Physical and Chemical Properties of Cow's Milk Yogurt Added Whey Protein Concentrate (WPC)

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Abstract. The purpose of this research was to examine the physical and chemical characteristics of cow's milk yogurt with the addition of WPC. The physical characteristics observed included color (L*, a*, b*, whiteness index, hue, chroma), texture (firmness, work of penetration, resistance to probe withdrawal), while the chemical characteristics observed included water content, total solids, and titratable acidity. The main research materials are fresh cow's milk, Whey Protein Concentrate (WPC), and starter yogurt. The study was conducted using a Completely Randomized Design (CRD) with 5 treatments and 4 replications. The treatments consisted of control (P0), adding WPC as much as 2% (P1), 4% (P2), 6% (P3), and 8% (P4) of the amount of milk. Data were analysed using analysis of variance and post-hoc orthogonal polynomial test. The results showed that the addition of WPC up to 8% caused a very significant difference to the water content, total solids, titratable acidity, firmness, and work of penetration of yogurt. However, the addition of WPC up to 8% did not cause a significant difference in the color characteristics of yogurt. Total solids of yogurt increased from 12.08% (control) to 17.74% along with the addition of WPC up to 8%. Based on the results of the research, it can be concluded that the addition of WPC up to 8% can decrease the water content, firmness, and work of penetration of yogurt, as well as increase the total solids and titratable acidity of yogurt. However, it did not cause a noticeable change in the color characteristics of yogurt. However, it did not cause a significant change in the color characteristics of yogurt.

Keywords: Yogurt, Cow's milk, WPC, Physical characteristics, Chemical characteristics

1. Introduction

Cow's milk is a source of animal protein that has balanced nutrition and is needed by the body. The body always needs nutrients for maintenance and growing. The development of dairy products today tends to lead to healthy foods, for example yogurt. Yogurt has advantages for people with lactose intolerance because during the process of making yoghurt, milk sugar levels decrease [1]. Yoghurt is widely consumed worldwide because of its delicious taste, good nutritional content, as a source of probiotics and yoghurt is also useful in overcoming digestive tract disorders.

The physical and chemical characteristics of yogurt are imperative because they can affect the acceptability of consumers and the shelf life of yoghurt. Among factors that affect the shelf life of yoghurt are the moisture content and additives. The addition of protein to milk causes an increase in total solids in milk, causing the resulting yoghurt to be thicker [2].

Problems that are often experienced in making yogurt are the onset of syneresis (the separation between curd and whey), low viscosity so that the yogurt looks watery, and decreases the water binding ability of the gel. These problems cause the quality of yoghurt to decrease and the shelf life of yoghurt to be shorter [3].

One way to overcome these problems requires the use of additional materials containing protein, for example whey protein concentrate (WPC). The use of protein ingredients in the manufacture of yoghurt can reduce the separation of whey, improve the texture, and chemical content of yogurt and extend its shelf life.
Problems in making yogurt such as the onset of syneresis, low viscosity, and low texture, it is necessary to conduct research on the addition of whey protein concentrate (WPC) during the manufacture of yoghurt from cow's milk, and its effect on physical and chemical characteristics. The addition of whey protein concentrate (WPC) is expected to improve the physical and chemical quality of yogurt, resulting in the product which is more attractive to consumers.

2. Materials and Methods

1.1 Research Materials

The main material used in this study was fresh cow's milk obtained from the Experimental Farm of the Faculty of Animal Science, Jenderal Soedirman University, yogurt starter, and whey protein concentrate (WPC).

