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EFFECT OF RIPENING TIME ON COLOUR AND TEXTURE PROPERTIES IN CHEESE

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ABSTRACT

The group of semi-hard cheeses is quite heterogenous and there are distinctions between individual representatives of this group. The aim of this paper was a comparison the colour changes and texture properties of semi-hard pasta filata cheeses during ripening. Spectrophotometer Konica Minolta CM-3500d was used for the colour measurements of cheese samples. Color parameters L* a* b* were determined for the edge part and for the middle part of samples. The texture properties of cheese were measured by TIRATEST 27025. Measurements were made for part following the edge and the middle part of samples as well. During ripening of cheese samples there were observed statistically significant changes in the colour parameters of the edge part of oiled cheese. Total colour difference (ΔE^*_{ab}) during storage was the most noticeable in first 10 days of ripening. In compare with changes in a* parameter of the edge part of cheese samples, red tone (a* parameter) in the middle part of cheese samples did not show so large change. The measured strenght of edge part of the cheese samples was in range between from 7.44 N up to 23.49 N. Firmness of middle part varied from 4.46 N to 24.40 N in 60 days of maturating.

Keywords: colour; texture; ripening; semi-hard cheese

INTRODUCTION

Clasify a cheese to group of semi-hard cheeses is very arbitrary. In comparision with other groups of cheeses (e.g., hard cheeses, smear-ripened varieties or pastra filata cheeses), the group of semi-hard cheeses is quite heterogenous and there are distinctions between individual representatives of this group. Semi-hard cheeses include Colby and Monterey (Cheddar typer cheeses), British Territorial varieties (Caerphilly, Lancashire), Slovak Bryndza cheese and Majorero cheese from Spain **(Fox, 2000)**. **Keresteš et al. (2016)** devided semi-hard cheeses into few smaller groups of cheeses (semi-soft cheeses, white cheeses, blue-veined cheeses and pasta filata cheeses).

Under common designation "Caciocavallo" fall Italian pasta filata cheese "Caciocavallo Silano" which obtained PDO mark, Caciocavalo Molisano etc., Balkanian types "Kashkaval Balkan" and Russian "Kashkavalo". In Nothern Italy is produced PDO pasta filata cheese "Provolone Valpadana" which is made by using a similar method but sold under the different names **(Piraino et al., 2005)**. Between pasta filata cheeses belong "Klenovecký syrec", "Ostiepok", "Parenica" and "Korbacik" which obtained PGI mark and have its origin in Slovak Republic **(Keresteš et al., 2016)**. One of the most important Turkish cheese varieties of pasta filata semi-hard cheese is "Kashar" cheese, which is similar to Caciocavallo, Provolone, Regusono, Kashkaval, and Mozzarella **(Kavas et al., 2015)**.

Most rennet-coagulated cheeses are ripened (matured) for period ranging from about 3 weeks to more than 2 years. Duration of the ripening inversely related to the moisture content of cheese **(Fox, 2000)**. Based on US Food and Drug Administration's 2013 Food Code, cheeses made of raw milk are devided into 30 categories based on pH and water activity. These attributes were used for control of vegetative cells and spores in non-heat-threated food. Category C1 is represented by semisoft stretched cheese "Provolone" and hard stretched "Cacciocavallo Siciliano" **(Trmčić et al., 2017)**.

The ripening is complex of biochemical processes which takes place under physical, microbial and enzymatic conditions. During ripening, composition, organoleptic properties and the structure are modified **(Fox, 2004; Spreer, 1998)**.

Lovayová et al. (2010) made semi-hard cheese with the addition of probiotic culture as additional cultures, monitored their survival during maturation and effect on the physicochemical and sensory evaluation of final product during ripening.

The physical properties of cheese (body/texture, melt/stretch, and colour) are influenced by the initial cheesemilk composition, manufacturing procedures, and maturation conditions **(Lucey, 2003)**.

The biggest change in texture properties occur in the first two days, but the solidification takes place and continues only for a few weeks to balance. The surface layers of the cheese faster loses moisture and change the chemical composition, which may be reflected in the rheological properties and other during maturation **(Nuath et al., 2000)**.

