Utilizing of the Guar Gum for Improving the Physiochemical, Rheological and Sensory Properties of Low-Energy Mozzarella Cheese

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Abstract

This study aimed to use the Guar Gum as a fat replacer and study its role for improving the physicochemical, rheological and sensory properties of Mozzarella cheese. The Guar Gum added to skimmed milk in different proportions 0.1%, 0.2%, 0.3%, 0.4% and 0.5% as A1, A2, A3, A4 and A5 treatment, respectively. In addition, there was the positive control C+ treatment, which made from whole milk and negative control C− treatment that made from skimmed milk without β-glucan. The chemical analyses were involved moisture, protein, fat, lactose, ash, soluble nitrogen and non-protein nitrogen as well as the physical analysis which involved the total acidity, pH, compression and elasticity were made. Besides, the sensory evaluation was conducted after processing directly and during storage at (5±1) °C for 150 days. The results indicated that the Guar Gum treatments had a high moisture content than C+ and C− treatment, which they were 48.66 and 51.40 %, while it ranged from 54.5% to 58.80% for Guar Gum treatments, when moisture contents was follow up during storage at (5±1) C for 150 days, the results indicated a significant reduction for all the treatments values. Fat content decreased significantly in all skimmed milk Guar Gum treatments but the lactose percentage was converged in all treatments. In addition, the Guar Gum was improved the rheological tests (compression and elasticity) of produced cheese as compared with C− treatment. The Guar Gum could increase the yield of cheese and improve the sensory properties of low-fat Mozzarella cheese as well as decrease the energy value of that cheese.

Keywords: Guar Gum, Sensory Properties, Low-Energy, Mozzarella Cheese

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Introduction

The consumer has become more aware and perception of the link between diet and healthy food, so the demand has started to increase of manufacture functional foods in, which natural alternatives used for providing a specific health benefit (Rinaldoni et al., 2014). Nowadays, global markets geared towards fulfilling consumer desires to provide functional foods with health benefits (Renda et al., 2015). The positive impact of functional foods encourages food producers to develop a new products that possess healthy properties that made a face challenge of identifying the type and nutritional value of these alternatives as well as its efficiency of functional properties (Stephen et al., 2017). Fat plays an important role in food as well as the main contributor to highlighting the flavor, consist of, texture, and consistency. Reducing or removing fat with maintaining sensory quality and consistency is the biggest challenge for food producers (Wu et al., 2013). The studies have shown that the removal of fat from dairy products negatively affected on its consist of and texture (Lukman et al., 2016). Therefore, the recent studies have tended to add some substances as substitutes for fats was called lipids similar (Fatmimetic) that could improve the rheological characteristics of the products. The fat substitutes possess a chemical composition differs to that of fats, but it possesses physical properties similar to fats when added to food products which provided the smooth texture and creamy taste in the mouth and viscosity that suit the quality of the manufactured product (Food Safety Network, 2014).

Dietary fibers were commonly use in recent years which including beta-glucan due to its a great ability to act as primary stimuli, prebiotic, and to increase immunity, reduce cholesterol and sugar in the blood, in addition its effects in reducing weight and cancer when they used as alternatives of fats in some food products (Knud et al., 2017). The cereals contain different types of soluble and insoluble fibers such as oats and barley contain a high proportion of insoluble fibers including Guar gum, which are water-loving colloids, high viscosity and fermented in the intestine by the intestinal flora, so they used as a good sources for producing free fat functional foods (Vlatrka et al., 2011). The Guar gum was utilized for improving the texture and the consist of cream cheese as well as the guar gum was improved the taste, flavor and viscosity of the juices (Ningtyas et al., 2017 and Steven, 2015). In recent years, many studies had conducted on the manufacture of different types of low-fat cheese such as mozzarella, cheddar, kashkaval and Edam. Therefore, the recent trends in the use of fat substitutes in
the dairy industry due to its good functional properties as well as their nutritional properties as some of them contain high levels of biologically active compounds, in addition to their effective role in reducing energy, strengthening the immune system, lowering cholesterol and improving the strength and texture of many free or low-fat dairy products (Maarten et al., 2015). Thus, the dairy products made from whole milk affect the health of the consumer and that the process of removing fat affects the consist of and texture of these products (Renda et al., 2015). Therefore, the current study was conducted and aimed to use the fat substitutes represented by Guar gum as substitutes of fats in free-fat mozzarella cheese and studied its effect on the physiochemical and biological properties of final product.

