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# Preparation and analysis of goat milk mozzarella cheese containing soluble fiber from *Acacia senegal* var. *kerensis*

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**Mozzarella cheese is one of the preferred ingredients for use in pizza. Goat milk is a good source of protein and calcium, possessing unique characteristics with a high proportion of small milk fat globules that contain a higher concentration of short chain, medium chain and polyunsaturated fatty acids than cow's milk. Its use in mozzarella cheese can therefore impart significant health benefits to consumers. However, despite these unique qualities, goat milk is underutilized in Kenya. Gum arabic is an excellent source of soluble dietary fiber, which can be used to boost fiber levels in cheese and other dairy products. Thus, the aim of this study was to investigate the feasibility of incorporating gum arabic as a source of fiber in goat mozzarella cheese without affecting the functionality of the cheese. Gum arabic powder at 2, 3 and 4% was incorporated into cheese during the salting process at room temperature (20 to 25°C). The functional properties of the cheese: stretchability, free oil formation and meltability were then determined. Sensory evaluation was conducted using 50 untrained sensory panelists on a 5-point hedonic scale. The results indicated that the use of gum arabic in mozzarella cheese up to a level of 3% improved the stretchability and meltability while reducing the free oil formation phenomenon. Texture, flavor, color and overall acceptability were also rated as best for samples containing gum arabic at a level of 3%. The results showed that the use of gum arabic can improve the functional properties, nutritional quality as well as sensory quality of goat milk mozzarella cheese.**

**Key words:** Gum arabic, dietary fiber, mozzarella cheese, goat milk, functional properties.

## INTRODUCTION

Cheese is an extremely versatile food product that has a wide range of flavor, textures and end uses. Cheese is a nutrient-dense food made from cows, buffalo, goats or sheep, by coagulation. Most cheese are not eaten alone

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but as part of another food. Cheese can be classified on the basis of the country of origin, fat content (milk type), texture, manufacturing technique, physical appearance like shape or moisture content. Mozzarella cheese belongs to a class of 'Pasta filata' family, which involves the principle of skilful stretching of the curd in hot water to obtain smooth texture in cheese. The cheese is soft, white, unripened, which may be consumed shortly after manufacture. The specific melting and stretching characteristics of Mozzarella cheese is highly appreciated in the manufacture of pizza in which it is a key ingredient (Atanu, 2001). Mozzarella cheese is a mild, white fresh cheese made by a special process where the curd is dipped into hot whey then stretched and kneaded to the desired consistency. At one point, mozzarella was made only from water buffalo milk. Now, it is usually made with cow's milk. There are two forms: regular and fresh. Regular mozzarella is available in low-fat and nonfat forms and has a semi-soft, elastic texture and is drier than fresh mozzarella. Fresh mozzarella is made from whole milk and has a softer texture and sweet, delicate flavor, and is typically packed in water or whey (Sulieman et al., 2012).

Mozzarella cheese has many health benefits; it is a good source of protein, vitamins and minerals. Consumption of mozzarella cheese may protect against gout, a painful condition that results in the buildup of uric acid crystals in the joints. The calcium found in mozzarella cheese also has its contribution in body weight loss and provides protection against breast cancer and metabolic syndrome, which is a group of conditions that increase the risk of developing heart disease or stroke (Ibrahim, 2003). Prevalence of obesity in the world has prompted the reduction of high fat diet consumption and an increase in the consumption of dietary fiber (Noronha et al., 2007). Increased awareness of people on fitness and healthy lifestyle has led to an increased demand for low-calorie foods in particular for low and reduced fat cheeses (Konuklar et al., 2004). Mozzarella cheese production has continually increased because of demand in the pizza industry as pizza toppings. It's clean, mild flavor, shredability, appealing melt and stretchability make it ideal for pizza. The increased use in pizza is raising health concerns because of its calorie dense nature (Kindstedt, 2004). Thus, despite cheese being a high fat diet, it is obvious that its demand is increasing and therefore, cannot be eliminated from the diet. Therefore, there is need for production of healthier cheese. As an ingredient in food, cheese is required to exhibit functional characteristics in the raw as well as cooked forms. Melting, stretching, free-oil formation, elasticity and browning are the functional properties considered to be significant for Mozzarella cheese. When a cheese is destined for its end use, some of its unique characteristics play a significant role in the products acceptability. Reducing fat, replacing fat with fat mimetics and enriching cheese with nutrients are some of the alternatives in this direction (McMahon et al., 1996; Mistry et al., 1996; Ryhänen et al., 2001). A reduction in fat content of cheese can be achieved by replacing it with several ingredients that provide the functionality of the missing fat. Hydrocolloids and carbohydrate-based fat replacers have been used safely as thickeners and stabilizers especially in dairy products such as sauces and dressing formulations. However, water-soluble additives such as soluble fiber tend to be washed away with whey (Lee and Brummel, 1990), further altering the composition of whey and resulting in less or no retention of that additive in cheese. Therefore, to make cheese a source of fiber, measures have to be taken not only to add fiber to milk but also get maximum retention in cheese (Fagan et al., 2006).

