

# Effect of Sodium Metabisulfite Soaking and Osmotic Dehydration Pre-Treatments on Physicochemical Characteristics of Dried Red Chili Pepper (*Capsicum annuum* L.)

Siswanti<sup>1\*</sup>, Mohammad Dhiyaul Ghaisan<sup>1</sup>, and Kawiji<sup>1</sup>

<sup>1</sup>Department of Food Science and Technology, Faculty of Agriculture, Universitas Sebelas Maret, Surakarta, Central Java, Indonesia

**Abstract.** Red chili peppers, being a valuable horticultural product, are easily affected by biochemical and microbial spoilage and thus demand practical and economical post-harvest treatments. There has been no research specifically investigating the combination of sodium metabisulfite soaking and osmotic dehydration treatments. This study presents the first comprehensive report on the synergistic effect of combining sodium metabisulfite soaking and osmotic dehydration for preserving the quality of dried red chili. Using a completely randomized design, the research assessed physical parameters (yield, weight loss, texture, color) and chemical attributes (moisture content, antioxidant activity, vitamin C, sulfite residue) across varying sodium metabisulfite concentrations and osmotic dehydration levels. Results demonstrated that pre-treatments significantly ( $p < 0.05$ ) improved physical characteristics, with notable increases in texture and color parameters and reductions in weight. Chemically, antioxidant activity significantly ( $p < 0.05$ ) increased by 9.53%–24.79%, while vitamin C levels decreased by 12.86%–35.73%. Sulfite residue and moisture content decreased notably post-treatment. The optimal treatment identified was soaking in 0.30% sodium metabisulfite followed by osmotic dehydration in 70°Brix sucrose solution, offering the best balance between quality preservation and chemical residual safety. This approach provides a practical method for maintaining red chili quality during drying, enhancing its post-harvest value.

## 1 Introduction

Vegetables and fruits are among the most valuable horticultural commodities, experiencing significant growth in production volume and market demand in Indonesia. The high-water content of these products, often exceeding 80%, makes them highly susceptible to rapid enzymatic degradation, microbial deterioration, and physical damage during post-harvest handling. Red chili peppers (*Capsicum annuum* L.) are particularly vulnerable due to their high water content, which ranges from 60-85%, and their naturally high respiration and

---

\* Corresponding author: [siswanti@staff.uns.ac.id](mailto:siswanti@staff.uns.ac.id)

enzymatic activities immediately after harvest [1]. This susceptibility results in quick quality deterioration, nutritional loss, and spoilage, which can greatly diminish their commercial value and lead to significant post-harvest losses, estimated at 25-35% globally. These losses not only reduce the economic return for producers but also contribute to food waste, highlighting the importance of effective post-harvest handling and preservation methods for red chili peppers.

Drying is widely recognized as a practical and economical post-harvest process that effectively extends the shelf life of vegetables and fruits by reducing their water activity and inhibiting microbial growth [2]. Hot air drying, in particular, is the most commonly used method because it is simple, affordable, and accessible for small-scale producers as well as industrial settings [3]. By removing moisture, drying not only preserves the product but also significantly reduces transportation costs due to weight reduction, making it suitable for storage and long-distance marketing. Nonetheless, the drying process, especially when using high temperatures, can cause undesirable changes in sensory qualities and nutritional compositions, such as the degradation of heat-sensitive nutrients like Vitamin C, pigments, and antioxidant compounds [3]. These changes can impair product quality, making it necessary to develop pre-treatment strategies to mitigate such adverse effects and maintain the nutritional, sensory, and visual qualities during drying.

Pre-treatment methods, including sulfite soaking and osmotic dehydration, have been extensively studied for their ability to better preserve the quality of dried products. Sulfite treatments, such as soaking in sodium metabisulfite solution, are highly effective in preventing enzymatic browning, discoloration, microbial growth, and pigment deterioration during drying and storage [1]. This chemical process involves bisulfite ions binding to color pigments, thereby stabilizing the product's appearance and prolonging shelf life. On the other hand, osmotic dehydration using hypertonic solutions serves as a non-thermal pre-treatment that facilitates water removal from fruits and vegetables without the adverse heat-related nutrient losses associated with blanching or boiling [4]. Osmotic dehydration relies on osmotic pressure differences, causing water to flow out of the tissue and solutes to diffuse inward, resulting in reduced water content while preserving more of the product's original nutrients and sensory attributes [5]. However, research on the combined application of sodium metabisulfite soaking and osmotic dehydration, specifically for red chili, remains limited. The synergistic effect of these pre-treatments on the physicochemical properties of dried red chili has not been thoroughly investigated. Combining these two pre-treatments could potentially enhance drying efficiency, improve product quality, and minimize nutrient losses, although research on their combined effect on red chili peppers remains limited. This study aims to investigate how the integration of sodium metabisulfite soaking with osmotic dehydration impacts various physicochemical properties, including color, texture, yield, moisture content, Vitamin C, antioxidant activity, and sulfite residue, to identify optimal conditions for producing high-quality dried red chili peppers.