Materials and methods

Materials

The use of full-fat raw cow's milk mixture in the manufacture of mozzarella cheese as the positive control treatment, as well as the skim milk was used in the manufacture of cheese as a negative control treatment. The cheese of treatments A1, A2, A3, A4 and A5 provided from dairy laboratory - College of Agricultural Engineering Sciences - Baghdad University. The microbial rennet was used in the manufacture of cheese produced by the Danish company Chris Hanson.

Methods

Processing of mozzarella cheese

Mozzarella cheese was manufactured according to the method mentioned (Fox et al., 2017a), where a quantity of raw cow's milk (mixture of bulk milk) was received from the dairy factory - College of Agriculture - University of Baghdad. Then, the raw cow's milk was divided into two treatments, the first treatment was left untreated (full fat milk) and used in the manufacture of C+ cheese (control) treatment and the second treatment (skim milk) was divided into two parts, the first part was left without any treatment and was used in the manufacture of cheese of negative control treatment (C\textsuperscript{-}), while the second part, the Guar gum was added as an alternative fat in the proportions 0.1\%, 0.2\%, 0.3\%, 0.4\%, and 0.5\% as A1, A2, A3, A4 and A5 treatment, respectively. Then, all the milk treatments
were homogenized, and pasteurization process was conducted at a temperature 63 °C for 30 min, and cooled at 25 °C. The citric acid was added to the all treatments until reaching the PH 5.3, then the temperature was gradually raised and the microbial rennet (Caimosin enzyme) prepared from the Danish company Chris Hanson was added after dissolving it with distilled water according to the instructions of the producing company and left half an hour until the coagulation occurred. Then, the coagulation was cut longitudinally and accidentally and left for 5 minutes without stirring and he discharge of the whey. After that, the temperature raised gradually with slow stirring until reaching 48-49 °C. Then the coagulation collected and served inside the hot whey until it became a ball. Then put it in water at a temperature of 9-11 °C. Then the cheese was salted with 15% salt solution for ten hours, then kept in the refrigerator at a temperature of 1 + 5 °C with vacuum bags and taken part of it to take the necessary tests after 1, 14, 30, 60, 90, 120 and 150 days of storage.

Sensory evaluation

Sensory evaluation for mozzarella cheese treatments were conducted in the Department of Food Science-College of Agricultural Engineering Sciences- University of Baghdad by a number of professors with specialization according to the sensory evaluation form used by (Edam, 1998).

Physicochemical analysis of mozzarella cheese

The proportion of moisture, protein, fat, ash, pH and total acidity in cheese were estimated according to the method mentioned in (Bradley, 2010) and the fat proportion was estimated according to (Min and Ellefson, 2010).

Rheological measurements of mozzarella cheese

1. Examination of compressibility
The pressure strength of cheese models under study was estimated using a special uniaxial compression device. It is equipped with a cylinder with a diameter of 49 mm that measures the small parts of Newton units with some modifications (Shendi, 2012). The cheese sample cut in a cylindrical shape with a diameter of 2.4 cm and a height of 1.6 cm at a temperature of 6 °C. In order to prevent moisture loss from the sample, it placed in an airtight container. Then it took out and saved at room temperature for four hours before testing, put it in the machine and put pressure on it by dropping the non-axial compressor on it at a speed of 50 mm. One minute until the sample is broken, and the reading recorded in Newton units.

2. Examination of elasticity

The elasticity of cheese models using the known weightlifting method was estimated by placing the cheese sample on the support of the scale corresponding to the scale and putting weights on it with fixed weights and calculating the compression distance at which the descent stops and the time required for that. Then the weights are lifted and the time required for the sample to return to its original position is calculated before compression.