The rheological properties of cheese are those that determine its response to a stress or strain (e.g., compression, shearing, or cutting) that is applied during processing (e.g., portioning, slicing) and consumption (slicing, chewing). These properties include intrinsic characteristics such as elasticity, viscosity, and viscoelasticity that are related primarily to the composition, structure, and strength of the attractions between the structural elements of the cheese **(Fox, 2000)**.

Physical attributes such as unmelted and melted states of matter were observed in low-moisture part-skim pizza Mozzarella which is the variety of pasta filata cheese used extensively as a topping on baked dishes in North America **(Lucey, 2008)**.

Several articles focusing on texture, rheological and physical properties of pasta filata cheeses depending on method of cheese production or different storage conditions have been published. **Hwang et al. (2015)** investigated effect of drying and storage on the rheological characteristics of Mozzarella cheese.

Impact of the thermo-mechanical threatments and hot brining on composition, yield, solid loss, microstructure and hardness of pasta filata cheese were proved **(Bähler, 2016; Banville, 2016)**.

The aim of this paper was a comparison the colour changes and texture properties of semi-hard pasta filata cheeses during ripening.

MATERIAL AND METHODOLOGY

Making of cheese samples

This research was carried out in Biotechnology Pavilion M, financed by the OP VaVpI CZ.1.05/4.1.00/04.0135 project at the Department of Food Technology at Mendel University.

Milk for manufacturing came from Holstein dairy cows originally from South Moravia region. The elementary analysis of basic components of milk was conducted in Table 1.

Milk for making of cheese samples was subjected to heat threatment. Raw milk was heated at 72 °C for 30 s and then was immediately cooled to 33 °C. Acidification was performed by adding cheese culture TM1 (Bulgaricus, Czech Republic) and MC1 (Bulgaricus, Czech Republic). Milk was held at 32 °C during 40 min and 10 mL 36% CaCl was added.

Coagulation (renneting) was induced by the commercial chymosin rennet Naturen 145 IMCU (CH.HANSEN, Denmark). For 70 L vat was needed 40 mL of chymosin rennet. Forty minutes later followed cutting of curd into small cubes (15 mm x 15 mm). After next 15 min 18 L of whey was removed from the vat and replaced by 15 L of warm water (40 °C).

Mixture was heated and agitated at 40 °C for 30 min and after that moulding and formation of curd were done. The curd was filled into forms and whey was separated. Formating and pressing lasted 45 min, then the curd was turned and pressed next 20 min.

Cheese samples were fermented for 20 hours. After this time of fermentation, Pasta Filata threatment was applied. Samples were placed into vat full of warm water (85 °C) for 2 min for a pasta filata surface. Next step was salting in salt brine (18% NaCl) for 20 hours at 10 °C.

Drying and resting lasted in a chamber (12 °C) for 2

Figure 1 Cheese samples.

Table 1 Composition of milk for cheesemaking.

Parameter	Value	Method (Standard)
Dry matter	12.69%	gravimetry (ISO 6731:2010)
Fat	3.60%	Gerber (ISO 2446:2008)
Protein	3.19%	Kjeldahl (EN ISO 8968-1:2002)
Lactose	4.92%	Polarimetry (ČSN 570530)
Titr. acidity	6.50SH	Soxhlet-Henkel (ČSN 570530)

days. Cheese samples were treated by oil (rape seed oil, Czech Republic). Maturation of threated cheeses took place in ripening chamber at 12 ±1 °C, relative humidity 85% for 85 days. A total of 40 cheese samples were produced due to study chemical parameters, colour and texture during ripening. Cheese samples were analyzed after each 10, 20, 30, 40, 60 and 85 days.

Cheese samples (loaves) had cylidrical shape, average height 33.7 mm and average width 71.8 mm. Cheese loaves weight varied between 112 g to 140 g. Cheese samples are shown in Figure 1.

