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The Compositional, Textural, Color and Structural Characteristics of Cantal cheese made from Raw, Thermized, and Pasteurized milk

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ABSTRACT

The compositional, textural, color and structural properties of the three major categories of Cantal cheese (produced in the France), made from pasteurized, thermized and raw cheese milk, were determined. Also, this paper gives a critical evaluation of the use of fluorescence spectroscopy for measuring the molecular structural changes in Cantal cheese caused by heat-treatment. Significant differences were observed between Cantal cheeses in their compositional characteristics. Heat treatment resulted in significant increases in the levels of pH, reduction in the contents of fat, protein, calcium and phosphorus in the cheese. Proteolysis was significantly higher in the raw Cantal cheeses milk. Heat treatment significantly influenced color, since color values \(L^*, b^*, \) and \(-a^*\) were high in cheeses made from raw milk than made from thermized or pasteurized milk, while the heat treatment effect was not significant for \(-a^*\) values. Texture attributes of raw and heat-treated milk cheeses were not significantly different. 100% of correct classification was obtained for cheeses by applying FDA to fluorescence spectral data (tryptophan and vitamin A). It is shown that tryptophan emission or vitamin A excitation fluorescence spectra of cheeses may be considered as a characteristic fingerprint which allows the cheese samples to be discriminated, since it were retained information related to molecular structural changes resulting from heat treatment of cheese milk. Thus, it was concluded from this study, fluorescence spectroscopy method can discriminate cheese samples according to heat treatment of cheese milk and combined with multivariate statistical methods were used to as an alternative method without use of chemicals, time-consuming and sample preparation.

Key words: Fluorescence spectroscopy, chemometrics, texture, color, rheology, heat treatment, thermization, pasteurization, raw milk cheese.

Introduction

Cheese characteristics strongly depend on technological processes which is in turn affecting on the composition, dynamics, and interactions between components of the cheese. Of all these characteristics, texture and color are the most important criteria used to evaluate cheese quality by consumers. Several steps in the cheese making process are known to affect on these characteristics. The heat treatments are usually the first step in cheese making. The effects of heat treatment on the components of milk (proteins, lipids, carbohydrates and minerals) are very important for the final product character, since they undergo modifications that affect the quality attributes of cheese (Burton, 1984).

In dairy processes, heat treatment of cheese milk is intended to reduce microbial loads and eliminate pathogens and most of the spoilage microorganisms that may be present in milk. However, milk pasteurization is also known to adversely affect the development of many quality attributes of cheese. Milk pasteurization affects cheese texture, giving rise to an open structure with numerous and irregular cavities that is less firm and more fracturable compared with that of raw milk cheeses (Creamer & Olson 1982; Buffa et al. 2001). Milk for cheese manufacture is generally pasteurized at 72°C typically for 15 to 35s. There are a number of alternatives to pasteurization for the decontamination of cheese milk: thermization- heat treatment at a sub-pasteurization temperature (typically 50-65°C/5-15s); thermization is intended to reduce the microflora of raw milk, minimize changes in milk quality and processability prior to conversion into product. Although thermization does not meet the requirements for pasteurization from the public health viewpoint, it is widely used for cheese milk and in combination with other hurdles, e.g., cooking of the cheese curd, low pH, high salt in moisture, is probably adequate to render good-quality milk free of pathogens and food poisoning bacteria.

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About 700,000 tonnes of raw milk cheeses are produced annually in Europe, particularly in France, Italy and Switzerland. Raw-milk cheeses constitute a major portion of French cheeses with an appellation of origin. These cheeses are highly praised for their expressive sensory characteristics, their ties to unique areas of production and production techniques that have been handed down for generations. About 15% (210,000 tons/year) of ripened French cheese is made from raw milk (Odet, 1999). Cantal cheese is one of the 42 cheeses Protected Denomination of Origin (PDO) produced in France. It is uncooked, hard cheese produced in the Massif Central area of France, made from raw, thermized and pasteurized cow’s milk. Its making process is very similar to Cheddar cheese.