3. Examination of solubility

This test was conducted according to the method described by (Kosikowski and Mistry, 1999), the cheese treatments with a diameter of 10 mm and a thickness of 10 mm were inserted into the oven at a temperature of 90.6 °C for 3 minutes and measured the average diameter.

4. Examination of elongation

The elongation of cheese treatments was measured after cut to 10 x 10 mm to match the device's operation. As for measuring the susceptibility of cheese treatments to elongation, the samples were cut with a sharp and hollow tool to obtain cylinder-shaped samples measuring 30 x 10 mm. The sample
was fixed to the device and the metal base to measure the elasticity of the device and pressure was applied to it to measure the resistance of the sample to elongation (AL-Darwash et al., 2014).

Cheese yield calculation

The cheese yield was calculated by the weight of the resulting cheese mass to the weight of the milk used (Kosikowski and Mistry, 1999), as in the following equation

\[
\% \text{ cheese yield} = \frac{\text{cheese (g)}}{\text{milk (g)}} \times 100
\]

Statistical analysis

The Statistical Analysis System (SAS, 2012) was used to study the effect of different parameters. Least significant difference (LSD) between the mean values of treatments were determined.

Results and discussion

Sensory evaluation of mozzarella cheese treatments
From the results, the high scores granted to the cheese incorporated with guar gum as compared to the scores granted to the cheese C treatment (Table 1). It is also noted an improvement in the sensory properties by increasing the added percentage of the guar gum and reach to the best in the treatment (A2) with an added 0.2%. This is in line with Alnemr et al (2013), the deterioration of the sensory properties of low-fat kurash cheese free from fatty alternatives. The results also agreed with his findings Sipahioglu et al (1999), which noted that the positive control treatment of C+ soft cheese made from whole milk exceeds the superiority of the negative control treatment C- made from skim milk in the sensory evaluation.

Table 1: Sensory evaluation of mozzarella cheese treatments during storage period at (5 ± 1) °C for 150 days.

* Each number in the table represents an average of triplicate.

*A1= low fat mozzarella cheese incorporated with 0.1% guar gum, A2= low fat mozzarella cheese incorporated with 0.2% guar gum, A3= low fat mozzarella cheese incorporated with 0.3% guar gum, A4= low fat mozzarella cheese incorporated with 0.4% guar gum and A5= low fat mozzarella cheese incorporated with 0.5% guar gum.
Physicochemical analysis of mozzarella cheese treatments

1. Moisture analysis

In Table 2, there are two differences between the moisture proportions of the cheese C+ treatment and the treatment of the cheese containing the guar gum, high moisture levels were observed in the cheese containing the guar gum, and the low proportion of moisture for all treatments during storage were observed after 150 days for the C+ and C− treatment were 0.44% and 22.47%, respectively. Whereas, the moisture values immediately after manufacture for the C+ and C− treatment were 48.66% and 51.40%, respectively. As for the treatments were added the guar gum, the moisture for A2 treatment was 58%, and this was consistence with Al-Badrani (2017) which indicated a decrease in the moisture content of soft cheese with progress in the storage period.

2. Protein analysis

The results of the statistical analysis showed there was a significant difference (P<0.05) between the C+ treatment and the treatment that containing the guar gum, the treatment that containing the glue gum reached 20.03% of protein immediately after manufacturing. The protein proportion for C+ and C− treatment were 26.1% and 88.28%, respectively immediately after manufacture. In addition, it also noticed in Table (2) that the proportion of protein increased during storage for all treatments after 150 days of storage such as C+ and C− were 27.50% and 29.9% with the treatment that containing guar gum was 21.20%, respectively. The reason for the high percentage of protein during storage is probably due to the loss in moisture, which leads to an increase in the proportion of total solids, including protein. The results were consistent with Scattar et al (2015) which indicated a high level of protein in negative control cheese (C− treatment) which free from additives that alternative of fat, as protein becomes the dominant and constitutes the largest percentage of total solids in the absence of fat.