## **2 Material and Method**

### **2.1 Drying Pre-Treatments**

Red chili peppers were sourced from Tawangmangu, Central Java. Samples were prepared by sorting, washing, and cutting lengthwise into two equal parts while retaining the seeds, and were then weighed to  $175 \pm 0.5$  grams. Pre-treatment involved soaking the prepared chili samples in a sodium metabisulfite ( $\text{Na}_2\text{S}_2\text{O}_5$ ) solution at room temperature ( $25^\circ\text{C}$ ) for 15 minutes. Five different concentrations of  $\text{Na}_2\text{S}_2\text{O}_5$  solution were investigated: 0.20%, 0.25%, 0.30%, 0.35%, and 0.40% (w/v). The preparation of the sodium metabisulfite solution was performed following the study of (2), with the concentration determined in

percentage by weight (%W/V) as in equation (1). This was followed by a 30-minute resting period designed to reduce residual soaking water prior to dehydration.

The pre-treated red chili samples then underwent osmotic dehydration using a concentrated 70°Brix sucrose solution. The high osmotic concentration was selected to achieve optimal water loss and water content reduction, which also aids in maintaining color and flavor quality [6]. Preparation of the osmotic solution was performed following the study of [7], which can be calculated with equation (2). A critical mass ratio of 4:1 between the osmotic solution and the chili sample was maintained throughout the process to prevent significant dilution of the osmotic medium [8]. The samples were soaked in the sucrose solution for 3 hours at 25°C, followed by a 30-minute draining period. Finally, the osmotically dehydrated peppers were dried in a cabinet dryer at a controlled temperature of 60°C for 12 hours. The drying temperature was specifically chosen to minimize enzymatic browning and Maillard reactions while ensuring good color and bioactive compound retention [8]. The dried chili peppers were then stored in plastic packaging containing silica gel and kept in a dry room.

$$(\%W/V) = \frac{\text{solute (gram)}}{\text{solvent (mL)}} \times 100 \quad (1)$$

$$^{\circ}\text{Brix} = \frac{\text{solute (gram)}}{\text{solute (gram) + solvent (gram)}} \quad (2)$$

## 2.2 Experimental Design

The experimental design for determining the type of treatment for the red chili pepper samples used a completely randomized design (CRD) with a single factor (Na<sub>2</sub>S<sub>2</sub>O<sub>5</sub> concentration) at 6 levels as shown in Table 1, with a four of replications, referring to the studies by [2] with modifications to the treatment levels applied.

**Table 1.** Design Experiment

Treatments	Description
P0	Control (without any pre-treatment)
P1	Na <sub>2</sub> S <sub>2</sub> O <sub>5</sub> 0.20 (%w/v) and osmotic solution 70°Brix
P2	Na <sub>2</sub> S <sub>2</sub> O <sub>5</sub> 0.25 (%w/v) and osmotic solution 70°Brix
P3	Na <sub>2</sub> S <sub>2</sub> O <sub>5</sub> 0.30 (%w/v) and osmotic solution 70°Brix
P4	Na <sub>2</sub> S <sub>2</sub> O <sub>5</sub> 0.35 (%w/v) and osmotic solution 70°Brix
P5	Na <sub>2</sub> S <sub>2</sub> O <sub>5</sub> 0.40 (%w/v) and osmotic solution 70°Brix

## 2.3 Yield Measurement

The mass of the red chili pepper samples was weighed at the beginning of drying (hour 0) and at the end of the drying period (hour 12). The obtained mass was then calculated using the equation (3) where the sample mass at hour 12 represents the final weight of the material, while the sample weight at hour 0 represents the initial weight of the material.

$$\text{Yield} = \frac{\text{Final weight of material}}{\text{Initial weight of material}} \times 100\% \quad (3)$$

## 2.4 Weight Loss Measurement

The measurement of weight loss in this study was conducted using the method which involves comparing the weight difference before and after drying, as given by the equation (4) where W<sub>i</sub> is the initial sample mass before drying and W<sub>t</sub> is the sample mass at time t

being observed. In this study, observations were made every two hours, providing data on the mass every two hours.

$$\text{Weight Loss (\%)} = \frac{W_i - W_t}{W_i} \times 100 \quad (4)$$

## 2.5 Texture Analysis

The texture of dried red chili peppers in this study was analyzed using a mimetic method. The instrument used in this study for the mimetic method was *Universal Texture Machine* (UTM ASTM D-882). The parameters observed included hardness, cohesiveness, and gumminess.