Colour measurement

Spectrophotometer Konica Minolta CM-3500d (Japan) were used for colour measurements. The instrument processed measured data using the SpectraMagic software version NX. Color standardization was performed using white and black standard cylinder. Color measurement was made in accordance with Commission Internationale de l´Eclairage (CIE, 1978). Standart daylight (light source D65) was used as the reference illuminant. For all samples were determined three color parameters, L* (lightness), a* (green-red value), and b* (blue-yellow value). Color parameters of samples were measured on the basis of reflected light retrospectively captured by detector of spectrophotometer (reflectance SCE mode). The size of the aperture of the optical system was adjusted to 8 mm.

Sample preparation was carried out as follows: cheese loaves were cut in half and colour measurements always took place on the inner surfaces of each half of cheese loaves. Color parameters were determined for the edge part and for the middle part of samples and measurements were made in triplicate. There were observed L* a* b* parameters depending on the length of maturation.

The differences between the samples were evaluated either in individual parameters (L* a* b*), or by using the total colour difference (ΔE^*_{ab}) that is dedicated from the already measured parameters and calculated using following formula (1):

$$\Delta E^*_{ab} = [(\Delta L^*)^2+(\Delta a^*)^2+(\Delta b^*)^2]^{1/2} \quad (1)$$

Zmeškal et al. (2002) said, that resulting difference in colours are from undetectable to very pronounced or interfering. This change is an accepted method of evaluating colour difference. Final values of ΔE^*_{ab} were compared with a range by Zmeškal (Table 2).

Texture properties of cheese

The texture properties of cheese were measured by TIRATEST 27025 (TIRA Maschinenbau GmbH, Germany) – universal testing machine measuring of various materials for tensile, pressure and bending resistance. The samples were cut in half for texture measurements the inner consistence of maturing cheese.

Measurements were made in triplicate for part following the edge of cheese (0.5 cm from the external surface) and for middle part of samples as well. The method with a 200 N compression load cell with a crosshead speed of 100 $mm.min^{-1}$ was used. The texture properties were determined through the penetration with cylindrical probe with diameter 3 mm to the depth 16 mm.

Similar trend as values measured in the edge part of cheese samples is detectable in the middle part of oiled cheese. Parameter L* (lightness) decreased during period from 0 to 60 day of ripening. The darkest middle part of cheese samples was detected in 60 days of ripening (L* 80.29). In compare with values measured in the edge part, higher values were measured for parameter b* (yellow axis). Yellow tone values were in range between from 16.26 (0 day) up to 20.32 (60 day).

Statistical analysis

For determining statistically significant difference in ripening on individual parameters was used program STATISTICA 12.

RESULTS AND DISCUSSION

During ripening of cheese samples there were observed

Table 2 Colour difference based on the total difference **(Zmeškal et al. 2002)**.

ΔE^*_{ab}	**Colour difference**
0.0 – 0.2	imperceptible
0.2 – 0.5	very light
0.5 – 1.5	light
1.5 – 3.0	clearly perceptible
3.0 – 6.0	middle
6.0 – 12.0	significant
12.0 – 16.0	very significant
more then 16.0	interference

Table 3 Colour characteristic of the edge part of oiled cheeses during ripening.

Days of ripening		**0**	**10**	**20**	**30**	**40**	**60**	**85**
L* (D65)	*M*	89.56^{d}	86.69^{a}	85.89^{a}	84.04^{c}	82.80^{b}	82.30^{b}	85.71^{a}
	SD	0.26	0.47	0.82	0.59	0.58	0.13	0.83
a* (D65)	*M*	0.52^{b}	0.49^{b}	0.14^{a}	0.12^{a}	0.04^{a}	0.19^{ac}	0.51^{b}
	SD	0.12	0.14	0.05	0.05	0.12	0.06	0.13
b* (D65)	*M*	15.83^{c}	17.36^{b}	18.53^{a}	18.54^{a}	17.39^{b}	18.78^{a}	18.62^{a}
	SD	0.42	0.59	0.48	0.22	0.08	0.64	0.15
ΔE^*_{ab}		---	4.29	3.18	1.58	2.08	1.06	2.93

