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Effect of Different Fat Milk Contents on Physicochemical and Sensory Properties of Gouda Cheese

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Gouda is a semi-hard Dutch cheese and can be made from cow, buffalo, and goat milk. This study was performed to investigate the effect of different fat levels on the physicochemical and sensory properties of Gouda cheese. Buffalo milk with two different fat contents (55.40 and 3.37%) and one control sample from cow milk were used to prepare Gouda cheese. Different formulations showed a significant effect on the proximate analysis except for ash content in pasteurised milk and protein content in Gouda cheese. For TPA, hardness showed a significant effect on day 0 and day 15 but insignificant on day 30, while springiness showed a significant effect on day 0 until day 30. Sensory evaluations show that taste and overall acceptance attributes were significant, while aroma, colour, and texture were insignificant. Based on the TPA analysis and sensory evaluation, it can be concluded that Gouda cheese from buffalo milk with 3.37% fat content is the best formulation and showed the lowest deviation from control (gouda cheese from cow milk).

Keywords: gouda; cheese; buffalo milk; fat content; product development

I. INTRODUCTION

Gouda is a semi-hard and full-fat Dutch cheese that was first made in its name in Holland. Gouda is a wheel-shaped cheese typically ranging in size from 4 to 20 kilograms and the flavour is buttery and slightly sweet with a firm texture (Jo *et al.,* 2018). Gouda cheese is a small part of United States production, with about 13.25 billion pounds of total cheese were produced annually (AgMRC, 2021). In Gouda cheese, small holes, known as "eyes," from within the cheese as described by Luyten *et al.* (1991). The production of gas causes the eyes by cheese microbiota. Gouda is a ripened firm/semi-hard cheese in conformity with General Standard for Cheese (CODEX STAN 283-1978). The body has a near white or ivory through to light yellow or yellow colour. A firm-textured (when pressed by thumb) texture, suitable for cutting, with few to plentiful, more or less round pin's head to pea-sized (or mostly up to 10 mm in diameter) gas holes, distributed in a reasonably regular manner throughout the interior of the cheese, but few openings and splits are acceptable. For Gouda ready for consumption, the ripening procedure to develop flavour and body characteristics usually are from 3 weeks at 10–17 °C depending on the extent of maturity required. Alternative ripening conditions (including the addition of ripening-enhancing enzymes) may be used, provided the cheese exhibits similar physical, biochemical, and sensory properties as those achieved by the previously stated ripening procedure.

The amount of milk fat not only affect the quality and nutritional value of Gouda cheese but also have a great flavour contribution. High levels of short- and intermediate-chain fatty acids found in milk fat, which are released during the enzymatic degradation of fat or lipolysis, will directly affect cheese flavour. Lipases in cheese are derived from milk, rennet, starter and nonstarter bacteria, or added lipases. Gouda cheese is an internally bacteria-ripened cheese with lack of lipolytic activities when it is made from pasteurised (García-Cano *et al.,* 2020). Therefore, lactic acid bacteria (LAB) containing intracellular lipolytic

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enzymes are released into the cheese matrix upon cell lysis. McSweeney and Sousa (2000) suggested that LAB may be responsible for the liberation of high levels of free fatty acids over extended ripening periods of Gouda cheese.

Some researchers have been done on the application of buffalo milk. Jo *et al.* (2018) developed the sensory and chemical properties profile of 36 Gouda cheese products from five different countries. Bertola *et al.* (2000) worked on the effect of ripening conditions on the texture of Gouda cheese. Next, Murtaza *et al.* (2013) developed a descriptive sensory profile of cow and buffalo milk cheddar cheese prepared using indigenous cultures. Besides, Mihaiu *et al.* (2010) researched the nutritional and functional value of buffalo milk. However, there is no application on texture profile analysis in the different fat levels of buffalo milk in Gouda cheeses has been done before. Limited research related to buffalo milk products and yet not fully utilised. Hence, more research on buffalo milk and its products, mainly in cheese, needs to be done to find out more on benefits or impacts towards human health and quality on food and can be as main dairy products in the future. Thus, the objectives of the study were to determine the physicochemical, texture and sensory properties of buffalo milk Gouda cheese with different levels of fat.

II. MATERIALS AND METHOD

A. Materials

Raw buffalo and cow milk samples were procured from Dengkil, Selangor and kept at 4°C during transportation to the laboratory. Calcium chloride, $CaCl_2$ was purchased from Evachem (Selangor, Malaysia). Mesophilic C101 starter culture and rennet were purchased from New England Cheese Making Supply Company (S.Deerfield, MA).