Gum arabic, an edible, dried, gummy exudate from the stem and branches of *Acacia senegal* is rich in non-viscous soluble fiber (Phillips and Phillips, 2011; Phillips et al., 2008; Doi et al., 2006). In Kenya, gum arabic is from *A. senegal* var. *kerensis*. In the food industry, gum arabic is used as an emulsifier, stabilizer and a thickening agent mainly in soft drinks, syrup, gummy candies and marshmallows as well as a source of soluble fiber in low calorie and dietetic beverages (Verbeken et al., 2003). Due to its low viscosity (300 cP maximum in a 1% solution), it can be used to boost fiber levels in a food or beverage without drastically altering the final viscosity. However, there are no studies on the utilization of gum arabic from *A. senegal* var. *kerensis* in goat milk mozzarella cheese.

Therefore, the aim of this study was to investigate the feasibility of enriching goat milk Mozzarella cheese with gum arabic from *Acacia senegal* var. *kerensis* as a source of fiber without affecting the functionality of this cheese.

## MATERIALS AND METHODS

The present study was conducted at the Guildford Dairy Institute, Egerton University, Kenya and Jomo Kenyatta University of Agriculture and Technology, Kenya.

Goat milk was obtained from the Tatton Dairy Unit at Egerton University while gum arabic was obtained from Isiolo, Kenya.

### Preparation of goat milk Mozzarella cheese at laboratory level

Ten liters of high quality goat milk was pasteurized at 63°C for 30 min and then cooled to 32°C. To adjust the pH to between 5.1 and 5.3, 16 and 18 g of citric acid was added. To enhance curd formation, 2 ml liquid rennet diluted with 40 ml of water was added. Curd cutting followed after 15 min to facilitate drainage of whey. The temperature was increased to between 43 and 45°C for another 15 to 30 min with continuous stirring. The whey was then drained and the curd hand squeezed to remove excess whey. This was followed by microwaving for 1 min, and then hand worked and stretched. Salting was done at 1.6% with addition of *A. senegal* var. *kerensis* powder at 2, 3 and 4% into the cheese. Finally, the curd was microwaved for 30 s and then worked into ovoid shapes (Zeng, 2004).

### Rheological properties

#### *Determination of meltability*

The modified Schreiber test was used to determine the meltability of cheese (Muthukumarappan et al., 1999). Five grams of cheese, 35 mm in diameter, 21-mm high disc, was heated in a forced-air convection oven (110°C) for 5 min. The sample discs were formed by boring the cheese blocks using a stainless-steel ring (35-mm i.d. and 25-mm high). The increased melted area (mm) in the cheese was determined using a graph paper. The ratio of the melted cheese area and original area was taken as an indicator of cheese meltability.

