The influence of ripening of semi-hard goat cheese in oil on its physicochemical composition and sensory properties

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ABSTRACT

The aim of this paper was to determine the influence of ripening of semi-hard goat cheese in oil (mixture of Mljet’s extra-virgin olive oil and refined sunflower oil; 50:50) on its physicochemical composition and sensory properties, as well as to determine the optimal time of immersion of the cheese in oil. Five batches of cheeses were produced, and the cheeses of the same batch were randomly divided into 3 groups according to the ripening method: (1) ripening in air (control group, treatment 1), (2) ripening in oil after 10 d of ripening in air (treatment 2), (3) ripening in oil after 20 d of ripening in air (treatment 3). Cheeses were sampled during ripening at d 0, 10, 20, 30, 45, and 60, and physicochemical analyses were performed. Oil as a ripening medium for cheese prevented water loss from the cheese (groups 2 and 3), and significantly lowest contents of dry matter, protein, fat, saturated fatty acids (SFA), unsaturated fatty acids (UFA), oleic acid, and salt were found in group 2. Group 3 had the highest contents of fat, SFA, UFA, and oleic acid. Prolonged ripening of the cheese in air before immersion in oil resulted in greater water loss and the formation of such cheese structure that allowed oil to penetrate the cheese. Water retention and oil penetration into the cheese altered the physicochemical composition of the goat cheese, having a significantly positive effect on the sensory characteristics, particularly color, texture, and taste, allowing the cheese to be consumed even when goat milk is not produced due to seasonality.

Key words: semi-hard goat cheese, ripening in oil, physicochemical composition, sensory properties

INTRODUCTION

Traditional dairy products are an important part of the modern diet, and by choosing traditional cheeses, consumers not only show their concern for nature, the origin of raw materials and products, but also contribute to the preservation of tradition and the promotion of economic development (Tudor Kalit et al., 2014; Miller and Lu, 2019), especially in areas with limited resources such as islands (Matutinović et al., 2007). A special group of traditional cheeses are goat milk cheeses, which can be traditionally preserved in oil. Traditional cheesemakers from the Croatian islands of Brač and Krk use olive oil for cheese preservation, whereas cheeses in southern Croatia—in the city of Dubrovnik and on the island of Mljet—are preserved in a mixture of olive and sunflower oil. The moment of immersion of the cheese in oil is not standardized. Cheeses from the islands of Brač and Krk continue to ripen in oil after at least 2 mo of ripening in air, whereas cheeses from Dubrovnik and Mljet are immersed in oil after 7 d of ripening in air (Caput et al., 2003; Barukčić and Tudor Kalit, 2019). Manchego, a Spanish hard cheese made from sheep milk, is often submerged in olive oil after 3 mo of ripening and kept in this medium until consumption (Ordoñez et al., 1978; Ordoñez and Burgos, 1980). The conditions during cheese ripening, such as temperature and relative humidity in the room and ripening media such as oil, animal skin, plastic or stone containers, brine or spices, control the physicochemical changes and biochemical processes of glycolysis, proteolysis, and lipolysis that can lead to characteristic sensory properties of the cheese (Ordoñez et al., 1978; Ordoñez and Burgos, 1980; Havranek et al., 2014; Tolentino Marinho et al., 2015; Tudor Kalit et al., 2020). Thus, cheeses ripened in the animal skin (Sir iz mišine, Tulum, Darfīyeh, Bouzeza) have a unique and piquant smell, taste, and aroma, which is a consequence of intense lipolysis and proteolysis during the specific ripening conditions in the skin (Tudor Kalit et al., 2020; Gün and Seydim, 2022). This implies anaerobic conditions (i.e., lower air permeability of the skin compared with the cheese rind [Tudor Kalit et al., 2014], but higher compared with plastic or stone containers) which serve as an alternative medium for ripening (Tarakçı and Durmuş, 2016). Moisture content is one of the most important parameters affecting the course of ripening and sensory characteristics of cheese (Havranek et al., 2014). For
example, animal skin has higher water permeability than a plastic container and lower permeability than the natural cheese rind, which affects the DM content in cheese and its sensory properties (Ceylan et al., 2007; Hayaloglu et al., 2007a; Tudor Kalit et al., 2014). Due to the constant moisture loss during cheese ripening, the intensity of biochemical processes decreases steadily. A higher moisture content in cheese leads to a better conformational structure of the enzyme, which intensifies the biochemical processes (Fox et al., 2017). Therefore, in terms of biochemical reactions, it is crucial to define the point at which the cheese stops ripening in air and continues ripening in oil.