1.2 Research Design and Procedure

The research was done experimentally in the laboratory. Treatments were arranged in a Completely Randomized Design (CRD) with 5 treatments and 4 replicates. The procedure for making yoghurt followed that described by [4], which began with the preparation of equipment. Fresh cow's milk was heated to the temperature of 80 °C for 15 minutes. WPC was added according to the treatment, namely 0% (as control or P0), addition of 2% (P1), 4% (P2), 6% (P3), and 8% (P4). The temperature of the milk was then lowered to 40°C, then yogurt starter was added at the rate of one gram per 1000 g milk. The milk was incubated 40ºC for 6 hours to allow the fermentation process. Fresh-plain yoghurt was stored in the refrigerator overnight, then the moisture content, total solids, total titratable acidity, color and texture of the yogurt were measured.

1.3 Variables Measurement

1.3.1 Moisture Content and Total Solids

Measurement of yoghurt moisture content was carried out by thermogravimetric method [5]. Calculation of moisture content using the formula:

$$\text{Moisture content} = \frac{(\text{initial weight (g)} - \text{final weight (g)})}{(\text{initial weight (g)})}\ x\ 100$$

The measurement of total solids of yoghurt was carried out by calculating using the following formula:

$$\text{Total solids} = 100 - \text{Moisture Content (\%)}$$

1.3.2 Total Titratable Acidity

The measurement of total titratable acidity (TTA) of yoghurt was carried out by the titration method [6]. A total of 10 ml yoghurt was transferred into an Erlenmeyer flask, then 2 drops of 1% pp indicator was added. The sample was titrated with a 0.1 N NaOH solution until appeared a constant pink color. The formula for calculating the total titratable acidity was calculated as follows:

$$\text{TTA (\%)} = = \frac{base\ volume\ x\ base\ normality\ x\ 90}{sample\ volume\ x\ 1000}\ x\ 100\%$$

1.3.3 Color Measurement

Color measurement of yogurt was carried out using the *color reader* [7]. The yogurt sample (20 mL) was stirred thoroughly before measurement. The color reader was affixed to the surface of the yoghurt, then the test button on the color reader was pressed. Color indexes included L* (brightness), a* (red to green), and b* (yellow to blue). The hue (1), chroma (2) and whiteness index (WI) (3) was calculated according to [8] as follows:

$$\text{Hue} = h^* = \tan^{-1}\left(\frac{a^*}{b^*}\right) \quad (1)$$

$$\text{Chroma} = C^* = \sqrt{(a^{*2} + b^{*2})} \quad (2)$$

$$WI = 100 - \sqrt{((100 - L^*)^2) + a^{*2} + b^{*2}} \quad (3)$$

1.3.4 Texture

Texture measurement, which was firmness, work of penetration and resistance to probe withdrawal, was carried out using a Food Texture Analyzer (TA-XT Sable Microsystem, UK) with a cylindrical probe [9].

1.4 Data Analysis

The data was analyzed using one-way ANOVA with SPSS Statistics version 22.

3. Results and Discussion

1.5 Chemical Characteristics of Yogurt

Research shows that the moisture content, total solids, and total titratable acidity of cow's milk yogurt were significantly influenced (P<0.01) with the addition of WPC. The moisture content decreased as the WPC increased. In contrast, the total solids increased as the WPC increased. Meanwhile, the total titratable acidity tended to increase Table 1.

Table 1. Moisture content, total solids, and total titratable acidity of yogurt from cow's milk with the addition of whey protein concentrate (WPC).

Whey Protein Concentrate (%)	Variables		
	Moisture Content (%)	Total Solids (%)	Total Titratable Acidity (%)
0	$87.93^{d} \pm 0.42$	$12.08^{a} \pm 0.42$	$1.13^{ab} \pm 0.03$
2	$85.32^{c} \pm 0.51$	$14.69^{b} \pm 0.51$	$1.08^{a} \pm 0.13$
4	$84.12^{b} \pm 0.54$	$15.88^{c} \pm 0.54$	$1.15^{ab} \pm 0.15$
6	$83.66^{b} \pm 0.77$	$16.34^{c} \pm 0.77$	$1.34^{bc} \pm 0.11$
8	$82.26^{a} \pm 0.41$	$17.74^{d} \pm 0.41$	$1.43^{c} \pm 0.02$
Significancy	**	**	**

