The quality of corn milk-based cheese analogue made with virgin coconut oil as a fat substitute and with various emulsifiers

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The quality of corn milk-based cheese analogue made with virgin coconut oil as a fat substitute and with various emulsifiers

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Abstract. Cheese analogues can be produced by modifying ingredients to produce low-fat cheese. Low-fat cheese generally has a less preferable texture and taste, so it is used as a fat substitute. Virgin coconut oil (VCO) is commonly used as a fat substitute because it can reduce total cholesterol, triglycerides, phospholipids and low-density lipoprotein (LDL) cholesterol, and increase high-density lipoprotein (HDL) cholesterol in the blood. In this study, we aimed to: 1) determine the effect of VCO concentration on the quality of corn milk-based cheddar cheese analogue; and 2) study the effect of emulsifier type on the quality of the cheese analogue. This research used experimental methods with a randomized group design. Two factors were studied: the concentration of VCO (i.e. 15%, 20%, 25%) and type of emulsifier (Span 80, Tween 80 (1%), Span 80:Tween 80 (1:1)). The observed variables included yield, total solids, total titrated acidity, moisture content, fat content, protein content, and sensory properties. The results showed that an increase in VCO concentration of 15–25% in the cheese analogue-making process increased fat and moisture content, but reduced sensory value. The emulsifiers did not influence the physicochemical variables and sensory properties of the produced cheese analogue significantly. The best cheese analogue was produced using 25% VCO and Tween 80. The characteristics of this product were: 59.93% bb yield, 54.62% moisture content, 30.2 degrees Brix total solids, pH 5.62, 19.96% fat content, 11.51% soluble protein with colour sensory value of 3.84 (yellowish white), scent value of 4.07 (slightly typical of cheese), taste value of 5.48 (slightly salty), texture value of 2.55 (not hard) and favourite value of 4.38 (slightly favourable).

Keywords: cheese analogue, virgin coconut oil, Span 80, Tween 80

1. Introduction

The consumption of cheese in the world increases every year. In 2017, the increase in cheese consumption in Indonesia reached 0.252 ounces per year. To anticipate the increasing demand for cheese, cheese products are being developed using raw materials other than cow milk, and are known as cheese analogues. Cheese analogues, also termed imitation cheese, are a cheese-like product in which fat, milk protein or both are partly or wholly replaced by non-milk components, mainly from vegetable ingredients such as rice bran oil, sunflower seeds, or other plants [1-3]. During cheese analogue

production the fat that usually comes from milk is replaced by oil or vegetable fat. This reduces the level of saturated fatty acids and the risk of cardiovascular diseases [4-5].

Corn milk is an innovative product that has been used to replace cow milk and to reduce fat levels in cheese. Corn milk-based cheese analogues have been produced by [6-7] with low yield levels. Filler material such as whey protein can be used to increase the yield level. Virgin coconut oil (VCO), which contains unsaturated fatty acids, is used as a fat substitute. According to [8], the addition of oil has a significant influence on customer acceptance and cheese texture and structure.

The use of vegetable oil with skim milk requires emulsifiers with a hydrophilic–lipophilic balance (HLB) value of 9–14 to produce a stable emulsion [9]. In the present, the emulsifiers Tween 80 and Span 80 were used to maintain the product's stability. The addition of VCO and emulsifier significantly influences the cheese analogue quality. Therefore, VCO concentration and emulsifier type are related to the physicochemical quality of the resultant cheese analogue.

This research aimed to 1) determine the effect of VCO concentration on the quality of a corn milk-based cheddar cheese analogue; 2) study the effect of emulsifier type on cheese analogue quality, and 3) determine the best product and its characteristics.

2. Experimental details

2.1. Ingredients

The ingredients used in this study were sweet corn from the wage market Purwokerto, whey protein concentrate (PT Naturelle Inti Global), VCO (CV Mutia, Yogyakarta), Span 80 (CV Prima chemical), Tween 80 (CV Prima chemical), and ingredients for analysis. The materials included the equipment for cheese analogue production and analysis tools.

2.2. Cheese analogue production

The cheese analogue production consisted of two parts: corn milk production and cheese analogue production. The corn milk was produced based on the method described by Aini *et al* [10]. The cheese analogue was produced using the modified method [6].

