



## Effect of different O<sub>2</sub>/CO<sub>2</sub> permeable foils on aging of semi-hard goat cheese



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### ARTICLE INFO

#### Article history:

Received 30 April 2018

Received in revised form

10 November 2018

Accepted 12 November 2018

Available online 10 December 2018

### ABSTRACT

The present study focuses on the effect of gas permeability on dry matter, colour, inner- and outer texture, and sensory properties of foil-ripened 0.5 kg semi-hard goat cheese during 3 weeks of ripening (13 °C; 88% relative humidity). The characteristics of the packaging foils applied were made of different materials and varied in thickness, gas permeability (CO<sub>2</sub>, O<sub>2</sub>) and water vapour permeability. All ripening foils decreased the inner lightness of samples after 3 weeks; however, yellowness was influenced by the gas permeation. The equalisation of outer- and inner hardness was measurable after 1 week of ripening; gas permeability contributed to the speeding up of this process. The difference between inner and outer elasticity declined until 1.5 weeks. Sensory evaluation revealed that the foil with permeabilities (cm<sup>3</sup> m<sup>-2</sup> 24 h<sup>-1</sup> 1 atm<sup>-1</sup>) for O<sub>2</sub>, CO<sub>2</sub> and water vapour of 400, 1250 and 15, respectively, contributed to best appearance, taste and texture.

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### 1. Introduction

Ripening or maturing is a crucial step in cheese manufacture as this allows the given cheese to reach its characteristic odour, taste and texture due to the breakdown of proteins, lipids and carbohydrates. In case of the semi-hard cheese category, products need 3–6 weeks ripening under controlled temperature and humidity. This normal ripening procedure is time consuming and involves high labour cost. Nowadays, traditional cheese types like Gouda, Edam, Maasdam and Emmental are commonly available in foil-ripened version. These foils are oxygen-, carbon dioxide-, and water vapour-permeable and can fit to given maturing conditions for the selected cheese type. The main advantage for the cheesemaker is that the procedure of ripening can be simplified: there is no need to coat and turn cheeses (Papademas & Bintsis, 2018), and the cheese can dry under controlled moisture levels. In case of a moisture-permeable film, the cheese will dry the same way as natural ripened cheese (Van Gurp, Hooft, Krijgsman, & Stroeks, 2007) or in other cases, moisture-impermeable foil types can be

used, which may significantly reduce the moisture loss during ripening (Dusterhoft, Engels, & Huppertz, 2017).

According to Wyder, Bachmann, and Puchan (1999), there is still in-depth ripening, which contributes to a relatively high share of small breakdown products (nonprotein nitrogen and pH 4.6-soluble nitrogen) in foil-ripened cheeses. Others reported less intense proteolysis and ammonia production during ripening (Duval et al., 2018). Temperature of ripening is also crucial for the cheese microflora, as the use of cool ripening (5 °C) contributes to less production of flavour compounds (acetoin and propionate) by the cheese microbiota (Cem Duru et al., 2018), which contributes to sensory deficiencies for a given product.

The effect of ripening foils on cheese maturation has been investigated mainly for soft and hard cheese types. Van Grup et al. (2007) studied the ripening of semi-hard and hard cheese on 13 °C, 85% relative humidity (RH), for 4 weeks. They concluded that the appropriate foil should have preferably at least a 25 μm thickness, 30–45 g m<sup>-2</sup> 24 h<sup>-1</sup> water vapour permeability and 20–50 cm<sup>3</sup> m<sup>-2</sup> 24 h<sup>-1</sup> atm oxygen permeability to obtain the best conditions for cheese ripening. Italian scientists analysed Stracciano (soft cheese) over 28 days of ripening at 4 °C applying high-density polyethylene (HDPE), active packaging with potassium sorbate (AOV) and paper-polyethylene as a reference (Marcuzzo, Peressini, &

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Sensidoni, 2012). According to their study, both HDPE and AOV foils were suitable to avoid microbiological spoilage while ensuring the same texture and sensory properties of Stracchiano cheese. Another good example for this category is the work on French Saint-Nectaire by Picque et al. (2011) who applied foils with low (LWP), medium (MWP) and high (HWP) water vapour permeability during 4 weeks of ripening. LWP totally inhibited “cheese-breathing”, dry matter content remained stable. Although the number of colony forming units (cfu) of moulds and yeasts decreased, orange and red fat dots appeared on the cheese surface. In case of MWP and HWP-packaged cheese samples, “cheese-breathing” was possible, but mould and yeast counts were not reduced.

