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The effect of turmeric extract on the pH, water holding capacity (WHC), and color of Stirred Yogurt

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Abstract
This study aimed to evaluate the effect of turmeric extract (*Curcuma longa L.*) addition on the pH, water holding capacity (WHC), and color of stirred yogurt. The experiment was arranged in a completely randomized design (CRD) with three treatments of turmeric extract concentrations (5%, 10%, and 15%) and six replications. Data were analyzed using analysis of variance (ANOVA), and if significant differences were found ($p<0.05$), Duncan's Multiple Range Test (DMRT) was conducted as a post-hoc analysis. The results showed that increasing turmeric extract concentrations had a significant effect ($p<0.05$) on the pH, WHC, and color parameters of the yogurt. The treatment with 5% turmeric extract resulted in the most optimal pH and WHC values, along with acceptable sensory color. The decrease in WHC at higher turmeric concentrations was likely due to interactions between curcumin and other phenolic compounds with milk proteins, which interfered with gel network formation. Additionally, the higher pH values at increased turmeric concentrations may have contributed to the reduced water retention ability of the yogurt. These findings indicate that turmeric extract has potential as a functional additive in yogurt production, but its application must be optimized to maintain physical stability.

Keywords: Yogurt, turmeric extract, pH, WHC, color

Introduction

Yogurt is a widely favored fermented dairy product around the world, partly due to its high nutritional content, including protein, calcium, and vitamins, as well as its health benefits related to probiotic activity (Tamime & Robinson, 2007) [12]. Yogurt is produced through the fermentation of lactose by lactic acid bacteria, primarily Streptococcus thermophilus and Lactobacillus delbrueckii subsp. bulgaricus, which produce lactic acid and the characteristic flavor compounds of yogurt (Chandan & Kilara, 2013 [3]; Hartati *et al*, 2019a) [6, 7].

Yogurt can be made in the form of stirred yogurt, which is yogurt that is stirred after fermentation to achieve a uniform consistency and a smoother texture (Lucey, 2004 [8], Hartati *et al*, 2019b) [6, 7].

In the yogurt-making process, other components are usually added to enhance the functional value and sensory appeal of the yogurt product, and the addition of natural ingredients containing bioactive compounds has become an attractive strategy. Turmeric (*Curcuma longa L.*), as a spice plant rich in curcumin, is known to have high antioxidant, anti-inflammatory, and antimicrobial activities (Buniowska-Olejnik *et al*, 2023) [2]. The pigment present in turmeric, curcumin, functions as a natural dye and has been widely used as a natural food coloring (Allan *et al*., 2020). Turmeric extract will affect the physicochemical characteristics of stirred yogurt, including pH, water holding capacity (WHC), and color. pH is related to the microbiological condition and the final texture of the product (Dong *et al*., 2022) [4]. WHC indicates the ability to retain free water, which will influence syneresis and texture density (Sodini *et al*., 2004).

The added natural color will also affect consumer preferences in choosing yogurt (Martin *et al*., 2016). However, the addition of turmeric extract can affect the physicochemical characteristics of stirred yogurt, including pH, water holding capacity (WHC), and color. The pH value is closely related to the microbiological stability and the final texture of the product (Dong *et al*., 2022) [4], while WHC describes the ability of yogurt to retain free water, which affects syneresis and texture density (Sodini *et al*., 2004). Additionally, the color of the product significantly affects the perception of quality and consumer preferences, especially in products with the addition of natural coloring agents (Buniowska-Olejnik *et al*, 2023) [2]. Therefore, this study aims to evaluate the effect of adding turmeric extract on the physicochemical characteristics of stirred yogurt, particularly on the parameters of pH, WHC, and color. This research is expected to provide a scientific basis for the development of functional yogurt products based on natural ingredients and with high market competitiveness.

Materials and methods

Preparation of Turmeric Extract

The procedure for preparing turmeric extract generally involves the following steps: Clean the turmeric rhizomes from dirt and outer skin, then wash thoroughly under running water. Slice or cut the turmeric rhizomes into small pieces, then dry them and grind using a blender until they become a fine powder. The resulting turmeric powder is then mixed with distilled water in a 1:1 ratio and heated at 80°C for 30 minutes. The final product is turmeric extract.