#### *Determination of stretchability*

Stretchability test was done according to Kosikowski (1982) as modified by Ghosh and Singh (1990). A sample of 10 g cheese was put in a 250 ml beaker containing ¾ of its volume of hot water maintained at 80 to 83°C in a water bath and held in the beaker for about 3 min. A glass rod was then inserted into the molten cheese sample and pulled out slowly after 3 turns by hand to ensure proper adherence of the product to the glass rod. Cheese thread formation was observed when the rod was gradually lifted. The length of the thread formed was measured in centimeters. Longer threads indicated better stretching characteristics. The length of the thread was taken as the stretchability parameter.

#### *Determination of free oil formation*

Free oil (FO) formation was determined following the modified Babcock procedure developed by Kindstedt and Rippe (1990). Eighteen grams shredded goat milk mozzarella cheese sample was weighed into 50% Paley-Babcock cheese bottles and placed in boiling water bath for 4 min to melt the samples. 20 ml of distilled water (57.5°C) was added and the samples centrifuged at 0.224 g (27.87π rads/s or 13.93 Hz) at 57.5°C for 10 min. A 1:1 mixture of methanol and distilled water was added to attain a final volume in the calibrated portion of the neck. The samples were centrifuged for 2 min and then rocked gently for 10 s to dislodge any trapped oil droplets. The bottles were centrifuged again for 2 min, rocked for 10 s, and then centrifuged for a final 2 min. The bottles were tempered in 57.5°C water bath for 5 min before addition of glymol to facilitate reading of the calibrated neck. FO was calculated as a percentage in cheese.

### Proximate analysis

The proximate chemical analysis of laboratory-made goat milk mozzarella cheeses were carried out to determine crude fiber, protein, moisture content and fat content. Crude fiber content was done following the Prosky method (AOAC Method 985.29), crude protein the AOAC method 920.123, moisture content following AOAC method 926.08 (AOAC, 2000) while the fat content was determined following the ISO 3433:2008 (IDF 222, 2008) method.

### Sensory evaluation

Sensory analysis was conducted using untrained panelists. A panel of 50 was selected to evaluate cheese on a 5-point hedonic scale rating, (5- like extremely, 4- like moderately, 3- neither like nor dislike, 2- dislike moderately and 1- dislike extremely) for appearance, texture, flavor and overall acceptability (Meilgaard et al., 2006).

### Statistical analysis

The experiment was laid out in a completely randomized design (CRD) with 3 replications. To increase precision, the experiment was repeated 4 times. Data on functionality tests, proximate analysis and sensory analysis were analyzed using Statistical Analysis System (SAS) package, version 9.1.3 (SAS, 2006). Analyses of variance were performed using Generalized Linear Model (GLM) procedure. Significant differences were determined at 5% level of significance and means separated using least significant difference (LSD) test to evaluate the influence of gum arabic addition on the functional properties and acceptability of goat milk mozzarella cheese. The data are presented as mean ± standard deviation.

## RESULTS AND DISCUSSION

### Effects of gum arabic level on the functional properties of goat milk mozzarella cheese

The results of functional properties of goat milk mozzarella cheese containing gum arabic from *A. senegal* var. *kerensis* are presented in Table 1.

#### *Meltability*

Meltability is the ability of cheese particles to flow in a continuous uniform melted mass (Kindstedt and Fox, 1993). Addition of gum arabic had non-significant effect ($P \geq 0.05$) on the meltability of mozzarella cheese. However, samples containing 4% gum arabic had the highest meltability value (Table 1). Thus, gum arabic has the potential of improving the meltability of mozzarella cheese when added at higher levels. According to Fife et al. (1996), low fat cheeses and part-skim mozzarella cheese do not melt. Reduction of fat content in mozzarella cheese reduces the meltability value. However, in this study, despite the reduction in fat content, there was no effect on the meltability value. This is possibly because gum arabic can give the functionality of fat in cheese. Thus, gum arabic at low levels can be used as a fat replacer with minimal alteration in meltability of mozzarella cheese. This is in agreement with Oberg et al. (2015) who used modified corn starch and xanthan gum as fat replacers in low fat mozzarella cheese where they improved the meltability of the resulting cheese.