Van Gurp et al. (2007) immersed vacuum foils in natamycin, which could contribute to inhibition of mould growth. However, vacuum packaging can be disadvantageous as it may disturb the cheese loaf when applying vacuum, therefore it can cause irregular cheese holes, if applied in fast rate (McSweeney, 2007). Lazić and Curaković (1997) examined on addition to vacuum packaging, the effect of modified atmosphere (90% CO<sub>2</sub>, 10% N<sub>2</sub>, 10% O<sub>2</sub>) on Kashkaval cheese. This packaging method contributed to softer texture independent from the applied foil types (PP (PVDC)/PE, PETP/PE).

Talevski, Srbinovska, Santa, and Mateva (2017) concluded that the degree of proteolysis and the cheese yield were also dependent of the applied foils, whereas polymer emulsion could be the best solution for Kashkaval cheese to ensure rind protection during ripening.

Despite the fact that cheese made exclusively from goat milk has a growing market, there is a lack of literature related to their ripening (Miloradovic et al., 2017) compared with cheese made from raw or pasteurised cows' milk.

Our research aim was to study the effect of ripening foils differing in O<sub>2</sub>-, CO<sub>2</sub>-, and water vapour-permeability on the technofunctional properties of semi-hard goat cheese to determine the one ensuring the best texture and sensory properties over 3 weeks of ripening.

## 2. Materials and methods

### 2.1. Semi-hard goat cheese manufacture and ripening

Semi-hard goat cheese (fat, 28.8%, w/w, including the saturated fat 18.6%, w/w; protein, 23.5%, w/w; salt, 1.6%, w/w) was kindly provided during ripening on a weekly basis by a Hungarian mid-sized cheese manufacturer (Bacs-Kiskun County). The cheese was made of pasteurised (72 °C, 15 s) goats' milk (fat, 4.0%, protein, 3.8%). Samples were sliced from a 19 cm diameter 3 kg cheese wheel into 0.5 kg triangles. All samples were packed in foils with different gas permeability (Table 1) and ripened for 3 weeks in a controlled ripening chamber (13 °C, 88% RH). The experiment was replicated twice.

**Table 1**  
Gas permeability characteristics of applied foils.<sup>a</sup>

Parameter	Foils		
Name used in paper	Low	Medium	High
Product name	DSM Package (without natamycin)	FLEXO FCX	FLEXO FCC
Layers	PA/TPEE	PS/PVDC/PE	PS/PVDC/PE
Foil thickness (µm)	50	52	52
Permeability (cm <sup>3</sup> m <sup>-2</sup> 24 h <sup>-1</sup> 1 atm <sup>-1</sup> )	35	200	400
Oxygen			
Carbon dioxide	150	800	1250
Water vapour	14	14	15
Manufacturer/Importer	Südpack Verpackungs GmbH & Co., Ochsenhausen, Germany <sup>M</sup>	Kalle Hungaria Ltd., Budapest, Hungary <sup>I</sup>	Kalle Hungaria Ltd., Budapest, Hungary <sup>I</sup>

<sup>a</sup> Abbreviations: PA, polyamide; TPE, thermoplastic polyether ester; PS, polystyrol; PVDC, polyvinylidene chloride; PE, polyethylene; M, Manufacturer; I, Importer.

### 2.2. Monitoring of chemical and physical changes

Semi-hard goat cheese samples were analysed for dry matter, pH and colour measurement on a weekly basis. Dry matter content was measured with Sartorius Thermo Control YTC 01 L (Sartorius Stedim Plastics GmbH, Goettingen, Germany) at 105 °C. The pH was determined with Testo 206 portable pH meter (Testo AG., Limburg an der Lahn, Germany). Colour measurement was performed with Minolta Chroma Meter CHR-400 tristimulus colour measuring system (Konica Minolta Sensing Inc., Japan). CIELAB values (lightness, L\*; redness, a\* and yellowness, b\*) were measured on central parts of inner surface of cheese samples.