The changes that occur during cheese ripening in oil are almost unexplored, except for 2 studies on the ripening of Manchego cheese in olive oil conducted more than 4 decades ago (Ordoñez et al., 1978; Ordoñez and Burgos, 1980). Knowledge about the influence of cheese ripening in oil on physicochemical composition and sensory characteristics is limited. Therefore, the aim of this research was to investigate the influence of ripening of semi-hard goat cheese in oil on its physicochemical composition and sensory properties and to determine the optimal time for immersion of the cheese in oil.

**MATERIALS AND METHODS**

Dairy products (semi-hard goat cheese) and an oil mixture (extra-virgin olive oil and commercial refined sunflower oil) were used for this study. Therefore, no ethical approval was required.

**Semi-Hard Goat Cheese Production**

Following the standard semi-hard cheese manufacturing technology, 5 batches of goat cheese were produced in the pilot plant of the Department of Dairy Science at the University of Zagreb Faculty of Agriculture (Croatia). Each batch of semi-hard goat cheese was produced from 100 L of raw whole goat milk (Saanen goat breed). The milk was collected during evening and morning milking and stored in a cooling tank at 4°C before cheese making.

The filtered milk (100 L) was heated to 31°C and then lysozyme (Lysozyme granular, Proquiga Biotech S.A., Spain: 5 g of lysozyme dissolved for 15 min in 1.5 dL of distilled water), freeze-dried mixed-starter cultures (Lyofast MT 096 FEN 5 UC, Sacco Srl, Italy: 1.352 g; 1/5 of sachet’s weight for 100 L of milk) and rennet powder (Caglificio Clerici Spa, Italy: 4 g of rennet powder dissolved for 10 min in 1.5 dL of distilled water) were added according to the manufacturer’s procedures and guidelines. After coagulation (setting time was between 50 and 60 min), the curd was cut into uniform walnut-sized grains with sharp edges using a cheese harp. The curd grains were heated to 39°C with constant stirring (stirring until the temperature was reached and stirring at a constant temperature for 30 min) and then evenly placed in the plastic molds and pressed with weights. After pressing and turning the cheese each time the weights were changed (2–3 h process) and a pH of 5.4 to 5.5 was reached, the cheeses were dry-salted, stored overnight in the refrigerator, washed in the morning, and subjected to ripening.

Cheeses of the same batch were randomly divided into 3 groups according to the ripening method: (1) ripening in air (control group, treatment 1) for 60 d, (2) ripening in oil for 50 d after 10 d of ripening in air (treatment 2), (3) ripening in oil for 40 d after 20 d of ripening in air (treatment 3). The temperature in the ripening chamber was 15°C to 17°C, and the relative humidity was 70% to 80%. The cheeses of groups 2 and 3 were placed in plastic vats (Figure 1) with lids filled with a mixture of extra-virgin olive oil from the island of Mljet and commercial refined sunflower oil (ratio 50:50).

**Cheese Sampling**

A total of 65 cheeses were produced (13 per batch: control group: 6 cheeses, group 2: 4 cheeses and group 3: 3 cheeses). The initial weight of cheeses was about...
800 g, and the initial dimensions were 12 cm × 4 cm. During ripening, whole cheeses were sampled: control group on d 0, 10, 20, 30, 45, 60; group 2 on d 20, 30, 45, 60; and group 3 on d 30, 45, and 60. Each cheese represents a sample (experimental unit) according to the ripening method and the day of sampling.

To avoid dehydration, the samples were packed in plastic bags and transported to the laboratory with a mobile cooler at a temperature of 4°C. The cheese samples were marked and stored at −80°C until the physicochemical analyses were performed.

**Physicochemical Analysis**

The physicochemical analyses were performed at the Reference Laboratory for Milk and Dairy Products at the University of Zagreb Faculty of Agriculture (Croatia).

Analyses of cheese curd (d 0) and cheese after 10, 20, 30, 45, and 60 d of ripening in different media (air, oil mixture) included determination of: pH by potentiometric method (Mettler Toledo, portable pH meter, according to the manufacturer’s instructions), DM content by reference method 5534 (ISO, 2004), fat content by Van Gulik method (ISO, 2008), fatty acid content (total SFA, UFA, oleic fatty acid) by GLC (ISO, 2002), protein content by the Kjeldahl method (ISO, 2014), and salt content (chloride) by potentiometry (ISO, 2006).