Different superscripts on the same column show a significant differences (P<0.05); ns = non significant; * = significant; and ** = highly significant

The addition of WPC to yogurt decreases the moisture content but increase the total solids content. This due to the nature of WPC which can form gels because the protein can bind water. Similar report by [10] and [11], that an increase in protein concentration increased total solids but lower the water content of yoghurt. The addition of WPC also increases the content of nutrients in yogurt [12]. Yogurt with the addition of WPC 6% and 8% has met the yoghurt water content standard based on SNI 2981:2009, which is 83 – 84% [13]. The yogurt produced has a total solids between 12.08 and 17.74%. Based on the national standard SNI 2981:2009, yogurt products have a minimum of 8.2% total solids [13].

The increase in total solids also results in an increase in the viscosity of yogurt. The result corresponds to [14] which reported that a decrease in water content results in an increase in viscosity. Based on the research of [15], yogurt with a total solid of 12% to 14% showed excellent consistency. The increase in total solids due to the addition of WPC leads to an increase in the consistency of the yogurt. [16] report that the addition of WPC protein contributes to shaping the consistency of yogurt.

Water in fermented products is needed by lactic acid bacteria in carrying out the fermentation process [17]. However, [18] reported that the higher the total solids, the higher the total lactic acid bacteria.

Table 1 shows that the addition of WPC causes a marked change in the total titratable acidity of yogurt. Yogurt has a total acid between 1.08 ± 0.13% to 1.43 ± 0.02%. An increase in WPC leads to an increase in the total acid in yogurt. Highest acid content was obtained from yogurt with 8% WPC. Total acid in yogurt with WPC is still in the normal total acid range according to [13] that is, between 0.5 and 2.0%.

An increase in total acid production correlates with an increase in the content of nutrients that can be utilized by lactic acid bacteria. Yogurt lactic acid bacteria, namely *Streptococcus thermophillus* and *Lactobacillus bulgaricus*, convert lactose into lactic acid through a fermentation process. The same was also reported by [19] that increased lactic acid has a positive correlation with total titratable acid. [15] state that the nutritional content in milk made into yogurt affects the acidity level of yogurt. The content of nutrients affects the activity of lactic acid bacteria [20]. Lactic acid is produced through the process of glycolysis of lactose into pyruvic acid and finally into lactic acid [10].

1.6 Yogurt color

Table 2 shows that the addition of WHC up to 8% did not cause a significant change (P>0.05) in yogurt color. Color index measured includes L*, a*, b*, hue, chroma, and whiteness index.

Table 2. Color indices of yogurt with the addition of whey protein concentrate (WPC)

Indices	Whey Protein Concentrate (%)				
	0	2	4	6	8
L*	$48.43^{a} \pm 1.65$	$43.39^{a} \pm 4.37$	$45.08^{a} \pm 3.88$	$46.65^{a} \pm 5.72$	$43.94^{a} \pm 2.01$
a*	$-4.18^{a} \pm 0.23$	$-4.20^{a} \pm 0.05$	$-4.11^{a} \pm 0.11$	$-4.19^{a} \pm 0.55$	$-4.41^{a} \pm 0.16$
b*	$19.49^{a} \pm 0.77$	$18.36^{a} \pm 1.26$	$18.87^{a} \pm 1.32$	$17.80^{a} \pm 4.38$	$18.67^{a} \pm 0.77$
Hue	$-12.11^{a} \pm 1.03$	$-12.92^{a} \pm 0.93$	$-12.34^{a} \pm 1.01$	$-14.09^{a} \pm 5.27$	$-13.30^{a} \pm 0.97$
Chroma	$19.94^{a} \pm 0.72$	$18.84^{a} \pm 1.22$	$19.32^{a} \pm 1.28$	$18.34^{a} \pm 4.12$	$19.19^{a} \pm 0.72$
WI	$44.76^{a} \pm 1.40$	$40.29^{a} \pm 3.73$	$41.75^{a} \pm 3.32$	$43.37^{a} \pm 4.08$	$40.74^{a} \pm 1.67$

The addition of WPC did not cause a significant difference (P>0.05) in yogurt color. WI : Whiteness index.