3. Fat analysis

The percentage of fat for C+ and C− treatment were 21.50% and 00.2%, respectively, the Table (2) also showed the presence of significant differences (P <0.05) in the fat percentage between the C +
treatment and the cheese treatment that containing the guar gum, whose percentage immediately after manufacturing was 2.00%. The results also noted that the percentage of fat increased for all treatments and storage periods, so after 150 days of C+ and C− treatment were 22.70% and 3.1% and the cheese treatment that containing guar gum was 2.30%, respectively. These results were corresponded with Al-Jasser and Al-Dogan (2009), they indicated that the high percentage of fat in Domiaty cheese during storage due to whey exudation and low moisture which lead to the high percentage of total solids.

4. Ash analysis

The results noted that there is an increase in the proportion of cheese ash for the treatment that guar gum was added as compared to the C+ and C- control treatments. As the proportion of ash was 1.80 and 1.65% as C+ and C- treatment immediately after manufacturing. Whereas, the ash proportion in the treatment of cheese that had the guar gum was 2.55%, respectively due to the effect of guar gum as fat alternative, which leads to a high ash content of the cheese (El-Baz, 2013). It is also noticed from the table (2), the high proportion of ash during storage and also for all treatments such as after 150 days for the C+ and C- treatment were 3.50 and 2.80% as well as for the cheese that incorporated with guar gum was 3.30%, respectively.

Table (2): Physicochemical analysis of Mozzarella cheese treatments during storage period at (5 ± 1) °C for 150 days.

*C+ = Positive control cheese, C− = Negative control cheese, A2= low fat mozzarella cheese

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Mozzarella cheese age (days)</th>
<th>Moisture %</th>
<th>Protein %</th>
<th>Fat %</th>
<th>Ash %</th>
<th>PH</th>
<th>Total acisity %</th>
</tr>
</thead>
<tbody>
<tr>
<td>C+</td>
<td>0</td>
<td>48.66</td>
<td>26.10</td>
<td>21.50</td>
<td>1.80</td>
<td>5.42</td>
<td>0.50</td>
</tr>
<tr>
<td></td>
<td>150</td>
<td>44.00</td>
<td>27.50</td>
<td>22.70</td>
<td>3.50</td>
<td>4.60</td>
<td>0.77</td>
</tr>
<tr>
<td>C−</td>
<td>0</td>
<td>51.40</td>
<td>28.88</td>
<td>2.10</td>
<td>1.65</td>
<td>5.32</td>
<td>0.61</td>
</tr>
<tr>
<td></td>
<td>150</td>
<td>74.22</td>
<td>29.90</td>
<td>3.10</td>
<td>2.80</td>
<td>4.80</td>
<td>0.87</td>
</tr>
<tr>
<td>A2</td>
<td>0</td>
<td>55.00</td>
<td>20.03</td>
<td>2.00</td>
<td>2.55</td>
<td>5.50</td>
<td>0.45</td>
</tr>
<tr>
<td></td>
<td>150</td>
<td>58.50</td>
<td>21.20</td>
<td>8.10</td>
<td>3.30</td>
<td>5.00</td>
<td>0.70</td>
</tr>
</tbody>
</table>

incorporated with 0.2% guar gum.
5. **PH value analysis**

The results in table (2) showed, there are no significant differences in pH values between different cheese treatments. The pH value immediately after manufacture for the treatment C+ and C- was 5.42 and 5.32, and its value for the treatment of cheese containing guar gum was 5.50, respectively. It is also noticed that the pH values decreased during storage, the C+ and C- treatment were 4.60 and 4.80 for 150 days, respectively, and the cheese treatment which contained the guar gum was 5.00, respectively. Therefore, the results of the statistical analysis indicate that there are significant differences within a single treatment between the beginning and end of the storage period for all treatment.

6. **Total acidity analysis**

The proportions of total acidity for the treatment C+ and C- were 0.77% and 0.87% for 150 days of storage, and the treatment of cheese that incorporated with guar gum was 0.70%, respectively (table 2). The total acidity immediately after manufacture for the treatment C+ and C- were 0.50 and 0.61%, and the cheese of the treatment containing guar gum was 0.45%, respectively due to the part of lactose sugar was converted to lactic acid in the end of storage stage. Finally, the results showed that there are no significant differences in the values of total acidity between the first and last day of storage for all treatments.

