Sarjana International Journal of Sustainable Food and Agriculture

Journal homepage:
https://sarjanaintelek.my/index.php/sijsfa/index
ISSN: 3093-7086

Effects of Gelatin and Inulin on the Physicochemical and Sensory Properties of Low-Fat Yogurt

Norliza Julmohammad[1,*], Nur Syafiqa Mohd Zarir[1], Huong Yew Sen[1], Nurul Huda[2], Md Jahurul Haque Akanda[3], Mohd Dona Sintang[4]

1 Food Security Laboratory, Food Science and Nutrition, Universiti Malaysia Sabah, Jalan UMS, 88400 Kota Kinabalu, Sabah, Malaysia
2 Faculty of Fisheries and Marine Science, Universitas Brawijaya, Malang 65415, East Java, Indonesia
3 Department of Agriculture, School of Agriculture, University of Arkansas, 1200 North University Dr., M/S 4913, Pine Bluff, Arkansas 71601, United States of America
4 Nestle Research and Development Centre, Singapore 618802, Singapore

ARTICLE INFO

Article history:
Received 3 February 2025
Received in revised form 19 March 2025
Accepted 20 May 2025
Available online 20 June 2025

Keywords:
Low-fat yogurt; gelatin; inulin; physicochemical; sensory properties

ABSTRACT

Low-fat yogurt contains reduced saturated fat, offering cardiovascular benefits while retaining essential nutrients present in full-fat yogurt. Despite its lighter texture and reduced creaminess, the incorporation of functional ingredients can improve its texture, consistency, and taste while maintaining lower fat content. However, certain sensory and physicochemical attributes may be compromised in low-fat yogurt due to its reduced fat content. Therefore, this study aims to evaluate the effects of gelatin and inulin supplementation on the physicochemical and sensory properties of low-fat yogurt. The concentration of gelatin and inulin added was 1, 2 and 3%. Gelatin offered a better texture and appearance for sensory analysis; however, increased levels of gelatin negatively affected the attribute mentioned. On the other hand, inulin had a better effect on aroma and taste. Inulin recorded the highest overall acceptability of 6.04 ± 0.90. The two best samples were chosen from sensory analysis for further proximate and physicochemical analysis. Syneresis of yogurt was significantly reduced upon the addition of gelatin with measurements of 2.30, 1.42, and 0.90 on days 1, 7, and 14. Lightness (L*) and yellowness (b*) of low-fat yogurt increased with gelatin and decreased with inulin. Hardness and adhesiveness were significantly improved upon the addition of gelatin, while inulin gave a significant difference in springiness compared to gelatin and standard. In conclusion, the addition of inulin and gelatin in low-fat yogurt has a significant effect on improving its attributes.

1. Introduction

Yogurt has been consumed as part of a daily diet for thousands of years. The term yogurt is originally derived from the Turkish word “yoğurmak”, representing thickening, coagulating, or curdling [1]. Yogurt is a famous dairy product that is primarily produced by the fermentation of lactic

* *Corresponding author.*
E-mail address: norliza@ums.edu.my

https://doi.org/10.37934/sijsfa.1.1.1729

acid bacteria, namely *Streptococcus thermophiles* and *Lactobacillus bulgaricus.* Lactose from the milk is fermented to produce lactic acid, resulting in a decreased pH and casein coagulation, giving the final product a viscous gel-like texture with a sour, tart taste [2-5]. Yogurt is an essential source of nutrients, consisting of proteins, calcium, probiotics, and multivitamins [2,5-6]. Therefore, consumers favour yogurt as a functional dairy product, as it offers many health benefits, such as maintaining healthier microbial balance in the gastrointestinal system through its probiotics, improving weight management, reducing lactose intolerance, and enhancing bone and teeth health [5,7-8]. In supermarkets and retailers, yogurt can be found in various forms, such as whole milk yogurt, skim milk yogurt, fruit yogurt, and yogurt drinks.

Heavy consumption of high-fat meals can easily lead to weight gain and obesity, eventually developing into chronic diseases like cardiovascular diseases and fatty liver. A regular whole milk yogurt (≥3.25%) with a higher milk fat content may contribute to a higher fat intake. Hence, health-conscious consumers are looking for healthier options, such as low-fat (0.5–2.0%) or non-fat yogurts (<0.5%), on the market [4]. However, due to the reduction in fat in yogurts, low-fat yogurts do not exhibit similar sensory and textural characteristics as regular ones, causing syneresis and having poor flavour [9-10]. According to Zhao *et al*., [4], fat composition is responsible for the firmness, mouthfeel, and creamy flavour of regular yogurts.

