

## The Effect of Using Tween 80 as A Foaming Agent on Drying Corn-Yogurt Using the Foam-Mat Method

Nur Aini <sup>a,\*</sup>, Ratih Tiara Dewi <sup>b</sup>, Pepita Haryanti <sup>a</sup>, Vincentius Prihananto <sup>a</sup>, Anita Khairunnisa <sup>a</sup>, Budi Sustrawan <sup>a</sup>, Hadana Sabila Arsyistawa <sup>b</sup>, Annisa Fitriati <sup>c</sup>, Indarto <sup>d</sup>, Banun Diyah Probowati <sup>e</sup>

<sup>a</sup> Department of Food Technology, Faculty of Agriculture, Universitas Jenderal Soedirman, Purwokerto, Indonesia

<sup>b</sup> Magister of Science, Faculty of Agriculture, Universitas Jenderal Soedirman, Purwokerto, Indonesia

<sup>c</sup> Department of Food Technology and Nutrition, Mahasarakham University, Maha Sarakham Province, Thailand

<sup>d</sup> Department of Agricultural Engineering, Faculty of Agricultural Technology, Jember University, Jember, Indonesia

<sup>e</sup> Department of Agricultural Industrial Technology, Faculty of Agriculture, Trunojoyo Madura University, Bangkalan, Indonesia

\*Corresponding author, Email: [nur.aini@unsoed.ac.id](mailto:nur.aini@unsoed.ac.id)

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### ABSTRACT

The public's appetite for foods that are both satiating and offer distinct functional benefits has driven an increasing demand for functional foods. Corn yogurt is a type of functional food now under development. Corn yogurt is a fermented product with a relatively high moisture content and low protein content. To increase the protein content, it is fortified with spirulina and soy protein isolate. To extend its shelf life, corn yogurt is made into powder form using the foam mat drying method. This study contributes to determining the effect of Tween 80 concentration as a foaming agent on the physicochemical, functional, and sensory properties of corn-yogurt powder. Corn yogurt fortified with spirulina and soy protein isolate was dried using the foam-mat method, with maltodextrin and Tween 80 as foaming agents. The foaming agents were mixed for 8 minutes until foaming occurred, and the fortified yogurt was incorporated using the folding method. The mixture was poured onto a glass plate and dried in a cabinet dryer at 60 °C for 8 h. The dried sample was ground and sieved through 80 mesh. The dried yogurt has a protein content of 4.08–4.329%. The pH of the corn yogurt was lower than the range specified by the Indonesian National Standard (3.54–3.62); hence, this product was sourer than typical yogurts. The best corn yogurt powder was prepared with 1.75% Tween 80 and had 72.67% antioxidant activity, 133.76 µg/100 g β-carotene, and  $9.22 \times 10^7$  log CFU/g lactic acid bacteria. This fortified corn yogurt powder shows potential as an alternative functional food product because of its functional compounds and high protein content.

### KEYWORDS

Corn-yogurt; Foam-mat drying; Powder; Solubility; Tween 80

### 1. INTRODUCTION

The growing health consciousness has amplified the demand for functional foods. Corn is a source of functional foods due to its content of dietary fiber, iron, and β-carotene (provitamin A). Transforming maize into yogurt presents a viable functional food option, particularly for individuals with lactose sensitivity. Aini et al. (2017) [1] has researched the formulation of maize yogurt as an alternative functional food. The protein yield generated in this study remained insufficient and did not meet yogurt protein criteria. Fortification using high-protein dietary sources is necessary to enhance the protein content of corn yogurt. Spirulina is a marine organism in Indonesia that is rich in protein, vitamins, calcium, and fiber [2]. Adding spirulina to yogurt production enhances protein and fiber content while also serving as a stabilizer, resulting in a smoother texture [3]. Excessive addition of spirulina may lead to an unpleasant fishy taste [4]. The unpleasant fishy taste can be mitigated by using substances that conceal the flavor of spirulina, such as soy protein isolate. Soy protein isolate is a high-protein dietary component that also conceals the fishy taste of

spirulina. Soy protein isolate is a dietary additive that comprises advantageous bioactive constituents. The incorporation of soy protein isolate into yogurt products will influence organoleptic qualities, aroma, and flavor, and may enhance yogurt viscosity [5].

Corn yogurt has a high moisture content, so it is easily spoiled [6]. Corn yogurt packaged in polyethylene terephthalate bottles and stored at 15 °C was reported to have a shelf life of 39 days [6]. By contrast, corn yogurt packed in glass bottles and stored at 15 °C had a shelf life of 3.8 months [7]. However, glass bottles are more expensive and susceptible to damage. Therefore, a practical yogurt preservation technique is needed to extend the product's shelf life. One such technique is drying, because yogurt powder offers a longer shelf life than liquid yogurt [8].