## 2.6 Color Analysis

Color analysis in this study will be performed using colorimetric techniques with a Konica Minolta CR-400 (Japan) chromameter. For color analysis, specify the illuminant and observer angle (e.g., D65, 10°). Color analysis with a chromameter will produce the Hunter's Lab Colorimetric System, which is represented by numerical values of the three color chromas: L, a, and b.

## 2.7 Determination of Moisture Content

The procedure for testing moisture content using thermogravimetry method. First, the sample is ground into a powder. A weighing bottle, size 40 x 25, is then placed in an oven for 15 minutes at 105°C with the lid open, then cooled in a desiccator to remove moisture and weighed (A). A 2 g sample is weighed into a pre-dried crucible (B), then placed in an oven at 105°C for more than 6 hours with the lid open. Once the desired time is reached, the porcelain crucible or weighing bottle is cooled in a desiccator for 30 minutes with the lid closed and weighed (C). This step is repeated until a constant weight is achieved. From the resulting data, the moisture content on a wet basis can be calculated using the equation (5).

$$\% \text{ Moisture Content (wet basis)} = \frac{B-C}{B-A} \quad (5)$$

## 2.8 Determination of Antioxidant Activity

The antioxidant activity was determined using the DPPH (2,2-diphenyl-1-picrylhydrazyl) method, in which antioxidant compounds donate hydrogen atoms to neutralize DPPH radicals, causing a color change from purple to yellow that can be quantified by UV-Vis spectrophotometry at 517 nm. 0.1 mM DPPH solution (Sigma-Aldrich, US) was prepared in ethanol (Merck, Germany) using the equation (6), and 1 g of the powdered sample was extracted in 10 mL of ethanol, filtered through Whatman No. 41 paper, and reacted with 4 mL of the DPPH solution. After mixing and incubating in the dark for 30 minutes, the absorbance was measured, and antioxidant activity was expressed as the percentage of inhibition using equation (7).

$$M = \frac{\text{massa DPPH}}{\text{Mr DPPH}} \times \frac{1000}{\text{Volume Pelarut}} \quad (6)$$

$$\% \text{ inhibition} = \left( 1 - \frac{\text{absorbance of sample}}{\text{absorbance of control (DPPH)}} \right) \times 100\% \quad (7)$$

## 2.9 Determination of Vitamin C

Vitamin C content was determined following [9]. A 100 ppm ascorbic acid standard solution was prepared by dissolving 5 mg of ascorbic acid in 50 mL of distilled water in an aluminum foil-covered flask, followed by the preparation of standard series (2–10 ppm) to construct a calibration curve based on absorbance-concentration linear regression at the maximum wavelength (200–400 nm). For sample analysis, dried red chili was ground into powder, and 5 g of the powder was dissolved in 100 mL of distilled water, homogenized, and filtered through Whatman No. 40 paper. A 1 mL aliquot of the filtrate was diluted to 25 mL, and the absorbance was measured using a UV-Vis spectrophotometer to determine Vitamin C concentration based on the calibration curve using the linear regression as equation (8) where  $a$  is the regression constant,  $b$  is the regression coefficient,  $y$  is the absorbance, and  $x$  is the concentration. The formula for calculating the Vitamin C content in the sample follows the equation (9). The Vitamin C content obtained in ppm (mg/L) is then entered into the equation (10), where  $A$  represents the percentage of the measured sample (%),  $Z$  is the sample weight (mg),  $C$  is the obtained concentration (mg/L),  $FP$  is the dilution factor, and  $V$  is the sample volume (mL).

$$y = a + bx \tag{8}$$

$$\text{Vitamin C (ppm)} = \frac{\text{ascorbic acid (mg)}}{\text{sample (mg)}} \times 100\% \tag{9}$$

$$A(\%) = \frac{C \times V}{Z} \times FP \tag{10}$$

## 2.10 Determination of Sulfite Residue

The determination of sulfite residue adding 700 mL of water to a three-necked boiling flask and bring it to a boil. Add 25 grams of the sample to a Kjeldahl flask, then add 200 mL of 7.4% HCl. Connect the boiling flask and Kjeldahl flask with a steam distillation apparatus and its condenser to form a Monier-Williams distillation setup. Prepare a 250 mL Erlenmeyer flask at the outlet to collect the distillate. Each distillate sample is titrated with 0.1 N Na-thiosulfate until the color changes from brown to yellow. Add 5 mL of 0.1 N iodine solution, then add 2 drops of 2% starch as an indicator, and continue titrating with 0.1 N Na-thiosulfate until the blue color disappears. Prepare a blank solution in the same manner without adding the sample. With the volume of titrant for both the sample and blank recorded, calculations are then performed using equation (11).