With these problems in mind, studies have been conducted to reduce undesirable defects and improve the quality while maintaining the low-fat content of yogurts using suitable food additives. Fat replacers have been used in the manufacturing of low-fat yogurts, where their function is to alleviate the unpleasant properties of the final product that might occur due to the reduced fat content. Aside from being low in calories, fat replacers are also known as substances that can imitate the physical and sensory attributes of fat in food, with their thickening, stabilising properties, and water-holding capacity [4]. Based on their composition, fat replacers can be divided into three groups, mainly lipid, protein, and carbohydrate-based, and they can either be used alone or as a blend [4,11].

Gelatin is a standard protein-based fat replacer incorporated into many low-fat food products to compensate for the defects caused by fat removal. It is an animal-based hydrocolloid, mainly derived from bovine, porcine, or fish collagens [9,12]. Gelatin possesses superior gelling properties, and thus, it has been employed in the food industry as a food thickener and stabiliser [9]. Previous studies by Mudgil *et al*., [13] proved that 0.5-1.25% gelatin supplementation in camel milk yogurts eliminated whey separation and reduced syneresis. Nevertheless, the sensory aspects, particularly the taste and flavour of camel milk yogurts with gelatin, were rated lower comparatively to the regular bovine and camel milk yogurts [13].

Inulin also permits the manufacture of low-fat foods without compromising the taste or texture. The sources of inulin vary, mainly from plant sources, such as chicory roots, bananas, asparagus, and artichoke [7]. It is a carbohydrate-based fat replacer, demonstrating low calories and prebiotic properties, which is always considered a healthier hydrocolloid [10,14]. Likewise, the addition of inulin improved the quality of yogurts, but significant differences between syneresis during storage were observed for 1-3% of inulin [15]. The highest 3% inulin concentration in yogurts exhibited a higher syneresis than 2% [15]. Therefore, an appropriate quantity of fat replacers (gelatin and inulin) incorporated in the low-fat yogurt samples is crucial in deciding the qualities of the final products.

In this study, low-fat yogurt samples were fortified with gelatin and inulin, with 1, 2, and 3% concentrations, respectively. The objectives of this study were to determine the consumer acceptance of these fortified low-fat yogurts as well as to investigate the physicochemical changes in these samples. A key research gap exists in the need for more studies on fat replacers in low-fat yogurt, particularly those that consider consumer sensory preferences and physicochemical properties.

2. Methodology

2.1 Yogurt Sample Preparation

The yogurt samples were prepared according to Mudgil *et al.*, [13] with minor modifications. Low-fat milk was obtained from local stores in Kota Kinabalu, Sabah. The milk was heated in a water bath for 10 minutes at 80-85°C for whey protein denaturation. Different concentrations of gelatin or inulin (1%, 2%, and 3%) were added to the milk and appropriately dissolved to prepare a total of six formulation mixtures. The mixtures were allowed to cool down to 45°C, and commercial yogurt cultures were inoculated into the mixtures. Each sample prepared was poured into transparent cups and covered with a lid. They were labelled as per the level of gelatin or inulin added. After inoculation, the yogurt samples were incubated for 6 hours at 43°C or until the pH reached 4.6. The samples underwent fermentation, cooled rapidly at 4°C, and were stored for further analysis.

2.2 Sensory Evaluation

Sensory evaluation was conducted to assess consumer acceptance of yogurt samples fortified with gelatin and inulin. The hedonic test was performed at the University Malaysia Sabah (UMS) with 50 randomly selected students who served as panellists. Prior to the evaluation, panellists were trained on the sensory attributes to be assessed, including appearance, aroma, texture, taste, and overall acceptability, to ensure consistent and reliable results. The seven yogurt samples were presented in transparent cups at 4°C, each assigned a 3-digit random code to eliminate bias. Clean water was provided to panellists between samples to cleanse their palates [16]. The sensory attributes were rated using a 7-point hedonic scale (7 = very much liked, 6 = liked a lot, 5 = liked, 4 = neither like nor dislike, 3 = disliked, 2 = much disliked, 1 = very much disliked).

2.3 Proximate Analysis

The proximate composition, including moisture, ash, protein, fat, and crude fibre content of the yogurt samples, was determined using the respective standard AOAC methods [17]. The total carbohydrate content was determined by calculating the difference obtained by subtracting the total percentage of moisture, ash, protein, fat, and crude fibre content from 100%.

2.4 pH

pH measurements were determined using a digital pH meter during the 0, 1, and 2nd weeks of yogurt storage. The glass electrode of the pH meter was rinsed with distilled water and wiped gently before calibration. It was then immersed in the homogenised yogurt samples after mixing with distilled water to take a pH reading in triplicate at room temperature [15].