Several analytical chemical methods have been described to characterize heat-induced changes in cheese quality. Tedious and time-consuming chemical methods are often replaced by more rapid and noninvasive spectroscopic methods (Karoui & De Baerdemaeker, 2007). Caseins in cheese contain the amino acid tryptophan and vitamin A, which are naturally occurring fluorescent substances. When milk is subjected to thermal treatment, many changes occur in milk like denaturation of protein, degradation of some fluorophores (tryptophan residues in proteins, vitamins), and development of some new fluorophores (Maillard-reaction products), which consequently changes the fluorescence signals of cheese. Measure the spectra of tryptophan in cheese by using fluorescence spectroscopy have been used to predict the microstructure of cheese (Karoui et al. 2003; Garimella et al., 2005). On another note, fluorescence spectroscopy has also been used to evaluate changes in protein-lipids interaction by measuring the fluorescence properties of vitamin A spectra (Dufour et al., 2001).

Interpretation of spectroscopic data commonly requires the use of chemometrics to draw conclusions. There have been several reports on the use of multivariate statistical analysis for evaluation of fluorescence spectral data obtained by the use of fluorescence spectroscopy analysis to monitor changes in protein-lipids interaction in cheese making and ripening (Karoui & De Baerdemaeker, 2007). In that sense, Dufour and Riaublanc (1997) used a front-face fluorescence method to distinguish between raw, heated, homogenised and homogenised + heated milks by multivariate statistical analysis (Principal Component Analysis and Discriminant Analysis) of fluorescence spectral data and obtained results equal to or better than physicochemical analysis.

The objectives of this research were (1) to evaluate the influence of heat treatments on the main quality characteristics of Cantal cheeses ripened for 90 days that may influence the consumers’ acceptance: compositional, textural, color characteristics of Cantal cheeses made from raw, thermized, pasteurized milk, (2) to investigate the potential of fluorescence spectroscopy coupled with chemometric tools as a rapid and low-cost technique for monitoring cheese molecular structural characteristic.

1. Materials and Methods:

1.1. Cheese Samples:

Thirteen Cantal cheeses ripened for 90 days made from raw, thermized and pasteurized cow’s milk weighing between 2 and 3 kg were purchased directly from the manufacturers location in the Auvergne region in France. Slices were cut off in the middle of the cheese height 2 cm from the rind, for physico-chemical, rheological and spectroscopy fluorescence analysis.

1.2. Physicochemical analysis:

For these determinations, the outer part of the cheese samples (2 mm under the crust) was removed and a part of about 900 g was grated to yield particles of 1mm, as described by (Guinee et al., 2000). Grated cheese samples (900 g) were analyses for pH, moisture, fat, protein, water-soluble nitrogen/total nitrogen (WSN/TN%), salt, ash contents using IDF methods (Guinee et al., 2000). Total calcium was determined in resulting ash by an atomic absorption spectroscopy as described by (IDF, 2003). The phosphorus content was determined colorimetrically (AOAC, 1995, method number 991.25). All analyses were done in triplicate and the results reported as mean ± standard deviation.

1.3. Color Measurements:

Cheese color was determined using a colorimeter CR-400 (Konica Minolta, Tokyo, Japan). The \( L^* \), \( a^* \), and \( b^* \) color measurements were determined according to the CIELAB color space (CIE 1976) with reference to \( D_65 \) (natural daylight, the color warmth of 6500K) and observation angle 10°. The following parameters were determined; \( L^* \) (lightness or whiteness; \( L^*=0 \) for black and \( L^*=100 \) for white color), \( a^* \) (red-green components, \( -a^*= \) greenness and \( +a^*= \) redness) and \( b^* \) (yellow-blue components, \( -b^*= \) blueness and \( +b^*= \) yellowness). The colorimeter was calibrated with a white standard plate 3.5 cm thick layer (\( X = 0.3155, Y =0.3319, Z =94.0 \) before the measurements. Total color differences were calculated (\( \Delta E \)) using the formula:

\[
\Delta E = \sqrt{\Delta L^2 + \Delta a^2 + \Delta b^2}
\]

(Buffa et al., 2001). Values of \( \Delta E \) were calculated to compare pasteurized with
thermized cheese milk. Color measurements were made 5 times, 1 on the middle and 4 on different parts of cheese surface after removing a 0.5 cm layer of upper surface and the results represented as mean ± standard deviation.

