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Characteristics of high-protein corn yogurt with the addition of soy protein isolate and spirulina

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Abstract

Corn milk yogurt is a fermented product that has a low protein content. One of the efforts to increase the protein content of corn milk yogurt is by adding spirulina and soy protein isolate as a source of high protein. The objectives of this research are 1) to study the formulation of high protein corn milk yogurt with the addition of spirulina and soy protein isolate; 2) to study the characteristics of corn milk yogurt. Corn yogurt with the addition of spirulina (0.08, 0.12 and 0.16%) and soy protein isolate (4.5, 8.5 and 12.5%) were tested for physicochemical and sensory characteristics. Results revealed Corn yogurt addition with of 0.08-0.16% spirulina and 4.5 - 12.5% soy protein isolates have protein content of 1.94 - 7.04%, water content of 76.0-81.1%, fat content of 0.66 – 1.17%, 14.5-16.6% of carbohydrate content, viscosity of 328.3-1128.7 mPas, total solids 16.01-17.93oBrix, pH of 3.41-3.67, lactic acid bacteria of 51 x 107 CFU/ml – 76 x107 CFU/ml. Corn yogurt has sensory characteristics including yogurt taste of 2.60-3.68, green color of 2.42-3.82, yellow color of 1.45-2.53, corn flavor 2.27-2.60, beany flavor 2.70-3.17, spirulina flavor 2.23-3.08, viscosity 2.62-3.82 and preference of 2.25-2.9. The best formulation for making corn yogurt is a combination treatment with 8.5% soy protein isolate concentration and 0.12% spirulina with a protein content of 5.41%. While yogurt is preferred, this formula still needs some fine tuning to eliminate the fishy scent caused by the spirulina

INTRODUCTION

Particularly for those who are lactose intolerant, a functional alternative food can be made by processing corn into corn juice and yogurt (Aini et. al., 2021). Except for the low protein level of only 2%, Aini et. al. (2017) have demonstrated how to produce corn juice and prebiotic corn juice (corn yogurt) as functional food alternatives that adhere to standards. The daily protein requirement per person is 57 grams per person (Santoso, 2022), so the protein levels must be increased to meet daily needs and standards. One way to increase the protein content of corn yogurt is by fortifying it with high-protein ingredients. Spirulina is a marine

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biota found in Indonesia high in protein, vitamins, calcium, and fiber (Marlina & Nurhayati, 2020). According to Barkallah et. al. (2017), spirulina added to yogurt not only increases protein and fiber levels but also functions as a stabilizer, softening the texture. Debbabi et. al. (2019) have stated that adding 0.12% spirulina can increase the nutritional value of yogurt and does not affect consumer acceptance. However, adding 0.24% spirulina affects the aroma and taste. According to Darwish (2017), adding 0.1% spirulina produces kareish cheese with a protein content of 12%.

The protein content in corn milk yogurt is an important parameter in determining the quality of yogurt. Yogurt made from corn milk contains 2.72% protein, while the protein standard in yogurt products is 3.5%. The low protein content in corn milk yogurt is influenced by the use of yogurt raw materials, namely corn milk, which on average has a high carbohydrate content and is low in protein and fat (Yasni & Maulidya, 2014), as a result the protein content produced by the product is lower compared to yogurt. The SNI 01-2981-2009 quality standard determines that the quality standard for protein content in yogurt is a minimum of 2.7%.

The fishy taste can be overcome by adding ingredients that can cover the fishy taste of spirulina, one of which is soy protein isolate. Apart from covering up the fishy taste of spirulina, soy protein isolate is a food ingredient with high protein content. Soy protein isolate is a food ingredient that contains useful bioactive components. The addition of soy protein isolate to yogurt products will affect the organoleptic properties, aroma, taste and can increase the viscosity of yogurt (Xu et. al., 2022). Corn yogurt fortified with spirulina and soy protein isolate needs to be formulated appropriately to produce corn milk yogurt with the best sensory and chemical properties.