Processing yogurt into powder requires careful execution to obtain a product with adequate physicochemical, functional, and sensory characteristics. Santos et al. (2018) [8] developed a method to prepare yogurt powder using freeze-drying. Yogurt powder could be of interest to the food industry [5], [6]. However, freeze-drying is expensive; thus, alternative drying methods are needed. One such method is foam-mat drying, where a foaming agent is added to aid in the drying process [11]. The foam mat drying process is effectively used to produce fruit powders due to its rapid drying at lower temperatures, preservation of high nutritional value, ease of reconstitution, and cost-effectiveness. The drying procedure of this foam mat is significantly more economical than freeze-drying and spray-drying for the manufacturing of fruit powders [12].

The foam-mat drying method can accelerate the drying process because drying products like foams quicken the evaporation of water from the material and the process is feasible at low temperatures [11]. Dry foods manufactured using foam-mat drying are highly soluble and absorb water easily [13]. Foam-mat drying has been applied to fruit juice, soy milk, and cheese [14], [15], [16], [17]. Studies have shown that foods subjected to foam-mat drying exhibit characteristics similar to the original product when reconstituted [18].

Foam-mat drying is not a new method but, until now, it has not been applied to drying corn yogurt. A study reported the production of yogurt powder using foam-mat drying but the product was made with cow's milk [19]. Research on foam-mat drying to make corn yogurt powder is expected to extend the product's shelf life and facilitate its distribution and use. Nevertheless, foaming agents and fillers are required to manufacture yogurt powder using foam-mat drying [20]. Foaming agents help form a porous structure in the material [21]. Using maltodextrin and Tween 80 in foam-mat drying can accelerate the drying process, increase the solids in the final product, and protect it from heat during drying [22]. In foam mat drying, the amount of Tween 80 as a foaming agent must be determined to ensure optimal process and product performance. This study sought to determine the optimal Tween 80 concentration for producing corn yogurt powder with optimal physicochemical, functional, and sensory characteristics. Yogurt-corn in powder form is expected to facilitate transportation, storage, and increase its shelf life.

## 2. MATERIALS AND METHODS

### 2.1. Materials

The main ingredient was sweet corn of the Madu variety, obtained from Danalaya Village, Sumbang District, Banyumas, Indonesia. The supporting ingredients were soy protein isolate (Para Agribusiness Bandung, Indonesia), spirulina powder (Ceres Food, Indonesia), commercial powdered yogurt starter (*Streptococcus thermophilus* and *Lactobacillus bulgaricus*), skim milk, sugar, kappa carrageenan, mineral water, Tween 80, and maltodextrin.

### 2.2. Preparation of Corn Yogurt

To produce corn yogurt, 300 mL of corn milk was mixed with 36 g of skim milk, 24 g of sucrose, 0.36 g of spirulina powder, 25.5 g of soy protein isolate, and 0.12 g of carrageenan. The mixture was pasteurized at 80–85 °C for 30 minutes and then cooled to 42 °C. Then, a 5% yogurt starter was added, and the mixture was incubated at 37 °C for 16 hours.

### 2.3. Making Yogurt Powder using Foam-Mat Drying

The method of Rizqiati et al. (2020) [23], was used. Tween 80 and maltodextrin were mixed for 8 min until a foam formed. The corn yogurt was then added to the foaming agents and homogenized using the folding method. Next, the mixture was poured onto a glass plate to a thickness of  $\pm 2$  mm and dried for 8 h at 60 °C in a cabinet dryer. The dried sample was ground and sieved through an 80-mesh sieve to obtain yogurt powder.

### 2.4. Moisture Analysis

The oven method was used to determine the water content. Weighing an empty dish and adding about 2 grams of sample to it was the process for figuring out the water content. For six hours, place the dish and its contents in an oven set between 100–120 °C. After 6 hours, take the dish out and let it cool for 5–10 minutes in a desiccator before weighing it. Weigh the sample until its weight remains constant after drying it once more in the oven [24].

### 2.5. Fat Analysis

The Soxhlet technique was used to calculate the fat content. The filter paper was dried for one hour at 105 °C in an oven. After 15 minutes of cooling in a desiccator, the filter paper was weighed (W2). Next, a 5 g sample was weighed (W1) and wrapped in a sleeve-shaped piece of filter paper. Put together the extraction apparatus, which includes a condenser, Soxhlet, fat flask, and heating mantle. After that, the sample was put in the Soxhlet and enough benzene solvent was added for one and a half cycles. The extraction process lasts for approximately six hours, or until the solvent re-enters the clear fat flask through the syringe. The extraction product was cooked for one hour at 105 °C in an oven. After 15 minutes of cooling in a desiccator, the fat paper was weighed (W3). The fat content was calculated using the equation (1) [24].

$$\text{Fat (\%)} = \frac{W3 - W2}{W1} \times 100 \quad (1)$$

### 2.6. Protein Analysis

The Kjeldahl technique was used to calculate protein content. The process was concentrated H<sub>2</sub>SO<sub>4</sub> was added to the blank without the sample after the sample had been put in a tube. After that, it was destroyed for two to three hours at a temperature of 200 to 250 °C (until the color turns clear green). Five mL of distilled water were mixed with the sample. After the sample had been distilled, the distillate was collected in an Erlenmeyer flask filled with boric acid, and methyl red indicator (MR) was added dropwise. Titrating with 0.02 N HCl until the color becomes pink completes the distillation process. Equations (2) and (3) was used to determine the protein content [24].

$$\text{Nitrogen total (\%)} = \frac{\text{mL of HCl (sample - blank)}}{\text{sample weight (g)}} \times N \text{ HCl} \times \text{MW of nitrogen} \times 100 \quad (2)$$

$$\text{Protein content (\%)} = \%N \times \text{protein conversion factor} \quad (3)$$

where, N is the normality of HCl for titration, MW of nitrogen is 14, and the protein conversion factor is 6.25.