1.4. Rheological measurments:

For rheological characteristics, cheeses were sliced into thin disks (2 mm thick and 20 mm diameter) with a cheese slicer. The dynamic oscillatory analyses were performed with a rheometer (CP 20, TA Instrument, Guyancourt, France) with plate geometry of 20 mm diameter. Oscillation analyses were performed in the linear viscoelastic region by applying force (0.5 N) at a constant frequency of 1Hz and the temperature was fixed at 20°C (Karoui et al., 2003). Data were collected and rheological parameters were calculated using TA instrument software programme. The recorded data included the elastic component G' (storage modulus), the viscous component G" (loss modulus), the phase angle (tan δ), and the complex viscosity (η*). All analyses were made in triplicate.

1.5. Fluorescence Spectroscopy:

Fluorescence spectra were recorded using a SLM 4800C spectrofluorimeter (Bioritech, Chamarande, France) mounted with a front-surface accessory. The incidence angle of the excitation radiation was set at 56°. Spectra of cheese samples (3 cm × 1 cm × 0.3 cm) mounted between two quartz slides were recorded at 20°C with emission and excitation slits set at 4 nm. The emission spectra of tryptophan residues (305-400 nm) were recorded with the excitation wavelength set at 290 nm and the excitation spectra of vitamin A (260-350 nm) were recorded with the emission wavelength set at 410 nm (Boubellouta and Dufour, 2008). All spectra were corrected for instrumental distortions in excitation using a rhodamine cell in the reference channel. For each cheese sample, three spectra were recorded.

1.6. Statistical Analysis:

Statistical analysis was carried out using XLSTAT software version 2007 (Addinsoft, France). Significance differences of physiochemical parameters among cheese samples was determined by analysis of variance (one-way ANOVA) using the least square difference method (LSD). Differences were considered significant at the P < 0.05 level.

Analysis of spectra:

In order to reduce scattering effects, the fluorescence spectra were normalized by reducing the area under each spectrum to a value of 1 according to (Bertrand & Scotter, 1992). Principal component analysis (PCA) was applied to the normalized spectra to investigate differences between the cheese samples. This statistical multivariate treatment made it possible to draw similarity maps of the samples (Bertrand & Scotter, 1992). The discriminant ability of the spectral data was investigated by applying factorial discriminant analysis (FDA) to the first 10 principal components resulting from the PCA applied to the spectral data. The aim of this technique is to predict the membership of an individual to a qualitative group defined as a preliminary (Safar et al., 1994). A group was created for each cheese (i.e., Raw, Thermized and Pasteurized cheeses milk). FDA assesses new synthetic variables called "discriminant factors", which are linear combinations of the selected PCs, and allows a better separation of the centres of gravity of the considered groups. For each cheese, the distance from the various centres of gravity of group is calculated. The cheese is assigned to the group where its distance between the centre of gravity is the shortest. Comparison of the assigned group to the real group is an indicator of the quality of the discrimination.

Results and Discussion

Compositional characteristics of Cantal cheese:

The effect of heat treatments on the compositional characteristics of Cantal cheeses samples ripened for 90 days are reported in Table (1). Heat treatments had the largest impact on cheese composition, significantly (P < 0.05) affecting in all compositional characteristics.
**pH and proteolysis:**

As shown in Table (1) Cantal cheeses made from thermized and pasteurized milk had pH values higher than raw Cantal cheese milk, although no significance difference between thermized and pasteurized cheese milk. This may be attributed to the high microbial content of raw milk cheese and the greater utilization of lactic acid leading to low pH value, while pasteurized milk cheese contained the lowest bacterial content owing to the effect of pasteurization (Barr and Tamime, 2010). Levels of WSN/TN%, as an index of proteolysis, were significantly \( P < 0.05 \) higher in raw-milk cheeses than in thermized and pasteurized milk cheeses. The lower rate of ripening in heat treated milk cheese may be due to the destructive effect of heat treatment on the natural flora and milk enzymes which in turn affect fat and protein degradation (Lucey & Fox, 1993).

**Moisture content:**

Thermized milk and pasteurized milk cheese revealed higher moisture than raw milk cheese and were significantly differences among the cheese samples (Table 1). This may be attributed to the effect of pasteurization on k-casein forming complex with \( \beta \)-lactoglobulin which increase water-holding capacity (Lucey & Kelly 1994; Fox et al. 2000).