Adding an excess of spirulina can result in a fishy flavour that is not preferred. This challenge can be overcome by adding ingredients that cover the fishy taste, including soy protein isolate (SPI). In addition to covering the fishy flavour of spirulina, SPI has a high protein content. The fishy taste can be overcome by adding ingredients that can cover the fishy taste of spirulina, one of which is soy protein isolate. Apart from covering up the fishy taste of spirulina, soy protein isolate is a food ingredient with high protein content. SPI was used as a functional ingredient and potential source of intrinsic bioactives, notably isoflavones, saponins, protease inhibitors, phytosterols (β-sitosterol, campesterol, stigmasterol) and minor phenolics. During processing or gastrointestinal digestion, SPI can also yield bioactive peptides derived from β-conglycinin and glycinin with reported antioxidant, ACE-inhibitory, anti-inflammatory, hypocholesterolemia and DPP-IV–inhibitory activities (Zheng et. al., 2022). According to Xu et. al. (2022), the addition of SPI to yogurt will affect the organoleptic properties, aroma, and taste of yogurt, as well as increase the viscosity.

SPI is widely used as a substitute for food products, especially those made from meat. Using protein isolate usually reduces production costs and results in products of good quality that are acceptable to consumers (Aanisah et. al., 2018). SPI is added to food products as a binding agent because it has a good binding capacity for water and fat and can form gels. According to Djonu et. al. (2022), adding 7.5% protein isolate to catfish kamaboko produced the highest protein content, 12.79%. Meanwhile, according to (Rizqiati et. al., 2020), using 2.5% protein isolate produces the highest total dissolved solids, solubility, and degree of brightness in powdered kefir.

Spirulina fortification and the use of protein isolates in making corn yogurt have not been studied before. Therefore, this research was conducted to determine the optimal formulation of corn milk yogurt fortified with spirulina and SPI and study its properties. Determination of the best formulation was carried out from the results of protein content analysis, sensory results and other supporting analysis results.

MATERIALS AND METHODS

Materials

The ingredients used were advanta variety sweet corn obtained from farmers in Sumbang District, Banyumas, Indonesia, SPI, spirulina powder, commercial yogurt starter powder (*Streptococcus thermophilus* and *Lactobacillus bulgaricus*), Indoprima skim milk, Gulaku sucrose, carrageenan kappa, glycerol monostearate, and other analytical ingredients. The equipment used in this study included a steamer, blender, glass bottle, glass jar, stirrer, magnetic stirrer, refrigerator, aluminum foil, refractometer, pH meter, test tube, test tube, beaker, measuring cup, water bath, Soxhlet flask, Kjeldahl flask, porcelain cup, and other analytical equipment.

Production of corn yogurt

Making corn yogurt begins with making corn milk. Preparation of corn milk includes steaming the corn, grinding the corn with the addition of water at a ratio of 1:3 (m/v), filtering to obtain the filtrate, cooking the filtrate for 15 minutes at 70 to 80°C, and storing it in bottles at room temperature. The next step is to make yogurt from corn milk.

First, 300 ml of corn milk was added to 12% skim milk, 8% sucrose, spirulina powder (0.08%, 0.12%, and 0.16%) and SPI. For 30 minutes, the mixture is pasteurised at 80 to 85 °C. After that, the pasteurised milk was cooled to 42 °C. A yogurt starter containing *S. thermophilus* and *L. bulgaricus* was then added at a concentration of 5%. The mixture was then incubated in a sterile container for 16 hours at 37 °C. The presentation of ingredients in the corn milk yogurt formulation is presented in Table 1.

Data analysis

Data analysis on each data obtained from testing physicochemical (moisture content using gravimetri (AOAC, 2005), total soluble solids (AOAC, 2005), protein content using Kjeldahl method (AOAC, 2005), viscosity using viscometer (Graça et. al., 2022), syneresis (Bernardino-Nicanor et. al., 2021) , fat content (AOAC, 2005), pH, carbohydrates by difference (AOAC, 2005); lactic acid bacteria (Arslaner et al., 2019); and sensory characteristics (taste, color intensity, flavor, texture, overall acceptability). Data was analyzed using ANOVA (analysis of variance) test at α = 5% level with 95% confidence level. If the test results have a significant effect, it will be continued with the Duncan Multiple Range Test (DMRT) test.

Sensory analysis

The test was conducted on 20 trained panelists. The selected panelists were trained by being given instructions on the concept, objectives and approach. then given an exercise by testing the product where they can use their perception of quality attributes. the exercise was carried out for one hour every day for one week. Variables tested included taste (typical yogurt taste), color intensity (yellow and green color), flavor (corn flavor, spirulina and nut flavor), texture and overall acceptability. This organoleptic test will be tested using a scoring method with a scale of 1-5.