$$SO_2 \text{ Total (ppm)} = \frac{(\text{Blank Vol.} - \text{Sample Vol.}) \times 3.2}{\text{Sample (g)}} \times 1000 \tag{11}$$

## 2.11 Statistical Analysis

The data obtained is then processed using the One-Way ANOVA method with IBM SPSS 25. If significant differences are found, further analysis is conducted using Duncan's Multiple Range Test with a significance level of 95% ( $\alpha = 0.05$ ).

## 2.12 Effectiveness Index

In addition to statistical analysis, the determination of the best sample is performed. The best sample is selected from six samples based on physicochemical analysis. This determination is conducted through the Effectiveness Index Test.

### 3 Results and Discussion

#### 3.1 Use Yield

The yield values of dried chili peppers are presented in Table 2. The control sample (P0) exhibited the highest yield (22.40%), which was significantly different ( $p < 0.05$ ) from all pre-treated samples (P1–P5). The reduced yield in pre-treated samples was due to greater water removal during osmotic dehydration, resulting in lower final mass after drying. Yield is highly influenced by residual moisture content in dried products. Chili peppers subjected to hypertonic sucrose solution experienced plasmolysis and tissue dehydration, which enhanced drying efficiency and consequently reduced product yield [1,5]. No significant differences were observed among all osmotic-treated samples ( $p > 0.05$ ), likely due to the constant osmotic solution concentration used (70°Brix), which led to a similar extent of initial water loss.

**Table 2.** Yield Obtained

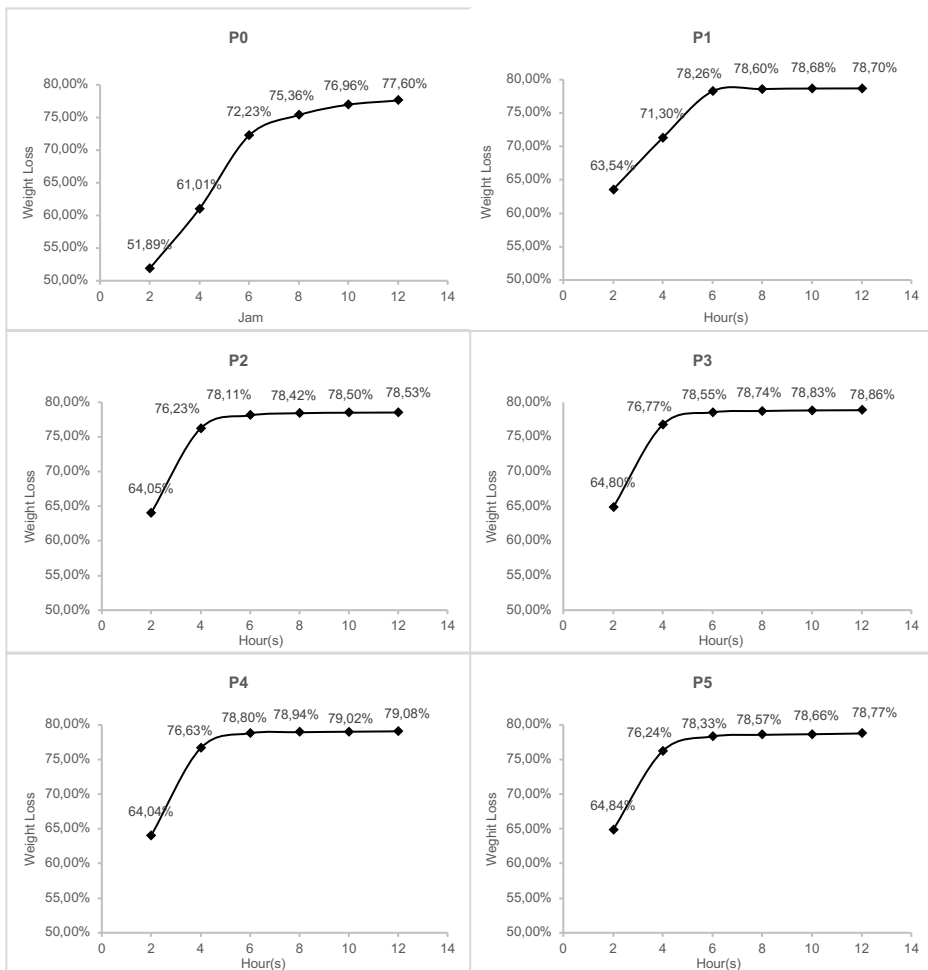
Sample	Yield (%)
P0	22.40 ± 0.002 <sup>a</sup>
P1	21.30 ± 0.004 <sup>b</sup>
P2	21.48 ± 0.005 <sup>b</sup>
P3	21.14 ± 0.007 <sup>b</sup>
P4	20.92 ± 0.005 <sup>b</sup>
P5	21.23 ± 0.004 <sup>b</sup>

