

**STRESS ANALYSIS AS A DETERMINANT OF SALAMI RENNET CHEESE RIPENING***Jerzy A. Balejko**Department of Food Process Engineering, Agricultural University of Szczecin, Szczecin*

Key words: dairy products, ripening, mechanical properties, texture

Changes of mechanical properties of the Salami rennet cheese were monitored during 12 weeks of the ripening process. The dynamic method of direct measurement of sinusoidal changes of stress and deformation and computer analysis of the thermodynamic state of the material under study were applied.

The analysis of changes of stress level during the ripening process and a comparison with the analytical method, showed usefulness of the method applied. The speed of the method applied makes it possible to get instant qualification of stages of Salami cheese ripening process. The analysis of stress values in the cheeses section under study was proved to be a useful method for determining the ripening rate.

**INTRODUCTION**

The main objective of a food processing engineer is to satisfy consumer's expectations regarding food quality, the latter concerning the appearance taste and smell, texture and nutritive value. The product's quality is also influenced by storage conditions and packaging.

At least six out of twelve raw materials are subject to ripening through biological and chemical changes in order to produce a product ready for consumption. The quality of certain products depends on a number of physical and chemical factors, such as temperature, humidity, salt content, oxygen access and the duration of ripening in particular.

It is possible to determine the degree of cheese maturity by either sensory assessment of its smell, taste, appearance and colour or with methods of chemical analysis [Ziajka, 1997; Budslawski, 1973; PN-73/A-86232] by determining contents of various forms of nitric compounds in cheese in the relation to total nitrogen. Contents of soluble nitric compounds are a measure of the range of ripening, however concentrations of N-amino compounds are a measure of the depth of ripening [Ziajka, 1997].

After the production and salting, cheeses do not exhibit typical sensory properties. They are slightly sour and salty, their texture is rubber-like and brittle and they produce their specific smell and taste, proper structure and consistency during the ripening process.

The ripening can be defined as a combination of direct biological processes which occur in controlled thermal and humid conditions and result in relevant changes of carbohydrates, proteins, fats and mineral salts as well as the generation of substances influencing organoleptic characteristics of cheeses.

The ripening can be divided into two phases: (1) preliminary ripening – changes initiated by the lactic fermentation during the processing of curds and slurry, shaping, salting and during the first days of ripening, and (2) proper ripening – changes of lactic acid, degradation of proteins, fats and changes in mineral salts.

The methods used to determine the ripening rate were based on organoleptic testing which, in fact, does not make it possible to monitor changes in texture parameters over the entire ripening process.

Rheological properties of cheese combine the texture which includes such significant traits as appearance, taste and feel by touch characteristics, elasticity and surface quality. The structure and consistency are also closely related to texture. The former covers the concentration, size, shape and location of structural elements and their relations, while the latter concerns mechanical properties, such as plasticity, hardness, brittleness and spreadability.

There were numerous attempts made to find rheological models for foodstuffs from among which dairy products, mainly soft and hard cheeses, play a key role. The research covered the development of mechanical analogous equivalents and formulas of the rheological state of a cheese under study [Konstance & Holsinger, 1992; Peleg, 1979; Shoemaker *et al.*, 1992; Shukla & Rizvi, 1995; Ustunol *et al.*, 1995; Yun *et al.*, 1994]. Many instrumental techniques, namely small strain methods and large strain tests (*e.g.* texture profile analysis, uniaxial compression and torsion), are used to measure the physical properties of cheeses that are, up to a certain extent, related to sensory characteristics [Wium & Qvist, 1998; Drake *et al.*, 1999; Fox *et al.*, 2000; Breuil & Meullenet, 2001; Truong & Dauber, 2001; Kuo *et al.*, 2000].

The purpose of the study was to assess the usability of

the instrumental dynamic method for measuring stress to identify the degree of Salami cheese ripening during the ripening process.

## MATERIALS AND METHODS

Dynamic measurements of internal stresses were carried out by means of the uniaxial penetration on a device developed at the Agricultural University of Szczecin [Patent Specification PL380030]. Salami cheese, (45% water content, 45% fat content, ZN-93/OSM B-rd/A-2) made on the 4 April 2003 at Regional Dairy Cooperative in was subject to testing. During the ripening the cheese was kept at a temperature of 10°C and relative humidity of 45%. The first measurement was taken three days after the cheese production date.

In all stages of the ripening, *i.e.* after 1, 3, 5, 7, 9 and 12 weeks, samples of initial height  $H_0=0.015$  m and diameter of 0.08 m were prepared.