The test procedure for yogurt samples (5 grams) was presented in sterile sealed cups and labeled with a random three-digit code. Yogurt samples were served at a temperature of 4 - 10 ^{o}C after storage at 4^{o}C. For the viscosity texture test, panelists were encouraged to stir the yogurt samples first. Then an assessment form is provided for panelists which consists of the identity of the panelist, description of the test, number of samples and test variables on the product. In the sample testing process, panelists will be asked to taste 9 product samples, the duration of sensory testing ranges from approximately 2 hours, with an estimate of 1 panelist 10 minutes. then the panelists provide an assessment of the product on the form that has been provided by assessing the sensory properties based on consumer acceptance. The results of the panelist assessment are then given to the researcher and the document will be guaranteed confidentiality.

Design experimental

This study used a complete randomized factorial design. Two factors used were spirulina concentration (0.08%, 0.12% and 0.16%) and SPI concentration (4.5%, 8.5% and 12.5%). Based on these factors, there were 9 treatment combinations with 3 replications. The treatments applied include P0S0 (control without the addition of spirulina and SPI), P1S1 (4.5% SPI and 0.08% spirulina), P1S2 (4.5% SPI and 0.12% spirulina), P1S3 (4.5% SPI and 0.16% spirulina), P2S1 (8, 5% SPI and 0.08% spirulina), P2S2 (8.5% SPI and 0.12% spirulina), P2S3 (8.5% SPI and 0.16% spirulina), P3S1 (12.5% SPI and 0.08% spirulina), P3S2 (12.5% SPI and 0.12% spirulina), P3S3 (12.5% SPI and 0.16% spirulina). Data were analyzed using analysis of variance (ANOVA). Duncan's Multiple Range Test (DMRT) was used if significant differences were detected.

Ethics statements

This research was approved by the BRIN Chemistry Field ethics committee (060/KE.04/SK/11/2023)

Table 1. Corn yogurt formulation

Bahan	Weight								
	P1S1	P1S2	P1S3	P2S1	P2S2	P2S3	P3S1	P3S2	P3S3
Corn yogurt (ml)	300	300	300	300	300	300	300	300	300
Skim milk (g)	36	36	36	36	36	36	36	36	36
Sugar (g)	24	24	24	24	24	24	24	24	24
Starter yogurt (g)	15	15	15	15	15	15	15	15	15
Spirulina (%)	0,08	0,12	0,16	0,08	0,12	0,16	0,08	0,12	0,16
Soy isolate protein (%)	4,5	4,5	4,5	8,5	8,5	8,5	12,5	12,5	12,5

RESULTS

Moisture content

As SPI is added to the yogurt, the moisture decreases (Figure 1). The water content of corn yogurt with 4.5% added SPI is 80.7%, almost the same as corn yogurt without added SPI, according to Aini et al. (2017), that is, 80.4%. Meanwhile, adding 8.5% and 12.5% SPI produces corn yogurt with lower water content. SPI contains amphipathic proteins with hydrophilic amino acid groups on the outside that bind with water and hydrophobic groups on the inside that do not bind with water. Therefore, the more added SPI, the lower the water content of the yogurt. The water content of corn yogurt in this research is higher than corn yogurt with added sweet potato and soy yogurt, according to Aini et. al. (2017), 77.3% and 70.98%, respectively.

The water content will affect the viscosity of the yogurt: low water content will produce yogurt with a denser texture (Bezerril et. al., 2021). As the viscosity increases, the water binding capacity increases, decreasing the water content (Tortoe et. al., 2019).

Total soluble solid

The total soluble solids of the yogurt significantly changed after the SPI was added. The soluble solids of the yogurt increased with the amount of added SPI (Figure 1). El-Kholy et. al. (2020) have stated that the total sugar, lactic acid, and organic acids produced by microorganisms, pigments, proteins, and vitamins should all be considered total dissolved solids. Because SPI contains various components, the more is added, the higher the total amount of solids in the yogurt. This is also consistent with the work of Wang et. al. (2021), which states that the addition of SPI raises the total solids content of yogurt. The spirulina fortification treatment as well as the interaction between spirulina (0.08; 0.12 and 0.16%) and soy protein isolate (4.5; 8.5; and 12.5%) had no significant effect on total solids, possibly due to the concentration of ingredients used that did not have a significant effect on the parameters tested. This result is based on Bchir et. al., (2019) in their research stated that the addition of spirulina more than 0.5% has the most significant effect where the high content of solids in yogurt is influenced by the level of protein added. So it can be seen that the concentration of spirulina added is quite small so that it does not have a significant effect on the protein content.

