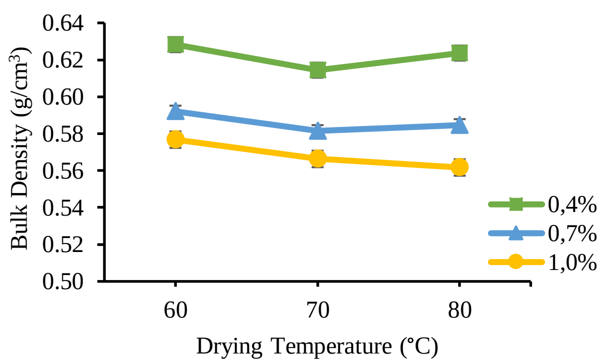

Figure 7. Effect of treatment on bulk density of tomato powder

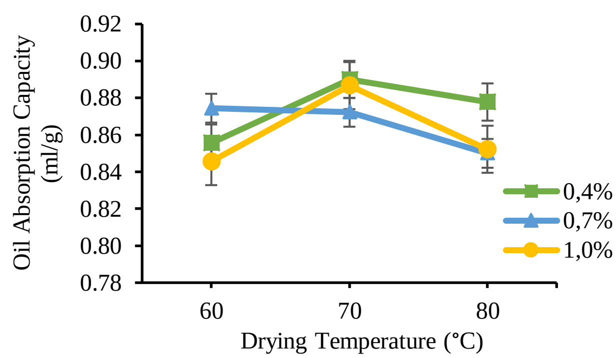

Figure 8. Effect of treatment on oil absorption capacity of tomato powder

3.8. Oil Absorption Capacity

Oil absorption capacity can be influenced by several factors, including protein content, particle size, structure, and protein denaturation level of the material (Purbasari & Putri, 2021b). Based on Figure 8, it can be observed that variations in temperature and tween 80 concentration do not affect the oil absorption capacity. From the oil absorption capacity measurement results, the oil absorption capacity values of tomato powder range from 0.85 to 0.89 ml/g. The highest oil absorption capacity value, 0.89 ml/g, was obtained from the combination of 70°C temperature and 0.4% tween 80 concentration. Meanwhile, the lowest oil absorption capacity value, 0.85 ml/g, was obtained from the combination of 60°C temperature and 1.0% tween 80 concentration. Oil absorption is an important property in food formulation as it can enhance the taste and mouthfeel of food (Odoemelam, 2003).

3.9. Angle of Repose

The angle of repose is greatly influenced by particle size, shape, characteristics, moisture content, specific weight, and heap density (Khalil, 1999). Based on Figure 9, it is known that higher concentrations of tween 80 result in lower angle of repose values of tomato powder. According to Mayasari *et al*., (2019), the higher the use of tween 80, the lower the resulting moisture content, and vice versa. Khalil (1999) mentioned that the higher the moisture content, the higher the angle of repose. From the angle of repose measurement results, the angle of repose values of tomato powder range from 33.65 to 36.09°. The highest angle of repose value, 36.09°, was obtained from the combination of 60°C temperature and 0.4% tween 80 concentration. Meanwhile, the lowest angle of repose value, 33.65°, was obtained from the combination of 60 °C temperature and 1.0% tween 80 concentration. According to Fitriani *et al*., (2020), the smaller the angle of repose value, the better the quality of the material due to the uniform particle size, resulting in good powder flowability.

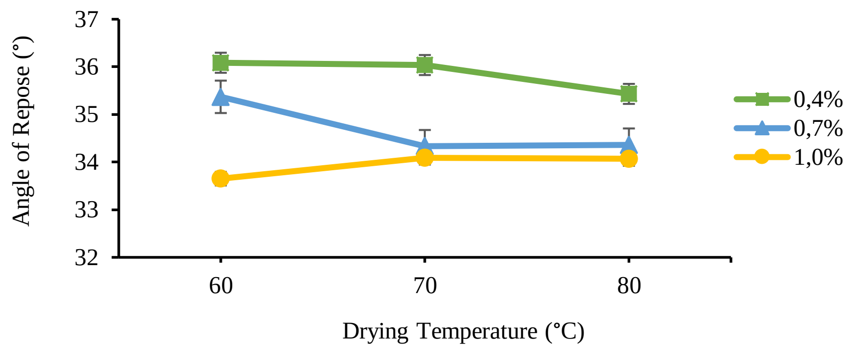

Figure 9. Relationship between angle of repose and drying temperature at various concentrations of tween 80

3.10. Statistical Analysis of the Treatment Effects

Two-way ANOVA was used to determine if there were differences in the means between variations in temperature and tween 80 concentration on the physical quality variables of tomato powder. Two-way ANOVA was conducted using Microsoft Excel 2019 with a significance level of $\alpha \leq 0.05$. Based on Table 1, it is known that the temperature treatment has an effect on several observation variables, including smoothness degree, grain size, and moisture content. Meanwhile, the tween 80 treatment affects observation variables such as color (L, a, b), bulk density, and heap angle. Observation variables showing significant differences to the temperature or tween 80 treatment were then subjected to Duncan's test to determine significant differences in each temperature or tween 80 variation. The results of the Duncan's test are seen in Table 2 and Table 3.