### 2.7. Ash Analysis

The drying ash method was used to assess the ash content. Weighing an empty dish, weighing around 2 g of sample, and adding it to the empty dish was the process for figuring out the ash content. After that, put it in an incinerator and burn it until the weight stays constant and gray ash was produced. There were two steps to the incineration process. Next, let it cool in a desiccator before weighing it [24].

## 2.8. pH Analysis

Measure the pH (acidity level) with a pH meter that had been calibrated using buffer solutions with pH values of 4 and 7. To measure the sample, took 20 mL and rinsed the electrode with pure water. After used tissue to dry it, the electrode was submerged in the sample. The electrode was submerged for some time. The stabilized pH value was being read [25].

## 2.9. Solubility Analysis

To evaluate the solubility of powdered yogurt, weigh one gram of the sample (a), dissolve it in 20 mL of distilled water at 50 °C, and then filter the mixture through filter paper. After 30 minutes of oven drying at 105 °C, the filter paper is weighed (b). After filtration, drying was done until a consistent weight was achieved. Equation (4) can be used to determine solubility [26].

$$\text{Solubility} = 1 - \left(\frac{c-b}{a}\right) \times 100 \quad (4)$$

## 2.10. Bulk Density

The density of the sample was measured by placing the material in a measuring cup to a certain volume without compacting it, then weighing the material. The density of the sample was calculated by dividing the material by the volume of space it occupied. The density of the sample was expressed in units of kg/m<sup>3</sup> or g/ml [27].

## 2.11. Water Activity

Water activity ( $a_w$ ) was assessed using an electronic  $a_w$  meter. The sample was placed in the testing device, then water activity testing was carried out for approximately 2 minutes, after which the water activity measurement results were recorded [17].

## 2.12. Probiotic Viability

The material was subjected to a microbiological investigation that included a total LAB (lactic acid bacteria) test using the plate count method (total plate count). The total LAB that grew on MRSA (Man Rogosa and Sharpe Agar) culture media was used to calculate the total LAB. The sample was diluted with distilled water at a ratio of 1:9 in order to calculate the total LAB. Dilution was done between 10<sup>1</sup> and 10<sup>8</sup>. One milliliter of the material was diluted with 9 mL of sterile distilled water in the initial dilution. One milliliter of the sample diluted in the first dilution was added to 9 mL of sterile distilled water to perform the second dilution. The method used for the second dilution was also used for the third and subsequent dilutions [27].

MRSA culture media were used for plating. As much as 65.13 g of MRS agar were dissolved in 1000 mL of distilled water to create 1000 mL of MRS agar. The MRS agar solution was then autoclaved at 121 °C for 15 minutes to sterilize it. Plating involves adding ± 10 mL of lukewarm MRS agar to a Petri dish containing 1 mL of the diluted material. Plating is done in triplicate using a 10<sup>6</sup>–10<sup>8</sup> dilution. To guarantee homogeneity, the Petri dishes are then swirled. The semi-solid bacteria and MRS agar-containing dishes are incubated upside down at 37 °C for 48 hours [27].

## 2.13. β-carotene

Five grams of the sample were weighed before being put in an Erlenmeyer flask. To make grinding easier, pure carotene-free sand and petroleum ether 1:1 acetone was added to a porcelain mortar. After grinding the material with petroleum ether 1:1 acetone until all of the carotene (yellow) extract is gone, gather the filtrate in an Erlenmeyer flask. Two layers should form after the filtrate was placed in a separating funnel, 50 mL of distilled water are added, shaken, and left for 5 minutes. The unreacted acetone fraction dissolved in water makes up the lower layer, while the carotene fraction in petroleum ether makes up the upper layer. Gather the top layer in an Erlenmeyer flask and discard the bottom layer. To absorb any leftover water or distilled water, add anhydrous Na<sub>2</sub>SO<sub>4</sub>. After adding petroleum ether to a specific volume, used a

spectrophotometer adjusted at 450 nm to measure the absorbance. Note the results and compute the carotenoid/total carotene ratio [28].