B. Raw Milk Preparation and Standardisation

The fresh milk was pasteurised at 63°C for 30 min in a water bath to kill pathogenic microorganisms and cooled to 4°C in an ice bath. The fat level adjustment for pasteurised buffalo milk was made by using disk bowl separation. The skimmed milk (0.1 – 0.3%) and cream (20 – 30%) was separated according to their density. After that, the skimmed milk was mixed with whole milk for fat adjustment by using a homogeniser (3 – 4%) according to the Pearson Square Method. Finally, the adjustment milk was verified by using the Gerber method. Table 1 shows the type of milk and the percentage of fat content used in sample Gouda Cheese 1 (GC1), sample Gouda Cheese 2 (GC2), and Gouda Cheese 3 (GC3).

Table 1. Fat content adjustment of milk samples.

Sample	Component	
	Type of Milk	**Fat Content (%)**
GC1(Control)	Cow	3.87 ± 0.15^b
GC2	Buffalo	5.40 ± 0.96^a
GC3	Buffalo	3.37 ± 0.15^b

GC1: Gouda Cheese 1, GC2: Gouda Cheese 2, GC3: Gouda Cheese 3 (GC3).

C. Production of Gouda Cheese

A Gouda cheese was prepared from 4 L pasteurised milk, and the milk was heated in a water bath until the temperature reached 30 – 33°C. Table 2 shows the formulation of gouda cheese processing. Firstly, 1.25 g of calcium chloride, $CaCl_2$ was added, followed by 3.75 g of Mesophilic C101 starter culture and left for 30 min. After that, 3.75 g of rennet was diluted in 60 mL of water before added to the milk by stirring and left for 40 min at 30 - 33°C. Once the curd was formed, it was slowly stirred for 15 min for whey protein removal. After $\frac{1}{3}$ of whey protein was removed, water (at 60°C) was added again until the curd reached 34 - 35°C and stirred for 10 min. Next, half of the whey protein was removed and replaced with water (at 60°C) until the curd reached 36 - 37°C. Stirring was continued for another 10 min before the curd settled down for 15 – 20 min. After that, all water was removed, the curd was transferred into a mould, and pressed with 6 – 8 kg of weight for 30 min on both sides. The step was continued using a higher weight of 12 – 15 kg for 6 – 8 hr. On the next day, the curd was removed from the mould and immersed it in salt solution (10 -20% w/w) for overnight. Finally, the curd was air dried at room temperature (≈25°C) for 3 days. Then, the curd was packed with vacuum packaging and stored (ripening process) in the refrigerator at 10 - 17°C for 4 weeks – 1 year, depending on Gouda cheese's firmness.

Table 2. Formulation on Gouda cheese processing.

Parameter	Sample		
	GC1(Control)	GC2	GC3
Type of Milk	Cow	Buffalo	Buffalo
Fat (%)	≈3.87	≈5.23	≈3.37
Calcium chloride (g)	1.25	1.25	1.25
Starter Culture (g)	3.75	3.75	3.75
Rennet (g)	3.75	3.75	3.75

GC1: Gouda Cheese 1, GC2: Gouda Cheese 2, GC3: Gouda Cheese 3.

D. Proximate Analysis

The crude protein analysis was determined from nitrogen content using the Micro Kjeldahl method (AOAC, 2000). Gerber method was used to determine the fat content in milk (AOAC, 2000). The ash content and the moisture content was measured using the oven method (AOAC, 2000).

E. Texture Profile Analysis

Cheese samples from the refrigerator were prepared by cutting the cheese cubes from each treatment at 2 cm × 2 cm × 2 cm (length, height, and width) and left at 25°C ± 2 for 1 hr. Then these cubes were compressed at the rate of 60 mm/min on a texture profile analyser (TA.HD *Plus Connect,* Stable Micro Systems Ltd., Surrey, UK) at room temperature. The result was recorded as the force used to compress the cheese sample up to 75% of its original height in two consecutive compressions. The recorded texture properties for Gouda cheese were hardness, cohesiveness, adhesiveness, springiness, gumminess, and chewiness.