2.3. Experimental design

We used experimental methods with a random group design. The factors examined included: (1) VCO concentration (15%, 20%, 25%) and emulsifier type (Span 80, Tween 80, combined Span 80:Tween 80 (1:1)). Three replications were conducted for this experiment, so there were 27 test units.

2.4. Analysis of samples

The variables tested included pH [11], total solids [11], total titrated acid, moisture content [12], fat content [12], soluble protein and sensory properties (colour, flavour, taste, texture, preference). The result of physicochemical variables was analyzed using analysis of variance (ANOVA). If the analysis showed a significant influence, it was followed by the DMRT (Duncan multiple-range test) with a 95% confidence interval.

3. Results and discussion

3.1. Characteristics of the product

3.1.1. Yield. The concentration of VCO and emulsifier type did not influence the yield significantly. The average levels of cheese analogue from 15%, 20% and 25% VCO were 58.49%, 59.51% and 58.26%, respectively (figure 1). We suspect that the results were derived because the same proportion

of whey protein, i.e. 20%, was used in all samples. This corresponds with the study by [13], where the same proportions of whey protein concentrate resulted in similar yield concentrations.

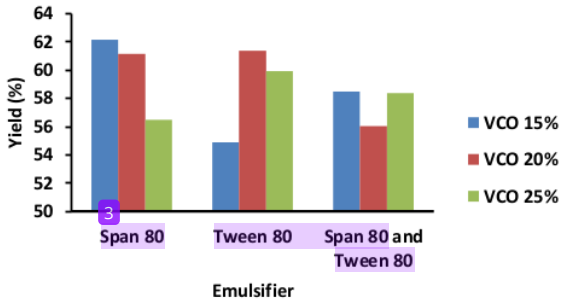

Figure 1. Yield of the corn milk-based cheddar cheese analogue according to emulsifier and VCO concentration combinations.

The yield rate of cheese analogue produced with Span 80, Tween 80 and the combined Span 80 plus Tween 80 was 59.91%, 58.72%, and 57.63%, respectively. The yield rate of cheese analogue produced with Span 80 tended to be higher compared to the other two treatments. This shows that Span 80 is the best emulsifier for maintaining fat and protein stability in the cheese analogue. According to [14], Span 80 is better for stabilizing emulsions compared to Tween 80. Meanwhile, the combination of Span 80 and Tween 80 did not have a significant effect on stabilizing the emulsion.
Protein and fat content are the influencing factors of yield. According to Abd El-Salam [13], there is a linear correlation between yield and the concentrations of protein and fat. Higher protein and fat concentrations increase yield. This corresponds with Stankey *et al* [15], who found that adding 0.5% microparticulate whey protein to low-fat cheddar cheese increased the yield and sensory values.
The yield value of the cheese analogue was 54.87%–62.12%; higher than the findings by Aini *et al.* [6], who reported a yield of 14.262%–17.072%. In the present research, we used whey protein concentrate, and gum arabic as filler, resulting in a higher yield.

3.1.2. pH. The variance analysis showed that VCO concentration and emulsifier type and interaction did not influence the pH value significantly. This was apparently due to the indirect addition of acid during production via the use of the same proportion of papain for all treatments. The pH of the cheese analogue was 5.48–5.82 (figure 2).

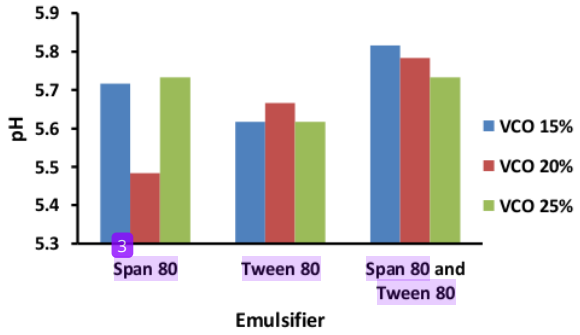

Figure 2. pH of the corn milk-based cheddar cheese analogue according to emulsifier and VCO concentration combinations.