Before analysis, cheese samples were stored at room temperature, and cheese slices (~100 g) were cut from the core to the rind. The rind was cut off, and the remainder was grated. All physicochemical analyses were performed in duplicate.

**Sensory Evaluation**

The sensory properties of the cheeses were evaluated on the last day of the 60-d ripening period by a group of 7 panelists (scientific staff: 4 women, 3 men; ages 33–55) trained in sensory evaluation at the University of Zagreb Faculty of Agriculture, Croatia (ISO, 2009a). Cheese samples, randomly labeled with a 3-digit number, were blind tested. Before testing, the cheeses were tempered at room temperature. During evaluation, the assessors used water, almonds, bread, and apples to counteract the aftertaste. Cheese samples were scored based on an established list of defects with an overall quality score. The attributes evaluated were appearance (maximum score of 2), color (maximum score of 1), body (maximum score of 2), texture (maximum score of 3), odor (maximum score of 2), and taste (maximum score of 10), with the highest total score achievable being 20 (ISO, 2009a,b,c).

**Statistical Analysis**

Statistical procedures were performed in SPSS version 21 (IBM Corp., 2012). The 2-way ANOVA and the general linear model (GLM) were used to study the effects of the different ripening methods on the changes in the physicochemical composition of the cheese during ripening. The ripening methods and ripening time were included as fixed factors, while the physicochemical parameters were considered as dependent variables.

The effect of the different ripening methods on the sensory characteristics of the cheese was tested using the one-way ANOVA and the GLM. The ripening methods were used as a fixed factor, while the sensory properties were the dependent variable.

When significant effects were found, the least significant difference test was used to evaluate differences between treatment means. Significance was indicated by \( P < 0.05 \).

**RESULTS AND DISCUSSION**

**Physicochemical Properties**

Cheese is a biochemically dynamic product and undergoes significant changes during its ripening (McSweeney and Sousa, 2000). Cheese ripening involves lactose metabolism, lipolysis, and proteolysis, which are influenced by many factors (Prieto et al., 2000; McSweeney, 2004; Moreira et al., 2020).

The changes in physicochemical composition during ripening of semi-hard goat cheese according to the ripening method are shown in Figures 2, 3, 4, 5, 6, 7, 8, and 9, and the comparison between treatments is shown in Table 1.

The ripening treatment had a significant effect \( (P < 0.01) \) on the DM content of the cheese (Table 1). As can be seen in Figure 2, ripening time had a significant effect on the DM content of the cheese in all groups \( (P < 0.01) \) but was particularly significant in the control group (35% increase on d 60 compared with d 0). Most of the moisture loss occurred at the beginning of ripening, before the cheeses in groups 2 and 3 were submerged in the oil mixture (d 10 and 20). Fresno and Álvarez (2012), in their studies on the chemical changes during ripening of Majorero goat cheese and on the effect of ripening time on the chemical characteristics of Palmero goat cheese (Álvarez and Fresno, 2021), also found that moisture loss was greatest during the first 15 d of ripening and less pronounced in the latter stages. A similar trend was reported by Álvarez et al. (2007) and Rako et al. (2019).

Moisture loss during ripening of cheese on the shelf is a result of microbiological growth, production of lactic...
acid, and evaporation of water from the cheese (Ceylan et al., 2007; Havranek et al., 2014). Oil as a ripening medium prevents moisture loss (Figure 2). Tudor Kalit et al. (2012) made similar observations for lambskin sack as a ripening medium. However, because lambskin is a semi-permeable medium, there is greater moisture loss after 60 d of ripening in skin, resulting in a higher average DM content in the cheese (68.16%) compared with ripening in oil in both groups (treatment 2: ~60.08%; treatment 3: ~65.00%). According to Hayaloglu et al. (2007a), plastic barrels used as a substitute for goat-skin sacks (tulums) have lower moisture permeability, which is the reason why Tulum cheese has a lower DM content (49.14%) after 60 d of ripening in plastic barrels than cheese ripened in other media (animal skin or oil). Ceylan et al. (2007) produced Tulum cheese using the traditional method and modified procedures in plastic barrels and ceramic pots. On d 60 of ripening, the DM content in plastic barrels (54.78%) and ceramic pots (59.82%) was lower than that in goatskin sacks (65.06%) due to the poor permeability of plastic and ceramic compared with skin as a ripening medium.