#### *Free oil formation*

Free oil formation/oiling off is regarded as a defect of this

**Table 1.** Functional properties of goat milk mozzarella cheese containing gum arabic.

| Gum arabic level (%) | Meltability (mm) | Free oil (%) | Stretchability (cm) |
|---|---|---|---|
| 0 (Control) | 15.67 ± 1.27[a] | 5.92 ± 0.74[a] | 43.83 ± 0.75[c] |
| 2 | 16.43 ± 1.40[a] | 5.08 ± 0.86[ab] | 45.50 ± 1.38[b] |
| 3 | 16.60 ± 1.13[a] | 4.25 ± 0.61[bc] | 47.33 ± 1.21[a] |
| 4 | 16.73 ± 1.05[a] | 3.75 ±.52[c] | 41.33 ± 1.21[d] |

Means are presented as mean ± standard deviation. Means in the same column with different letters are significantly different ($P < 0.05$).

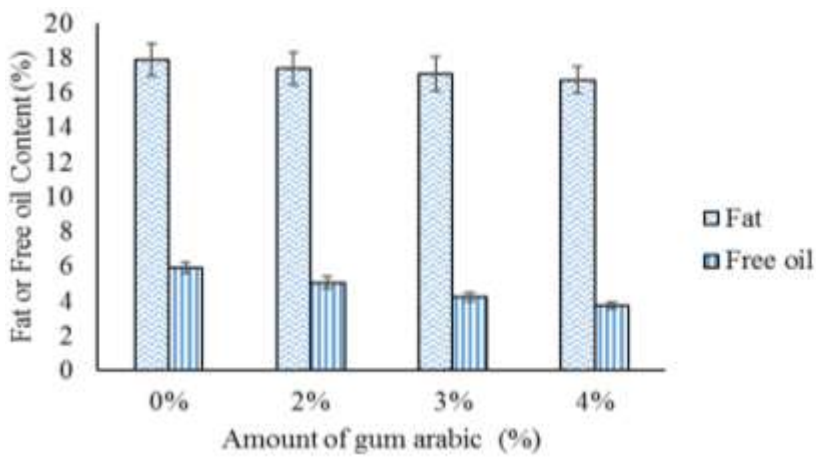


**Figure 1.** Comparison between the fat content and free oil formation in mozzarella cheese.

type of cheese when melted on the top of pie. The excessive free oil in Mozzarella cheese is of major quality problem. There was a significant decrease ($P < 0.05$) in free oil formation with an increase in gum arabic level (Table 1). Control samples had the highest free oil formation. However, this was not significantly different ($P \geq 0.05$) from the sample containing 2% gum arabic.

Comparison between the amount of fat and the free oil formation for goat milk mozzarella cheese containing gum arabic is shown in Figure 1.

There was a significant positive correlation ($r$ = 0.68283; $P$ = 0.0002) between free oil formation and the fat content of goat milk mozzarella cheese. It appears that, the slight reduction in fat content and increase in gum arabic level caused a significant ($P < 0.05$) reduction in free oil formation. Kindstedt et al. (1992) reported similar results when a little emulsifying salt was added to mozzarella cheese, resulting in a decrease in free oil formation. The addition of emulsifying salts to mozzarella cheese causes a change in the polymorphic framework of cheese due to the emulsifying properties of the salts (Tunick et al., 1989) and thus the decrease in the free oil formation. Gum arabic has been found to have both hydrophilic and amphiphilic properties that enhance its ability to bind water as well as fat in food products (Mugo, 2012; Ray et al., 1995; Randall et al., 1988). The reduction of free oil formation in goat milk mozzarella cheese containing gum arabic can be attributed to the emulsifying abilities of gum arabic.

### *Stretchability*

Stretchability is defined as the ease and extent to which melted Mozzarella can be drawn to form string (Gunasekaren and Mehmet, 2003). There was a significant increase ($P < 0.05$) in stretchability with gum arabic level increase up to 3%. In addition, increasing gum arabic level beyond 3% resulted in a decrease in stretchability (Table 1).