The recovered filtrate is transferred into a chromatography column with the following criteria for the  $\beta$ -carotene analysis, as much as 1 cm in diameter and 25 cm in length. One centimeter of glass wool, 2 cm of  $\text{Al}_2\text{O}_3$ , 2 cm of anhydrous  $\text{Na}_2\text{SO}_4$ , and 1 cm of cotton wool were placed at the bottom of the column. After that, the chromatography column was heated to 180 °C for 2 hours. After the filtrate was added to the column, the droplets that emerged were collected as  $\beta$ -carotene in an Erlenmeyer flask. After that, petroleum ether 10:1 acetone was used to wash the column. Petroleum ether was then used to dilute the obtained filtrate to a specific volume. At a wavelength of 450 nm, measure the absorbance. Note the information gathered and compute it as  $\beta$ -carotene. Make a standard curve for  $\beta$ -carotene [28].

#### 2.14. Antioxidant Activity

The antioxidant test's capacity to absorb DPPH free radicals was examined. The following are the stages of analysis. 0.39 g of DPPH powder (MW of 394.32) were dissolved in 10 mL of methanol (p.a) to create a 0.1 mM DPPH solution. A 100 mL volumetric flask was filled with 100  $\mu\text{L}$  of the 0.1 M DPPH solution, then methanol was added until the DPPH limit mark (0.1 mM) was reached. After that, a 100 mL volumetric flask was filled with 4 g of sample that had been dissolved in methanol up to the limit. To create a 40,000 ppm extract stock solution, 2 mL of each test solution concentration were put in a test tube, followed by the addition of 2 mL of 0.1 mM DPPH solution, homogenization by vortex, and 30 minutes of incubation in a dark room. Next, absorbance was measured at 517 nm. The percentage of inhibition was then used to express radical scavenging activity, which could be computed using equation (5) [28].

$$\text{Inhibition (\%)} = \left( \frac{\text{DPPH absorbance} - \text{sample absorbance}}{\text{DPPH absorbance}} \right) \times 100 \quad (5)$$

#### 2.15. Dietary Fiber Content

After weighing and placing 0.5 g of the sample in an Erlenmeyer flask, 50 mL of pH 7 phosphate buffer were added. The Erlenmeyer flask holding the sample was then filled with 0.1 mL of  $\alpha$ -amylase. It was cooked for half an hour at 100 °C in a water bath, stirring periodically. After removing the sample and letting it cool, add 5 mL of 1 N HCl and 20 mL of distilled water. The Erlenmeyer flask containing the sample should next be heated in a water bath for 30 minutes after adding 1 mL of 1% pepsin. After that, the Erlenmeyer flask was taken out and filled with 0.1 mL of  $\beta$ -amylase and 5 mL of 1 N NaOH. After being covered, the Erlenmeyer flask was incubated for 1 hour in a water bath. Constant filter paper with a specified weight was used to filter it. As much as 10 mL of ethanol and 10 mL of acetone were used to wash the sample. After being dried for 1 night at 105 °C in an oven, the sample was chilled in a desiccator before being weighed to establish its ultimate weight (insoluble dietary fiber). After adjusting the filtrate's volume to 100 mL, 400 mL of warm 95% ethanol were added. An hour was given for the filtrate to settle. After that, the filtrate was filtered through ash-free filter paper, cleaned with two 10 mL ethanol and 10 mL acetone, dried overnight at 105 °C in an oven, put in a desiccator, and weighed to find the final weight (soluble dietary fiber). Equation (6) can be used to determine the total amount of dietary fiber [24].

$$\text{Total dietary fiber} = \text{insoluble dietary fiber} + \text{soluble dietary fiber} \quad (6)$$

#### 2.16. Sensory Qualities Analysis

A sensory analysis was conducted on the corn yogurt powder and reconstituted yogurt at a yogurt/water ratio of 1/5. Twenty non-trained panellists assessed the products for 5 profile, such as taste, color, corn flavor, viscosity, and overall preference, to measure the sensory parameters [29].

### 2.17. Experimental Design and Data Analysis

This study used a completely randomized design, with Tween 80 concentration (0.75%, 1.25%, or 1.75%) as a factor. The physical, chemical, and microbiological parameters were subjected to an analysis of variance (ANOVA) at the  $\alpha = 5\%$  level. If the test results indicated a significant effect, a Duncan Multiple Range Test (DMRT) at  $\alpha = 5\%$  was conducted. The sensory test data were analyzed with the Friedman test, and if a significant effect was detected, a Wilcoxon test was performed. Then, the best treatment was determined using the De Garmo Effectiveness Index Test.

## 3. RESULTS AND DISCUSSION

### 3.1. Moisture Content

The higher the concentration of the foaming agent, the lower the water content of the corn yogurt powder (Table 1). Using Tween 80 as a foaming agent can accelerate the powder's drying time and thus lower the moisture content [30]. The presence of maltodextrin, which plays an important role in binding water to the material, also influenced the function of Tween 80 as a foaming agent. As a result, the moisture in the material evaporates readily, decreasing the final moisture content. These results are in accordance with Hariyadi (2018) [31] who stated that Tween 80, as a foaming agent, can accelerate drying time, resulting in a lower moisture content. According to Wahyuni (2021) [22], the use of Tween 80 as a foaming agent can reduce the moisture content of moringa leaf powder. According to Miskiyah (2019) [32], an inappropriate ratio of Tween 80 and maltodextrin concentrations can cause hardening on the surface of the powder product due to the large amount of free water remaining. Tween 80 reduced the moisture content of corn yogurt powder by 5.40%–8.82%. However, inappropriate concentrations of Tween 80 and maltodextrin may cause hardening on the powder's surface because of the large amount of free water remaining after dehydration. The decrease in the moisture content of corn yogurt powder with increased Tween 80 concentrations indicates that the concentrations used were appropriate.