Considering the DM content at the end of the ripening process, the cheeses of treatments 1 and 3 belong to the group of extra-hard cheeses (>66%), and the cheeses of treatment 2 belong to the group of hard cheeses (55%–66%; Havranek et al., 2014). What looks similar to excessive moisture loss in our study might be related to the size of the cheese in combination with the ripening conditions (higher temperature in the ripening chamber than in other studies). Franco et al. (2003), in their study of the traditional Spanish goat cheese

**Table 1.** Physicochemical composition of semi-hard goat cheese during ripening (results expressed as mean ± SE) according to different ripening treatments

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Treatment 1</th>
<th>Treatment 2</th>
<th>Treatment 3</th>
<th>Significance level</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM (g/100 g cheese)</td>
<td>62.96 ± 0.20</td>
<td>58.31 ± 0.21</td>
<td>61.10 ± 0.20</td>
<td>**</td>
</tr>
<tr>
<td>Protein (g/100 g cheese)</td>
<td>24.42 ± 0.27</td>
<td>22.73 ± 0.27</td>
<td>24.22 ± 0.26</td>
<td>**</td>
</tr>
<tr>
<td>Fat (g/100 g cheese)</td>
<td>32.68 ± 0.50</td>
<td>30.27 ± 0.50</td>
<td>33.06 ± 0.50</td>
<td>**</td>
</tr>
<tr>
<td>Salt (g/100 g cheese)</td>
<td>1.15 ± 0.07</td>
<td>0.98 ± 0.07</td>
<td>1.03 ± 0.06</td>
<td>**</td>
</tr>
<tr>
<td>pH</td>
<td>5.22 ± 0.01</td>
<td>5.25 ± 0.01</td>
<td>5.23 ± 0.01</td>
<td>NS</td>
</tr>
<tr>
<td>UFA</td>
<td>9.25 ± 0.09</td>
<td>8.64 ± 0.09</td>
<td>9.38 ± 0.08</td>
<td>*</td>
</tr>
<tr>
<td>Oleic acid</td>
<td>7.66 ± 0.07</td>
<td>6.98 ± 0.06</td>
<td>7.68 ± 0.07</td>
<td>**</td>
</tr>
<tr>
<td>SFA</td>
<td>18.89 ± 0.19</td>
<td>17.40 ± 0.18</td>
<td>19.14 ± 0.19</td>
<td>**</td>
</tr>
</tbody>
</table>

* Means in the same row marked with different letters differ significantly.
1 Treatment 1 (control group, group 1) = cheese ripening in air (60 d).
2 Treatment 2 (group 2) = cheese ripening in oil for 50 d after 10 d of ripening in air.
3 Treatment 3 (group 3) = cheese ripening in oil for 40 d after 20 d of ripening in air.
* P < 0.05; ** P < 0.01.

**Figure 2.** Dry matter content during the ripening of semi-hard goat cheese. Treatment 1 (control group, group 1) = cheese ripening in air (60 d); treatment 2 (group 2) = cheese ripening in oil for 50 d after 10 d of ripening in air; treatment 3 (group 3) = cheese ripening in oil for 40 d after 20 d of ripening in air. Means marked with different letters on each line of individual treatment differ significantly (a–f; P < 0.01).
Babia-Laciana, noted that the progressive increase in DM content during ripening could be due to the small size of the cheeses, which significantly increased the surface area exposed to the atmosphere and thus water loss. Prieto et al. (2002) reported that the small size of the cheese increases the surface area per unit weight and favors dehydration.

The protein content gradually increased during ripening (Figure 3), which is a consequence of the decrease in the moisture content of the cheese (Hayaloglu et al., 2007b). It was also significantly (P < 0.01) affected by the ripening treatment (Table 1), which is particularly noticeable between the control group and group 2, but also between groups 2 and 3. The control group had the highest average protein content (24.42%), followed by group 3 (24.22%), which is directly related to the fact that the cheeses from these groups have the highest DM content (Table 1). Thus, the cheeses from group 2, which were immersed in the oil after only 10 d of ripening in air, had the lowest average protein content (22.73%), as there was no major moisture loss.