Preparation of Turmeric Stirred Yogurt

(Wulandari *et al*., 2010) [10] Cow's milk is mixed with skim milk powder at 5% of the total volume of raw material, and turmeric extract is added according to the treatment. The mixture is stirred until a homogeneous solution is formed. The mixture is then heated at 90°C for 30 minutes and cooled down to 42°C. Once the temperature reaches 42°C, yogurt starter culture is inoculated at 5% of the total volume. The mixture is incubated at 43°C for 6 hours. After

proper coagulation is formed, the fermented product is cooled in refrigeration (4-6°C) for 24 hours. The resulting stirred yogurt is stored under refrigeration.

Water Holding Capacity (WHC)

Regarding the determination of Water Holding Capacity (WHC) and further adapted, involves several steps. A 10 ml yogurt sample is weighed, followed by centrifugation at 3000 rpm for 10 minutes at room temperature. The whey separated during this process is then weighed. The WHC is calculated using the formula

$$WHC(\%) = \frac{A - B}{A} x\ 100$$

Note:

A = Initial Weight

B = Whey Weight (separated liquid)

pH Measurement

The pH value was measured using an electronic pH meter. Before use, the tip of the indicator electrode was rinsed with distilled water and cleaned with a tissue. The pH meter was then calibrated by immersing the electrode tip into buffer solutions of pH 4 and 7. After calibration, the electrode tip was immersed into the yogurt sample, and before measuring the pH of the next sample, the probe was rinsed with distilled water. The value recorded was the reading displayed once the pH meter had stabilized.

Colour

Color measurement (L, a, and b) was conducted using a colorimeter with the Engelen (2018) method by determining the red, blue, yellow, and green colors of the light. The light is absorbed by the sample. The sample was prepared in a 250 ml glass jar.

The L* value as a parameter of achromatic color brightness ranges from 0-100. The a* value as a parameter of chromatic color is a* = 0-100 for red and a- = 0-(-80) for green. The b* value as a parameter of chromatic color is b* = 0-70 for yellow and b- = 0-(-70) for blue.

The method used in this study was a completely randomized design (CRD) with 3 treatments and 6 replications, resulting in a total of 18 experimental units. The treatments involved the addition of different concentrations of turmeric extract to yogurt, as follows:

P1 = yogurt with 5% turmeric extract, P2 = yogurt with 10% turmeric extract, P3 = yogurt with 15% turmeric extract

Result and discussion

pH value

the acidity of stirred yogurt with the addition of turmeric extract is presented in Table 1. Based on Table 1, the addition of turmeric extract to stirred yogurt has a significant effect on the pH value ($p < 0.05$).

Table 1: pH of stirred yogurt with various concentrations of turmeric extract

Treatment	pH
5	4.59[a]
10	4.61[a]
15	5.06[b]

a-b Different superscripts in the same row represent significant differences ($p<0.05$).

The increasing concentration of turmeric extract from 5% to 15%, a significant increase in the pH value of the yogurt was observed. The highest pH in the treatment with 15% turmeric extract was 5.06, which was significantly different from the treatments with 5% (4.59) and 10% (4.61) turmeric concentrations. The pH value increased with the addition of turmeric extract, which is suspected to be due to the antimicrobial properties of the curcumin compound present in the turmeric extract. Curcumin, as an active compound, has the activity to inhibit the growth of lactic acid bacteria during the fermentation process, resulting in a decrease in lactic acid content and a higher pH in the produced yogurt (Aggarwal *et al*., 2007) [1]. Turmeric extract also has a pH of 6.8, which contributes to the pH of the stirred yogurt produced.

The pH value of the produced yogurt affects its physical quality, product stability, and consumer acceptance. yogurt with a pH that is too low is likely to experience syneresis and a taste that is too sour, while a pH that is too high can affect microbiological stability during storage (Dong *et al*., 2022) [4].

Water holding capacity (WHC)

The water holding capacity of stirred yogurt with various concentrations of turmeric extract is presented in Table 2. It is shown that all turmeric extract treatments differ significantly from one another, including the 5%, 10%, and 15% treatments.