### 2.3. Texture profile analysis

Each cheese was cut into horizontal halves (diameter, 12 mm; height, 12 mm). Samples were taken from the centre (inner, 40 mm from surface) and from the rind (outer, from surface). The prepared cheese core samples were tempered at 10 °C in a fridge before texture profile analysis (TPA), which was performed with TA.XTPlus (Stable Micro Systems, Godalming, UK) Texture Analyser using a 500 N load cell. The cheese core samples were axially compressed two times to 70% of their original height with 35 mm cylinder probe at a crosshead speed of 2 mm s<sup>-1</sup>. For each TPA, 10 samples per cheese were measured. Force-time deformation curves were evaluated with Texture Exponent 32 as the given software of TA.XTPlus. Hardness, and elasticity parameters were selected from TPA for data evaluation.

### 2.4. Sensory measurement

Sensory measurement was conducted after the 3rd week of ripening according to the Hungarian Standard (1988) and to directive No. 2–104 of Codex Alimentarius Hungaricus (CAH, 2012). The applied scoring test (max 100 points) is commonly used on national competitions of Hungarian handmade cheese products as Cheesemuster and Young Wine & Cheese Festival and was also published previously (Darnay et al., 2017). The sensory characteristics of cheeses were scored accordingly: appearance (15 point), inner colour (15 point), odour (15 point), taste (25 point), texture (15 point), cheese holes (15 point). The results are averages of scores of 10 trained panellists (23–59 y, 5 female, 5 male), who were selected from the academic staff of Szent István University.

### 2.5. Statistical analysis

Statistical data evaluation was performed with XLStat statistical software for Shapiro–Wilk Test to verify the assumptions of normality Furthermore, one-way ANOVA and two-way ANOVA

were applied for comparison of different variables (ripening time, foil type) on 95% and 99% confidence level.

### 3. Results and discussion

#### 3.1. Chemical and physical changes

##### 3.1.1. Changes of dry matter and pH

Dry matter content of samples is summarised in Table 2. The total solid content increased during ripening in accordance with other studies (Guizani, Al-Attabi, Kasapis, & Gaafar, 2006) due to possible surface evaporation of water. The shape and size of the cheese samples is of high importance, if the volume to surface area ratio is low, the loss of gas might be too high (Fröhlich-Wyder & Bachmann, 2008). Accordingly, gas permeability caused 2–4% moisture loss depending on foils. Our study revealed that the pH decreased slightly during ripening; however, it remained over pH 5.0, in contrast to semi-hard goat cheese ripened in aluminium foil (Guizani et al., 2006) that had lower pH values (pH 4.78–4.95). The pH decreasing tendency was not influenced by the different gas permeability of the applied foils (Table 2).

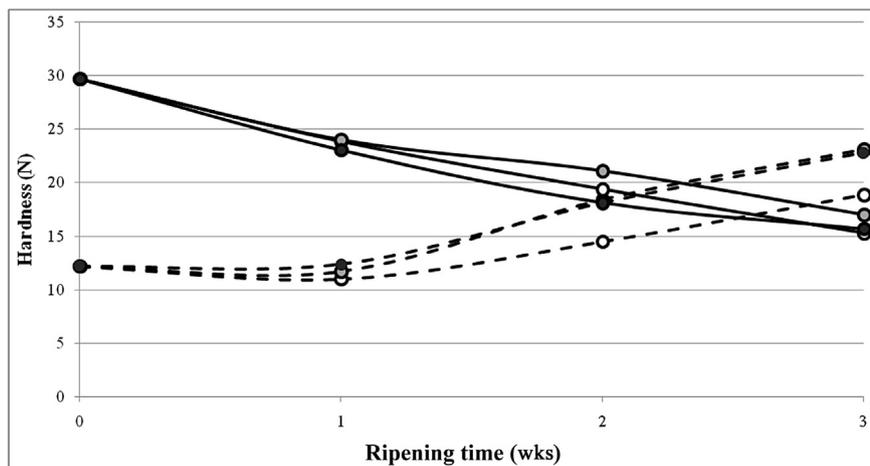
**Table 2**  
Changes of dry matter and pH for different ripening foils during ripening.