The values of fat content increased during the ripening period both in the control group and in the cheeses ripened in oil. The same trend was observed by Tudor Kalit et al. (2012) in cheese ripened in air and in lamb-skin sack. However, in our study, the ripening treatment resulted in a significant difference (P < 0.01) in fat content (%) between the control group and group 2, but also groups 2 and 3. The lowest average fat content was found in the cheeses of treatment 2 (30.27%), which was due to the moisture-protective role of oil as a ripening medium (Table 1). The average fat content in the cheeses of the control group was significantly (P < 0.01) higher (32.68%) compared with the group 2 cheeses, because of the concentrating effect caused by the moisture loss (Figure 4). Prolonged ripening of cheese in the air (group 3) before immersion in oil resulted in a large loss of moisture and the formation of such a cheese structure that allowed the oil to penetrate the cheese to a greater extent than in group 2. This was also confirmed by the discovery of oil droplets hidden in the eyes of the cheese, visible during sensory analysis on the cross-section of the cheese ripened in oil (Figure 10), and by the results of the fatty acid analyses (Table 1).

According to the Croatian Official Gazette (2009), the cheeses from our study belong to the group of full-fat cheeses in terms of fat content (≥45% and < 60% fat in DM), as the average fat content in DM (% F/DM) after 60 d of ripening was 53.42% in the control group, 52.39% in group 2, and 58.81% in group 3.

The triglycerides in ruminant milk fat are rich in short-chain fatty acids that, when released, contribute significantly to the flavor of many cheeses (McSweeney, 2004) because they are precursors of volatile compounds such as ketones, lactones, alcohols, esters, and aldehydes (Collins et al., 2003). Although various cheeses contain a highly digestible fat from a nutritional perspective, cheese is often associated with cardiovascular disease due to its high SFA content (Barać et al., 2018). However, there was no evidence to support the effect of dairy products on heart disease (Kanekanian, 2014). In fact, the fat in goat milk contains more UFA than cow milk (Wang et al., 2016), which may benefit human health by reducing the risk of obesity or preventing car-
diovascular episodes through n-3 and n-6 essential fatty acids (Simopoulos, 2008). Conjugated linoleic acid has shown anticancer and antiatherosclerosis effects while boosting immunity (Benjamin and Spener, 2009).

Ripening treatment resulted in a significant difference in SFA and UFA content ($P < 0.01, P < 0.05$) between the control group and group 2 and between groups 2 and 3, which is consistent with the results of fat content (Table 1). The highest average SFA and UFA content was found in the cheeses of group 3, followed by the control group and group 2. The content of oleic acid, the well-known MUFA in olive oil associated with a beneficial effect on human health (Kanekanian, 2014), followed the same trend and was highest in the cheeses of group 3. There was a significant difference ($P < 0.01$) between the control group and group 2, and between groups 2 and 3, which is in accordance with the results of fat content (Table 1). The higher content of UFA and oleic acid in group 3 compared with group 2 can be explained by the greater penetration of the oil into the cheese structure due to the greater water loss caused by the longer ripening time in air before immersion in the oil.

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**Figure 4.** Fat content during the ripening of semi-hard goat cheese. Treatment 1 (control group, group 1) = cheese ripening in air (60 d); treatment 2 (group 2) = cheese ripening in oil for 50 d after 10 d of ripening in air; treatment 3 (group 3) = cheese ripening in oil for 40 d after 20 d of ripening in air. Means marked with different letters on each line of individual treatment differ significantly (a–d; $P < 0.01$).

**Figure 5.** Unsaturated fatty acid content during the ripening of semi-hard goat cheese. Treatment 1 (control group, group 1) = cheese ripening in air (60 days); treatment 2 (group 2) = cheese ripening in oil for 50 d after 10 d of ripening in air; treatment 3 (group 3) = cheese ripening in oil for 40 d after 20 d of ripening in air. Means marked with different letters on each line of individual treatment differ significantly (a–e; $P < 0.01$).
In addition, the content of SFA and UFA, as well as oleic acid, was significantly ($P < 0.01$) affected by the ripening time (Figures 5, 6, and 7). The highest increase in UFA, SFA, and oleic acid content (more than 20% increase in the control group and group 3, and 15% in group 2) was observed between d 10 and 20 of ripening. The values of UFA, SFA and oleic acid almost stagnated after 30 d of ripening in group 2 due to the higher moisture content.