The results showed that the addition of WPC did not affect the color of the yogurt. WPC is white and soluble in water. [7] reported a higher L* in yogurt made from fresh goat milk at 63.36. This is possible due to the different types of milk used. The color of yogurt is influenced by solid composition of the yogurt such as proteins, fats, and vitamins originated from the milk [21]. The addition of WPC from 2 to 8% does not cause significant color changes of the yogurt, allegedly because when WPC dissolves in water then the color becomes clear or transparent. The light waves absorbed or reflected are still relatively the same so that the color of the product does not change much [22]. The increase in total yogurt solids due to an increase in WPC levels does not cause significant discoloration. [23] states that the color of yoghurt can occur due to several factors such as proteolysis process, increased acidity, temperature change and storage duration.

1.7 Yogurt texture

Table 3 shows that the texture of yogurt, namely firmness and work of penetration, is significantly affected (P<0.01) by the addition of WPC. Nevertheless, the effect of WPC addition on the resistance to yogurt withdrawal probe is not significant (P>0.05).

Table 3. Texture of yogurt made from cow's milk with the addition of whey protein concentrate (WPC)

Whey Protein Concentrate (%)	Texture		
	Firmness (g)	Work of penetration (g.s)	Resistance to Probe Withdrawal (g.s)
0	$16.49^{c} \pm 0.60$	$15.16^{b} \pm 2.27$	$-1.12^{a} \pm 0.15$
2	$16.00^{c} \pm 2.40$	$15.05^{b} \pm 4.16$	$-3.01^{a} \pm 1.61$
4	$14.55^{bc} \pm 1.33$	$13.84^{b} \pm 3.20$	$-3.34^{a} \pm 2.22$
6	$9.77^{a} \pm 2.34$	$7.58^{a} \pm 2.06$	$-1.56^{a} \pm 0.71$
8	$11.10^{ab} \pm 1.46$	$6.22^{a} \pm 1.23$	$-2.83^{a} \pm 0.76$
Significancy	**	**	ns

Means with different superscripts within the same column differences significantly (P<0,05); ns = not significant; * = significant; ** = very significant

Texture is an important parameter in set-type yogurt. This study produced yogurt with a firmness of 9.77 – 16.49 g, work of penetration of 6.22 – 15.16 g.s, and resistance to probe withdrawal which is -3.34 to -1.12 g.s. Data shows that WPC can be used to improve the texture of yogurt. [24] stated that the addition of additives can improve the quality of food products, one of which is the ability to bind water and form gels.
Data shows that the more WPC is added, the lower the firmness and work of penetration. The same result was also reported by [9]. According to [25] that WPC can improve the physical characteristics of yogurt such as improving the texture and homogeneity of the curd, which causes firmness in yogurt to have a declining trend. On the other hand, [15] reported that the higher the concentration of WPC, the higher the firmness of yogurt. Data also shows that the resistance to probe withdrawal of yogurt is not significantly affected by the different level of WPC. Apparently, WPC resulted in softer yogurt gel and hence reducing the texture parameter such as firmness and work of penetration. This provide opportunity to produce nutritionally denser yogurt with softer texture.

4 . Conclusions

The addition of up to 8% whey protein concentrate (WPC) to cow's milk produce yogurt with a lower water content, and a softer texture, especially firmness and work of penetration. On the other hand, the addition of WPC increases the total solids and total titratable acidity of yogurt. The color of yogurt is not affected by the addition of WPC. Based on this experiment, the addition of WPC to improve quality characteristics of yogurt can be done up to 8% (w/w).

5 . References

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