Ripening time (wks)	Dry matter (w/w, %)/pH		
	Low	Medium	High
0		53.96/5.30	
1	55.73/5.24	55.94/5.20	55.34/5.20
2	57.23/5.17	56.34/5.13	55.88/5.19
3	59.15/5.07	58.44/5.03	58.91/5.03

**Table 3**  
Changes of colour for different ripening foils during ripening.<sup>a</sup>

Ripening time (wks)	Lightness (L*)			Redness (a*)			Yellowness (b*)		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
0	86.38 ± 0.25	86.38 ± 0.25	86.38 ± 0.25	-2.34 ± 0.12	-2.34 ± 0.12	-2.34 ± 0.12	10.93 ± 0.31	10.93 ± 0.31	10.93 ± 0.31
1	84.51 ± 0.18	82.93 ± 0.23	86.13 ± 0.07	-2.46 ± 0.14	-2.37 ± 0.06	-2.51 ± 0.11	11.30 ± 0.36	11.78 ± 0.12	11.43 ± 0.21
2	83.14 ± 0.20	82.36 ± 0.17	83.95 ± 0.12	-2.90 ± 0.09	-2.43 ± 0.03	-2.48 ± 0.11	11.59 ± 0.21	11.96 ± 0.23	11.65 ± 0.32
3	82.85 ± 0.20	82.27 ± 0.26	84.08 ± 0.40	-2.88 ± 0.11	-2.85 ± 0.09	-3.13 ± 0.13	12.15 ± 0.15	12.39 ± 0.08	13.62 ± 0.15

<sup>a</sup> Values are means of three replicated trials ± standard deviation.



**Fig. 1.** The effect of different gas permeable foils (○, low; ●, medium; ●, high) on outer (solid line) and inner (dashed line) hardness (N) during ripening.

##### 3.1.2. Colour changes during ripening

The effect of ripening was monitored by measuring the inner lightness, redness and yellowness (Table 3) of cheese samples. Inner lightness decreased significantly ( $p < 0.01$ ) already after 1 week for “low” and “medium” foils; however, after 2 weeks of ripening the decreasing tendency could be determined independent of the gas permeability. Concerning colour saturation, the redness ( $a^*$ ) was only influenced by the ripening time ( $p < 0.01$ ), not by the foils; however, at the end of ripening all ripening foils contributed to higher yellowness ( $b^*$ ) compared with initial values. Furthermore, the yellowness increased with the gas permeation of the foils. According to our best knowledge, this phenomenon has not appeared in the scientific literature before, therefore further investigation is planned to examine the possible reasons, among them the effect of cheese manufacturing time.

#### 3.2. Texture profile analysis

##### 3.2.1. Hardness

Ripening foils contributed to decreasing outer hardness and to increasing inner hardness over 3 weeks of ripening (Fig. 1). The decreasing tendency between outer and inner hardness shows the possible equalisation of the cheese texture even within 3 weeks. This is in agreement with Nĕmcová, Šĕtina, and Valentová (2001), as their study showed that hardness was even throughout the cheese due to the maturation under ripening foil. The gas permeability of the foils significantly ( $p < 0.01$ ) affected the hardness of the samples. According to inner hardness of cheese, two groups could be separated based on gas permeability: Group 1, low; Group 2, medium and high. The Group 2 foils showed a consistent tendency, whereas Group 1 foil resulted in a rather uneven

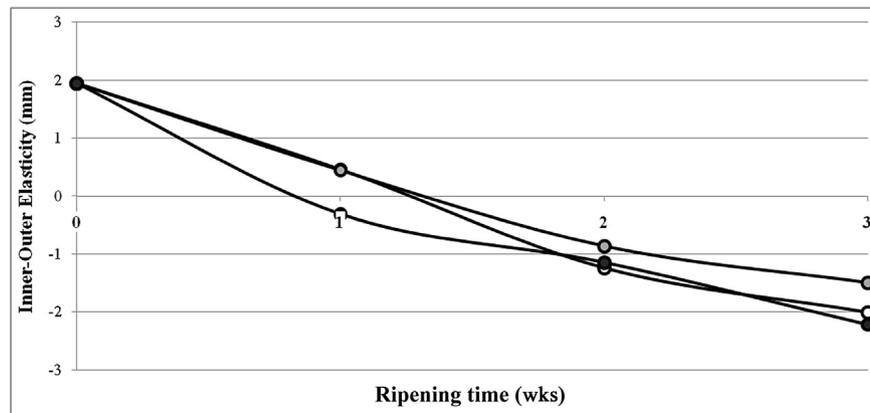


Fig. 2. The effect of different gas permeable foils (○, low; ●, medium; ●, high) on inner and outer elasticity (mm) during ripening.

equalisation of hardness. The low gas permeability allowed higher moisture loss from the surface than from the inner part of the cheese. This uneven moisture transport increased the time required for hardness equilibration between the inner and outer regions by “medium” and “high” foils between weeks 2 and 3 (Fig. 1).