F. Sensory Evaluation

After 35 days of storage, Gouda cheese samples were evaluated organoleptically by a 25-member panel recruited among staff and students of Universiti Putra Malaysia. They were served with GC1, GC2 and GC3 represented using a random three digits number. The sensory evaluation was conducted using a preference test with a hedonic scale. The samples were stored in a cold room at 5°C before the sensory assessment. They were instructed to indicate and determine how much they like or dislike the samples in the rating scale, which was disliked extremely (1), dislike moderately (2), dislike slightly (3), neither like nor dislike (4), like slightly (5), like moderately (6) or like extremely (7). The attributes of Gouda cheese chosen were colour, texture, aroma, taste, and overall acceptance.

G. Statistical Analysis

The Minitab statistical software (Minitab 17.0, Minitab Incorporation, USA) was used to analyse the results, and the data were expressed as mean ± standard deviation (SD). The significant difference ($p<0.05$) within means was analysed by analysis of variance (ANOVA).

III. RESULT AND DISCUSSION

A. Proximate Analysis

Proximate analysis was carried out to determine the elemental composition of moisture, ash, protein, and fat content on liquid milk and Gouda cheese according to AOAC (2000) method. However, the determination of fibre was removed from this analysis because there was no significant result in dairy products.

1. Liquid milk

The results regarding the proximate analysis of pasteurised buffalo and cow milk samples are given in Table 3. GC1, GC2, and GC3's moisture content was in the range of 82.92 to 86.60%. The statistical analysis showed that GC2 and GC3 have a significant result with GC1 because of the different types of milk used to make Gouda cheese. According to Arora *et al.* (2022), when compared to cow's milk (CM), buffalo milk (BM) is higher in total solids, protein, fat, and ash with a general composition of 82-83% water, 4-5% protein, 6-12% fat, 0.08% ash, 4-5.5 % lactose. For this reason, the percentage of moisture content in buffalo milk showed a slight decrease than moisture content in cow milk. Similarly, the statistical analysis further shows that protein content in buffalo milk was remarkably ($P<0.05$) higher than that of cow milk. The protein content of buffalo milk (GC2 and GC3) shows a more considerable difference (3.55%) than the cow milk (GC1) 2.71%, and this study was similar to Buzi *et al.* (2009). The higher protein content in buffalo milk than that of cow milk might be due to the concentration of both the casein and whey proteins reported higher in buffalo milk than that of cow milk (Ahmad *et al.,* 2013; Sindhu & Arora, 2011).

Table 3. Proximate analysis of pasteurised liquid milk.

Sample	Component			
	Moisture (%)	Ash (%)	Protein (%)	Fat (%)
GC1 (Control)	82.92 ± 0.27^{b}	0.83 ± 0.05^{a}	3.55 ± 0.10^{a}	3.87 ± 0.15^{b}
GC2	82.93 ± 0.27^{b}	0.83 ± 0.05^{a}	3.55 ± 0.10^{a}	5.40 ± 0.96^{a}
GC3	86.60 ± 0.07^{a}	0.79 ± 0.04^{a}	2.71 ± 0.13^{b}	3.37 ± 0.15^{b}

GC1: Gouda Cheese 1, GC2: Gouda Cheese 2, GC3: Gouda Cheese 3. Values are expressed as mean ± standard deviation (N=3) means with different letters within the same row are significantly different at the level of p<0.05.

Statistical observations revealed that fat content in buffalo milk was comparatively (P<0.05) higher than that of cow milk. The fat content in GC2 (5.40%) is almost double that of GC3 (3.37%) after the adjustment of fat content and GC1 (3.87%). Other than that, the ash content in GC2 and GC3 is different from GC1, and this finding aligns with the present study done by Barlowska *et al.* (2011). However, the difference is too small, and statistical analysis showed that this parameter does not show any significant difference between buffalo milk and cow milk. In general, this might be because of some factors that affect the milk components, such as variation in the animal's genetic make-up and milking in different seasons.

2. Gouda cheese

The effects of ripening on the chemical and physical characteristics of cheese have been well studied (Kuchroo & Fox, 1982). Massens (1999) worked on proteolysis of high-pressure-treated Gouda cheese, stating that the mean contents of moisture, protein, and fat were 42.5%, 26.2%, and 24.4%. Besides, the mean proximate composition of Gouda cheese on moisture, ash, protein, and fat contents were 42.31%, 3.56%, 23.13%, and 30.63% (Smit, 2000). Table 4 shows a proximate analysis of Gouda cheese.

Table 4. Proximate analysis of Gouda cheese.