Table 1. Summary of two-way ANOVA on the effect of Tween 80 and temperature on the physical quality of tomato powder

Factor	FM	D	MC	L	a	b	BD	OAC	AR
Tween 80	NS	NS	NS	**	**	**	**	NS	**
Temperature	*	*	**	NS	NS	NS	NS	NS	NS
Tween×Temp	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: ** Significant correlation at $\alpha \leq 0.01$; * Significant correlation at $\alpha \leq 0.05$

Table 2. DMRT test results for the effect of temperature variation

Temperature	Fineness Modulus (FM)	Average Particle Size (D)	Moisture Content
60 °C	1.74 ± 0.11^b	0.0137 ± 0.0011^b	6.27 ± 0.47^b
70 °C	1.46 ± 0.29^a	0.0115 ± 0.0025^a	5.64 ± 0.39^a
80 °C	1.48 ± 0.21^a	0.0115 ± 0.0017^a	5.37 ± 0.36^a

Note: Different letters within the same column indicate significant differences in statistics at $\alpha = 0.05$

Table 3. DMRT test results for the effect of tween 80 concentration variation

Tween 80	Brightness Level (L)	Redness Level (a)	Yellowing Level (b)	Bulk Density	Angle of Repose
0.40%	78.73 ± 0.66^{b}	12.76 ± 1.00^{a}	18.86 ± 1.41^{a}	0.62 ± 0.02^{c}	35.85 ± 1.33^{b}
0.70%	77.49 ± 1.58^{a}	13.36 ± 1.53^{ab}	20.77 ± 1.41^{b}	0.59 ± 0.01^{b}	34.69 ± 1.26^{ab}
1.00%	76.60 ± 0.64^{a}	14.26 ± 0.68^{b}	21.26 ± 1.14^{b}	0.57 ± 0.01^{a}	33.93 ± 1.37^{a}

Note: Different letters within the same column indicate significant differences in statistics at α = 0.05.

Based on Table 2, it is known that in the temperature treatments (60, 70, and 80°C), there are significant differences in physical quality variables including smoothness degree, mean grain size, and moisture content. Based on Table 3, it is also known that in the tween 80 concentration treatments (0.4, 0.7, and 1.0%), there are significant differences in physical quality variables including color (*L*, *a*, *b*), bulk density, and pour angle. This can be demonstrated by the different letter notations in the observed variable values produced.

Pearson correlation test is useful to determine the level of strength and direction of the relationship between temperature and tween 80 concentration on the observed variables, namely the physical quality of tomato powder. The results of the correlation test can be seen in Table 4. Based on the correlation test results in Table 4, it is shown that there are positive and negative values in the treatment variables. In the temperature treatment, positive correlation values are observed in color parameters (*L* and *b*), and negative correlation values are observed in *FM*, *D*, moisture content, color parameter *a*, bulk density, oil absorption capacity, and pour angle. Meanwhile, in the tween 80 treatment, positive correlation values are observed in *FM*, *D*, moisture content, and color parameters (*a* and *b*), while negative correlation values are observed in color parameter *L*, bulk density, oil absorption capacity, and pour angle. Positive values indicate a direct relationship between treatment variables and observed variables, while negative values indicate the opposite.

Table 4. Correlation test results of observed variables with treatment variables

Observed Variable	Values			Treatment Variables	
	Minimum	Maximum	Average	Temperature	Tween 80
FM	1.11	2.05	1.56	-0.439*	0.12
D	0.0088	0.017	0.0122	-0.436*	0.126
Moisture Content	4.72	6.86	5.76	-0.681**	0.008
L	75.4	80.38	77.61	0.057	-0.658**
a	10.2	15.26	13.46	-0.029	0.498**
b	15.95	23.26	20.3	0.163	0.603**
Bulk Density	0.56	0.65	0.59	-0.142	-0.870**
Oil Absorption Capacity	0.78	0.97	0.87	-0.01	-0.117
Angle of repose	32.14	38.41	34.83	-0.115	-0.531**

Note: ** Significant correlation at α ≤ 0.01; * Significant correlation at α ≤ 0.05

4. CONCLUSION AND RECOMMENDATIONS

The physical quality results of tomato powder fall within the following ranges: FM values range from 1.19 to 1.77; D values range from 0.0094 to 0.0141 mm; moisture content values range from 5.36 to 6.48%wb; brightness level (L) values range from 76.20 to 79.01; redness level (a) values range from 12.51 to 14.81; yellowness level (b) values range from 18.21 to 21.73; bulk density values range from 0.56 to 0.63 g/ml; oil absorption values range from 0.85 to 0.89 ml/g; and angle of repose values range from 34.07 to 36.09°. The physical quality of tomato powder produced is more influenced by the concentration of Tween 80 compared to temperature. The concentration of Tween 80 affects parameters such as brightness level (L), redness level (a), yellowness level (b), bulk density, and angle of repose. Meanwhile, temperature affects parameters such as fineness modulus (FM), mean particle size (D), and moisture content. Additionally, the interaction between temperature and Tween 80 does not significantly affect the physical quality parameters of the resulting tomato powder. Further research is needed with variations in temperature and the addition of different foaming agents or types of foaming agents to determine tomato powder with better quality.

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