The samples were subject to 25% penetration by a cylindrical mandrel, 0.010 m in diameter, (penetrator face  $S=0.00177$  sq.m.). The cycle duration was 1 sec for all tests. The surface of each sample was divided into 25 spots (Figure 1), at which internal stresses were measured. The testing covered 3 consecutive runs for each elementary area (A1, A2, A3...D).

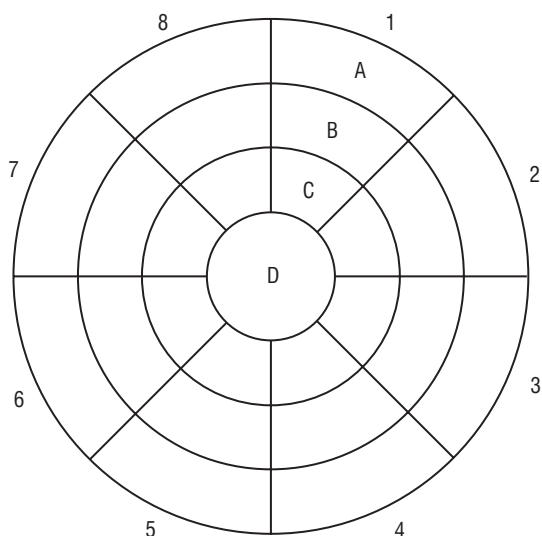


FIGURE 1. Elementary areas at which stresses were taken.

The maturity means a rate of decomposition of casein and probably fats which takes place during the ripening period of cheese. It is measured by the quantity of casein hydrolysis products and given by a range and depth of ripening [Ziajka, 1997]. The content of soluble nitrogen compounds is a measure of the ripening range, whereas the content of compounds of amino acids reflects the ripening depth. The parameters apply to the control of cheese ripening process, that is why the samples were subjected to a chemical analysis to determine the content of the total, soluble and amino nitrogen in order to estimate the suitability of the method concerned. To determine the content of nitrogen compounds used was made of the Kjeldahl method and a Kjeltec Sys-

tem 1026 (Tekator, Sweden) device. The samples subjected to testing were taken from the following areas: central area (zone D, Figure 1), intermediate area (zones B and C) and surroundings (zone A).

Total nitrogen (TN) was determined with the Kjeldahl method by means of a Kjeltec system 1026 (Tekator, Sweden) apparatus. A sample of 0.6 g taken for combustion was weighed on electronic scales WPS 720 (Radwag, Radom, Poland) with the accuracy of 0.001 g, then the sample was put into a glass flask together with a selenium mixture added as a catalyst and burnt in a Digestion System 6 1007 Digaster (Tekator, Sweden) oven in the atmosphere of concentrated  $H_2SO_4$  at 400°C to obtain a clear solution.

Non-protein nitrogen (NPN) was determined as above, and sampled into a flask 10 mL of TCA extract. The TCA extract was prepared as follows: a sample of crushed cheese (50 g) was weighed on type RPT 9553 technical scales (Radwag, Radom, Poland) with the accuracy of 0.1 g and put into a 450-mL glass homogenizer jar, and 200 mL of 5% TCA (trichloroacetic acid) was added to the jar. The homogenization was effected at the speed of 13.000 rpm for 30 sec on type MPW homogenizer (Mechanika Precyzyjna, Warsaw). After a 5-min break the homogenization continued for another 30 sec. The system remained still for 30 min and homogenate was filtered through a filter paper with an average filtering rate into 250-mL dry bottles made of dark glass.

The Pope's and Stevens' method was used to determine  $\alpha$ -amine nitrogen [Pope & Stevens, 1939], in TCA cheese extracts. Each determination was made in three replications.

The ripening range and depth were determined according to the following formulas:

$$\text{Ripening range} = \frac{N - \text{soluble}}{N - \text{total}} \cdot 100\%$$

$$\text{Ripening depth} = \frac{N - \text{amino}}{N - \text{soluble}} \cdot 100\%$$

An analysis of variance was carried out using Statistica procedure to describe relationships between stress, ripening time, range of ripening and depth of ripening. A multiple linear regression model was used to describe relationships between stress, ripening time, range of ripening and depth of ripening.

## RESULTS AND DISCUSSION

The graphic interpretation of the stress distribution in the consecutive phases of the ripening (Figure 2) shows the differentiation of the stress state in time. The distribution of stress changes dramatically and shows a significant difference in hardness between the inner area (zones A1 through A8, Figure 1) and the outer area of the sample (zone D).