There was a significant difference ($P < 0.01$) in average salt content between air- and oil-ripened cheeses (Table 1). During the first 10 d of ripening, the salt con-

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**Figure 6.** Oleic acid content during the ripening of semi-hard goat cheese. Treatment 1 (control group, group 1) = cheese ripening in air (60 d); Treatment 2 (group 2) = cheese ripening in oil for 50 d after 10 d of ripening in air; Treatment 3 (group 3) = cheese ripening in oil for 40 d after 20 d of ripening in air. Means marked with different letters on each line of individual treatment differ significantly (a–d; $P < 0.01$).

**Figure 7.** Saturated fatty acid content during the ripening of semi-hard goat cheese. Treatment 1 (control group, group 1) = cheese ripening in air (60 d); Treatment 2 (group 2) = cheese ripening in oil for 50 d after 10 d of ripening in air; Treatment 3 (group 3) = cheese ripening in oil for 40 d after 20 d of ripening in air. Means marked with different letters on each line of individual treatment differ significantly (a–d; $P < 0.01$).
tent increased rapidly and then continued to increase during ripening (Figure 8). It differed significantly ($P < 0.01$, $P < 0.05$) throughout the ripening process of the control cheeses and the cheeses of groups 2 and 3.

A similar trend was observed by Tudor Kalit et al. (2012) at the beginning of ripening in both cheeses, namely those ripened in the animal skin sack and in air. After 15 d, salt content continued to increase and was slightly higher in air-ripened cheese than in cheese in the animal skin sack, but not significantly. The highest salt content (d 60) in our study was also found in the control group (1.53%), which was a consequence of the higher moisture loss (concentration effect) during ripening (Figure 2).

Although there was no demonstrated effect of ripening treatment on pH (Table 1), it varied significantly ($P < 0.01$) during the ripening period within each group (Figure 9). The initial average pH of the cheeses was 5.32 and showed a decreasing value until d 20 of ripening, when it began to slowly increase, which agrees with the observations of different authors for other goat cheeses (Álvarez et al., 2007; Fresno and Álvarez, 2012).

Group 2 had the highest pH values throughout the ripening period, followed by the results of group 3 cheeses (Figure 9). Cheeses ripened in oil had a slightly higher final pH (5.38) than the control group cheeses (5.36) on d 60 of ripening, as did cheeses ripened in a lambskin sack (5.08) compared with cheeses ripened in the rind (4.93; Tudor Kalit et al., 2012). The pH increased more rapidly between d 20 and 45 of ripening for cheeses ripened in oil than for cheeses ripened in air, probably due to anaerobic conditions and water retention in the cheese during ripening in oil. The latter is probably caused by higher proteolysis leading to the alkalizing effect of amines and ammonia generated through protein degradation during ripening (Franco et al., 2001; Hayaloglu et al., 2007a; Tudor Kalit et al., 2012).

Because the pH of cheese during ripening depends on the metabolic activity of lactic acid bacteria (McSweeney, 2004; Álvarez et al., 2007), the increase in pH can also be explained by the decreased content of residual lactose and the decreased production of lactic acid (Akın et al., 2003; Havranek et al., 2014).

**Sensory Properties**

Sensory evaluation of semi-hard goat cheese ripened under different conditions showed that the cheese from group 3 had significantly ($P < 0.05$) the highest total score (Table 2). Although the treatment did not have a noticeable effect on the appearance and cross-section of the cheeses between the groups, there were significant differences between the control group and the cheeses ripened in oil for the most important cheese attribute—taste ($P < 0.05$). According to the results, ripening in oil also seems to improve color and texture.

Air ripening caused a major moisture loss, which had a negative effect on the texture of the control cheese (group 1), affecting its palatability and consequently its
consumption after a longer ripening period. In contrast, the loss of moisture during ripening in air (groups 2 and 3) before ripening in oil resulted in the formation of such a cheese structure that allowed the oil to penetrate the cheese (Figures 4, 5, and 6), which improved its textural properties. In addition, due to longer ripening in the oil, group 2 received the lowest score in the evaluation of the odor, and it differed significantly ($P < 0.05$) from the control group and group 3.