According to Felfoul *et al* [16], the pH of cheese is not influenced by decreased fat or the addition of fat substitutes. The pH of full-fat cheese is 5.06; that of reduced-fat cheese is 5.07; that of cheese made with olive oil is 4.98. Abd El-Salam stated that the pH of cheese is not affected by the addition of canola oil, whey protein concentrate or emulsifier [13]. The pH value produced by several treatment combinations was 6.5–6.7. This value is higher than that of our cheese analogue, as the pH of corn milk is generally lower than that of cow milk (6.7). The pH of our cheese analogue corresponds with that of [6] and [7], who stated that the pH of the cheddar cheese analogue from corn milk extract ranged from 5.3–6.4.

3.1.3. Total solids. VCO concentration and emulsifier type and interaction did not affect the total solid significantly. The total dissolved solids of the cheese analogue containing 15%, 20% and 25% VCO were 29 degrees Brix (°Bx), 29.6°Bx and 29°Bx, respectively (figure 3). The soluble solids of the cheese analogue made using Span 80 and Tween 80 were 29°Bx and 29.5°Bx, respectively; the cheese analogue made using the combination of Span 80 and Tween 80 had soluble solids of 29°Bx.

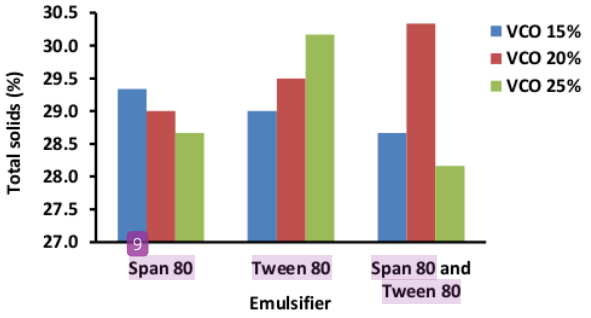

Figure 3. Soluble solids of corn milk-based cheese analogue according to emulsifier and VCO concentration combinations.

Here, the range of total solids of 28.2°Bx–30.3°Bx is higher compared to the corn milk-based cheddar cheese analogue produced by Aini [6], which was 19°Bx. This difference appears to stem from the use of additional ingredients during cheese analogue production, namely whey protein concentrate and gum arabic. According to Stankey *et al* [15], the amount of solids added during production affects the total value of dissolved solids.

The high value of soluble solids might be caused by the fatty acid content in the VCO. According to Villarino [17], lauric acid is the dominant fatty acid in VCO, ranging from 46%–48%, followed by myristic acid and stearic acid. Organic acid in the form of fatty acids (lauric acid, myristic acid, stearic acid) is a type of acid that can increase the total value of dissolved solids. However, the difference in VCO concentration did not have a significant effect on the total value of dissolved solids.

3.1.4. Titrated acidity. Variance analysis showed that VCO concentration and emulsifier type and interaction did not affect the total titrated acid significantly. The average value of total titrated acid in the cheese analogue produced from 15%, 20% and 25% VCO were 1.67%, 1.79% and 1.64%, respectively (figure 4). Regarding emulsifier type, the average total titrated acid in cheese analogue made with Span 80 and Tween 80 was 1.83% and 1.71%, respectively; that of cheese analogue made with the combination of Span 80 and Tween 80 was 1.56%.

Total titrated acid is the amount of lactic acid formed during fermentation as the result of the breakdown of lactose by lactic acid bacteria [18]. In the present cheese analogue, the whey protein concentrate was the source of lactose. According to Stankey *et al* [15], whey protein concentrate contains 1%–80% lactose, which is hydrolyzed during fermentation and produces lactic acid. We assume that using the same concentration of whey protein concentrate for all treatments is one of the factors that caused the

non-significant total titrated acid value. Here, the cheese analogue contained lactic acid levels according to the National Standard (1992): 0.5%–2.0%.