The addition of guar gum to mozzarella cheese as 0.2% provided the best result compared to the other treatment. The results also noted that the scores granted to the most properties with the progress of storage. These results consistent with Hamad and Ismail (2013) they found that all the sensory characteristics of soft cheese gradually diminished with the advance of storage. Finally, the results of the statistical analysis indicated that there were no significant differences in the degrees granted to all properties and for all treatments on the first day. However, with the advancement of the storage periods, the cheese treatments added to the guar gum, especially the 0.2% treatment was the best treatment in sensory characteristics.
Rheological measurements of mozzarella cheese

1. Compressibility of mozzarella cheese treatments

The figures (1,2 and 3) showed the results of the hardness test for C + treatment cheese made from whole milk and negative C- treatment cheese made from skim milk and A2 treatment cheese was added with 0.2% guar gum for 150-days of storage period. The figure (1) showed there are clear differences of force applied for the different cheese samples; this indicated the difference in its hardness according to its chemical composition, the type of milk was used in its manufacture and the type of alternative substance for fat. It was noted that the hardness of the negative control cheese treatment (C-) was higher than the hardness of the positive control cheese treatment (C +) and the hardness of the cheese treatment incorporated with guar gum. The results were consistent with Zisu and Shah (2005) they found the hardness of skim milk of mozzarella cheese was higher than the treatments was added with fat alternatives represented by extra-polysaccharide. The results were also corresponded with Al-Hadithi (2015), which found that the braids cheese made from skim milk had a higher hardness than the cheese incorporated with plant fat-based alternatives represented by 0.25% of CMC and guar gum.

![Figure 1](image_url)

**Figure 1** The force required to compress of cheese samples produced from full fat milk (C +) during storage at (5 ± 1) °C for 150 days
In addition, the fat grains in low-fat cheese were little and small in comparison with the fat grains in full fat cheese (Sipahioglu et al., 1999).

Figure 2 The force required to compress of cheese samples produced from skim milk (C -) during storage at (5 ± 1) °C for 150 days

Figure 3 The force required to compress of cheese samples produced from skim milk incorporated with guar gum (A2) during storage at (5 ± 1) °C for 150 days

2. Elasticity of mozzarella cheese treatments

Figures (4,5,6) showed the results of the susceptibility of cheese test to resistance weights placed on for a fixed period of time and to return to its original position that it was before shedding weights immediately after manufacture for the C +, C- and A2 cheese treatment. The figures noted, there were clear differences in the time that take for the return of the different cheese samples to their original
position and therefore their differences in the degree of elasticity they possess, which was affected by their chemical composition, the type and quantity of the alternative material for added fat. It noted that the negative control treatment (C−), took a longer time to return to normal, compared to a positive control treatment (C+) that took shorter time to return to its original state. These consistence with Koca and Metin (2004) of the high elasticity of fresh full-fat Cashar cheese treatment as compared to the low-fat treatment made from skim milk due to the high protein content of this treatment is made from skim milk, which gives it a compact and rough protein template in which the spongy nature that the presence of fat gives in the protein template, as in the case of treatment C−, that makes it easy to return the cheese block to its original position. The figure also showed, the high elasticity of cheese treatment with added A2 guar gum, thus shortening the time for its return to its original position as compared to the negative control treatment.

**Figure 4:** Time required to Measure the elasticity of the cheese samples produced from full fat milk (C+) during storage at (5 ± 1) °C for 150 days.
This is consistent with Al-Badrani (2017) he found that manufacturing of soft cheese using fat substitutes such as CMC and anolene added as 0.2% and 2%, respectively, took less time to return to normal state as compared to a negative control treatment that took a longer time to return to its original state.