Protein content

The protein content of the corn yogurt is impacted by the interaction between spirulina and SPI (Figure 2). The amount of spirulina and SPI added determines the protein content. Adding 12.5% SPI and 0.16% spirulina to corn yogurt yielded the highest protein content. Soy protein isolate has a protein content of at least 90% (Zhang et. al., 2018). Likewise, spirulina has a protein content of 60%–70% (Bianco et. al., 2022).Therefore, the protein level of yogurt rises as more of each is added. According to Wambui et. al. (2017), adding SPI increases protein content.

The interaction of protein content in SPI and spirulina affects the protein content of the yogurt produced, spirulina has resistance to the heating process, so that the protein content contained in spirulina during heat treatment can be maintained. The results of this study are in line with research conducted by Koli et. al., (2022); Marco et. al., (2014) explained that the nutritional content of pasta enriched by spirulina remained intact in the final product after cooking and only experienced a marginal decrease in protein caused by washing of 11-19.51% on a dry weight basis.

Although the concentration of spirulina in the fortification process is lower than that of IPK, spirulina plays a more important role in the preparation of yogurt protein content.

According to Ye et. al. (2022), the viscosity of yogurt increases with protein content. Proteins binding to water results in a higher viscosity. According to, the proteins will be coagulated by acid and form a gel. Thus, the higher the protein content, the more protein will be coagulated, increasing the viscosity of the gel. According to Indonesian National Standard number 01-2981-2009, the minimum protein content of yogurt is 2,7%. Corn yogurts with 12.5% and 8.5% added SPI fulfil this standard.

Viscosity

The viscosity, which reflects the stiffness and consistency of the yogurt, as well as its flavour, tissue shape, and stability, is a crucial consideration in the evaluation of yogurt (Ye et. al., 2022). The more SPI added, the greater the viscosity of the yogurt will be (Figure 3). This is because soy protein isolate can foam, bind to water, emulsify, and form films (Akinwale et. al., 2017). The more SPI is added, the higher the protein content, raising the viscosity of the yogurt. This is consistent with the work of Ye et. al. (2022), which states that the viscosity of yogurt increases as protein content increases. As shown in Figure 1, a higher protein content results in a lower water content and a higher on viscosity results from a lower water content. According to Ardabilchi Marand et. al. (2020), the protein will be coagulated by acids and form a gel; the higher the protein content, the more coagulated, resulting in a firmer gel and increased viscosity.

Syneresis

The physical characteristics of the yogurt, including the way the whey separates (syneresis), are crucial to its quality and popularity with customers (Falah et. al., 2021). Therefore, inhibiting syneresis is advised to increase the water retention of the yogurt. The syneresis declines as SPI levels rise (Figure 3). This is because SPI can raise the total solids while lowering syneresis. This is consistent with the results of Silva et. al. (2012), which indicate that syneresis tends to decline as total solids rise. Because syneresis is one of the parameters of physical damage occurring in yogurt, a high syneresis value indicates that the quality of the yogurt has decreased. This suggests that the addition of SPI, which stabilises the whey separation, can be used successfully in producing yogurts.

pH Value

An important sign of yogurt quality is its pH. The pH of the corn yogurt was unaffected by the addition of spirulina or SPI. In this study, the corn yogurt had a pH between 3.42 and 3.67 (Table 1). The pH of this corn yogurt is too low because yogurt should have a pH of 3.80 to 4.50, per Indonesian National Standard number 01-2981-2009.

Decreased pH results from the fermentation process due to the accumulation of lactic acid, the main product of bacterial activity. The pH of probiotic corn juice is 2.55–4.46, almost the same as that of yogurt, which is 4 (FDA, 2009). This pH is also close to that of yogurt made from cow's milk, 3.7 to 4.33 (Arslaner et. al., 2019). The reduced pH of yogurt is caused by *S. thermophilus*, while *L. bulgaricus* converts lactose into lactic acid. The conversion of lactose to lactic acid also lowers the pH and increases the total acids, so that as more culture is added, the pH decreases and the total acids increase. This result also agrees with Mardiana et. al. (2020), which showed that the amount of culture added significantly affects the pH and total acids of the yogurt.