**Protein and fat contents:**

The fat content of the heat-treated cheese milk was significantly lower \( P<0.05 \) than the raw cheese milk, while the protein content in the heat-treated cheese milk was significantly higher with compare with raw Cantal cheeses (Table 1). The decrease in levels of protein and fat with heat treatments are due to concomitant increase in moisture, and hence, the reduction in level of cheese dry matter (Guinee et al. 1996; Bulca et al. 2004; Guinee et al. 2006).

**Ash and salt contents:**

No major differences in the ash contents were noticeable between raw and thermized cheese milk. Concerning the salt %, the higher salt content was detected in raw cheese milk than the other types of cheeses. Higher levels of salt induce a swelling of the casein phase with subsequent adsorption and absorption of moisture by the casein matrix. Salt content significantly affects cheese structure by increases the level of protein hydration and results in a swelling of the protein matrix (solubilization of caseins). Increased protein hydration results in decreased protein-protein interactions and increased protein-water interactions (Bulca et al. 2004; Celik et al. 2005; Considine et al. 2007; Donato & Guyomarc'h 2009).

**Calcium and phosphorus contents:**

Calcium and phosphorus contents significantly differed in cheese samples (Table 1). A non significant difference was noted in Ca and P contents between thermized and pasteurized cheeses. Heat treatment resulted in significant increases in the levels of pH, reduction in the contents of fat, protein, calcium and phosphorus in the cheese (Lucey & Fox 1993; Lucey & Kelly 1994; Lucey et al. 2001).

**Table 1:** Mean (±SD) of the compositional characteristics and color values of Cantal cheese made from raw, thermized and pasteurized cow’s milk. One-Way ANOVA was applied to data and values with different superscript letter are significantly different \( (P<0.05, \text{ LSD test}) \).

<table>
<thead>
<tr>
<th>Compositional parameters</th>
<th>Cantal cheese made from</th>
<th>Raw milk</th>
<th>Thermized milk</th>
<th>Pasteurized milk</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>5.23 (±0.01)(^a)</td>
<td>5.37 (±0.01)(^a)</td>
<td>5.38 (±0.01)(^a)</td>
<td></td>
</tr>
<tr>
<td>Moisture (%)</td>
<td>39.62 (±0.25)(^c)</td>
<td>41.30 (±0.19)(^a)</td>
<td>39.96 (±0.11)(^a)</td>
<td></td>
</tr>
<tr>
<td>Fat (%)</td>
<td>32.85 (±0.14)(^a)</td>
<td>31.58 (±0.14)(^b)</td>
<td>30.50 (±0.00)(^b)</td>
<td></td>
</tr>
<tr>
<td>Protein (%)</td>
<td>24.48 (±0.08)(^a)</td>
<td>25.18 (±0.19)(^b)</td>
<td>28.38 (±0.46)(^b)</td>
<td></td>
</tr>
<tr>
<td>WSN/TN %</td>
<td>26.09 (±0.25)(^c)</td>
<td>22.04 (±0.43)(^a)</td>
<td>23.89 (±0.58)(^b)</td>
<td></td>
</tr>
<tr>
<td>Salt (%)</td>
<td>4.25 (±0.01)(^c)</td>
<td>4.24 (±0.02)(^a)</td>
<td>3.87 (±0.01)(^b)</td>
<td></td>
</tr>
<tr>
<td>Total Ca (%)</td>
<td>0.612 (±0.10)(^b)</td>
<td>0.824 (±0.01)(^a)</td>
<td>0.790 (±0.05)(^a)</td>
<td></td>
</tr>
<tr>
<td>Total P (%)</td>
<td>0.478(±0.15)(^a)</td>
<td>0.529(±0.13)(^b)</td>
<td>0.527(±0.23)(^b)</td>
<td></td>
</tr>
<tr>
<td>Cheese Color values</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L* value</td>
<td>80.91 (±0.53)(^a)</td>
<td>79.47 (±0.70)(^a)</td>
<td>79.92 (±0.96)(^a)</td>
<td></td>
</tr>
<tr>
<td>a* value</td>
<td>-2.77 (±0.11)(^b)</td>
<td>-1.78 (±2.76)(^a)</td>
<td>-2.34 (±0.11)(^a)</td>
<td></td>
</tr>
<tr>
<td>b* value</td>
<td>23.63 (±0.80)(^a)</td>
<td>22.73 (±0.39)(^b)</td>
<td>20.93 (±2.45)(^b)</td>
<td></td>
</tr>
<tr>
<td>ΔE</td>
<td>--</td>
<td>2.58 (±0.72)(^b)</td>
<td>2.87 (±0.30)(^b)</td>
<td></td>
</tr>
</tbody>
</table>
The color of cheese is an important factor in the consumer appeal of the product. The cheese color is influenced by several factors including light scattering of fat, protein particles and water drops (Rudan et al. 1998). Table (1) presents the mean values obtained for L*, a*, and b* parameters of the Cantal cheeses made from raw, thermized and pasteurized milks. The results illustrated that the color parameters (L*, a* and b* values) were higher in raw Cantal cheeses milk than the other cheeses made from heated milk, although, there was no significant difference between the thermized and pasteurized milk cheese concerning the L* values. With regard to the red component (- a*) was not significant ($P < 0.05$) between the cheeses, indicating that the pasteurization of milk had not an effect on a* value. The b* values were significantly differed between all cheeses. However, the changes in b* value for thermized Cantal cheese milk were much smaller than those found for pasteurized Cantal cheese milk.