Table 2: WHC of stirred yogurt with various concentrations of turmeric extract

Treatment	WHC (%)
5	46.0[a]
10	42.8 [b]
15	40.5[c]

a-c Different superscripts in the same row represent significant differences ($p<0.05$).

The higher the concentration of turmeric extract added, the lower the WHC value tends to be. The treatment with 5% turmeric extract resulted in the highest WHC value at 46.0%, followed by 10% (42.8%), and the lowest was observed at 15% concentration (40.5%). WHC refers to the yogurt's ability to retain water and is associated with its viscosity, texture, and the release of whey, commonly known as syneresis. A high WHC indicates a dense and stable gel structure in yogurt and contributes to the product's sensory quality (Sodini *et al*., 2004, Wulandari *et al*, 2024). The decrease in WHC at higher turmeric concentrations is suspected to be caused by interactions between curcumin and other phenolic compounds with milk proteins, which may interfere with protein network formation during fermentation (Martin *et al*., 2016). These compounds might compete with casein for water binding or hinder the formation of inter-protein bonds necessary for creating a firm gel matrix.

In addition, the increase in pH observed at higher turmeric extract concentrations (as shown in Table 1) may also contribute to the reduction in WHC. A higher pH can reduce the degree of protein denaturation and aggregation during fermentation, resulting in a looser gel structure that is less capable of retaining water (Lucey, 2004) [8].

Color

The color of stirred yogurt with various concentrations of turmeric extract is presented in Table 3. The color parameters are based on the CIE Lab color system*, namely the L* value (lightness), a* (red-green spectrum), and b* (yellow-blue spectrum).

Table 3: Color of stirred yogurt with various concentrations of turmeric extract

Treatment	L*	a*	b*
5%	79,03[a]	-3,50[b]	26,22[c]
10%	66,08[b]	-5,49[b]	32,96[b]
15%	64,76[b]	1,57[a]	41,00[a]

a-c Different superscripts in the same row represent significant differences ($p<0.05$).

Table 3 shows the color values of yogurt based on the CIE Lab* color system, namely L* (lightness), a* (red-green spectrum), and b* (yellow-blue spectrum), with the addition of turmeric extract at concentrations of 5%, 10%, and 15%. The results indicate that the concentration of turmeric extract significantly affects the color characteristics of the produced yogurt.

With the increase in turmeric extract, the L value significantly decreased, indicating that the yogurt color became darker. The highest L* value was found in the 5% treatment (79.03[a]), while the 10% and 15% treatments showed significantly lower L* values (66.08[b] and 64.76[b]), indicating an increase in color intensity due to curcumin pigments (Partio *et al*, 2023) [10].

The value of a changed from negative to positive, indicating a significant change. The 5% and 10% treatments had negative a* values (-3.50[b] and -5.49[b]), which showed a tendency towards a greenish color, while the 15% treatment showed a positive value of 1.57[a], indicating a shift towards a reddish color due to the dominance of turmeric pigments. The b* value, which indicates yellowness, significantly increases with the addition of turmeric extract. This indicates an increase in the yellow color from the curcumin pigment, which is the main characteristic of turmeric (Gao *et al*, 2022) [5]. This is consistent with previous research stating that milk supplemented with turmeric has a higher b value. Thus, the addition of turmeric extract significantly affects the color of the yogurt, making it more yellow, darker, and tending towards reddish at higher concentrations.

Conclusion

The addition of turmeric extract in the production of stirred yogurt significantly affects the pH value, water-holding capacity (WHC), and color characteristics of the product. The higher the concentration of turmeric extract, the lower the pH of the yogurt tends to be, which can be attributed to the acidic nature of the phenolic compounds in turmeric. Increasing the concentration of turmeric extract also enhances WHC, indicating a better water retention capacity of the yogurt and a potential reduction in syneresis. In terms of color, the addition of turmeric decreases the brightness value (L*) but increases the b* value (yellowness), in line with the increased intensity of the curcumin pigment. At high concentrations (15%), the a* value also changes to positive, indicating a tendency towards a reddish color.

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