### 3.2.2. Elasticity

Elasticity was measured after the second compression of the cheese cores both on inner and outer part of the samples. Elasticity is a key property of semi-hard goat cheeses (Garcia, Rovira, Boutoial, & Lopez, 2014) and a recognisable effect of ripening on elasticity has already been demonstrated by other scientists (Attaie, 2005; Moraes, Santos, Barcelos, Lopes, & Egito, 2018) with objective texture measurement. According to our knowledge, there is no study to present the difference between inner and outer elasticity during ripening. Our results show a decreasing difference between these parameters between weeks 1 and 2 (Fig. 2). However, after this period the outer elasticity was seen to increase more rapidly than the inner one. These results highlight that further investigation is needed to fully understand the texture-modifying effects of cheese ripening.

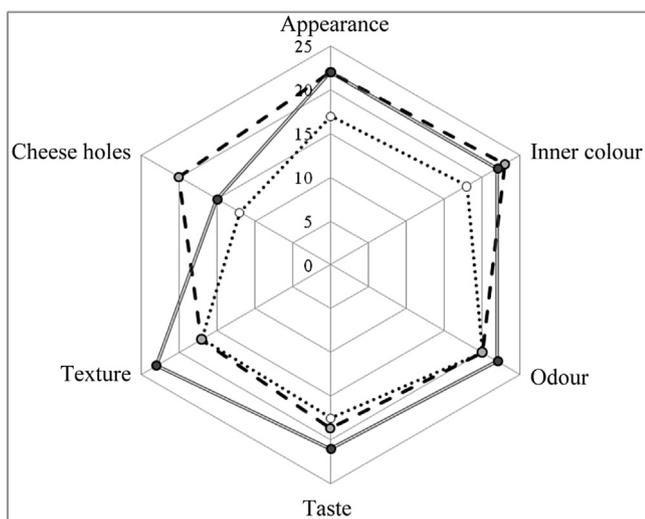


Fig. 3. The effect of different gas permeable foils (○ and dotted line, low; ● and dashed line, medium; ● and double line, high) on sensory evaluation of cheese samples by 10 trained panellists at the end of ripening on the 3rd week. The scoring test applied had different maximum scores for some attributes, but these were harmonised to present different properties on one scale.

### 3.3. Sensory analysis

Sensory analysis revealed clear differences among ripening foils in terms of appearance, taste, texture and cheese holes (Fig. 3). Appearance was enhanced by the higher CO<sub>2</sub>– and O<sub>2</sub> gas permeability of “medium” and “high” foils. Panellists could not determine yellowness difference between “medium” and “high” foils, therefore the inner colour scores remained unaffected. Panellists evaluated these foil ripened cheeses as having better taste and texture than foil “low”. Texture scores demonstrate that the highest outer elasticity of foil “high” was preferred the most by the panellists. Moreover, cheese holes exhibited a more regular distribution. Modelling CO<sub>2</sub> transfer in the future could be helpful to follow growth of the eyes during ripening as applied by Acerbi, Guillard, Saubanere, Guillaume, and Gontard (2018) for Swiss-type cheese. These results are in accordance with Marcuzzo et al. (2012), who could also demonstrate a difference in consumer acceptance depending on the applied packaging.

### 4. Conclusions

This paper demonstrates that the higher the gas permeation the better is the favourable yellow cheese colour and the rate of the hardness equalisation of semi-hard goat cheese. Further research is needed to understand the elasticity changes experienced during ripening. Our results show that the application of high gas permeability foil can ensure the best product quality in case of semi-hard goat cheese.

### Acknowledgement

We would like to express our profound gratitude to Kalle Hungary and DSM Food Specialites for providing us with ripening foils for our research purposes.

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