In order to determine the effect of heat treatments applied to cheese milk on the total color of the investigated cheeses, total color difference ($\Delta E$) was calculated according to the formula given by (Buffa et al. 2001). Although the lowest value of this parameter was observed for thermized cheeses with a value of 2.58 and the highest one was observed for pasteurized cheese ($\Delta E=2.87$), no significant difference was found among them ($P < 0.05$). The almost identical color values found in thermized and pasteurized cheeses could be attributed to their similar structure.

Textural attributes of Cantal cheese:

The textural properties of a food product can be achieved by examination of its rheological behavior. In Figure (1), effects of heat treatments on elastic modulus ($G'$, elastic rigidity), viscous modulus ($G''$, viscous rigidity), tan $\delta$ (indication of relative viscous and elastic components) and $\eta^*$ (complex viscosity) of the three Cantal cheese are shown. Briefly, the heat treatment gave rise to an increase of $G'$ and $G''$ values. Since, the raw Cantal cheese had significantly lower $G'$, $G''$, tan $\delta$ and $\eta^*$ than the other cheeses (Figure 1).

The adverse effects of heat treatments (HT) on texture attributes are probably due, in part, to the presence of denatured whey protein-k-casein complexes on the surface of the rennet-treated micelles and in other part, adverse effect of HT on cheese constituents (reduction in fat, WSN/TN%; increase in protein, pH, ca, p contents) (Visser 1991). Increase in contribution of whey proteins in gel network cause significantly increase in storage modulus ($G'$) because denatured whey proteins act as bridging material between casein particles, which would increase the number and strength of bonds (Kelly & O'Kennedy 2001; Pastorino et al. 2003). These results are in agreement with the work of other investigators (Vliet & Keeteles 1995; Lucey & Singh 1997; Lucey et al. 1997; Kelly & O'Kennedy 2001; Lucey et al. 2001; Vaziri et al. 2001).

Molecular structural characteristics of Cantal cheese:

Fluorescence spectroscopy method have be used to evaluate the structural characteristics of cheeses via evaluation the fluorescent properties of tryptophan residues in the proteins and vitamin A in the fat globules of cheese (Herbert et al. 2000; Karoui & Dufour 2003; Karoui & De Baerdemaeker 2007; Dufour 2010).

Fig. 1: The effect of heat treatment on textural attributes ($G'$, $G''$, tan $\delta$ and $\eta^*$) of Cantal cheeses made from raw, thermized and pasteurized milk.

Color values of Cantal cheese:

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Fluorescence properties of protein tryptophan and of vitamin A in the fat globules:

Figure (2) shows the tryptophan emission (Fig. 2 A) and vitamin A excitation (Fig. 2 B) fluorescence spectra of the Cantal cheeses manufacture from raw, thermized and pasteurized. Concerning tryptophan emission spectra of the three cheeses exhibited a maximum at about 339 nm for all investigated cheeses, while the shape of tryptophan spectra varied slightly among the three cheeses (Fig. 2 a).