In the first weeks of cheese ripening the greatest changes of stress are observed both in the centre of the samples under study and peripheries. The stresses noted in the centres of the samples (zone D) were higher by 25% and by 15% in the outer area (A) after 3 days and 10 days of the ripening, respectively. The stresses in the cheese were stabilised at the constant level after the balancing of the chemical composition and the internal stress stated within the whole block of cheese after ripening for 12 weeks under identical thermal and moisture conditions.

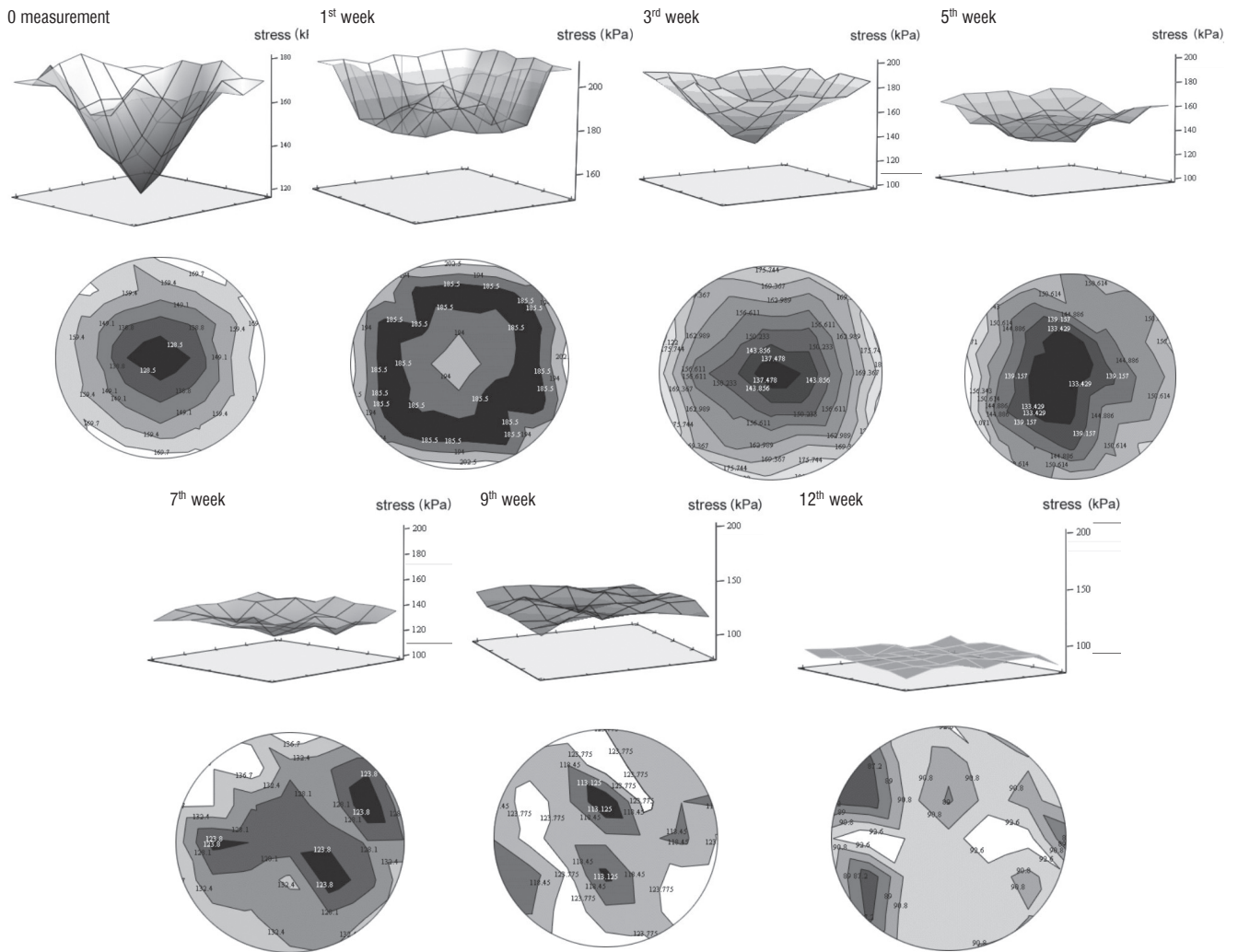


FIGURE 2. Distribution of mean values of maximum stress in samples of Salami cheese.

The analysis of changes in mean stress values throughout consecutive phases of cheese ripening (Figure 3) enables determining the direction of ripening (equalization of the chemical composition) which follows from the center zone outwards.