Cho et. al. (2020) have asserted that the pH and acid content of yogurt are related. A decrease in the number of H^+ ions brought on by a decrease in the total acids results in increased pH. The pH decreases because of acid formation in the fermentation products, or vice versa, as the concentration of hydrogen ions rises. The main acid that results from the fermentation of yogurt is lactic acid. According to Thyab et. al. (2022), citric acid, acetic acid (5.3%), formic acid (2.4%), succinic acid (2.4%), and a few other acids comprise 28% of the acid in yogurt. Lactic acid, however, makes up 59% of the acid in yogurt.

Total lactic acid bacteria

The viability of acidogenic bacteria is the most crucial quality factor in yogurt. In this assay, the quantity of fermentative bacteria was determined, including *L. bulgaricus* and *S. thermophilus,* known for fermenting the sugar in milk into lactic and other organic acids. Adding protein isolate and spirulina did not significantly alter the number of lactic acid bacteria. This study found 51 x 10^7– 76 x10^7 CFU/ml of lactic acid bacteria in the corn yogurt. This result is less than the 8.56–9.02 log CFU/ml value for lactic acid bacteria in sweet potato extract–added corn yogurt (Aini et. al., 2017) because the fiber in sweet potatoes serves as a substrate for the development of probiotics, resulting in higher levels of lactic acid bacteria.

L. bulgaricus is a lactic acid bacteria that has the potential to produce functional food, as stated by Nyanzi et. al. (2021). This study demonstrates that using *L. bulgaricus* and *S. thermophilus* cultures results in products with a total lactic acid that can fulfil probiotic food ingredient standards and transform corn yogurt into a functional food by adding soy protein isolate and spirulina. Yogurt almost meets the requirements of a probiotic food. The recommended probiotic dose is 8 log CFU/g per serving (Nyanzi et. al., 2021). The minimum total lactic acid bacteria in probiotic food is 6 log CFU/g at expiration, according to Mardiana et. al. (2020).

Sensory properties

Sensory analysis, one of the most widely used techniques for describing food quality, is crucial for determining consumer acceptance of yogurt products. Figure 4 shows the impact of various formulations (SPI and spirulina) on the sensory evaluation of the yogurt samples. A trained panel recorded these average ratings from yogurt samples.

The combination of SPI and spirulina concentrations has a significant effect on the taste of corn yogurt. The taste value of corn yogurt is 2.60–3.57, which means it has a slightly sweet-sour taste. The taste of yogurt is caused by the chemical compounds produced: lactic acid, acetal aldehyde, acetic acid, and other volatile compounds. The higher the concentration of SPI and spirulina, the less sour the taste.

Yogurt color is influenced by the ratio of SPI and spirulina. The intensity of the green color in fortified corn yogurt has a response value ranging from 2.42 to 3.82, namely slightly green to green in color. This green color comes from the chlorophyll pigment of spirulina, where every gram of dried spirulina contains 3.34 mg of chlorophyll a which is the main pigment in spirulina. Yogurt has a color that ranges from slightly yellow to slightly yellow or a color value of 1.45–2.53. Due to the presence of carotene in corn, corn yogurt has a yellowish color. In fortified corn yogurt, the yellow color intensity value decreased with increasing addition of SPI and spirulina.

This is because SPI is brownish in color and spirulina is green. The main pigment in spirulina, chlorophyll a, which makes up 3.34 mg of every gram of dried spirulina, gives the food its characteristic green color (Vishwakarma et. al., 2022). The color of this corn yogurt is slightly different from corn yogurt which is added with sweet potato extract, namely a slightly reddish yellow color, according to Aini et. al. (2017).

The aroma and taste of corn yogurt depends on how much spirulina and SPI are present. Yogurt made from corn smells like corn, nuts, and spirulina. The aroma of corn ranges from 2.30-2.6 which indicates it is very potent. The amount of spirulina and SPI added determines how much corn flavor is present in the yogurt. The nutty aroma of yogurt is strongly influenced by fortification with SPI and spirulina. SPI gives foods a nutty aroma. This corn yogurt has a beany taste value of 2.7–3.17 which indicates a strong taste. Based on the results of sensory tests, spirulina has a strong aroma which is also found in corn yogurt (average 2.23-3.13). Luize et. al. (2019) claim that adding spirulina to food will provide a unique aroma.