2.5 Titratable Acidity

The titratable acidity of the yogurt samples was determined using the titration method [15] with some modifications. 10 g of yogurt was poured into a conical flask and mixed with 20 mL of sterile distilled water before being titrated with 0.1M of NaOH solution. Phenolphthalein was used as the indicator, and the titration was carried out until a faint pink colour was obtained. The grams of lactic acid per 100 g of product (TA) was calculated using the following Eq. (1):

$$\text{TA} = \frac{\text{Volume of sodium hydroxide (NaOH) used (mL)} \times 0.9}{\text{mass of the sample (g)}} \quad (1)$$

2.6 Syneresis

The centrifugal method used for the whey separation of yogurt was modified from Mary *et al*. [6]. 25-40 g of yogurt samples at 5°C were transferred to 50 mL centrifuge tubes and centrifuged at 2150 RPM for 20 minutes. The quantity (g) of supernatant liquid separated at the top of the coagulum inside the centrifuge tubes was weighed and calculated to measure the degree of whey syneresis of the respective yogurt samples using the following Eq. (2):

$$\text{Ratio of syneresis (\%)} = \frac{\text{The volume of supernatant (g)}}{\text{Initial weight of yogurt sample (g)}} \times 100 \quad (2)$$

2.7 Viscosity

A shear viscosity test was conducted using a rotational rheometer with a cone and plate measuring system at 25 ± 0.1°C. The tests were conducted at a controlled rate mode with the shear rate range at 0.1–100/s [15]. A total of triplicate measurements were taken for each sample. The yogurt sample underwent stirring for 30 seconds and recovered for 10 minutes in the container before the shear viscosity test started. The determination of viscosity was held for each sample at 1, 7, and 14 days of storage.

2.8 Colour

Yogurt samples were measured for colour in the L*, a*, b* system, where L* represents lightness, a* represents redness, and b* represents yellowness, using a colourimeter. A fixed amount of yogurt samples were poured into the measurement cup, and the L*a*b* values were determined during 1, 7, and 14 days of storage.

2.9 Texture

The texture of the yogurt samples was determined using the texture analyser, which was equipped with a 5 kg load cell [13]. Immediately upon removal from the storage, the samples were tested in a beaker using an extrusion disc (Ø = 35 mm) operating at a fixed test speed of 1.0 mms^{-1} to a depth of 30 mm. Using the Texture Expert Exceed, the force-time curves were analysed, and the textural attribute expressed was hardness. Each sample underwent triplicate measurements to increase the reliability of the results.

2.10 Statistical Analysis

Each analysis was conducted in triplicate. Data were presented as mean ± standard deviation and analysed using One-way ANOVA by SPSS 26.0. The significant differences were at $p < 0.05$.

3. Results

3.1 Sensory Evaluation

The yogurts were analysed based on five different attributes: appearance, aroma, texture, taste, and acceptability. The mean score from the evaluation is shown in table 1.

Table 1
The mean hedonic score of different types of yogurt sample

Samples	Mean score				
	Appearance	Aroma	Texture	Taste	Acceptability
Standard	3.94 ± 0.47^{cd}	4.78 ± 0.62^{bc}	3.80 ± 0.45^{d}	4.06 ± 0.42^{c}	3.86 ± 0.50^{c}
1% Inulin	6.02 ± 0.62^{a}	5.12 ± 0.44^{a}	5.06 ± 0.47^{b}	5.86 ± 0.64^{a}	6.04 ± 0.90^{a}
2% Inulin	5.50 ± 0.71^{b}	4.98 ± 0.47^{ab}	4.64 ± 0.49^{c}	4.78 ± 0.47^{b}	5.02 ± 0.38^{b}
3% Inulin	4.24 ± 0.63^{c}	4.06 ± 0.42^{d}	3.38 ± 0.64^{e}	3.82 ± 0.60^{de}	3.38 ± 0.60^{d}
1% Gelatin	5.36 ± 0.49^{b}	4.68 ± 0.51^{c}	6.10 ± 0.51^{a}	4.44 ± 0.50^{c}	5.02 ± 0.77^{b}
2% Gelatin	3.78 ± 0.65^{d}	3.52 ± 0.51^{e}	3.64 ± 0.83^{de}	3.50 ± 0.61^{e}	2.88 ± 0.61^{e}
3% Gelatin	3.08 ± 0.63^{e}	2.68 ± 0.47^{f}	1.92 ± 0.34^{f}	2.70 ± 0.61^{f}	1.88 ± 0.39^{f}

Means ± standard deviations in a column for the same parameter with different alphabetical superscripts are significantly different ($p < 0.05$).