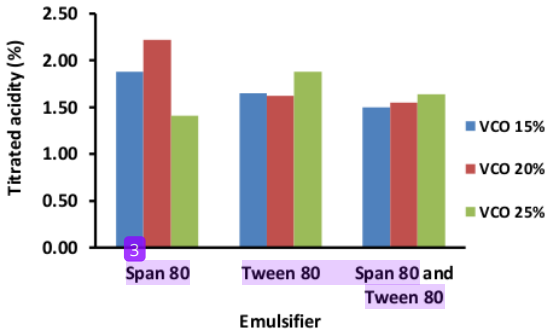

Figure 4. Titrated acidity of corn milk-based cheddar cheese analogue according to emulsifier and VCO concentration combinations.

3.1.5. Fat content. The variance analysis showed that the VCO concentration, but not the emulsifier type and interaction, affected the fat content in the cheese analogue significantly. The addition of higher VCO concentrations increased fat content. The cheese analogue with the highest fat content (19.24% dry basis [db]) was produced by the addition of 25% VCO (figure 5), while that with the lowest fat content (13.95% db) was produced by the addition of 15% VCO. The low lipid content in the cheese analogue means that it can be categorized as low-fat cheese. According to Stankey *et al* [15], cheese can be categorized into four groups according to its fat content. Low-fat cheese contains 10–25% fat.

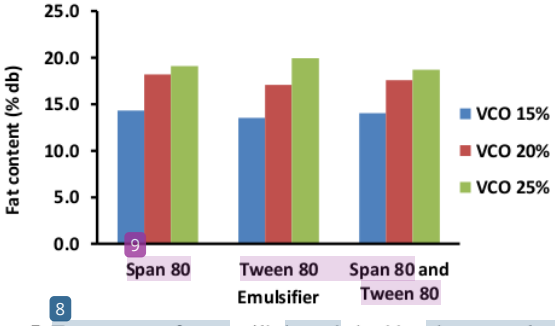

Figure 5. Fat content of corn milk-based cheddar cheese analogue according to emulsifier and VCO concentration combinations.

Compared to cow-milk cheese, the present cheese analogue had much lower fat content. According to Ramel and Marangoni [19], the fat content of cow milk-based cheese containing canola oil, whey protein concentrate and emulsifier is influenced by the fat content of the cow milk, the emulsifier mixture and interaction and the whey protein concentrate. The fat content of cheese containing canola oil, whey protein concentrate and emulsifier is 11.9%–13.4%. According to Abd El-Salam [13], the fat content of cheese containing olive oil (41.36%) is lower than that of full-fat cheese (44.55%), but is higher than that of reduced-fat cheese (37.68%). The difference in the fat content of all three samples was also influenced by the addition of water during cheese production. In addition, the loss of fat content can be influenced by the HLB value of the emulsifier mixture.

The type of emulsifier had no effect on the fat content of the cheese analogue. The fat content of the cheese analogues containing Span 80, Tween 80 and the combination of Span 80 and Tween 80 was

17.19% bk, 16.84% bk and 16.76% bk, respectively. The HLB value of Span 80 (sorbitan monooleate), Tween 80 (polyethylene sorbitan monooleate) and the combination of Span 80 and Tween 80 (0.5:0.5) is 4.3, 15.0 and 9.65, respectively [20]. According to Abd El-Salam [13], the emulsifier mixture suitable for cheese production is 0.5:0.2:0.3 polyethylene sorbitan monostearate:sorbitan monostearate:monostearate glycerol, with a HLB value of 9.3, to increase the size of fat droplets. This is in contrast with Lobato-Calleros *et al* [21] due to the incorrect HLB value for mixing the emulsifiers.

3.1.6. Moisture content. The VCO concentration had a significant effect on the moisture content of the cheese analogue, while the emulsifier type and interaction did not. The cheese analogue produced with 15% VCO had the highest water content of 60.78%, followed by 56.78% for 20% VCO and 55.93% for 25% VCO (figure 6).

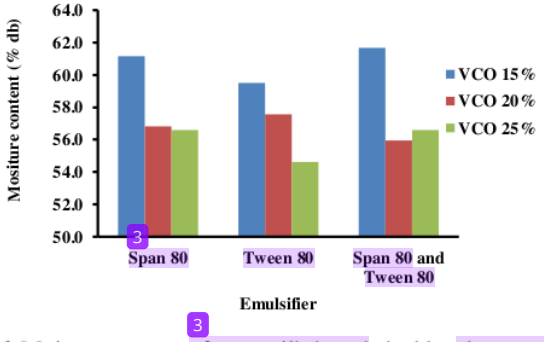

Figure 6. Moisture content of corn milk-based cheddar cheese analogue according to emulsifier and VCO concentration combinations.