Similar results were observed when xanthan gum was added in mozzarella cheese. According to Oberg et al. (2015), xanthan gum functioned best as a fat mimetic, producing a low fat string cheese that most closely visually resembled commercial string cheese made using low-moisture part skim (LMPS) milk. Fat mimetics act through binding extra water, which creates a lubricity

**Table 2.** Proximate composition (%) of mozzarella cheese containing gum arabic.

| Gum arabic level (%) | Moisture | Protein | Fat | Fiber |
|---|---|---|---|---|
| 0 (Control) | 43.50 ± 3.22[a] | 28.28 ± 1.90[a] | 17.92 ± 2.29[a] | 0.00 ± 0.00[a] |
| 2 | 42.40 ± 1.63[a] | 27.32 ± 1.30[ab] | 17.42 ± 2.27[a] | 1.74 ± 0.16[b] |
| 3 | 42.01 ± 3.05[a] | 27.25 ± 1.07[ab] | 17.08 ± 2.40[a] | 2.44 ± 0.08[c] |
| 4 | 41.01 ± 1.91[a] | 26.07 ± 1.15[b] | 16.75 ± 1.94[a] | 3.41 ± 0.30[d] |

Means are presented as Mean ± SD. Means on the same column with the same letter are not significantly different ($P \geq 0.05$).

similar to full-fat products. However, they cannot replace the non-polar properties of fat such as flavor carrying capacity (McMahon et al., 1996). Gum arabic, a binder of moisture in dairy products (Mugo, 2012) was able to bind moisture in mozzarella cheese resulting in stretchability improvement in the final mozzarella cheese.

Further increase to 4% gum arabic significantly ($P < 0.05$) reduced the stretchability score. The stretch properties of mozzarella depend on the interactions between casein micelles. The more the casein network is interconnected, the more the cheese stretches. On the other hand, if the interaction between casein micelles is lost, the stretchability of mozzarella is decreased (Johnson, 2000). Adding more gum beyond 3% may have reduced the casein-casein interaction and thus the decrease in stretchability. Furthermore, according to Johnson (2000), fewer interactions would result in better melting properties which is observed at 4% gum level.

## Effect of gum level on the proximate composition of goat milk mozzarella cheese

The results of proximate composition of goat milk mozzarella cheese containing gum arabic are presented in Table 2. Addition of gum arabic slightly reduced the moisture content of the resulting mozzarella cheese although the difference was not significant ($P \geq 0.05$). Similar results were reported when xanthan gum was used as a fat mimetic in low-moisture part skim (LMPS) mozzarella cheese without any increase in moisture content (Oberg et al., 2015). The reduction in moisture content may be attributed to the low moisture content of gum arabic since the gum was incorporated in dry form. Further study can be conducted to utilize gum in solution form since it has shown an increase in moisture content when guar gum was added in solution form (Oliveira et al., 2011). The moisture content values of 45 to 52% (Table 2) are in the range of cheese classified as low moisture mozzarella cheese (Jana and Mandal, 2011).

The protein content of mozzarella cheese ranged between 26.07 ± 1.15 and 28.28 ± 1.90%. This was lower but comparable to the work of Osman et al. (2009) for cow milk mozzarella cheese. In their study, they reported the protein content of mozzarella cheese to be 23.33 ± 2.12%. There was a significant decrease ($P < 0.05$) in protein content with addition of gum arabic. Control samples with no gum had the highest protein content which was not significantly different ($P \geq 0.05$) from the samples containing 2 and 3% gum arabic. Addition of gum arabic to 4% resulted in more reduction in protein content, which was significantly different ($P < 0.05$) from the control sample. This was expected since gum arabic has very low protein content (4.55%) as compared to cheese. As shown in Figure 2, there was a decrease in the stretchability of the resulting cheese indicating a possible connection between the protein content and the stretchability of mozzarella cheeses. This is because the melt and stretch of cheese, are determined by the interaction of casein molecules (Lucey et al., 2003).