Based on the overall average value of the results of the panelist acceptance test of fortified yogurt products, it is known that sample P1S2 has the highest average value of all parameters tested, namely 3.3 (Kind of like-Like), The use of a lower concentration of spirulina and a higher concentration of IPK results in spirulina flavor having a lower flavor identification score compared to IPK flavor so that it can be stated that the combination of fortification ingredients using IPK can overcome the unfavorable aroma of spirulina.

A key aspect of yogurt quality is its viscosity. The viscosity level of corn yogurt based on sensory test results is between 2.62 and 3.93, which means it is between slightly thick and thick. The viscosity of corn yogurt increased with the addition of spirulina and SPI. This is because the increase in total dissolved solids is supported by dissolved solids data (Figure 1). The viscometry results as shown in Figure 3 are in accordance with the sensory test results.

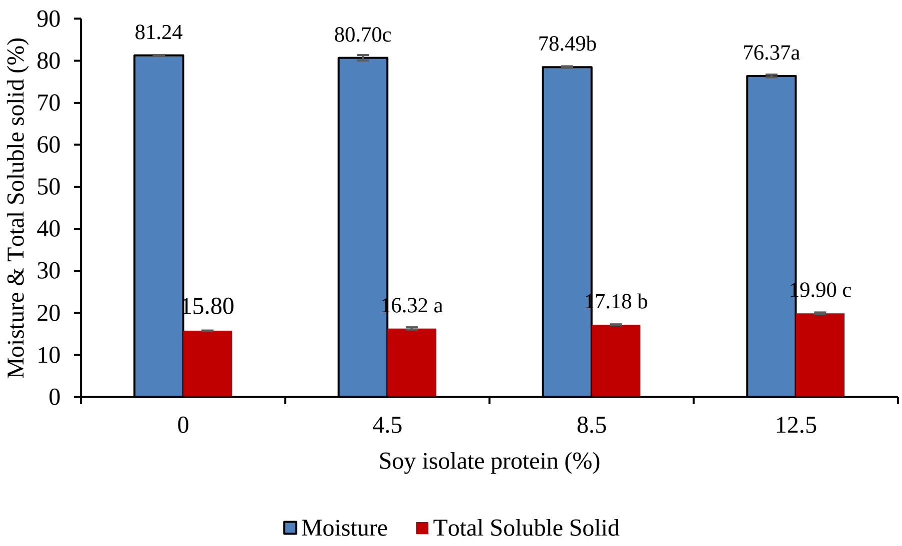

Figure 1. Total soluble solids and moisture of corn yogurt with the addition of varied amounts of soy protein isolate

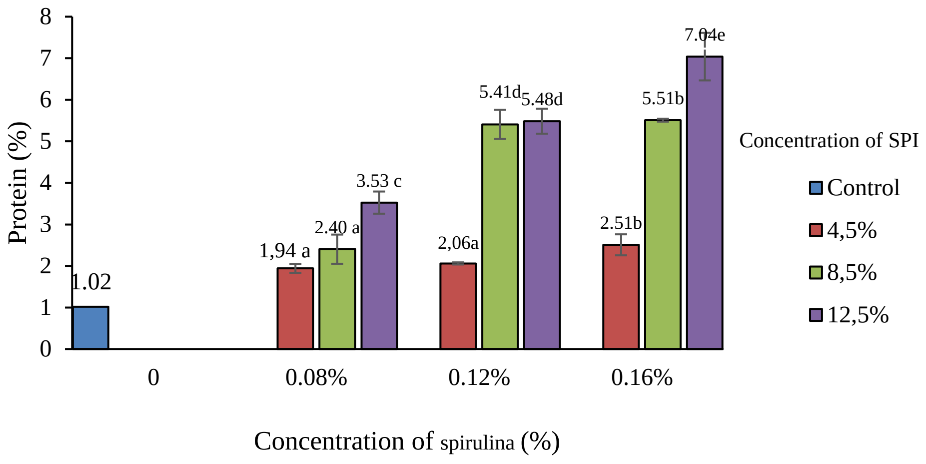

Figure 2. The effect of adding soy protein isolate (SPI) and spirulina on protein content of corn yogurt