The reduction of fat content or the use of fat substitutes impact the moisture content of cheese analogues. The lubricity properties of water are decreased during viscosity and it will fill the space between the globula and the casein molecule [16]. According to Lobato-Calleros *et al* [21], cheese water content is dependent on the mixture of emulsifier, whey protein concentrate and milk fat content. Higher milk fat and canola oil emulsion will produce a higher amount of fat, preventing the formation of protein bonds. Therefore, the use of whey protein concentrate is appropriate for improving the water-binding capacity and for increasing water retention in low-fat cheese. The moisture content of cheese containing canola oil, whey protein concentrate and emulsifier is 61.7%–66.3%. This result is not much different from that of the present cheese analogue, i.e. 57.43%–61.35%.

3.1.7. Soluble protein. VCO concentration, and emulsifier type and interaction did not influence the dissolved protein levels of the cheese analogue significantly. The soluble protein content of the cheese analogue containing 15%, 20% and 25% VCO was 9.57% db, 8.75% db and 9.35% db, respectively (figure 7). The dissolved protein levels of the cheese analogue containing Span 80, Tween 80 and the combination of Span 80 and Tween 80 were 8.70% db, 9.65% db and 9.32% db, respectively. The non-significant value of the dissolved protein content is assumed to have been caused by the use of protein additives in the form of the 20% whey protein concentrate in all three samples. According to Dhanraj *et al* [9], protein content is influenced by the emulsifier mixture and whey protein concentrate. The

emulsifier mixture will maintain the canola oil emulsion, inhibit syneresis and decrease protein reduction.

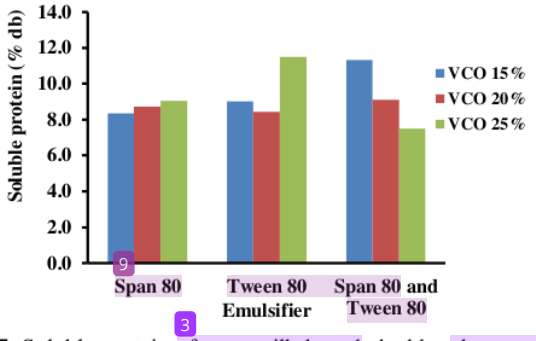

Figure 7. Soluble protein of corn milk-based cheddar cheese analogue according to emulsifier and VCO concentration combinations.

The protein content of the cheese analogue was 7.34%–9.97%, which is lower than that of the cheese analogue containing canola oil, whey protein concentrate and emulsifiers, which ranged 14.9%–18.2% [21], and was also lower than that of the cheese analogue produced by Abd El-Salam [13], which contained 12%–13.61% protein.

3.1.8. Sensory characteristics. The combination of VCO concentration and emulsifier type affected the colour of the cheese analogue significantly. The cheese analogue with the highest colour was obtained from treatment A2B2 (20% VCO and Tween 80), with a value of 4.11 (whitish-yellow); the lowest colour was obtained from A2B3 and A3B3 treatment with a value of 3.82 (white yellowish) (figure 8). The main factor affecting the yellow colour of the cheese analogue was sweet corn, which was the main material and contains anthocyanin pigment compounds (anthocyanidin, aglycone, glucoside) and carotenoids [22].

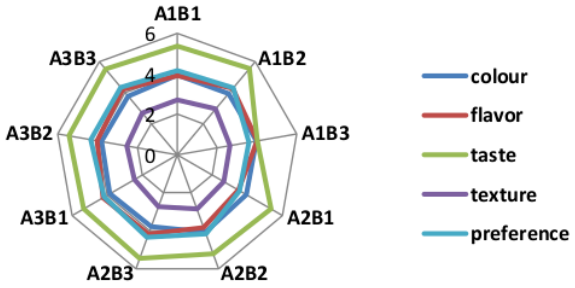

Figure 8. Sensory characteristics of corn milk-based cheddar cheese analogue according to emulsifier and VCO concentration combinations.