This difference in the shape of the spectra among the three cheeses could be due to the difference in environments of the tryptophan residues resulting from the differences in the structure of cheese matrices (Herbert 1999; Herbert et al. 2000). Indeed, the changes of the environment and solvent viscosity could be change the fluorescence properties of tryptophan as has been reported previously by (Dufour & Riaublanc 1997; Dufour et al. 2001)

With regard to vitamin A, the shape of the spectra showed two maxima at 320 and 305 nm. The shapes of the spectra scanned on cheese samples were overall similar, varying mainly in the maximum/shoulder intensity ratios. The changes in the shapes of the vitamin A spectra could be related to the modification in the physical state of triglycerides in the fat globules as well as to different protein–lipid interactions (Herbert 1999). Indeed, the shape of the vitamin A spectrum depends on the physical state of the triglycerides and the heat treatment applied to the milk during cheese manufacture (Dufour & Riaublanc 1997; Herbert et al. 2000).
Multivariate analysis of spectral data:

To compare the ability of tryptophan emission and/or vitamin A excitation fluorescence spectra to emphasize the similarities and differences among the cheese samples, PCA, in a first step, was carried out separately on each spectral data set (tryptophan and vitamin A) and in a second step FDA was applied on the first 10 PCs of PCA performed on each spectral data set to cheese discrimination.

Cheese discrimination from their tryptophan emission fluorescence spectra:

Firstly, PCA performed on tryptophan emission spectra (30 observations and 100 variables), the similarity map of the two first PCs allowed a good discrimination of pasteurized Cantal cheese from raw and thermized cheese milk (Fig. 3). Indeed, according to PC 1 which took into account 84.2% of the total variance, pasteurized Cantal cheeses presented negative scores, whereas those produced from raw and thermized had positive scores. Less good discrimination was obtained from the similarity map of the tryptophan fluorescence spectra for Cantal manufactured from raw or thermized cheese milk.

Secondly, FDA was performed on the first 10 PCs of PCA performed on the tryptophan spectral data. The data matrix for FDA included 30 objects and 10 variables (the first 10 principal components).
pasteurized Cantal cheeses were observed on the left, whereas cheeses from the raw and thermized were observed on the right. Raw Cantal cheeses were discriminated than thermized Cantal cheeses according to discriminant factor 2. 100% correct classification was obtained for the three investigated cheeses.

Cheese discrimination from vitamin A excitation fluorescence spectra:

Firstly, the PCA performed on vitamin A excitation spectra (30 observations and 80 variables) and the similarity map of the PCA performed on vitamin A fluorescence data set is shown in Figure (5). Again, a quite good separation of thermized Cantal cheese (TM) was observed according to the PC1 accounting for 62.70% of the total variance. However, less good discrimination was obtained between the raw and pasteurized Cantal cheese.

Secondly, FDA was performed on the first10 PCs of PCA performed on the vitamin A spectra. The data matrix for FDA included 30 objects and 10 variables (the first 10 principal components). The similarity map defined by the discriminant factors 1 and 2 took into account 100% of the total variance with discriminant factor 1 accounting for 98.87% (Fig. 6). A discrimination of raw Cantal cheese from the others was essentially observed according to discriminant factor 1, where pasteurized Cantal cheeses were observed on the right, whereas thermized and raw Cantal cheeses were observed on the left. The discriminant factor 2 essentially discriminated raw from thermized Cantal cheeses (Fig. 6). 100% correct classification was obtained for the three investigated cheeses (data not shown).

Fig. 5: Principal component analysis similarity map determined by principal components 1 and 2 for the vitamin A fluorescence spectra of Cantal cheeses made from raw (○), thermized (△) and pasteurized milk (●).

Fig. 6: Discriminant analysis similarity map determined by discriminant factors 1 (F₁) and 2 (F₂) of the FDA performed on the first10 PCs of PCA of vitamin A fluorescence spectra of Cantal cheeses made raw (○), thermized (△) and pasteurized milk (●).
Conclusion:

There were considerable variations in the chemical, color and textural properties of Cantal cheese made from raw, thermized and pasteurized milk. These differences probably reflect processing condition used in these cheeses. Raw Cantal cheeses milk significantly differed in color and texture from the others cheeses made with thermized or pasteurized milk. The structural changes as determined by rheological and fluorescence modified the level of rheological parameters (elastic and viscous moduli) and the shape of spectra of tryptophan and vitamin A curves. It can be concluded that emission spectra of tryptophan and excitation spectra of vitamin A could be considered as fingerprints allowing a good identification of cheese samples according to their heat treatments.

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