The results showed that oil as a ripening medium generally improved the overall score compared with the control group, but the combination of prolonged cheese ripening in air before immersion in oil and shorter ripening in oil (group 3) allowed the development of better sensory attributes than in group 2. According to the results of this study, the optimal time for cheese immersion in oil is after 20 d of ripening in air. Similarly, Tudor Kalit et al. (2012, 2014) found that the ripening media have an important influence on the sensory properties of cheese. Compared with cheese ripened in a natural rind, cheese ripened in a lambskin sack has unique sensory characteristics due to the different biochemical processes resulting from the anaerobic ripening conditions in the animal skin sack.

According to Tudor Kalit et al. (2014), it could be concluded that the optimal ripening time of cheese in animal skin is 45 d, as the intensive proteolysis, accumulation of nitrogen fractions, degradation of short-chain fatty acids and accumulation of medium- and long-chain free fatty acids due to the ripening time and specific conditions (high temperatures in the cheese ripening room: 16°C to 18°C, contact material—lambskin) contributed to the lower sensory scores of Sir iz mišine after 45 d of ripening. Also, Yilmaz et al. (2005) re-

Table 2. Sensory analysis of semi-hard goat cheese (results expressed as mean ± SE)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Appearance</th>
<th>Color</th>
<th>Texture</th>
<th>Cross-section</th>
<th>Odor</th>
<th>Taste</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment 1(^1)</td>
<td>1.92 ± 0.32</td>
<td>0.85 ± 0.02(^a)</td>
<td>1.49 ± 0.03(^b)</td>
<td>2.64 ± 0.06</td>
<td>1.88 ± 0.03(^a)</td>
<td>8.99 ± 0.08(^c)</td>
<td>17.77 ± 0.13(^c)</td>
</tr>
<tr>
<td>Treatment 2(^2)</td>
<td>1.84 ± 0.31</td>
<td>0.92 ± 0.02(^a)</td>
<td>1.82 ± 0.03(^b)</td>
<td>2.80 ± 0.06</td>
<td>1.85 ± 0.03(^b)</td>
<td>9.25 ± 0.08(^b)</td>
<td>18.28 ± 0.13(^b)</td>
</tr>
<tr>
<td>Treatment 3(^3)</td>
<td>1.84 ± 0.32</td>
<td>0.98 ± 0.02(^a)</td>
<td>1.80 ± 0.02(^a)</td>
<td>2.73 ± 0.06</td>
<td>1.79 ± 0.02(^a)</td>
<td>9.52 ± 0.08(^a)</td>
<td>18.66 ± 0.13(^a)</td>
</tr>
</tbody>
</table>

\(^{a}\)Means in the same row marked with different letters differ significantly ($P < 0.05$).
\(^1\)Treatment 1 (control group, group 1) = cheese ripening in air (60 d).
\(^2\)Treatment 2 (group 2) = cheese ripening in oil for 50 d after 10 d of ripening in air.
\(^3\)Treatment 3 (group 3) = cheese ripening in oil for 40 d after 20 d of ripening in air.

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Figure 9. pH value during the ripening of semi-hard goat cheese. Treatment 1 (control group, group 1) = cheese ripening in air (60 d); treatment 2 (group 2) = cheese ripening in oil for 50 d after 10 d of ripening in air; treatment 3 (group 3) = cheese ripening in oil for 40 d after 20 d of ripening in air. Means marked with different letters on each line of individual treatment differ significantly (a–d; $P < 0.01$).
ported that the sensory scores of Tulum cheese started to decrease after 60 d of ripening. Albay and Şimşek (2022) reported the improvement of sensory properties (taste, texture, and color) of 90 d matured low-fat Tulum cheese with added inulin compared with Tulum cheese without added inulin.

CONCLUSIONS

The physicochemical composition and sensory properties of semi-hard goat cheese were influenced by the ripening method and duration. Prolonged ripening of cheese in the air before immersion in oil resulted in a great loss of moisture and the formation of such a cheese structure that allowed the oil to penetrate the cheese to a greater extent. The water retention caused by the anaerobic ripening conditions and the resulting penetration of oil into the cheese could have a positive effect on sensory characteristics of the cheese and allow its consumption during seasons when goat milk is not produced due to the highly seasonal lactation cycle of goats. This is of particular importance for goat cheese producers, as consumer interest has recently increased. In addition, the results of this study extend the knowledge of changes during cheese ripening in oil, which may be of interest to dairy industry and scientists.

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Levak et al.: RIPENING OF SEMI-HARD GOAT CHEESE IN OIL

8503


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