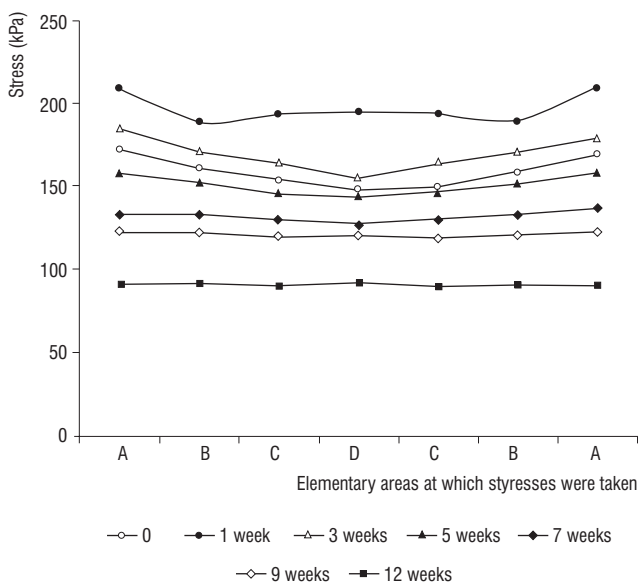


FIGURE 3. Changes in mean stress values throughout consecutive ripening phases.

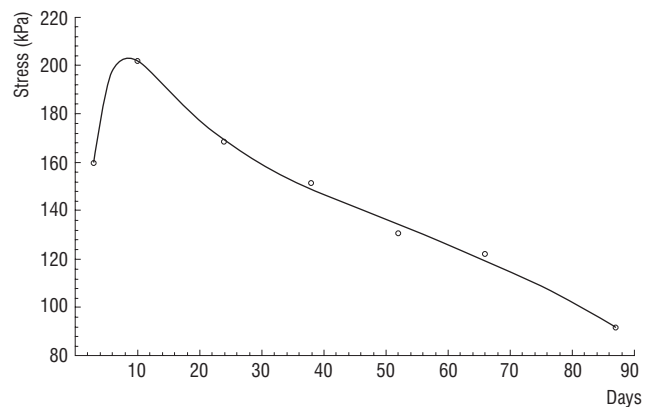


FIGURE 4. Mean values of maximum stress in samples of Salami cheese during the ripening period.

Changes of mean stress values during the ripening process (Figure 4) can be described by the following mathematical equation:

$$\sigma = a_0 + \sum_{i=1}^n a_i \cdot \log(t)^i$$

where:  $\sigma$  – stress (Pa),  $t$  – time of ripening period (days),  $a_0 \dots a_n$  – constant factors of equation (1).

TABLE 1. Mean values of maximum stress in samples of Salami cheese during the ripening period.

Ripening time (days)	Mean value of stress (kPa)
3	159.59
10	201.75
24	168.56
38	151.17
52	130.78
66	121.95
87	91.3

TABLE 2. Values of constant factors of equation (1).

Factor	Value
a <sub>0</sub>	253.88
a <sub>1</sub>	-404.61
a <sub>2</sub>	492.95
a <sub>3</sub>	-232.51
a <sub>4</sub>	47.60
a <sub>5</sub>	-3.61

On the basis of experimental data included in the Table 1, using the Marquardt-Levensberg procedure, the values of constant factors of equation (1) were assigned (Table 2) obtaining a high correlation from adjusting the theoretical curve to experimental data ( $r=0.998$ ).

Figures 5 and 6 show changes in the ripening depth and range in different zones of a sample during cheese ripening which do not make it possible to specify whether the cheese ripening process is completed or not.

Stress values were significantly correlated with the time of ripening. There was a statistically significant relationship between the variables at a confidence level of  $\alpha=0.01$ . The fitting of the multiple linear regression model describing relation-

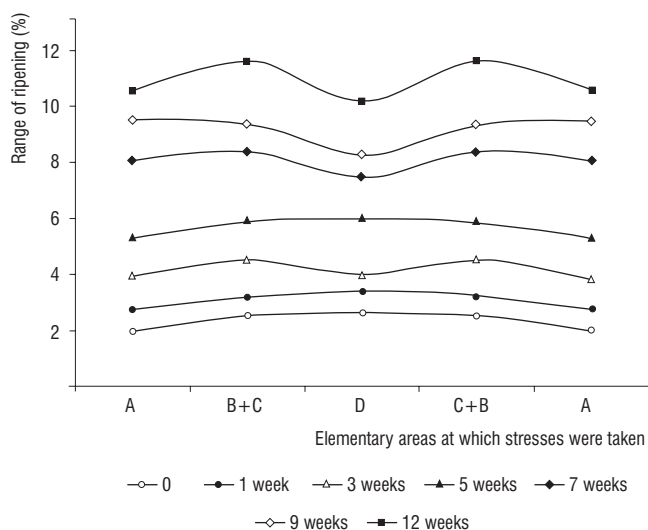


FIGURE 5. Changes of a ratio between non-protein nitrogen and total nitrogen during the ripening period.

ship between stress, ripening time, range of ripening and depth of ripening was conducted. The equation of the fitted model is:  $Y = 42.39 - 20.25*X + 8.08*X1 + 9.42*X2$ , where: Y – stress, X – weeks, X1 – range of ripening, and X2 – depth of ripening. The level of significance was determined as at least  $p<0.05$ .