For the texture, yogurt with 1% gelatin recorded the highest mean score and significantly differed from the other mean scores ($p < 0.05$). The incorporation of gelatin enhanced most of the desirable sensory attributes of yogurt, such as thickness, smoothness, and creaminess [12]. Gelatin can increase the firmness of yogurt and has a melting point at body temperature, helping to produce smooth and creamy mouthfeel, which further enhances the sensory experience during consumption [9]. These improved attributes allow low-fat yogurt to more closely resemble the sensory profile of regular full-fat yogurt, despite the reduction in fat content. This finding aligns with similar studies, such as those by Mudgil *et al*., [13], where gelatin was shown to improve the sensory qualities of low-fat yogurt, making it more appealing to consumers. However, increasing the levels of gelatin beyond 1% led to the formation of a lump-like appearance in the yogurt, causing a significant drop in the mean score for texture ($p < 0.05$), particularly in samples with 2% and 3% gelatin, which recorded mean scores of 3.64 and 1.92, respectively. This is consistent with other research, such as the study by Zhao *et al*., [4], which noted that excessive gelatin concentrations could negatively affect the texture of yogurt.

Inulin, a carbohydrate-based fat replacer, recorded the highest mean score of 5.86 for aroma, with 3% gelatin showing the lowest score of 1.92. The addition of inulin has been shown to improve the aroma of food products, as observed in the study by Gnanarathna *et al*., [15], where both cow and buffalo milk yogurt samples exhibited higher aroma scores with increasing inulin levels. However, exceeding 2% inulin led to a reduction in aroma scores, likely due to the higher fiber content, which can impact the overall sensory experience. This aligns with findings from Helal *et al*., [18], who reported a decrease in aroma scores of yogurts containing inulin as the fiber level increased beyond a certain threshold.

Regarding taste, both 1% and 2% inulin resulted in significantly higher mean scores of 5.86 and 4.78, respectively, compared to the standard low-fat yogurt (score of 4.06). However, increasing the inulin level to 3% caused a significant decrease in taste scores. This result mirrors findings in other studies, such as those by Gnanarathna *et al*., [15], who found that inulin improved yogurt taste by modulating creaminess and sweetness due to its fructose content. Additionally, Helal *et al*., [18] noted that while inulin improved yogurt flavor, it gradually declined during storage, suggesting that its effect on taste might diminish over time.

For overall acceptability, yogurt with 1% inulin recorded the highest mean score, followed by 2% inulin, 1% gelatin, the standard, 3% inulin, 2% gelatin, and 3% gelatin. Based on these results, the standard sample and yogurt samples with 1% inulin and 1% gelatin were chosen for further analysis to determine the effect of these fat replacers on the physicochemical properties of low-fat yogurt. This finding is in line with current consumer trends, where there is increasing demand for low-fat dairy alternatives that maintain a desirable sensory profile, with inulin and gelatin emerging as promising fat replacers in this context.

3.2 Proximate Composition

Table 2 illustrates the chemical composition of selected yogurt samples. The chemical composition determined were moisture content, ash content, crude protein content, fat content, and fibre content.

Table 2
Proximate composition of different types of yogurt samples

Samples	Chemical composition (%)				
	Moisture	Ash	Crude protein	Fat	Crude fiber
Standard	88.15	0.97	3.86	3.20	0
1% Inulin	86.76	1.16	4.25	2.41	0.82
1% Gelatin	83.21	1.88	7.13	2.70	0

Overall, major differences can be observed in moisture and crude protein content, while only minor differences were observed in ash, crude fiber, and fat content. Moisture content for yogurt with 1% gelatin recorded the lowest content of 83.21%, while standard and 1% inulin were 88.15% and 86.76%, respectively. This can be seen during the preparation of samples for moisture determination, where yogurt with 1% gelatin was in firm condition and not watery like standard and 1% inulin.

For crude protein content, yogurt with 1% gelatin recorded the highest content of 7.86%, while the standard was 3.86%, and yogurt with 1% inulin was 4.66%. The differences in protein content of gelatin can be attributed to the addition of gelatin as it was made up of proteins [12]. The crude protein content of low-fat yogurt with 1% gelatin observed in the present study was higher compared to the ones reported by Mudgil *et al*., [13] in camel milk yogurt, which was 4.54%.

3.3 pH and Acidity

The acidity of yogurt is the main characteristic that gives yogurt its sour and refreshing taste. Table 3 shows variations in pH and acidity during the storage period.

Table 3
pH and acidity of yogurt samples during storage period

Parameter	Samples	Storage period (Days)		
		1st	7th	14th
pH	Standard	4.53 ± 0.04^{b}	4.34 ± 0.07^{cd}	4.18 ± 0.03^{d}
	1% Inulin	4.67 ± 0.02^{ab}	4.44 ± 0.05^{bc}	4.32 ± 0.01^{cd}
	1% Gelatin	4.70 ± 0.04^{a}	4.64 ± 0.02^{ab}	4.57 ± 0.03^{b}
Acidity (%)	Standard	0.80 ± 0.01^{b}	0.85 ± 0.01^{b}	0.95± 0.04^{a}
	1% Inulin	0.75 ± 0.01^{c}	0.83 ± 0.03^{b}	0.90 ± 0.01^{a}

	1% Gelatin	0.70± 0.01^{c}	0.73 ± 0.01^{c}	0.80 ± 0.01^{b}

Means ± standard deviations in a row and column in the same parameter with different alphabetical superscripts are significantly different ($p < 0.05$).