Table 1. Characteristics of corn yogurt powder at Tween 80 concentration variation.

Parameters	Concentration of Tween 80 (%)		
	0.75	1.25	1.75
Lactic acid bacteria (log CFU/g)	8.29 ± 0.02 <sup>a</sup>	8.82 ± 0.14 <sup>b</sup>	9.22 ± 0.05 <sup>c</sup>
pH	3.62 ± 0.01 <sup>b</sup>	3.61 ± 0.01 <sup>b</sup>	3.54 ± 0.03 <sup>a</sup>
Solubility	70.71 ± 1.31 <sup>a</sup>	71.0 ± 1.49 <sup>b</sup>	73.81 ± 1.18 <sup>c</sup>
Water activity	0.56 ± 0.01 <sup>b</sup>	0.53 ± 0.02 <sup>ab</sup>	0.52 ± 0.02 <sup>a</sup>
Bulk density	0.69 ± 0.04 <sup>a</sup>	0.66 ± 0.04 <sup>a</sup>	0.62 ± 0.04 <sup>a</sup>
Moisture (%)	10.52 ± 0.50 <sup>b</sup>	9.52 ± 1.07 <sup>ab</sup>	9.08 ± 0.82 <sup>a</sup>
Ash (%)	2.65 ± 0.66 <sup>a</sup>	2.62 ± 0.13 <sup>a</sup>	2.52 ± 0.21 <sup>a</sup>
Fat (%)	4.45 ± 1.330 <sup>a</sup>	3.72 ± 1.72 <sup>a</sup>	3.49 ± 1.30 <sup>a</sup>
Protein (%)	4.33 ± 0.42 <sup>a</sup>	4.27 ± 0.48 <sup>a</sup>	4.08 ± 0.32 <sup>a</sup>
Antioxidants (%)	69.56 ± 0.66 <sup>a</sup>	71.44 ± 2.67 <sup>a</sup>	72.67 ± 2.87 <sup>a</sup>
β-carotene (μg/100g)	91.45 ± 2.67 <sup>a</sup>	103.43 ± 0.40 <sup>b</sup>	133.76 ± 7.61 <sup>c</sup>
Carbohydrates (%)	77.45 ± 1.01 <sup>a</sup>	77.25 ± 0.93 <sup>a</sup>	79.71 ± 2.60 <sup>a</sup>

Note: the number followed by different letters in a same row indicate a significant effect at the 5%.

### 3.1. Fat Content

The fat content of the powdered yogurt was 2.49%–3.07% (Table 1). These results indicate that, in some cases, the fat content of the powdered yogurt exceeded the Indonesian National Standard 2981:2009 [32] for yogurt (i.e., a maximum fat content of 3%). The high fat content was due to the ingredients used, especially spirulina, which has 6%–8% fat, and Tween 80 as a foaming agent. Tween 80 is a non-ionic surfactant consisting of fatty acid components [33]. Therefore, including these ingredients increases the fat content of the resulting powdered yogurt.

### 3.2. Protein Content

The concentration of the foaming agent does not affect the protein content of the yogurt powder. The measured protein content of the yogurt powder is 4.08%–4.33% and is higher than that of corn yogurt with added sweet potato (3.5%) [1]. This protein content is higher than Putri & Amrizal (2020) [34] who stated that the protein content of corn yogurt with the addition of sweet potatoes is 3.5%. Qi (2009) [35] stated that the protein content of cowpea yogurt powder is 2.18%–3.51%, also lower than the results of this study. The minimum protein content of yogurt powder is 3.5% so yogurt is said to have a high protein content if it has a protein content of more than 3.5% [36]. So, it can be concluded that this corn yogurt powder has a high protein content.

### 3.3. Ash Content

The concentration of Tween 80 does not significantly affect the ash content of the corn yogurt powder (Table 1). The ash content of the corn yogurt powder ranged from 2.32% to 2.37%, higher than the Indonesian National Standard 2981:2009 for yogurt [32] (a maximum of 1% protein). The ash content of food ingredients is closely related to their mineral content, the higher the mineral content, the higher the ash content. The ash content of corn yogurt powder is derived from the minerals in the raw materials used to make it, namely soy protein isolate and spirulina, which have ash contents of 3.5% and 6.88%, respectively.