*Values with the same superscripts are not significantly different ( $p > 0.05$ )*

#### 3.2 Weight Loss

Weight loss increased progressively during drying, with pre-treated samples showing significantly higher weight loss ( $p < 0.05$ ) than the control throughout the drying period (Figure 1). The faster rate of moisture diffusion in treated samples can be attributed to structural modifications caused by osmotic dehydration, which reduces intracellular water and increases tissue porosity, enhancing mass transfer.

The drying profile exhibited a typical logarithmic curve, where a rapid moisture loss occurred in the initial two hours followed by a gradual decline. This pattern aligns with common hot-air drying behavior in agricultural products. Osmotic dehydration facilitated water migration due to osmotic pressure gradients, contributing to increased weight loss and shortened effective drying duration (6).



**Fig. 1.** Red Chili Weight Loss Graph

### 3.3 Texture

Texture profile analysis (TPA) revealed significant differences among treatments in hardness, cohesiveness, and gumminess parameters. Based on Table 3, the sample pre-treated with 0.30% sodium metabisulphite and 70°Brix sucrose (P3) recorded the highest hardness (31.35 N) and gumminess (15.55 N). The control sample (P0) significantly differed ( $P < 0.05$ ) from samples P3 and P4 in hardness, from P2 and P3 in cohesiveness, and from P1, P2, P3, and P5 in gumminess. Osmotic dehydration enhanced the structural integrity of the samples, consistent with [10], who observed increased firmness and cohesiveness in sucrose-treated pomegranate tissue.

The improvement in texture can be attributed to sucrose diffusion into the tissue, forming a stable matrix and strengthening cell walls. The addition of sodium metabisulphite further contributed to maintaining texture stability, as sulfites preserve cellular structure and minimize enzymatic softening. Significant reductions in chili hardness after drying, the combination of sodium metabisulfite and osmotic dehydration effectively minimized structural degradation. Thus, the pre-treatment improved textural resilience, reducing hardness loss and enhancing cohesiveness and gumminess in dried red chili samples.

**Table 3.** Texture Profile Analysis

Sample	Hardness (N)	Cohesiveness	Gumminess (N)
P0	20.32 ± 3.244 <sup>a</sup>	0.27 ± 0.090 <sup>a</sup>	5.44 ± 1.343 <sup>a</sup>
P1	24.06 ± 0.770 <sup>ab</sup>	0.37 ± 0.144 <sup>ab</sup>	8.64 ± 3.374 <sup>bc</sup>
P2	23.03 ± 1.979 <sup>a</sup>	0.44 ± 0.047 <sup>b</sup>	11.13 ± 1.355 <sup>c</sup>
P3	31.35 ± 5.151 <sup>c</sup>	0.46 ± 0.081 <sup>b</sup>	15.55 ± 1.925 <sup>d</sup>
P4	28.81 ± 4.098 <sup>b</sup>	0.27 ± 0.065 <sup>a</sup>	6.87 ± 1.854 <sup>ab</sup>
P5	22.42 ± 2.599 <sup>a</sup>	0.40 ± 0.090 <sup>ab</sup>	8.69 ± 0.957 <sup>bc</sup>

Values with the same superscripts are not significantly different ( $p > 0.05$ )

### 3.4 Color

Based on Table 4, the control sample (P0) exhibited the lowest values of lightness (L), redness (a), and yellowness (b). The L value of the control significantly differed ( $P < 0.05$ ) from all pre-treated samples (P1–P5), with samples P4 and P5 showing the highest brightness (11.1% increase). This aligns with the studies of [11], who reported that sodium metabisulfite treatment enhances chili brightness. Similarly, redness (a) and yellowness (b) values increased with higher sodium metabisulfite concentrations, confirming that this pre-treatment improves color intensity.