Based on the results in table 3, the titratable acidity of yogurts ranged between 0.70 and 0.80% after the manufacture, and the readings recorded increased as the storage period increased. The titratable acidity of yogurt with 1% inulin observed in the study was lower than the value (0.88%) reported by Balthazar *et al*., [19] for ovine milk yogurt with 1% inulin addition. This, in return, shows that the acidity does not differ much between yogurt utilizing ovine's milk and cow's milk.

As the titratable acidity increased, the pH of yogurt samples decreased during the 14-day storage period. Lactic acid bacteria such as *S. thermophilus* and *L. bulgaricus* contained in yogurt are active even at refrigerated temperatures, and they can ferment lactose to lactic acid, which results in a gradual decline in pH and increment of acidity [3]. The pH values were observed to have a continuous reduction for every yogurt sample from day 1 until day 14. The starting pH for standard, 1% inulin, and 1% gelatin are 4.53, 4.67, and 4.70, respectively. At the end of the 14-day storage period, the final pH recorded for the samples were 4.18, 4.32, and 4.57, respectively. The results were in line with Mudgil *et al*., [13]and Balthazar *et al*., [19], where the camel milk yogurts with gelatin, and sheep milk yogurts with inulin, respectively, experienced similar decreasing pH and increasing acidity trends.

3.4 Syneresis

Syneresis is one of the attributes that play an important role in determining the quality of yogurt. Table 4 shows variations of syneresis of yogurt samples during the 14-days storage period.

Table 4
Syneresis of yogurt samples during storage period

Parameter	Samples	Storage period (Days)		
		1st	7th	14th
Syneresis (%)	Standard	7.34 ± 0.48^{d}	9.34 ± 0.15^{b}	13.25 ± 0.86^{a}
	1% Inulin	4.35 ± 0.34^{e}	3.34 ± 0.23^{e}	8.02 ± 0.18^{c}
	1% Gelatin	2.30 ± 0.11^{f}	1.42 ± 0.17^{f}	0.90 ± 0.17^{f}

Means ± standard deviations in a row and column in the same parameter with different alphabetical superscripts were significantly different ($p < 0.05$).

Syneresis is a crucial factor that can cause primary defects in yogurt. Syneresis is the separation of the whey (liquid) from the coagulum (gel), resulting in the shrinkage of the gel and phase separation in yogurt [7-8,13,20]. The three-dimensional protein network is compressed, leading to a reduction of the protein binding power, thus resulting in the withdrawal of water from the yogurt during storage [9,21]. The addition of gelatin and inulin in low-fat yogurts helps minimise the syneresis effect.

Based on the result in table 4, it can be observed that the yogurts developed syneresis upon manufacturing, in which the standard at 7.34%, yogurt with 1% inulin at 4.35%, and yogurt with 1% gelatin at 2.30%. Both the presence of gelatin and inulin reduced syneresis with a significantly lower index ($p < 0.05$). However, the syneresis was still recorded for both yogurts fortified with inulin and gelatin, possibly because they were not yet appropriately mixed, as the samples only underwent freezing overnight. The samples were left for fermentation for 8 hours, and therefore, it was believed that they were not yet completely fermented and, hence, the milk gel was not yet solidified.

On day 7, noticeable declines in syneresis were observed in both yogurts with gelatin and inulin, while standard had comparatively higher syneresis over storage ($p < 0.05$). The presence of gelatin helps to amend the texture of low-fat yogurts, causing them to have a low probability of syneresis, which results in a stronger gel network and matrix of the yogurts [13]. Interaction between gelatin and the casein micelles in yogurt helps in the development of durable 3D networks, followed by the reduction of serum separation of yogurts [22]. Based on table 4, syneresis was influenced by the storage time. The longer the storage time, the higher the values of syneresis. Shahbandari *et al*., [21] reported that the measurement of syneresis from the first day up to the 14th day shows a downward trend, but the values increased after the 14th day to the 28th day.

Considering the increase in storage time, syneresis also increases, which is potentially caused by the hydrolysis and digestion of protein by the microorganisms in the yogurt. Consequently, the yogurt possesses an undesirable texture where it loses its property, and disintegration happens between the casein micelles with water. Both standard yogurt and low-fat yogurt with gelatin had a significant increment in syneresis index from the previous week. Only yogurt with 1% inulin was not affected by syneresis after an additional week of storage. This finding was in agreement with Zhou *et al*., [7], in which syneresis was observed to be lower in yogurts with a lower concentration of inulin (0.5% and 1%). Nevertheless, unlike the findings from the present study, Mudgil *et al*., [13] suggested that camel milk yogurt with a 1% gelatin addition had a lower syneresis throughout 2 weeks of storage. Gnanarathna *et al*., [15] demonstrated that a difference in inulin levels (1, 2, and 3%) in yogurts would contribute to different outcomes with respect to syneresis. 2% inulin showed the best effect in alleviating syneresis defects, whereas both 1% and 3% promoted syneresis [15].