### 3.4. Lactic Acid Bacteria

The higher the concentration of Tween 80, the greater the number of lactic acid bacteria (LAB) (Table 1). Tween 80 is an emulsifier that also functions as a growth medium for LAB [37]. According to Qi et al. (2009) [35], Tween 80 is effective for cultivating *Lactobacillus*. This is because Tween 80 contains oleic acid, which can increase the growth rates of LAB and other bacterial groups [38]. The oleic acid in Tween 80 acts as an active ingredient in LAB culture media, where it is converted into cyclopropane acid, increasing the fluidity of LAB membranes to protect them from damage due to various environmental conditions, such as low pHs and extreme temperatures [39].

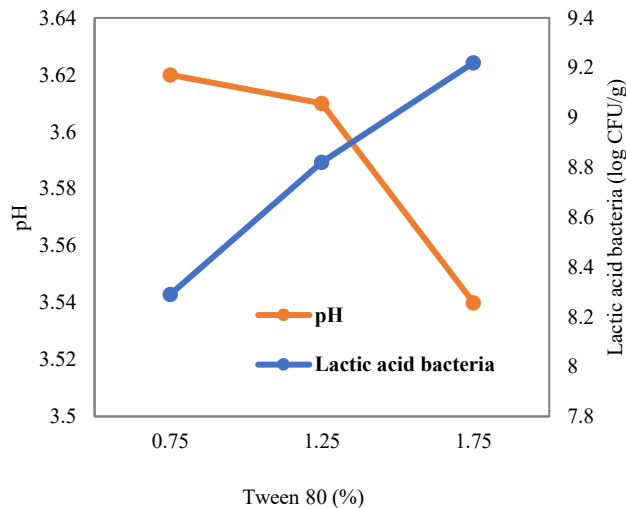


Figure 1. pH and lactic acid bacteria of corn-yogurt powder was affected by concentration of Tween 80.

### 3.5. pH Content

The higher the Tween 80 concentration, the lower the pH of the yogurt powder. The pH of the corn yogurt powder ranged from 3.54 to 3.62 (Table 1). According to the Indonesian National Standard, 2981:2009 [32] the pH of yogurt should be 3.8–4.4. However, the pH of the corn yogurt powder is lower. This result is likely influenced by LAB because the more LAB are present in the yogurt, the lower its pH

[40]. Hence, this result aligns with the measured LAB count (Figure 1) and is consistent with Zhao et al. (2021) [41], who stated that the pH of yogurt depends on the total LAB because they produce lactic acid. In addition, the low pH of Tween 80 further lowered the pH of the corn yogurt powder [42].

### 3.6. Solubility Content

The higher the Tween 80 concentration, the greater the solubility of corn yogurt powder in water. This is because of Tween 80's hygroscopic properties, which are due to hydroxyl groups that can bind water. The higher the solubility of powdered yogurt, the better its quality, because it can produce a perfect solution when water is added [8]. Tween 80 is a surfactant with high solubility in water, ethanol, and other solvents. Tween 80 can increase the solubility of materials because it has a free hydroxyl group from oxyethylene that can bind water. In addition, Tween 80 has a high hydrophilic-lipophilic balance value (1.5), indicating that its components can easily dissolve in water [43]. The results of this study align with a previous work that reported that the concentration of the foaming agent influences the material's solubility [44].

### 3.7. Bulk Density

The bulk density of the corn yogurt powder ranged from 0.62 to 0.69 g/mL. Bulk density is the ratio between the weight of the material and its volume, including the space between the particles of the material [45]. The bulk density of the powdered yogurt was not affected by the concentration of the foaming agent. This result confirms Malik and Sharma (2019) [46]. The concentration of the foaming agent does not affect the bulk density of powdered yogurt during foam-mat drying.

### 3.8. Water Activity

The higher the concentration of the foaming agent, the lower the water activity ( $a_w$ ) of the corn yogurt powder. This aligns with the moisture content results, which showed that a higher foaming agent concentration resulted in a corn yogurt powder with lower water activity. This occurred because maltodextrin maintained product stability during storage [30]. The water activity of the corn yogurt powder was 0.52–0.57. No data has been found regarding the  $a_w$  of powdered yogurt, but the  $a_w$  of corn yogurt is higher than that of drink powder enriched with pumpkin, which is 0.3–0.4. Water promotes microbial growth; thus, low moisture content can prevent microbial spoilage of food. Therefore,  $a_w$  in food ingredients is closely related to moisture content and shelf life [47]. Halim (2024) [48] assert that food powders with an  $a_w$  of 0.6 or lower are typically considered devoid of microbiological or biochemical processes.

### 3.9. Antioxidants

Antioxidants are compounds that function as free-radical scavengers. They are beneficial for the body as they slow or prevent oxidation reactions that can impair health [49]. The antioxidant content of the corn yogurt powder is 69.56%–72.67%. The antioxidant activity of this yogurt powder is higher than that of yogurts fortified with probiotic powders derived from *Lactobacillus acidophilus*, at 2.68%–5.94% [50]. The antioxidant activity of this yogurt powder is also higher than that of yogurt enriched with probiotics *Bifidobacterium longum* and red dragon fruit, at 10.41%–19.01% [51]. Tween 80 likely influenced the antioxidant levels because this foaming agent can protect the product from heat oxidation processes. Tween 80 can form a protective layer between the product's dispersed phase and continuous phase, and can thicken the film layer that protects the components of the generated foam system [33].