Addition of gum arabic in mozzarella cheese significantly ($P < 0.05$) increased the amount of dietary fiber in cheese. At 4% gum arabic level, highest significant ($P < 0.05$) fiber content was recorded to be 3.41 ± 0.30%. This is because of the high levels of fiber in gum arabic. Analysis of gum arabic used in this study showed that it had dietary fiber content of 78.099%. Since milk is deficient in dietary fiber, addition of gum arabic resulted in a significant increase in fiber levels in the resulting cheese. Therefore, the use of gum arabic in goat milk mozzarella cheese has the potential of not only reducing the fat content but also improving the nutritional quality of the cheese, thus making it healthier (Ryhänen et al., 2001).

## Effect of gum level on the sensory quality of goat milk mozzarella cheese

The results of sensory properties of goat milk mozzarella cheese containing gum arabic from *A. senegal* var. *kerensis* are listed in Table 3. Addition of gum arabic affected the sensory properties of goat milk mozzarella cheese. Texture rating was highest in the 3% gum arabic containing cheese with a mean of 4.00 ± 1.09 which was not significantly different ($P \geq 0.05$) from the one with 2% gum arabic. Further addition to 4% negatively affected the texture of the resulting cheese. According to Lobato-

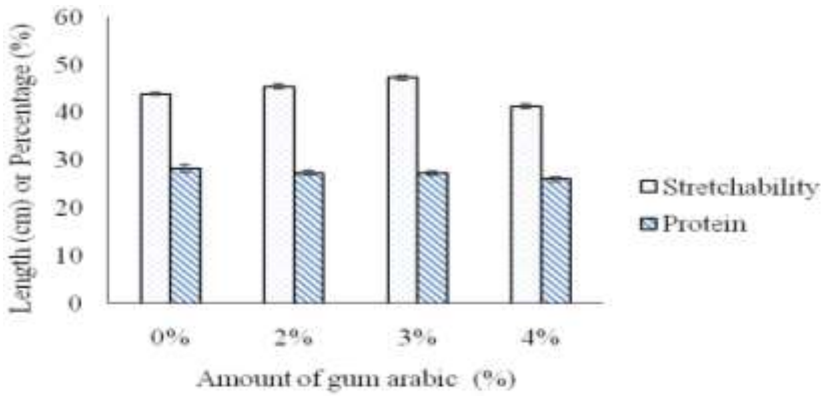


**Figure 2.** Comparison between the protein content and stretchability of goat milk mozzarella cheese.

**Table 3.** Sensory properties of goat milk mozzarella cheese containing gum arabic.

| Gum arabic level (%) | Sensory attributes | | | |
|---|---|---|---|---|
| | Texture | Flavor | Color | Overall Acceptability |
| 0 | 3.44 ± 1.30[b] | 3.38 ± 1.29[b] | 3.82 ± 0.96[ab] | 3.30 ± 1.40[b] |
| 2 | 3.94 ± 0.84[a] | 4.30 ± 0.91[a] | 4.02 ± 0.82[ab] | 4.08 ± 0.90[a] |
| 3 | 4.00 ± 1.09[a] | 4.16 ± 0.96[a] | 4.16 ± 0.68[a] | 4.06 ± 0.82[a] |
| 4 | 3.40 ± 1.14[b] | 3.70 ± 1.20[b] | 3.70 ± 1.04[b] | 3.80 ± 1.14[a] |

Means presented as mean± SD (standard deviation). Means on the same column with the same letter are not significantly different ($P \geq 0.05$).

Calleros et al. (2006) as fat content is reduced, more non-interrupted protein zones compose the cheese structure. Consequently, a high degree of cross-linking of protein molecules occurs, resulting in three-dimensional networks exhibiting high resistance to deformation. Oberg et al. (2015) indicated the use of xanthan gum at a level of 1% to improve the texture of mozzarella cheese as compared to control samples with no gum. In addition, the use of guar gum and gum arabic have been reported to improve the texture of cheese (Lashkari et al., 2008).