3.5 Viscosity

Table 5 shows variations in the viscosity measurement of yogurt samples during the storage period. The viscosity of the samples for standard and inulin had an upward trend from day 1 to day 7, but the trend went downward from day 7 onwards until the end of the storage period. Meanwhile, yogurt with 1% gelatin recorded continuous increments starting from day 1 until the end of the storage period. The addition of inulin was observed to significantly decrease the viscosity of yogurt due to inulin being spread out within the casein micelles and obstructing the formation of the protein matrix, which results in the formation of a weak gel [7,15]. A decrease in the pH of yogurt with the addition of inulin can also influence the viscosity of yogurt. The isoelectric point of casein is 4.6; therefore, a decrease in pH will increase the distance from the isoelectric point and reduce the stability of protein, which results in a reduction of the curd stability [23].

Table 5
Viscosity measurement of yogurt samples during storage period

Parameter	Samples	Storage period (Days)		
		1st	7th	14th
Viscosity (cP)	Standard	2352 ± 2.12^{e}	2200 ± 15.67^{e}	2012 ± 8.90^{e}
	1% Inulin	2479 ± 15.56^{e}	3860 ± 56.57^{d}	2312 ± 141.42^{e}
	1% Gelatin	10095 ± 134.35^{c}	11260 ± 14.14^{b}	13500 ± 141.42^{a}

Means ± standard deviations in a row and column in the same parameter with different alphabetical superscripts were significantly different ($p < 0.05$).

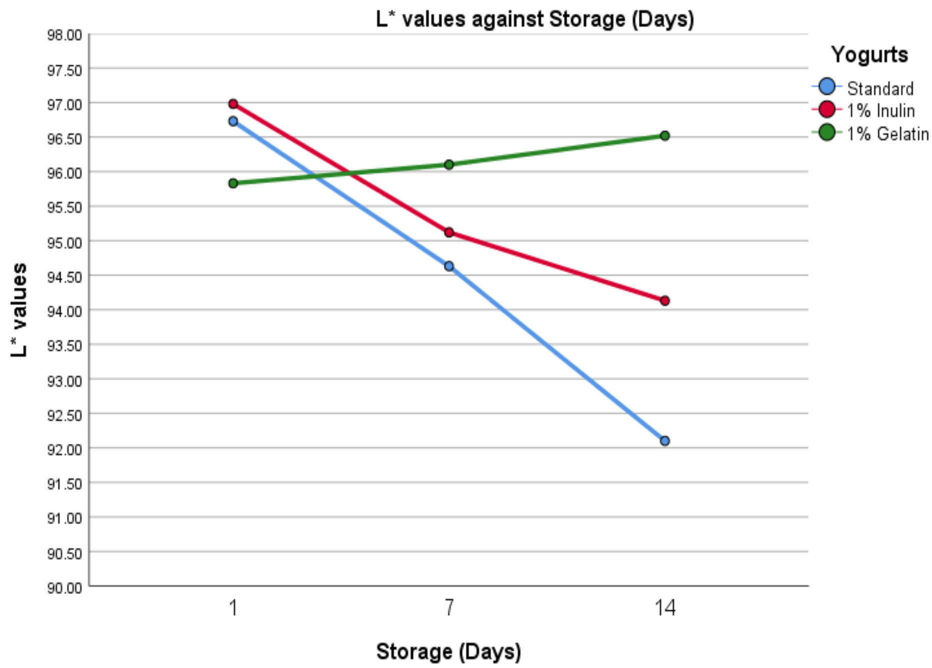
However, findings from other authors show that the incorporation of inulin in yogurt helps to improve the viscosity of yogurt. For instance, an increase in the viscosity of yogurt with the addition of inulin at 2 to 7% w/v was reported, which could be due to the total solids and properties of inulin that act as a thickener [24]. Shahbandari *et al*., [21] reported that as the storage period of stirred soy yogurt increases, the viscosity of stirred soy yogurt also increases. Upon storage, the binding of proteins with one another causes changes in the arrangement, which leads to an increase in the viscosity of yogurt during the storage period.

The protein content is the most important factor which influences the rheological and physical properties of yogurt. Increasing the amount of protein and relevant hydrocolloids increases gel firmness and decreases syneresis. Corresponding to this, Zhou *et al*., [7] indicated that the yogurts enriched with more polymerised whey proteins and less inulin showed a higher viscosity. This is in line with the results obtained where yogurt treated with gelatin had higher viscosity compared to standard and yogurt treated with inulin because of the higher protein content. Therefore, it can be related that syneresis is inversely proportional to viscosity, as the lower the syneresis, the higher the viscosity of yogurt.