Sample	Component			
	Moisture (%)	Ash (%)	Protein (%)	Fat (%)
GC1 (Control)	39.15 ± 0.50^{a}	3.92 ± 0.02^{b}	25.16 ± 0.26^{b}	17.00 ± 0.00^{b}
GC2	29.04 ± 1.27^{b}	3.31 ± 0.08^{c}	27.48 ± 0.80^{a}	25.50 ± 0.71^{a}
GC3	38.95 ± 0.75^{a}	4.17 ± 0.06^{a}	25.35 ± 1.57^{ab}	16.00 ± 0.00^{b}

GC1: Gouda Cheese 1, GC2: Gouda Cheese 2, GC3: Gouda Cheese 3. Values are expressed as mean ± standard deviation (N=3) means with different letters within the same row are significantly different at the level of p<0.05.

Factors such as moisture (P<0.05), ash (P<0.05), and fat (P<0.05) were significantly different between samples, but only protein showed the deviation between the result. The moisture content of different Gouda cheese samples used was in the range of 29.04 to 39.15%. The moisture content of GC2 was significantly different from GC1 and GC3 because of the ripening process, and also, a difference in fat level content impacts the moisture itself. The ash content of GC2 (3.31%) was significantly different from GC1 (3.92%) and GC3 (4.17%). Similarly, protein content for GC2 and GC3 is insignificant with GC1. The protein content of GC2 was highest (27.48%), followed by GC3 25.35% and GC1 25.16%. In addition, the fat content in GC2 (25.50%) is almost twice that of GC3 (16.00%) after the adjustment of fat content and GC1 (17.00%). This is due to the fat content used during the preparation of Gouda cheese in milk shows that GC2 has the highest percentage than GC1 and GC3 because of nature and milk composition itself.

B. Texture Profile Analysis

Texture Profile Analysis (TPA) is a popular double compression test used to determine the textural properties of foods. Figure 1 shows the hardness, springiness, cohesiveness, gumminess, and chewiness properties of