$^{a, b, c, d}$ – different superscripts in a line indicate a statistically significant difference at $p < 0.05$.

statistically demonstrative changes in the colour parameters of the edge part of oiled cheese. **Dufossé et al. (2005)** said that color is the clue for many qualities of food such as flavour, naturality or maturity, and influences consumer choices. Values of the L* parameter (lightness) declined from the start (0 day) till 60 days of ripening. In that context, the edge part of cheese turned dark during ripening. The darkest edge parts were apparent just 60 days of ripening. Lightness of sample in 80 days of ripening (L* 85.71) was statistically the most similar to the lightness between 10 – 20 days of ripening. Parameter a* (green-red axis) showed almost same trend as L* parameter. Values declined till 40 days of ripening. Red colour tone was the most obvious in the beginning (0 – 10 days of ripening) and at the end of experiment. Parameter b* represents blue-yellow axis. Yellow tone was least obvious at the start of experiment (0 day). Values of b* parameter rose till 30 days of ripening. There were no statistically significant differences between yellow tone of samples in 20, 30 days and 60, 85 days of ripening.

According to the criteria **Zmeškal et al. (2002)** is a total colour difference (ΔE^*_{ab}) during storage most noticeable in first 10 days of ripening. Changing in the parameters of edge part of oiled cheese during storage is given in Table 3.

Therefore, yellow tone was most saturated between 40 and 60 days of ripening. At the end of ripening (85 day), parameter b*, there was no statistically significant difference from values of parameter b* in 10, 20 and 30 days of ripening. In compare with changes in a* parameter of the edge part of cheese samples, red tone (a* parameter) in the middle part of cheese samples did not show so large change. Variability in the parameters of middle part of oiled cheese during storage is shown in Table 4.

From the values of parameter L* and b* it is evident that changes were more obvious for the middle part of oiled cheese. The middle parts showed less lightness and yellow tone (b*) was more saturated. Pasta filata cheeses were judged quite evenly colored and free of marbling or other deficiencies in color after 180 days of ripening according to **Santillo et al. (2012)**.

There are other techniques for treating the surface of cheeses. According to **Cetinkaya et al. (2005),** maturation of pasta filata cheese in bee wax for 7 days and over (10 days) had significant positive effects on the organoleptic properties of pasta filata cheese and these were distinguishable by the panelists.

Cheese samples in each stage of maturation were subjected to texture test. Texture of semihard pasta filata cheeses depend on several factors (coagulant, lactic acid microflora and time of ripening) in accordance with **Santillo et al. (2012)**.

Strenght needed to go over the internal matter was recorded. Measuring points were located in the edge and middle part of cheese sample cutted in half. Strenght was measured three times for each location. Variability in firmness for both, edge and middle part, is shown in Table 5.

The measured strenght of edge part of the cheese samples was in range between from 7.44 N up to 23.49 N. Therefore, firmness during maturating process increased three times. Cheese samples had soft consistency immediately after manufacturing and the lowest firmness was measured for middle part of cheese samples (4.46 N). The biggest change in firmness was occurred during first 10 days of ripening when sample became more than twice more rigid.

In first 30 days of maturation, the edge part of samples became more rigid. After 30 days of maturation, sample became softer for next 10 days. Firmness between 40 and 60 days showed almost the same values. There was no statistically significant difference between firmness in 30 days and 85 days of maturation.

Almost same trend were monitored in middle part of cheese sample. Firmness of middle part varied from 4.46 N to 24.40 N in 60 days of maturating.

Table 4 Colour characteristic of the middle part of oiled cheeses during ripening.