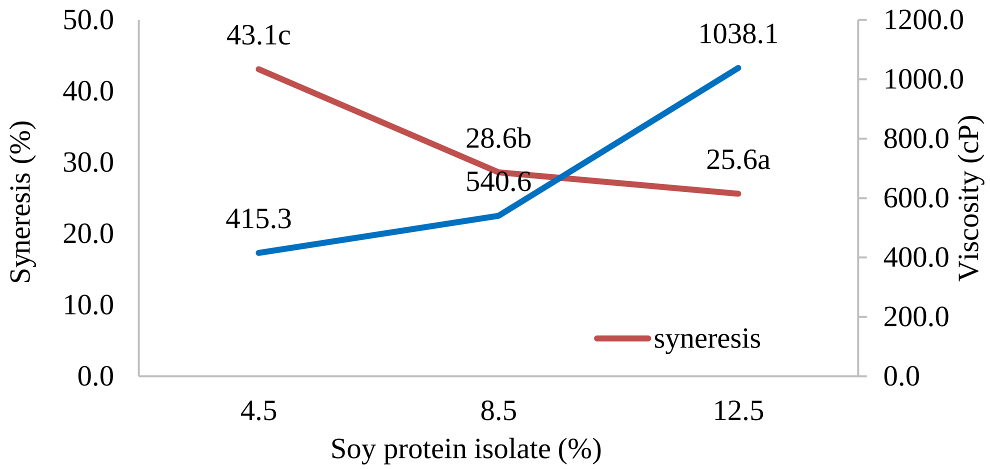

Figure 3. Viscosity and syneresis of corn yogurt with variation in the supplementation of soy protein isolate

Table 1 Fat content, carbohydrates, pH and lactic acid bacteria of corn yogurt with added soy protein isolate and spirulina

Product	Fat content %	pH	Carbohydrates %	Lactic acid bacteria (log CFU/ml)
Control	1.77±0,25	3.22±0,12	14.20±1.24	8,92±0,72
SPI 4.5% and spirulina 0.08%	1.17±0,45	3.42±0.33	14.95±1.55	8.82±0.01
SPI 8.5% and spirulina 0.08%	0.99±0.06	3.53±0.30	15.23±1.50	8.66±0.06
SPI 12.5% and spirulina 0.08%	0.66±0.05	3.63±0.14	16.59±3.43	8.56±0.54
SPI 4.5% and spirulina 0.12%	1.09±0.06	3.41±0.30	14.75±1.86	8.87±0.04
SPI 8.5% and spirulina 0.12%	0.87±0.03	3.56±0.12	15.14±2.62	8.79±0.13
SPI 12.5% and spirulina 0.12%	0.75±0.25	3.67±0.12	16.31±3.04	8.74±0.09
SPI 4.5% and spirulina 0.16%	0.85±0.22	3.52±0.37	14.54±2.11	8.93±0.05
SPI 8.5% and spirulina 0.16%	0.84±0.21	3.64±0.13	15.07±2.12	8.81±0.02
SPI 12.5% and spirulina 0.16%	0.67±0.25	3.64±0.02	16.26±2.12	8.79±0.13