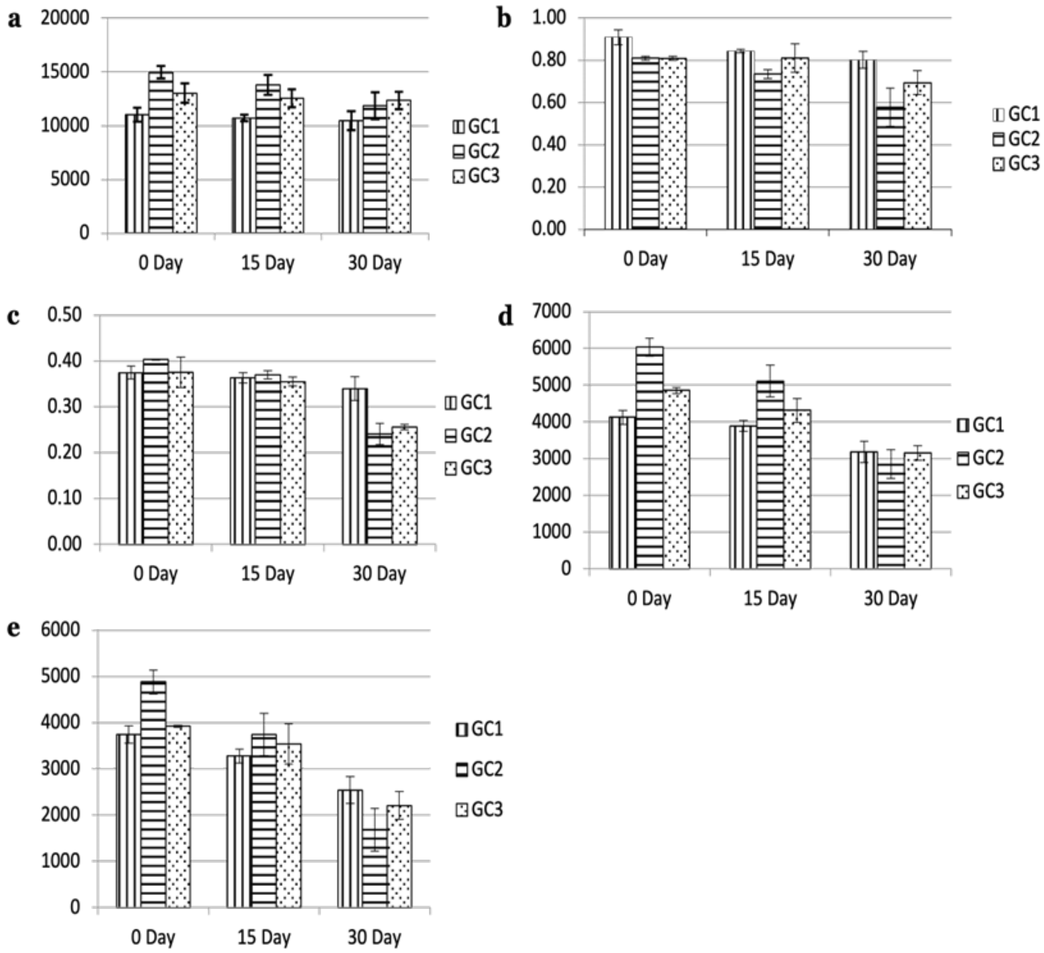

Figure 1. Texture profile analysis of Gouda cheese: (a) hardness, (b) springiness; (c) cohesiveness; (d) gumminess; and (e) chewiness. GC1: Gouda Cheese 1, GC2: Gouda Cheese 2, GC3: Gouda Cheese 3.

samples using TPA. GC2 had a significant effect on all measured parameters ($p < 0.05$). However, the hardness parameter for both GC1 and GC3 shows an insignificant effect by days of ripening. Hardness is an essential attribute of cheese to categorise the product into a particular group: very hard, semi-hard, semi-soft, soft, and fresh cheese (Fox *et al.*, 2000). Hardness is the highest force required for the cheese of the first compression. From Figure 1(a), hardness for GC2 significantly decreased from day 0 until day 30 but insignificantly for sample GC1 and GC3. This is because fat content makes the cheese softer over time. Casein molecules form into tiny bubbles called micelles, and these bubbles interact with each other to form a network that gives the cheese strength. In the centre of these micelles, we find fat. The more fat, the larger the micelles become, and the farther apart the casein gets. So, as a general rule, cheeses that are higher in fat have casein molecules that are farther apart from each other, and thus the network is weaker and yields a softer cheese (Johnson & Law, 2010).

Springiness is the height that the sample recovers by the second compression. From Figure 1(b), all samples show a significant decrease from day 0 to day 30. GC2 shows the highest reduction in springiness than GC1 and GC3. Due to the proteolytic breakdown of as_1-casein in cheese, the protein matrix is restructured and weakened, consequential in a softer, less elastic, and more melt-able cheese (Johnson & Law, 2010). Hence, this present study was found a similar trend and agreed with the previous. Cohesiveness in Figure 1(c) shows how well the products withstand a second compression. GC2 and GC3 showed a significant effect from day 0 to day 30, but GC1 shows insignificant effect on cohesiveness. Between GC2 and GC3, cohesiveness for GC2 shows the highest reduction than GC3. Different levels of fat in cheese affected cohesiveness due to the texture of the cheese with high fat content tends to get a lower firmness by ripening progressed.

Gumminess is the energy required to disintegrate a solid food into a small part until it is ready to swallow. In contrast, chewiness is the energy required to break down a solid food until it is ready to swallow. It has been established that chewing force and chewing movements are robustly influenced by food texture (Watts *et al.*, 2022). From Figure 1(d) and 1(e), both gumminess and chewiness show a significant effect from day 0 to day 30 for all samples. First, the chewiness was affected by gumminess and springiness. Then, gumminess was developed from the hardness and cohesiveness of the sample. Lower values of hardness and cohesiveness give a lower value of gumminess as well as chewiness. All the cheese samples became less firm as ripening progressed, which was in line with Murtaza (2016).

C. Cheese Yield

Cheese yield is usually defined as the mass of cheese obtained from a certain quantity of milk. When making cheese, individual milk components, including water, are converted to varying extents into the final cheese. The yield of cheese during production is very important to cheese manufacturers because of its profit and losses. Generally, 10 L of pasteurised cow milk can make only 1 kg of Gouda cheese and approximately 10% of the total volume of milk used. From Table 4, the weight loss among samples was similar, about 10 – 11% after the air-drying process. However, GC2 has more weight, followed by GC3 and GC1. This might be because of the difference in fat content and milk composition for each sample, and Hussain *et al.* (2013) reported that cheese yield from buffalo milk was the highest than cow milk. One of the apparent advantages derived from the increased yield is the lower cost for the cheese manufacture. The more cheese derived from the raw material, the less expensive it is to manufacture the cheese.

Table 5. Yield of Gouda cheese.

Sample	**Component**		
	Weight before (kg)	**Weight after (kg)**	**Weight loss (%)**
GC1 (Control)	0.454	0.351	10.3
GC2	0.770	0.670	10
GC3	0.695	0.585	11

GC1: Gouda Cheese 1, GC2: Gouda Cheese 2, GC3: Gouda Cheese 3.