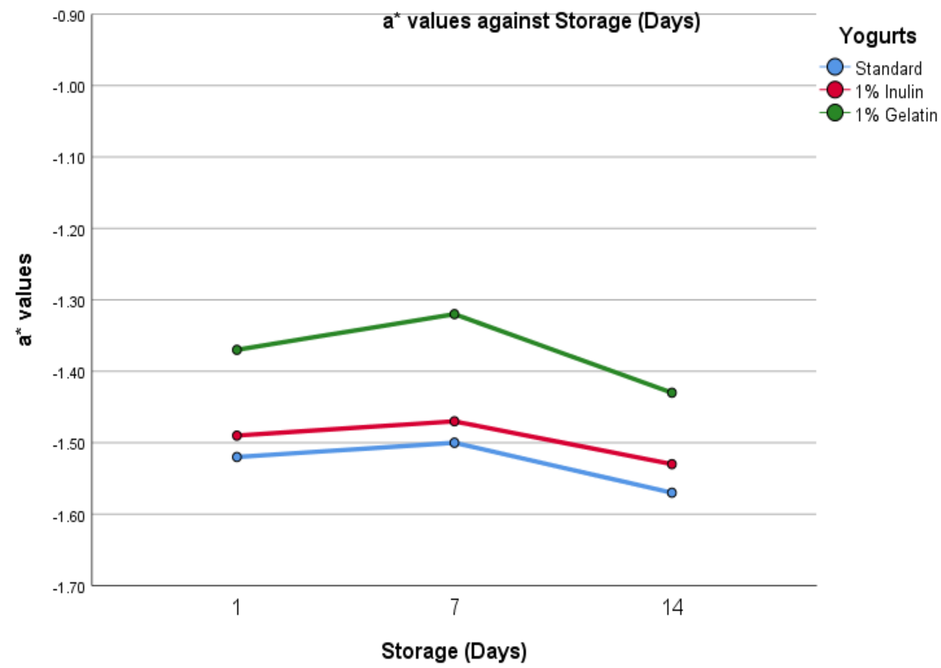
3.6 Colour

The changes in colour values of yogurt samples during the storage period are shown in Figure 1a, b and c.

(a)



(b)



(c)

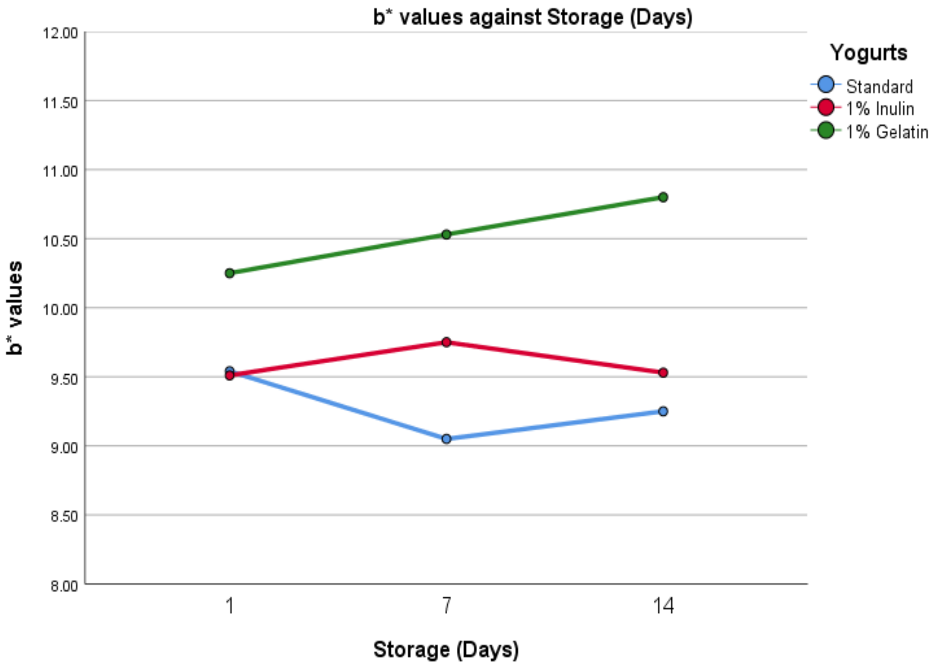


Fig. 1. The change in (a) L*, (b) a*, and (c) b* colour values of yogurt samples during the storage period

The L* values are defined as lightness, in which 100 represents white and zero represents black [16,20]. Based on the result in Figure 1a, the highest value of L* was observed in yogurt with inulin, followed by standard and yogurt with gelatin. As the storage period increased, L* values decreased in number except for gelatin. On day 7, L* values of yogurt with gelatin experienced an upward trend that lasted until the end of the storage period. This, in return, improved the appearance of yogurt as lightness was perceived as a desirable attribute in the appearance of yogurt.