### 3.10. $\beta$ -carotene Content

The  $\beta$ -carotene content increased as the foaming agent concentration increased, resulting in 91.45  $\mu\text{g}/100\text{ g}$  of  $\beta$ -carotene at 0.75%, 103.43  $\mu\text{g}/100\text{ g}$  at 1.25%, and 133.76  $\mu\text{g}/100\text{ g}$  at 1.75%.  $\beta$ -carotene concentrations in yogurt are affected by the raw ingredients, specifically yellow corn, which contains  $\beta$ -carotene of 22% [1]. High  $\beta$ -carotene levels are also influenced by spirulina, which contains 49.6 to 319.5  $\mu\text{g}/\text{g}$ . According to Barkallah (2027) [3], yogurt with added *Spirulina platensis* has a  $\beta$ -carotene content of 10.86%, while yogurt without added spirulina has a  $\beta$ -carotene content of 0%. Soy protein isolate has a  $\beta$ -

carotene content of 28.35  $\mu\text{g/g}$ , which also plays a role in the  $\beta$ -carotene content of corn yogurt.  $\beta$ -carotene concentrations rise with higher foaming-agent concentrations, 91.45  $\mu\text{g}/100\text{g}$ , 103.43  $\mu\text{g}/100\text{g}$ , and 133.76  $\mu\text{g}/100\text{g}$ . The elevation of  $\beta$ -carotene concentrations in powdered yogurt is also affected by Tween 80, a foaming agent that effectively acts as a surfactant to diminish surface tension in the solution. Consequently, using higher Tween 80 concentrations can mitigate foam formation, thereby dissolving  $\beta$ -carotene into the powdered yogurt solution [52].

### 3.11. Dietary Fiber

The higher the Tween 80 concentration, the higher the total dietary fiber content of the corn yogurt powder. According to the Indonesian National Standard 2981:2009 [32], yogurt should contain 2.9 mg per serving of dietary fiber. Hasneen et al. (2023) [53], reported that probiotic yogurt contained 0.57%–1.97% fiber, with the highest value observed in yogurt containing soy flour. Thus, adding soy protein isolate as a fortification ingredient increased the yogurt powder's fiber content.

### 3.12. Sensory Properties

The distinctive taste of yogurt is primarily due to lactic acid, which is produced by the metabolic activity of LAB during fermentation. In addition, yogurt's distinctive flavor is derived from volatile organic compounds, such as acetone, acetic acid, esters, acetaldehyde, lactic acid, diacetyl, 2,3-pentanedione, and others [25]. The panelists assigned scores of 3.23–3.92 to the taste of powdered yogurt (Figure 2) (“slightly sour” to “sour”). Yogurt's sourness decreased as the concentration of the foaming agent increased. This study's results align with those reported by Ratna et al. (2021) [54], who stated that a higher concentration of Tween 80 decreased yogurt's characteristic sourness.

Corn yogurt powder typically has a yellow-to-greenish color. Spirulina imparts a green hue, while corn milk and soy protein isolate have a natural yellowish color because they contain carotenoids [6]. The intensity of the yellow color of the yogurt powder was scored 2.48–2.73 (within the “slightly yellow” category) (Figure 2). The higher the concentration of Tween 80, the higher the intensity of the yellow color. Tween 80 as a foaming agent can increase the surface area of the material, accelerating the drying process and hindering the browning reaction due to heat during drying [22]. This maintains the color intensity of the original yogurt.

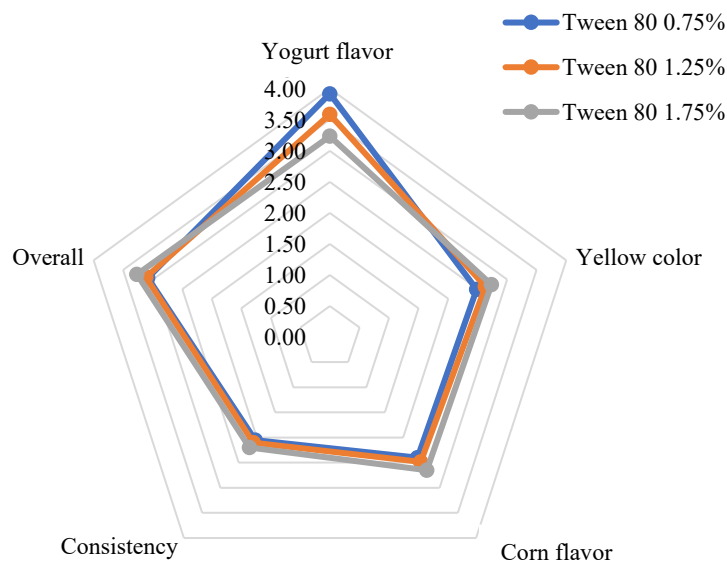


Figure 2. Sensory properties of corn-yogurt powder with variation of Tween-80 concentration.