D. Sensory Evaluation

Three samples from different levels of fat were prepared and analysed organoleptic for five attributes: colour, texture, aroma, taste, and overall acceptance. The results of the sensory evaluation of Gouda cheese are shown in Table 6 below. From the table, the result shows that there was no significant ($p > 0.05$) difference in sensory attributes of colour, texture, and aroma. However, there was a highly significant ($p < 0.05$) effect in taste and overall acceptance. The mean scores for the colour attributes were ranged between 3.64 ± 1.32 to 4.32 ± 1.06. GC2 with full fat buffalo milk has a very nearest score toward GC1, which is 4.28 ± 1.06. The colour of all samples does not show any significant effect due to no colouring agent was added up during cheese making. The higher level of fat in Gouda cheese production did not significantly affect the colour attribute, as was indicated by respondents.

The texture attribute shows that the texture is insignificantly affected by the different levels of fat content between samples. These results are contradicted with the results from TPA analysis, in which the springiness and cohesiveness showed significant differences between GC1 and both GC2 and GC3. The panellists were unable to differentiate the texture among the samples. This is because the panellists were untrained, and the texture attribute might be too general for them to identify.

From one-way ANOVA analysis, aroma attribute shows insignificantly different between sample GC1, GC2, and GC3. Again, GC2 (4.16 ± 1.52) shows the closed mean score with GC1 (4.44 ± 1.56) than GC3, which is 3.96 ± 1.74. The different fat level in cheese was not affected toward aroma attribute. For the taste attribute, the result shows a significant ($p < 0.05$) affected by the different levels of fat content between samples with the highest score was GC1, and the lowest mean score was GC2 (2.56 ± 1.45). GC2 shows the lowest mean score among samples. According to Jo *et al.,* (2018), higher concentrations of δ-decalactone, furaneol, sotolone, and homofuraneol were detected from Gouda cheeses with higher fat contents and longer age time and those made from raw milk. These compounds are produced from the conversion of peptides/AA or milk fats by enzymes from the lactic acid bacteria in the cheese (El Soda, 1993). Both δ-decalactoene and furaneol impart delicate, sweet, coconut- like flavours in Cheddar, Gouda, Parmesan, blue-type, and other cheeses, while sotolone imparts lovage-like odour quality in savoury foods that can enhance saltiness (Haag *et al.,* 2021). However, this result was not consistent with results by Murtaza (2013) that states fat content in buffalo milk cheese gives a higher score on flavour and texture than cow milk cheese.

The last attribute that was examined is overall acceptance. The results show that the overall acceptance of Gouda cheese was insignificantly affected ($p < 0.05$) by different levels of fat as for GC2 and GC3. Limitation of this study was no control from commercially available Gouda cheese was used for sensory analysis comparison, which might give a better picture on the acceptability of our Gouda cheese among the consumers.

Table 6. Sensory analysis results.

Sample	Attributes				
	Colour	**Texture**	**Aroma**	**Taste**	**Overall Acceptance**
GC1 (Control)	4.32± 1.77^a	3.60± 1.26^a	4.44± 1.56^a	4.04 ±1.49^a	4.12±1.20^a
GC2	4.28± 1.06^a	3.56± 1.42^a	4.16± 1.52^a	2.56 ±1.45^b	3.28±1.51^b
GC3	3.64± 1.32^a	3.04± 1.37^a	3.96± 1.74^a	2.96 ±1.10^b	2.80±0.96^b

GC1: Gouda Cheese 1, GC2: Gouda Cheese 2, GC3: Gouda Cheese 3. Values are expressed as mean ± standard deviation (N=3) means with different letters within the same row are significantly different at the level of $p<0.05$.

IV. CONCLUSION

In conclusion, buffalo milk cheese with 3.37% fat was selected as the best formulation because it showed a lower TPA and sensory evaluation deviation with GC1 (Control). The increase of fat on buffalo milk cheese negatively affects both their texture and flavour. The formulated Gouda cheese can be a promising energy source because of its low calorie and give a superior texture and the flavour of dairy milk products. A study on the packaging of the cheese during the ripening process shall be done by substituting vacuum packaging with wax to maintain a low reduction of moisture. Next, fat loss from the Gouda cheese can be minimised, and the lipolysis process can be inhibited. Finally, further research shall be done to improve the quality of Gouda cheese, especially its texture and flavour, by increasing the time for the ripening process.

V. ACKNOWLEDGEMENT

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