The colour of the cheese analogue was also influenced by the combination of VCO concentration and emulsifier. Tween 80 is a yellow oil and Span 80 is a thick yellow liquid [23], while VCO is almost transparent [17]. Mixing VCO and the emulsifier mixture into an emulsion produces a white, turbid emulsion [24]. Mixing these ingredients with corn milk will produce a yellow colour due to the presence of anthocyanin and carotenoid pigments [25].

The combination of VCO concentration and emulsifier type also affected the aroma of the cheese analogue significantly. Product A1B2 (15% VCO and Tween 80) had the highest aroma of 4.37 (little

typical of cheese), while product A2B1 (20% VCO and Span 80) produced the lowest aroma with a value of 3.55 (rather typical of cheese). The aroma of cheese is sour, sweet, boiled potato, butter-like and caramel, which is produced by acetic acid, butyric acid, methionyl, diacetyl, and homofuraneol [26]. According to Abd El-Salam [13], cheese analogues containing coconut oil can have a distinctive aroma because it contains high ethanol, dietan butan and acetic acid levels. VCO has an acidic, nutty and rancid aroma, where the sour aroma is produced by acetic acid during fermentation [17].

Besides VCO, the aroma of the cheese analogue was influenced by the aroma of whey protein concentrate. Whey protein concentrate contains volatile compounds consisting of butanoic acid, 2-acetyl-1-pyrroline, 2-methyl-3-ranthiol, 2,5-dimethyl-4-hydroxy-3-furanone, 2-nonenal, 2,6-nonadienal, and 2,4-decadienal, which each produces a specific aroma, such as cheesy, popcorn, brothy, maple, fatty, cucumber, and fatty/oxidized [13].

The combination of VCO concentration and emulsifier type had a significant effect on the taste of the cheese analogue. Product A1B2 (15% VCO and Tween 80) had the highest taste value of 5.59 (slightly salty), while product A1B3 (VCO 15% and Span 80 plus Tween 80) produced a taste value of 4.02 (neutral). VCO produces sweet and nutty tastes [17], while Tween 80 is bitter [27]. The main influencing factor of the taste of the cheese analogue was the combination of VCO concentration with emulsifier, because the VCO emulsion and emulsifier mixture can be used as a flavour carrier system. According to [28], who formulated microemulsions using aqua demineralization, a mixture of non-ionic surfactants (Tween 80 and Span 80) and VCO can be used as a system to produce strawberry, orange, or mint flavours. Therefore, the salt taste in cheese analogues can be produced by the taste of other additives, namely the salt bound by the VCO emulsion with the emulsifier mixture. The difference in the VCO concentration and the emulsifier type influences the character of the system, which affects the amount of bound salt and ultimately the taste. Another additive that can affect the taste of cheddar cheese analogue is whey protein concentrate. Whey protein concentrate has mild dairy flavours such as milky, and sweet aromatic and non-dairy flavours such as cardboard [29].

The combination of VCO concentration and emulsifier type had a significant effect on the texture of the cheese analogue. Product A1B2 (15% VCO and Tween 80) had the highest texture value of 3.00 (slightly hard), while product A3B1 (25% VCO and Span 80) had the lowest value taste of 2.45 (not hard). The texture of the cheese analogue was influenced by VCO concentration and protein content. According to [30], water can break down protein tissue and yield a smoother, softer texture to the cheese analogue. In addition, higher water content leads to a smoother texture. In the present study, higher VCO concentrations yielded softer textures.

The combination of VCO concentration and emulsifier type affected preference for the cheese analogue significantly. Product A3B3 (25% VCO and Span 80 plus Tween 80) had the highest preference score of 4.40 (rather preferable), while product A2B1 (20% VCO and Span 80) had the lowest score of 3.59 (slightly preferable). Panelists' levels of preference for the cheese analogue were influenced by factors such as colour, aroma, taste and texture. In general, all treatment combinations of the cheese analogue were received by the panelists.