The distinctive corn flavor of the yogurt derives from the aroma compounds acetaldehyde and diacetyl. The corn flavor is one of the parameters used to determine the quality of corn milk yogurt [7]. The powdered corn yogurt received a panelist score of 2.40–2.65 for corn flavor (“slightly strong” to “rather strong”). The higher the concentration of Tween 80, the stronger the corn flavor of the powdered yogurt. This reflects the increase in the total solids containing corn flavor. These results agree with Cahyani and Nadia (2022) [55], who reported stronger corn flavor with increased concentrations of Tween 80. The panelists rated their overall preference for the powdered yogurt samples as 2.10–2.33 (“slightly like” to “somewhat like”). The higher the concentration of the foaming agent, the higher the panelists’ overall preference score. This is because the foaming agent can maintain and improve the sensory properties of powdered yogurt (i.e., its taste, aroma, and texture) [55]. In addition, the foaming agent’s ability to form a film on the drying yogurt retains odor-active compounds that contribute to the sensory properties of the product. Moreover, it protects the product from damage during drying [56]. Our results corroborate the observations of Koli et al. (2022) [57] who found that spirulina supplementation improved consumers’ preference for pasta by enhancing its color, aroma, and appearance.

### 3.13. Yogurt Powder with The Best Treatment

Effectiveness index tests were conducted to determine the best treatment or formulation based on the results of physicochemical and sensory testing of the products. The results of the best treatment will be continued in the next stage of research (Table 2). Based on Table 2, the highest product value was obtained by formulation T1, which was selected as the best formula. The effectiveness index test results showed that using 0.75% Tween 80 during drying produced the corn yogurt powder with the best characteristics. The optimal yogurt powder had 10.52% moisture, 2.32% ash, 2.49% fat, 4.33% protein, 77.74% carbohydrate, 0.53% reducing sugar, a pH of 3.62, a solubility of 70.72%, a water activity of 0.56, and a bulk density of 0.69 g/mL. This yogurt powder had  $13.5 \times 10^7$  CFU/g LAB, 69.56% antioxidant activity, 91.45  $\mu\text{g}/100$  g  $\beta$ -carotene, and 3.23% total dietary fiber. The sensory property scores of the optimal corn yogurt were 3.92 (“slightly sour” to “sour”) for taste, 2.48 (“slightly yellow”) for color, 2.40 (“slightly strong” to “quite strong”) for corn flavor, (“slightly smooth” to “smooth”) for consistency, and 3.08 (“slightly like” to “like”) overall.

Table 2. Effectiveness index test.

Yoghurt powder formulation	Product value
T1	0.771
T2	0.499
T3	0.479

Note: T1 = Yogurt powder (0.75% Tween 80); T2 = Yogurt powder (1.25% Tween 80); T3 = Yogurt powder (1.75% Tween 80).

## 4. CONCLUSION

The foaming agent concentration affects the pH, solubility, water activity, functional properties (total lactic acid bacteria (LAB),  $\beta$ -carotene content, and total dietary fiber), and sensory properties (flavor, yellow color intensity, and overall preference) of yogurt powder. The optimal corn yogurt powder was produced with a Tween 80 concentration of 0.75% and had 4.08% protein, 73.81% solubility, 72.67% antioxidant activity, 133.76  $\mu\text{g}/100$  g  $\beta$ -carotene, and a total LAB count of  $9.22 \times 10^7$  log CFU/g. The corn yogurt powder was fairly acidic, with a pH of 3.54–3.62; thus, fruit extracts containing sugar can be added to it to stimulate the growth of LAB. The reconstituted yogurt powder exhibited sensory characteristics with a slightly sour taste (3.92), low intensities of green (2.38) and yellow (2.48) coloration, a slightly strong corn flavor (2.40), moderately strong beany (3.65) and spirulina (3.90) flavors, a moderately smooth texture (3.08), and an overall acceptability score of 3.08, indicating moderate consumer preference. The high solubility of the corn yogurt powder is related to water absorption and product shelf life. Therefore, further studies could evaluate the shelf life and ideal packaging for this product.

## AUTHOR CONTRIBUTION

All author contributed equally to the main contributor to this paper. All authors read and approved the final paper. **Nur Aini:** Supervision, conceptualization, funding acquisition. **Ratih Tiara Dewi:** Writing (original draft), formal analysis. **Pepita Haryanti:** Supervision, conceptualization. **Vincentius Prihananto:** Supervision, investigation. **Anita Khairunnisa:** Formal analysis. **Budi Sustriawan:** Statistical analysis. **Hadana Sabila Arsyistawa:** Writing (review & editing). **Annisa Fitriati:** editing. **Indarto:** Writing (review & editing). **Banun Diyah Probawati:** editing and reviewing.

## CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

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