The improvement in color quality is attributed to the inhibition of enzymatic browning by sulfite. Sulfite compounds inhibit polyphenol oxidase (PPO) and peroxidase by altering their protein structures, preventing melanoidin formation and reducing non-enzymatic browning. Additionally, osmotic dehydration reduces water activity and enzyme mobility, thereby minimizing oxidative reactions [6]. The color improvement observed in this study, especially in samples P4 and P5 was greater than that reported by [11], suggesting a synergistic effect between sodium metabisulfite soaking and osmotic dehydration in maintaining pigment stability.

**Table 4.** Color Analysis

Sampel	L	a	b
P0	49.22 ± 0.529 <sup>a</sup>	19.98 ± 0.284 <sup>a</sup>	25.11 ± 0.312 <sup>a</sup>
P1	50.56 ± 0.830 <sup>b</sup>	21.09 ± 0.183 <sup>b</sup>	26.17 ± 0.426 <sup>b</sup>
P2	51.17 ± 0.279 <sup>b</sup>	22.37 ± 0.538 <sup>c</sup>	27.25 ± 0.841 <sup>c</sup>
P3	52.81 ± 0.484 <sup>c</sup>	22.70 ± 0.557 <sup>c</sup>	29.44 ± 0.395 <sup>d</sup>
P4	54.86 ± 0.402 <sup>d</sup>	24.63 ± 0.508 <sup>d</sup>	29.89 ± 0.247 <sup>d</sup>
P5	55.37 ± 0.609 <sup>d</sup>	24.94 ± 0.472 <sup>d</sup>	31.09 ± 0.386 <sup>c</sup>

Values with the same superscripts are not significantly different ( $p > 0.05$ )

### 3.5 Moisture Content

As shown in Table 5, the control sample (P0) had the highest moisture content (12.22%), which differed significantly ( $P < 0.05$ ) from the pre-treated samples (P1–P5). No significant differences ( $P > 0.05$ ) were found among pre-treated samples, indicating that sodium metabisulfite concentration had little effect on moisture when the osmotic solution concentration was constant.

According to SNI 01-3389-2023, the maximum moisture content for dried red chili is 11%. Only the control sample exceeded this limit, while all pre-treated samples met the standard, confirming that osmotic dehydration effectively reduced water content. The lower moisture levels in pre-treated samples are attributed to their reduced initial water content due to osmotic soaking in 70°Brix sucrose solution, which promotes water diffusion and accelerates drying.

**Table 5.** Chemical Analysis

Sample	Moisture Content (%)	Antioxidant Activity (%)	Vitamin C (%)	Sulfite (ppm)	Residue
P0	12.22 ± 0.008 <sup>a</sup>	49.97 ± 0.973 <sup>a</sup>	1.13 ± 0.000 <sup>a</sup>	10.04 ± 0.355 <sup>a</sup>	
P1	10.49 ± 0.008 <sup>b</sup>	54.73 ± 0.959 <sup>b</sup>	0.74 ± 0.000 <sup>b</sup>	13.29 ± 0.121 <sup>b</sup>	
P2	10.62 ± 0.002 <sup>b</sup>	50.75 ± 0.850 <sup>a</sup>	0.98 ± 0.000 <sup>c</sup>	21.24 ± 0.764 <sup>c</sup>	
P3	10.60 ± 0.003 <sup>b</sup>	55.41 ± 0.838 <sup>b</sup>	0.93 ± 0.000 <sup>c</sup>	27.93 ± 0.766 <sup>d</sup>	
P4	10.59 ± 0.008 <sup>b</sup>	62.36 ± 0.983 <sup>c</sup>	0.84 ± 0.000 <sup>d</sup>	35.97 ± 0.958 <sup>e</sup>	
P5	10.85 ± 0.007 <sup>b</sup>	56.11 ± 0.730 <sup>b</sup>	0.72 ± 0.001 <sup>b</sup>	37.31 ± 0.561 <sup>e</sup>	

Values with the same superscripts are not significantly different ( $p > 0.05$ )

### 3.6 Antioxidant Activity

The antioxidant activity, expressed as % inhibition, was highest in sample P4 (0.35% sodium metabisulfite + 70°Brix osmotic solution), reaching 64.47%. The control sample (P0) differed significantly ( $P < 0.05$ ) from P1, P3, P4, and P5. The antioxidant activity among pre-treated samples ranged from 54.73% to 62.36%, showing an overall increase of 9.53–24.79% compared to the control. Similar results were reported by [12], who found that sulfite pre-treatment significantly enhanced antioxidant activity in dried fruits by protecting carotenoids and phenolic compounds from oxidation.