3.2. Characteristics of the best product

Based on the total index of effectiveness, we concluded that the best treatment combination is A3B2: a cheese analogue containing 25% VCO and Tween 80. The A3B2 treatment had a yield value of 59.93% bb, fat content of 19.96%, dissolved protein level of 11.51% bk, colour sensory value of 3.84 (yellowish white), aroma value of 4.07 (slightly typical of cheese), taste value of 5.48 (slightly salty), texture value of 2.55 (not hard) and preference value of 4.[illegible] (rather preferable).

The yield, fat content and dissolved protein content of the cheese analogue were lower than that of the cheese containing olive oil emulsion produced by [31]. That cheese analogue had a yield value of 139.58 g/L, fat content in the range of 41.36% and dissolved protein content in the range of 39.25%. Using cow milk as the basic ingredient yielded fat content of 15.65 g/L and dissolved protein content of 33.92 g/L. This is higher than the fat and protein content of corn milk.

The cheese analogue had higher yield and fat content, but lower protein content than that of Lobato-Calleros [21]. According to Lobato-Calleros *et al* [21], cheese made from cow milk and containing canola oil and whey protein concentrate at a ratio of 0.17:0.66:0.17 had a yield value of 14.8%, 13.4% fat content and 16.2% protein content.

Compared to the topical cheese analogue made from corn extract produced by Aini [6], the yield value of the topical cheese analogue was lower than that of the present cheese analogue (17.512%), as well as lower fat content (6.976%). However, it contained higher dissolved protein levels than the present cheese analogue (19.837%). Despite this, both cheese analogues had similar sensory properties: yellowish-white colour, distinctive cheese aroma, and texture that was neither hard nor soft.

In the present study, the fat content and dissolved protein levels of the cheese analogue did not differ significantly from the optimal results of Tallaga cheese containing 50% sunflower oil and 25% whey protein concentrate in the study by Abd El-Salam [13]. The fat content of the cheese analogue and Tallaga cheese was 19.96% bk and 20% bk, respectively, and the protein content was 11.51% and 12%, respectively.

4. Conclusion

Increasing the VCO concentration from 15% to 25% in the cheese analogue production increases the fat and water content while at the same time reducing the sensory properties. The addition of various emulsifier types does not significantly influence the physicochemical variables and sensory properties of the cheese analogue. The best cheese analogue was produced with treatment A3B2:25% VCO and Tween 80. This treatment produced a yield value of 59.93% bb, fat content of 19.96% db and dissolved protein content of 11.51% db with the following sensory properties: colour value of 3.84 (yellowish white), aroma value of 4.07 (slightly typical of cheese), taste value of 5.48 (slightly salty), texture value of 2.55 (not hard) and the favourite value is 4.38 (rather preferable).

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RUBRIC: 9TH-12TH SCIENCE ARGUMENT(CER)

CLAIM

Take an arguable position on the scientific topic and develop the essay around that stance.

ADVANCED	The essay introduces a precise, knowledgable, qualitative and/or quantitative claim based on the scientific topic or text(s), regarding the relationship between dependent and independent variables, and establishes the significance of the claim. The essay develops the claim and counterclaim fairly and thoroughly, distinguishing the claim from alternate or opposing claims.
PROFICIENT	The essay introduces a precise, qualitative and/or quantitative claim based on the scientific topic or text(s), regarding the relationship between dependent and independent variables. The essay develops the claim and counterclaim fairly, distinguishing the claim from alternate or opposing claims.
DEVELOPING	The essay introduces a qualitative and/or quantitative claim based on the scientific topic or text(s), regarding the relationship between dependent and independent variables, but it may be somewhat unclear. The essay may not present the claim and counterclaim evenly or objectively, failing to adequately distinguish the claim from alternate or opposing claims.
EMERGING	The essay does not clearly make a qualitative and/or quantitative claim based on the scientific topic or text(s), or the claim is overly simplistic or vague. The essay does not address counterclaims.

EVIDENCE

Include relevant facts, definitions, and examples to back up the claim.