Days of ripening		**0**	**10**	**20**	**30**	**40**	**60**	**85**
L* (D65)	*M*	87.93^{e}	85.14^{c}	84.09^{bc}	81.45^{a}	81.87^{a}	80.29^{d}	81.58^{a}
	SD	0.05	0.45	0.43	0.74	0.44	1.03	0.92
a* (D65)	*M*	0.61^{ab}	0.65^{b}	0.54^{ab}	0.54^{ab}	0.47^{ac}	0.36^{c}	0.54^{ab}
	SD	0.01	0.07	0.17	0.05	0.02	0.07	0.08
b* (D65)	*M*	16.26^{e}	18.44^{ab}	18.71^{ab}	19.28^{ac}	20.05^{cd}	20.32^{d}	19.02^{a}
	SD	0.02	0.40	0.90	0.30	0.33	0.68	0.38
ΔE^*_{ab}		---	2.44	1.56	1.49	1.32	2.85	1.42

Table 5 Firmness of edge and middle part of cheese samples.

	Edge part	**Middle part**
Days of ripening	**Firmness (N)**	**Firmness (N)**
0	7.44 ± 0.34^{c}	4.46 ± 0.38^{d}
10	18.59 ± 0.94^{d}	18.97 ± 0.88^{b}
20	21.68 ± 0.39^{a}	18.71 ± 0.94^{b}
30	23.49 ± 0.26^{b}	22.91 ± 0.47^{ac}
40	20.27 ± 1.10^{a}	21.93 ± 1.05^{a}
60	21.53 ± 0.32^{a}	24.40 ± 1.09^{c}
85	23.34 ± 0.10^{b}	22.56 ± 0.59^{a}

$^{a, b, c, d}$ – different superscripts in a column indicate a statistically significant difference at $p < 0.05$.

In first 10 days of ripening, the diference in firmness was more noticeable than in edge part in accordance with **Nuath et al. (2000).** There was no statistically significant difference between firmness in 85, 30 and 40 days of maturation. Strenght measured between 10 and 20 days of maturation was similar.

According to **Bertola et al. (2000)** cheese can be ripened packaged in plastic films of low gaseous permeability and the cheese had similar texture characteristics to that given by traditional ripening conditions (unpacked conditions). As well as rheological parameters, water content, pH and nonprotein nitrogen were temperature dependent. The ripening process in plastic films was accelerated by a temperature increase from 10 to 20 °C.

CONCLUSION

This paper was focused on the changes in colour and texture of semi-hard pasta filata cheese, treated by oil, during 85 day of ripening. Lightness of samples (L*) declined and yellow tone (parameter b*) was more pronounced during maturation. Firmness of samples correspond with L* and b* parameters in first 30 days of maturation. Content of water in cheese loaves was getting lower by evaporating from the surface, therefore cheese has become more rigid especially in first 10 days of ripening when the evaporating was the most pronounced.

REFERENCES

Banville, V., Chabot, D., Power, N., Pouliot, Y., Britten, M. 2016. Impact of thermo-mechanical treatments on composition, solid loss, microstructure, and rheological properties of pasta filata-type cheese. *International Dairy Journal*, vol. 61, p. 155-165. http://dx.doi.org/10.1016/j.idairyj.2016.05.004

Bähler, B., Kunz, A., Hinrichs J. 2016. Hot brining of pasta filata cheese: effect of sodium and calcium chloride on composition, yield, and hardness. *Dairy Science & Technology*, vol. 96, no. 5, p. 703-714. http://dx.doi.org/10.1007/s13594-016-0299-9

Bertola, N. C., Califano, A. N., Bevilacqua, A. E., Zaritzky, N. E. 2000. Effects of ripening conditions on the texture of Gouda cheese. *International Journal of Food Science and Technology*, vol. 35, no. 2, p. 207-214. http://dx.doi.org/10.1046/j.1365-2621.2000.00347.x

Cetinkaya, A., Yaman, H., Elmali, M., Karadagoglu, G. 2005. A Preliminary Study of Kashar Cheese and Its Organoleptic Qualities Matured in Bee Wax. *Internet Journal od Food Safety*, vol. 6, p. 1-4.

CIE (Commission Internationale de l´Eclairage):1978. *Recomendations on Uniform Color Spaces, Color Difference Equation, Psychometric Color Terms. Supplement No.2 to CIE Publication No. 15. Colorimetry*, Bureau Central de la CIE, Paris, France.