The enhanced antioxidant activity can be attributed to the protective role of sodium metabisulfite against oxidative degradation and the effect of osmotic dehydration in reducing water activity, thus limiting oxidation reactions [6]. The combined pre-treatment in this study yielded higher antioxidant activity than previous reports, suggesting a synergistic preservation effect between sulfite and osmotic treatment during drying.

### 3.7 Vitamin C

Table 5 shows significant differences ( $P < 0.05$ ) between the control sample (P0) and pre-treated samples (P1 to P5). The control sample has the highest vitamin C content at 1.1260%. Pre-treated samples have significantly lower vitamin C levels, with reductions ranging from 12.86% to 35.73%. The high vitamin C content in the control sample is due to the water solubility of ascorbic acid, which is polar due to its four hydroxyl groups, making it easily soluble in water. During osmotic dehydration, ascorbic acid is lost along with the water through leaching [13].

These results align with other studies of [7,14] who founds an 18.7% loss of vitamin C in cashew (*Anacardium occidentale* L.) due to leaching during osmotic treatment and lower vitamin C content in dried red chili pre-treated with 60°Brix osmotic dehydration compared to untreated chili. This study's smaller reduction of 12.86% suggests that the combination of sodium metabisulfite pre-treatment and osmotic dehydration slows vitamin C loss. Variations in results may be due to differences in chili types, drying temperatures, and osmotic solution concentrations.

### 3.8 Sulfite Residue

Sulfite residues originate from the conversion of sulfur dioxide (SO<sub>2</sub>) into bisulfite ions that penetrate fruit tissues and act as preservatives [1]. As shown in Table 5, the control sample (P0) had the lowest sulfite residue (10.04 ppm), while residues increased proportionally with sodium metabisulfite concentration.

All samples in this study complied with the safety limits established by BPOM Regulation No. 36/2013, which allows a maximum sulfite residue of 100 ppm in dried fruits

and vegetables. The acceptable daily intake (ADI) of 0.7 mg/kg body weight was also not exceeded. Therefore, the pre-treated dried red chili samples are considered safe for consumption, as the sulfite residues remained well below both regulatory and health thresholds.

### 3.9 Effectiveness Index

The best treatment in this study was determined using the effectiveness index method. This approach involves assigning weights to various parameters based on their significance in assessing the quality of the product. Each parameter is given a weight reflecting its importance and its alignment with relevant standards or regulations. For the dried red chili, the parameters were assigned weights as follows: moisture content (0.15), sulfite residue (0.14), color (L) (0.13), color (a) (0.12), color (b) (0.10), texture (hardness) (0.09), texture (cohesiveness) (0.08), texture (gumminess) (0.06), antioxidant activity (0.05), vitamin C content (0.04), yield (0.03), and weight loss at 12 hours (0.01).

The effectiveness index for each treatment was calculated based on these weights. The final values were as follows: Sample P0 (control) scored 0.221, Sample P1 (0.20% sodium metabisulfite and 70°Brix osmotic solution) scored 0.485, Sample P2 (0.25% sodium metabisulfite and 70°Brix osmotic solution) scored 0.538, Sample P3 (0.30% sodium metabisulfite and 70°Brix osmotic solution) scored 0.625, Sample P4 (0.35% sodium metabisulfite and 70°Brix osmotic solution) scored 0.610, and Sample P5 (0.40% sodium metabisulfite and 70°Brix osmotic solution) scored 0.603. Based on these results, Sample P3, which used 0.30% sodium metabisulfite and 70°Brix osmotic solution, emerged as the best treatment with the highest final value of 0.625.

## 4 Conclusion

The combination pre-treatment significantly ( $p < 0.05$ ) improved color, texture, and antioxidant activity while effectively reducing moisture content to meet the standard. Significant positive differences also observed in sulfite residue. Conversely, there was a significant negative impact on yield and vitamin C content, reflected in the decreased values for these parameters. Among the treatments tested, the best results were achieved with the combination of 0.30% sodium metabisulfite and 70°Brix osmotic solution (P3). Future studies should focus on the scaling-up process, sensory evaluation, and the application of this combined pre-treatment to other agricultural commodities.

### Acknowledgements

All the authors would like to thank the Sebelas Maret University for the provided funds through “*Penelitian Hibah Grup Riset (Penelitian HGR-UNS) A Potensi Sumber Daya Lokal Sebagai Bahan Tambahan Fungsional Alami untuk Meningkatkan Kualitas Produk Pangan*”, with contract number: 371/UN27.22/PT.01.03/2025.