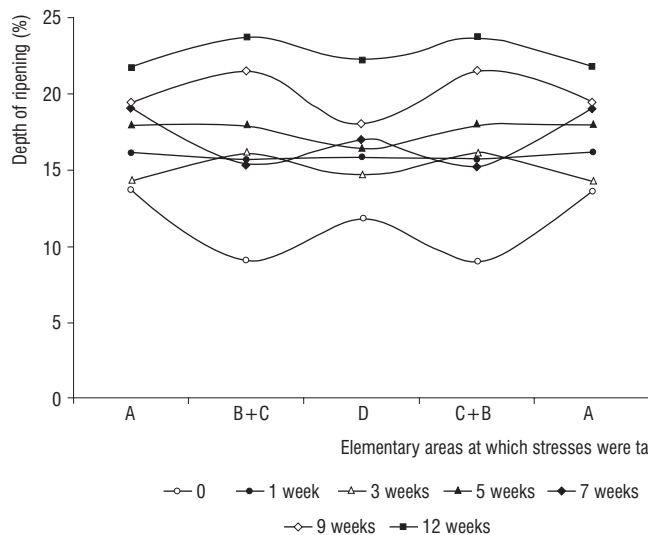


FIGURE 6. Changes of a ratio between amino nitrogen and total nitrogen during the ripening period.

In available rheological literature one can find works of tracing changes in the texture during the ripening process of cheese on the example of high-pressure-treated goats' milk [Buffa *et al.*, 2001] or cheddar cheese [Hort & Gryns, 1999], where the fracture stress of milk cheeses from day 1 to 60 was investigated indicating a significant effect of ripening time on fracturability, and correlating fracture stress to water soluble nitrogen and to moisture content. The rheological properties of Cheddar samples were determined using compression tests performed on an Instron Universal Testing Machine and were reported as a true stress and Young's modulus of 75% compression at a crosshead speed of 50 mm/min. Buffa *et al.* [2001] carried out tests of 80% uniaxial compression of cheese samples with a crosshead speed of 80 mm/min using a TA-TX2 Texture Analyzer (Stable Microsystem).

In both of the above-mentioned works, the level of deformation, speeds of penetration as well as the method of sample testing are different from these applied in the dynamic method. The dynamic method of uniaxial sinusoidal compression was applied for the first time to determine changes of stress during the ripening process of Salami cheese.

**CONCLUSIONS**

The analysis of changes in stress in the samples under study during the ripening process led to the following conclusions:

1. Stress values were significantly correlated with the time of ripening.
2. The distribution of stress in 12-week samples shown in Figure 2 means the completed ripening process.
3. The stress measurement method was found suitable for estimating cheese maturity.

4. The examination of stress during the ripening is a quicker, simpler and more efficient method to determine the maturity rate of Salami cheese.

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## ANALIZA STANU NAPRĘŻEŃ JAKO WYZNACZNIK STOPNIA DOJRZAŁOŚCI SERA SALAMI

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W trakcie eksperymentu śledzono zmiany właściwości mechanicznych sera Salami podczas dwunastu tygodni procesu dojrzewania. Stosując dynamiczną metodę wymuszeń sinusoidalnie zmiennego odkształcenia badano odpowiedź sprężystą próbek sera Salami oraz analizowano zmiany średnich wartości naprężeń w trakcie kolejnych faz dojrzewania. Po akwizycji i komputerowej analizie 200 punktów pomiarowych uzyskanych w trakcie jednego cyklu odkształcenia określano stan termodynamiczny próby.

Analiza zmian poziomu naprężeń w badanych próbach w trakcie procesu dojrzewania i porównanie z metodą analityczną wykazały przydatność metody pomiaru naprężeń do określania stopnia dojrzałości sera. Szybkość zastosowanej metody pozwoliła w ciągu jednej minuty uzyskać kompletną analizę stanu naprężeń w badanej próbce jak również określić stopień jej dojrzałości.