Dufossé, L., Galaup, P., Carlet, E., Flamin, C., Valla, A. 2005. Spectrocolorimetry in the CIE L*a*b* color space as useful tool for monitoring the ripening process and the quality of PDO red-smear soft cheeses. *Food Research International* vol. 38, no. 8-9, p. 919-924. https://doi.org/10.1016/j.foodres.2005.02.013

Fox, P. F., McSweeney, P. L. H., Cogan, T. M., Guinee, T. P. 2004. *Cheese: Chemistry, Physics and Microbiology.* 3rd ed. San Diego, USA : Elsevier Academic Press, 456 p. ISBN-10: 0-12-263652-x.

Fox, P. F., Guinee, T. P., Cogan, T. M., McSweeney, P. L. H. 2000. *Fundamentals of cheese Science.* 1st ed. USA : Aspen Publisher, Inc., 638 p. ISBN-10: 0-8342-1260-9.

Kavas, G., Kavas, N., Saygili, D. 2015. The effects of thyme and clove essential oil fortified edible films on the physical, chemical and microbiological characteristics of Kashar cheese. *Journal of Food Quality*, vol. 38, no. 6, p. 405-412. https://dx.doi.org/10.1111/jfq.12157

Keresteš, J. et al. 2016. *Mlieko vo výžive ľudí (Milk in human nutrition).* 1st ed. Bratislava, Slovak Republic : CAD press, 649 p. ISBN-13: 978-80-88969-72-3.

Lovayová, V., Dudriková, E., Nemcová R., Rimárová K. 2010. Influence of the riperning onto the growth of selected probiotic cultures in low-cooked cheese. *Potravinarstvo*, vol. 4, no. 3, p. 40-45. https://dx.doi.org/10.5219/29

Lucey, J. A., Johnson, M. E., Horne, D. S. 2003. Perspectives on the basis of the rheology and texture properties of cheese. *Journal of Dairy Science*, vol. 89, no. 9, p. 2725-2743. http://dx.doi.org/10.3168/jds.S0022-0302(03)73869-7

Lucey. J. A. 2008. Some perspectives on the use of cheese as a food ingredient. *Dairy Science & Technology*, vol. 88, no. 4, p. 573-594. http://dx.doi.org/10.1051/dst:2008010

Nuath, K., Hines, J. T., Harris, R. D. 2000. Cheese Rheology In F. J. Francis *Wiley Encyclopedia of Food Science and Technology*. Hoboken, USA : John Wiley & Sons, 2816 p. ISBN-13: 978-0-471-19285-5.

Piraino, P., Zotta, T., Ricciardi, A., Parente, E. 2005. Discrimination of commercial Caciocavallo cheeses on the basis of the diversity of lactic microflora and primary proteolysis. *International Dairy Journal*, vol. 15, no. 11. p. 1138-1149. http://dx.doi.org/10.1016/j.idairyj.2004.12.006

Spreer, E. 1998. *Milk and dairy product technology*. 1st ed., New York, USA : Marcel Dekker, Inc., 483 p. ISBN-10: 0-8247-0094-5.

Santillo, A., Caroprese, M., Ruggieri, D., Marino, R., Sevi, A., Albenzio, M. 2012. Consumer acceptance and sensory evaluation of Monti Dauni Meridionali Caciocavallo cheese. *Journal of Dairy Science*, vol. 95, no. 8, p. 4203-4208. http://dx.doi.org/10.3168/jds.2011-4777

Trmčić, A., Ralyea, R., Meunier-Goddik, L., Donnelly, C., Glass, K., D. Amico, D., Meredith, E., Kehler, M., Tranchina, N., McCue, C., Wiedmann, M. 2017. Consensus categorization of cheese based on water activity and pH-A rational approach to systemizing cheese diversity. *Journal of Dairy Science*, vol. 100, no. 1, p. 841-847. http://dx.doi.org/10.3168/jds.2016-11621

Zmeškal, O., Čeppan, M., Dzík, P. 2002. Color spaces and color management [online] s.a [cit. 2017-02-01] Available at: http://www.fch.vut.cz/lectures/imagesci/download/stud06_rozn02.pdf.

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