### Fundings

All the authors would like to thank the Sebelas Maret University for the provided funds through “*Penelitian Hibah Grup Riset (Penelitian HGR-UNS) A Potensi Sumber Daya Lokal Sebagai Bahan Tambahan Fungsional Alami untuk Meningkatkan Kualitas Produk Pangan*”, with contract number: 371/UN27.22/PT.01.03/2025.

### Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author contribution statement

Siswanti: Conceptualization, Methodology, Investigation, Writing- Original draft preparation.  
Mohammad Dhiyaul Ghaisan: Data curation, Writing- Original draft preparation. Kawiji: Validation,  
Writing- Reviewing and Editing.

## References

1. L. Z. Deng, A. S. Mujumdar, Q. Zhang, X. H. Yang, J. Wang, Z. A. Zheng, et al., Chemical and physical pretreatments of fruits and vegetables: Effects on drying characteristics and quality attributes – a comprehensive review, *Crit. Rev. Food Sci. Nutr.* **59**, 1408 (2017).
2. R. Sharma, V. Joshi, and M. Kaushal, Effect of pre-treatments and drying methods on quality attributes of sweet bell-pepper (*Capsicum annuum*) powder, *J. Food Sci. Technol.* **52**, 3433 (2015).
3. H. Pinar, N. Çetin, B. Ciftci, K. Karaman, and M. Kaplan, Biochemical composition, drying kinetics and chromatic parameters of red pepper as affected by cultivars and drying methods, *J. Food Compos. Anal.* **102**, (2021).
4. N. K. Rastogi, K. S. M. S. Raghavarao, K. Niranjana, and D. Knorr, Recent developments in osmotic dehydration: methods to enhance mass transfer, *Trends Food Sci. Technol.* **13**, 48 (2002).
5. A. Czurzyńska, H. Kowalska, K. Czajkowska, and A. Lenart, Osmotic dehydration in production of sustainable and healthy food, *Trends Food Sci. Technol.* **50**, 186 (2016).
6. A. K. Yadav and S. V. Singh, Osmotic dehydration of fruits and vegetables: a review, *J. Food Sci. Technol.* **51**, 1654 (2014).
7. M. M. Odewole and A. M. Olaniyan, Effect of osmotic dehydration pretreatments on drying rate and post-drying quality attributes of red bell pepper (*capsicum annum*), *Agric. Eng. Int. CIGR J.* **18**, 226 (2016).
8. K. An, H. Li, D. Zhao, S. Ding, H. Tao, and Z. Wang, Effect of Osmotic Dehydration with Pulsed Vacuum on Hot-Air Drying Kinetics and Quality Attributes of Cherry Tomatoes, *Dry. Technol.* **31**, 698 (2013).
9. S. Maryam, R. Razak, M. Baits, and A. F. Salim, Analysis of Vitamin C and Antioxidant Activity of *Capsicum frutescens* L. and *Capsicum annum* L. (curly and large chili variety), *Indones. J. Pharm. Sci. Technol.* **1**, 57 (2020).
10. B. Bchir, S. Besbes, H. Attia, and C. Blecker, Osmotic Dehydration of Pomegranate Seeds (*Punica granatum* l.): Effect of Freezing Pre-treatment, *J. Food Process. Eng.* **35**, 335 (2012).
11. H. Ramdani, R. A. Wicaksono, and M. A. Fachrudin, Penambahan Natrium Metabisulfite ( $\text{Na}_2\text{S}_2\text{O}_5$ ) terhadap Vitamin C dan Warna pada Proses Pengeringan Cabai Merah (*Capsicum annum* L.) dengan Tunnel Dehydrator, *J. Agronida* **4**, 88 (2019).
12. M. Lučić, N. Potkonjak, I. Sredović Ignjatović, S. Lević, Z. Dajić-Stevanović, S. Kolašinac, et al., Influence of Ultrasonic and Chemical Pretreatments on Quality Attributes of Dried Pepper (*Capsicum annum*), *Foods* **12**, 2468 (2023).
13. Y. Shete, S. Chavan, P. Champawat, and S. Jain, Reviews on osmotic dehydration of fruits and vegetables, *J. Pharmacogn. Phytochem.* **7**, 1964 (2018).
14. P. M. Azoubel, Â. A. El-Aouar, R. V. Tonon, L. E. Kurozawa, G. C. Antonio, F. E. X. Murr, et al., Effect of osmotic dehydration on the drying kinetics and quality of cashew apple, *Int. J. Food Sci. Technol.* **44**, 980 (2009).