Note: SPI = soy protein isolate

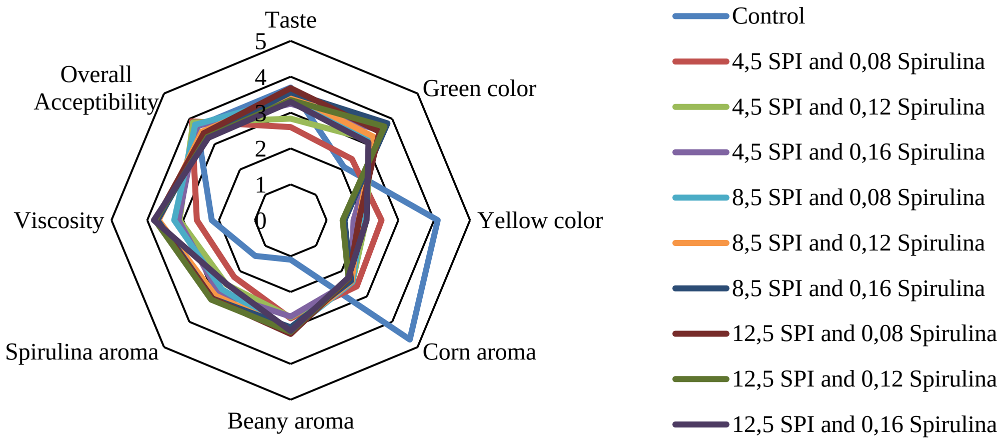

Figure 4. Sensory profile of corn yogurt supplemented with SPI and spirulina

Discussion

The protein content in some yogurt samples can be influenced by the quality of corn milk as a raw material, the concentration of fortifiers and protein degradation during the processing process. The protein content test results in control corn milk yogurt (without fortification) were 1.02%. The protein content of the control yogurt was lower than the fortified yogurt, besides that the protein content results were also smaller than the research conducted by Wardhani et. al., (2015) which produced corn milk yogurt with a protein content of 1.71%. The low protein content in corn milk yogurt can be influenced by the quality of corn milk which experiences a decrease in protein levels due to heat during the steaming and cooking process of corn milk (Meidini, 2019). The concentration of supplementation ingredients also affects protein levels. Bchir et. al., (2019) in their research stated that the use of a spirulina concentration of less than 0.5% was less significant in increasing the protein content of the ingredients. Apart from that, protein degradation in fortifier ingredients can cause protein levels to decrease, so that the lower the concentration of supplementation ingredients added, the lower the protein levels produced. Soy protein isolate will easily be damaged due to the heating process at temperatures above 50°C, especially during the drying process using cabinet drying (Rizqiati et. al., 2020). Damage to proteins in SPI is caused by denaturation which results in the destruction of hydrogen bonds resulting from the bonds between anthocyanin hydroxyl groups, amines and protein carbonyls so that the anthocyanins are released and damaged due to the heating process (Souza et. al., 2017).

The use of a lower spirulina concentration and a higher SPI concentration results in the spirulina flavor having a lower flavor identification score compared to the SPI flavor so it can be stated that the combination of fortification ingredients using SPI can overcome the undesirable aroma of spirulina. However, the results of the nutritional value of protein in the 8.5% SPI and 0.08% spirulina formulation did not reach the expected protein content target, namely containing protein of 2.44 below the minimum standard. This result was influenced by the use of a spirulina concentration of less than 2% so that protein levels did not increase significantly (Koli et. al., 2022). Apart from that, protein damage in very high SPI causes SPI to have less of a role in contributing to protein levels in fortified yogurt, as a result the protein content contained in yogurt is lower (Souza et. al., 2017).

The higher the concentration of spirulina (0.16%) and SPI (12.5%), the higher the protein content, viscosity, total solids, pH value and total LAB in yogurt, while the lower the water content, fat content, carbohydrate content and syneresis of yogurt. The higher the concentration of spirulina (0.16%) and SPI (12.5%), the higher the taste, green color, nut flavor, spirulina flavor, viscosity, while the intensity of yellow color, corn flavor, and overall liking value decreased. The best treatment in making yogurt fortified with soy protein isolate and spirulina is the P2S2 treatment, which is a combination of soy protein isolate concentration of 8.5% and spirulina concentration of 0.12% with a protein content of 5.41%.

There is a need for formula optimization and further testing regarding corn milk yogurt products supplemented with spirulina and soy protein isolate. The results of physicochemical and sensory analysis showed that the yogurt sample had a fairly high acidity level with a low pH of 3.41-3.67 so that fruit extracts containing sugar could be added which could stimulate LAB growth.

CONCLUSION

The addition of 8.5% SPI and 0.12% spirulina is the best formulation to produce high protein corn milk yogurt. Yogurt with the addition of SPI and spirulina has advantages in high protein content (5.41%), syneresis and low fat content. In addition, it also affects the taste, green color, nut aroma, spirulina aroma, viscosity, but the intensity of yellow color, corn flavor, and preference value decreased. This product can be used as an alternative probiotic drink for people who are lactose intolerant. More research needs to be done to reduce the beany and spirulina aroma in this product to make it more favorable.

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CONFLICT OF INTEREST

“The authors declare that there are no conflicts of interest.”

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