Flavor rating was highest in the gum arabic containing samples as compared to the control samples. Samples with 2% gum arabic were rated highest followed by 3% samples which were not significantly different ($P \geq 0.05$) from each other. Control samples and the sample containing gum at 4% were not significantly ($P \geq 0.05$) different although 4% samples had a higher rating. These results indicate an improvement in the flavor of the resulting product unlike the results of McMahon et al. (1996) who argued that a reduction in fat would affect the non-polar properties of fat such as flavor carrying capacity. However, these results are true when gum level was increased to 4%. It appears that the reduction of fat content in the 4% gum arabic containing sample affected the flavor carrying capacity of the fat. Other researchers have reported the ability of gum arabic to encapsulate flavors and aromatic compositions in food products (Kennedy et al., 2011) which may explain the retention of flavors in goat milk mozzarella cheese.

Color rating was highest at 3% gum arabic which was not significantly different ($P \geq 0.05$) from 2% and the control sample. The sample containing 4% gum had the lowest rating. According to Mistry (2001), low fat cheeses have undesirable color as compared to their full fat counterparts. Despite the minimal reduction in fat content, the rating for color was high for gum arabic sample at 3% addition. This means that, gum arabic can be used at this level with minimum effect on the color of goat milk mozzarella cheese. However, further addition seems to affect the color rating since more fat was replaced at 4% gum addition. Overall, samples containing gum arabic were significantly ($P < 0.05$) rated higher as compared to the control. Samples with 2% gum Arabic had the highest rating although not significantly different ($P \geq 0.05$) from the samples containing gum arabic at 3 and 4% in that order as shown in Figure 3. This means that gum arabic has potential for improving the appeal of goat milk mozzarella cheese. Similar results were

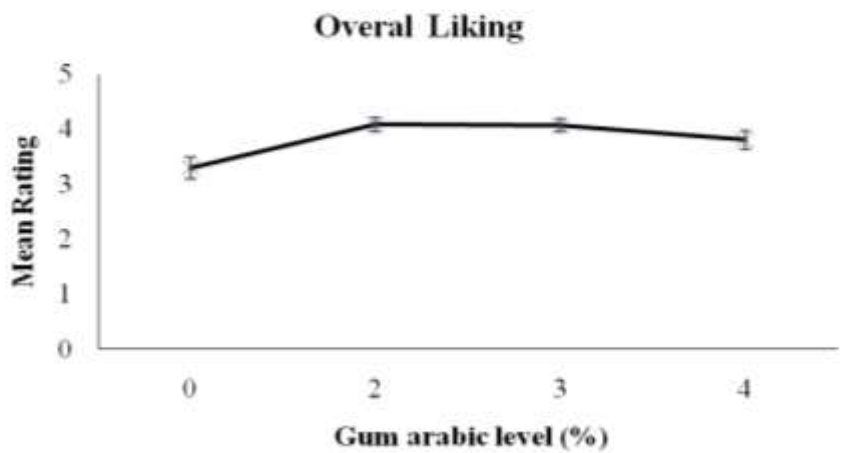


**Figure 3.** Overall acceptability of goat milk mozzarella cheese.

reported for other dairy products including yoghurt and ice cream (Mugo, 2012; Belitz et al., 2009).

## Conclusion

The results indicated that the use of gum arabic in goat milk mozzarella cheese up to a level of 3% improved the meltability while reducing the free oil formation. In addition, there was no significant effect in stretchability of mozzarella cheese. A significant reduction in protein content and an increase in fiber content of the resulting cheese was recorded. There was also a slight reduction in fat content as well as the moisture content of the resulting cheese. Texture, flavor, color and overall liking were best for samples containing gum arabic at a level of 3%. The results of this study indicate that the use of gum arabic has the potential of improving the functional properties as well as the nutritional composition of goat milk mozzarella cheese. The commercialization of the goat milk mozzarella cheese containing gum arabic from *A.cacia senegal* var. *kerensis* has the potential of improving the standard of living of communities in arid and semi-arid lands of Kenya where the raw materials are found. Incorporation of the gum in cheese will contribute to the sustainability of goat farming with the use of goat milk aiding in addressing the challenge of goat milk marketing. It is also worth noting that most of the goats are reared in arid and semi-arid lands where gum arabic is found, hence this work will contribute to their improved standard of living by creating a market for these produce.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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