3. Solubility of mozzarella cheese treatments

Solubility is one of the distinguishing characteristics of this cheese type that preferred by the consumer in the production of pies, pastries and pizza. One of the assistant factors of melting cheese is the low pH and heat, the cheese turns from solid to dissolve. The figures 7, 8 and 9 showed, the guar gum improved the solubility of mozzarella cheese by increasing the moisture levels of the cheese treatments as compared to the (C') treatment, the results showed that the A2 treatment had the highest melting value as compared to the (C') treatment due to its active role in preserving moisture. McMahon et al (1996) indicated that the addition of polysaccharides in the production of low-fat mozzarella was improved its solubility properties, as raising the moisture content in cheese has a direct role in

improving solubility. This variation in solubility values attributed to the susceptibility of the materials in their holding of moisture, so that the moisture has an effective role in improving the solubility of free fat mozzarella cheese. These results were corresponded with Al-Hadithi (2015), who concluded that the addition of vegetable-based fatty substitutes improved the solubility of mozzarella cheese as compared to the negative control treatment.

![Figure 7: Solubility of positive control treatment after manufacture (C+) and during storage at (5 ± 1) °C for 150 days.](image1)

![Figure 8: Solubility of negative control treatment after manufacture (C-) and during storage at (5 ± 1) °C for 150 days.](image2)
4. Elongation of mozzarella cheese treatments

The figures (10, 11 and 12) showed, the fat substitutes had improved the texture and smoothness of the A2 treatment and its ability to elongate in varying proportions as compared to the negative control treatment, which was characterized by the weak ability to elongate as it required a higher weight for the purpose of elongation compared to the A2 treatment. It is possible to determine the quality of mozzarella cheese by its ability to elongate with some effects such as temperature, pH, and storage period was included (Ak and Gunasekaran, 1995). The results are consistent with the findings of Al-Hadithi (2015), who found that adding CMC, Guar gum, and C. sebestena improved the texture and softness of the coagulation and its ability to elongate compared to the negative control treatment.
**Figure 10** The force required to elongate the positive control (C+) treatment during storage at (5 ± 1)°C for 150 days.

**Figure 11:** The force required to elongate the negative control (C-) treatment during storage at (5 ± 1)°C for 150 days.
Cheese yield calculation of mozzarella cheese treatments

The results showed the proportion of the yield in C + treatment after manufacture immediately was 10.0% (Table 3). These results are corresponded with Naththal (2012) he indicated that the yield of soft cheese made from whole milk was 12.78%. The results also noted, the statistical analysis showed there were significant differences (P <0.05) between the proportion of the cheese treatment C + and the treatment C− around 8.50% due to the cheese treatment C− is made from skim milk where the fat contributes a large percentage of the yield. The cheese made from skim milk characterized by a low percentage of its yield content due to a decrease in its total solids content, while the additives and according to its quantities added to the milk intended for the cheese industry in increasing its yield rate (Scott et al, 1998). On the other hand, it also noted there are significant differences between A2, C+ and C− treatment, which immediately reached 12.0% after processing. The results are consistent with Al-Hadithi (2015) he stated that the use of carbohydrate fat alternatives represented by CMC and guar gum and sebestenaC, when making low fat mozzarella cheese, which contributed for raising the yield percentage of cheese as compared with control treatment cheese, where the yield percentages of the mozzarella cheese made from skim milk incorporated with above fat substitutes were 13.13%, 12.84% and 10.33%, respectively as compared to the negative control treatment was 9.73%. The results also agreed with Al-Badrani (2017) who used fat substitutes represented by CMC and inulin in the manufacture of low-fat soft cheese, which contributed for raising the yield percentage of the cheese as
compared to the positive and negative control treatment, where the yield rate of positive and negative control treatment were 12.5% and 8.75%, respectively, whereas the treatments which incorporated with inulin and CMC were 18.25% and 15.13%, respectively. In conclusion, the results noted that the cheese treatment incorporated with guar gum (A2) had the best yield ratio in comparison with other treatments.

Table 3: The yield proportion of mozzarella cheese treatments

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Yield%</th>
</tr>
</thead>
<tbody>
<tr>
<td>C+</td>
<td>10</td>
</tr>
<tr>
<td>C-</td>
<td>8.5</td>
</tr>
<tr>
<td>A2</td>
<td>12</td>
</tr>
</tbody>
</table>

* Each number in the table represents an average of triplicate

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