Meanwhile, a* value is a difference in greenness-redness, given that a higher value defines redness while a lower value defines greenness [16,20]. Based on Figure 1, the standard has the lowest a* values, followed by inulin and gelatin. On day 7, the a* values for all the yogurt samples increased, but from day 7 to day 14, a downward trend was observed for the a* values.

A higher b* value indicates yellowness, while a lower b* value indicates blueness [16,20]. From Figure 1(c), the highest b* value observed was yogurt with gelatin. Upon fermentation and chilling, the yogurt started to turn yellowish, and prolonged storage gradually increased the values until the gelatin was completely spread out in the yogurt. During the storage period at day 7, b* values for inulin and standard experienced an upward trend, but the values then decreased until the storage period reached day 14.

3.7 Texture

The texture is an another important attribute in determining yogurt quality. Therefore, in this study, the hardness of yogurt at the end of the storage period was observed and tabulated in table 6.

Both gelatin and inulin enhanced the hardness value significantly as compared to the standard yogurt ($p < 0.05$), even if only a 1% level was added. Yogurt with 1% gelatin showed the highest reading, followed by 1% inulin and standard. This observation was in line with Mudgil *et al.*, [13], who reported that incorporating the gelatin level at 1.0% increased the hardness by as much as three folds, and the hardness will be further increased by seven-fold compared to that control camel milk yogurt if the gelatin level added was increased at 1.25%. Based on the data presented, the hardness of yogurt with 1.00% gelatin was 135 g, while at 1.25%, it was 301.3g [13].

Table 6
Hardness of different types of yogurts at the end of storage period

Parameter	Samples	Values
Hardness (g)	Standard	351.67^{c}
	1% Inulin	2353.33^{b}
	1% Gelatin	3433.33^{a}

Means ± standard deviations in a column in the same parameter with different alphabetical superscripts are significantly different ($p < 0.05$).

Meanwhile, Pancar *et al.*, [25] made a comparison of the addition of fish and cow gelatin to yogurt. Based on the observation of textural properties, hardness gradually increased during storage in all treated samples. The highest hardness value was determined in the cow gelatin added sample during the storage period [25]. Nevertheless, Helal *et al.*, [18] suggested that the addition of inulin reduced the hardness of yogurts during storage, which was different from the findings of the present study. Inulin can bind water in yogurts, creating a weaker protein gel network and contributing to lower hardness [18].

4. Conclusion

The hedonic responses of low-fat yogurts with added gelatin and inulin were successfully determined through sensory evaluation. Yogurt with inulin recorded the highest mean score for taste and aroma, while yogurt with gelatin recorded the highest mean score for texture. These results demonstrate that the addition of gelatin and inulin can significantly improve the sensory appeal of low-fat yogurt, enhancing consumer satisfaction. Additionally, the physicochemical properties of the yogurt were tested, and the results showed that the addition of gelatin and inulin did not cause any significant changes in pH or acidity. Yogurt with gelatin exhibited a notable reduction in syneresis from day 1 to day 14, while the reduction in syneresis in yogurt with inulin was less pronounced but still comparable to the standard yogurt. Regarding viscosity, only yogurt treated with gelatin showed an upward trend over the storage period, while yogurt with gelatin and the standard yogurt both experienced a downward trend from day 7 to day 14.

In conclusion, the addition of 1% inulin and 1% gelatin has a significant positive impact on the sensory attributes and quality of low-fat yogurts. These findings suggest that inulin and gelatin have potential as stabilizers in yogurt manufacturing. To optimize the formulation, it is recommended that the percentage of gelatin be limited to 1% (w/v) and inulin to 2% (w/v), as higher concentrations had a negative effect on both sensory and physicochemical properties.

While consumer acceptance was evaluated, further consideration of how these findings could inform yogurt production standards and align with market trends is needed. Understanding consumer preferences can guide manufacturers in developing formulations that meet the growing demand for healthier, functional dairy products. To build on this research, future studies should explore sensory descriptive analysis to better understand the sensory profiles of low-fat yogurts. Sensory descriptive analysis could be correlated with instrumental analysis, providing more in-depth insights into the product's characteristics. Additionally, microbiological evaluation should be incorporated to assess the shelf life of yogurt and determine whether the presence of gelatin and inulin contributes to extending the product's shelf life. These studies would enhance the practical implications of the research and help refine yogurt production processes, benefiting both consumers and manufacturers.

Acknowledgement
The authors are grateful to the Faculty of Food Science and Nutrition, Universiti Malaysia Sabah for the facilities provided.

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