ADVANCED	The essay supplies the most relevant and appropriate qualitative and/or quantitative data and evidence related to the scientific topic or text(s) to support its claim and counterclaim.
PROFICIENT	The essay supplies sufficient qualitative and/or quantitative data and evidence related to the scientific topic or text(s) to support its claim and counterclaim.
DEVELOPING	The essay supplies some qualitative and/or quantitative data and evidence, but it may not be closely related to the scientific topic or text(s), thereby not effectively supporting the essay's claim and counterclaim.
EMERGING	The essay supplies very little or no qualitative and/or quantitative data and evidence to support its claim and counterclaim.

REASONING

Explain how or why each piece of evidence supports the claim.

ADVANCED	The essay applies scientific ideas and principles in order to thoroughly explain how or why the cited evidence supports the claim. The essay demonstrates consistently logical reasoning and full understanding of the scientific topic and/or text(s), comprehensively stating the strengths and limitations of both the claim

	and counterclaim. The essay's explanations effectively anticipate the audience's knowledge level, concerns, values, and potential biases about this scientific topic.
PROFICIENT	The essay applies scientific ideas and principles in order to explain how or why the cited evidence supports the claim. The essay demonstrates some logical reasoning and understanding of the scientific topic and/or text(s) and states the strengths and limitations of both the claim and counterclaim. The essay's explanations anticipate the audience's knowledge level and concerns about this scientific topic.
DEVELOPING	The essay includes some reasoning and understanding of the scientific topic and/or text(s), but it does not effectively apply scientific ideas and principles to explain how or why the evidence supports the claim. The strengths and limitations of the claim and counterclaim may be unclear.
EMERGING	The essay does not demonstrate clear or relevant reasoning to support the claim or to demonstrate an understanding of the scientific topic and/or text(s).

FOCUS

Focus your writing on the purpose and task.

ADVANCED	The essay maintains strong focus on the purpose and task, using the whole essay to support and develop the claim and counterclaims fairly while thoroughly addressing the demands of the prompt.
PROFICIENT	The essay maintains focus on the purpose and task, using most of the essay to support and develop the claim and counterclaims while thoroughly addressing the demands of the prompt.
DEVELOPING	The essay may not fully address the demands of the prompt or stay focused on the purpose and task. The writing may stray off topic at times.
EMERGING	The essay does not maintain focus on purpose or task.

ORGANIZATION

Organize your writing in a logical sequence.

ADVANCED	The essay incorporates an effective organizational structure throughout that logically sequences the claim(s), counterclaims, reasons, and evidence. It also includes an effective introduction and a conclusion which follows from and supports the arguments presented. Transitional words and phrases are included to enhance the relationships between and among ideas (i.e. claim and reasons, reasons and evidence, claim and counterclaim) and to create cohesion and clarity throughout.
PROFICIENT	The essay incorporates an adequate organizational structure and transitional phrases throughout that establish clear relationships between and among the claim(s), counterclaims, reasons, and evidence, including an introduction and concluding statement or section.

DEVELOPING	The essay uses a basic organizational structure but relationships between and among ideas are not consistently clear. The essay moves from beginning to end; however, an introduction and/or conclusion may be overly formulaic, repetitious, or missing.
EMERGING	The essay does not have a clear organizational structure. An introduction and conclusion are not evident.

LANGUAGE

Pay close attention to your tone, style, word choice, and sentence structure when writing.

ADVANCED	The essay effectively establishes and maintains a formal style and objective tone and incorporates language that anticipates the reader's knowledge level, concerns, values, and potential biases. The essay demonstrates a clear command of conventions, while also consistently employing discipline-specific word choices and varied sentence structure.
PROFICIENT	The essay generally establishes and maintains a formal style and somewhat objective tone with few possible exceptions and incorporates language that anticipates the reader's knowledge level and concerns. The essay demonstrates a general command of conventions, while also employing discipline-specific word choices and some variety in sentence structure.
DEVELOPING	The essay attempts a formal style and objective tone, and language inconsistently shows an awareness of the reader's knowledge or concerns. The essay may contain errors in conventions that interfere with meaning. Some attempts at discipline-specific word choices are made, and sentence structure may not vary.
EMERGING	The essay is not formal in style or objective in tone and employs language that does not anticipate the reader's knowledge or concerns. The essay may contain pervasive errors in conventions that interfere with meaning. Word choice is not discipline-specific, and sentence structures are simplistic and unvaried.