# ASPECTS REGARDING THE BEHAVIOR OF MOLD CHEESE AT PENETRATION WITH CONES AND NEEDLES, AT MATURATION

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*The purpose of this study is to conduct a detailed investigation into the characteristics of moldy cheeses, aiming for a deeper understanding of the maturation process, the evolution of texture, and their physical properties. The penetration behavior of the Roquefort, Gorgonzola, Brie and Camembert cheeses is studied using both cone and needle methods, determining the depth of penetration at various points across the diameter of the circle circumscribed around samples of different geometrical shapes. The variation of shear tangential tension of these cheeses is determined in relation to the penetration depth, and the logarithmic-type variation law is verified for the relationship between these characteristic quantities.*

**Keywords**: ripened cheese, physical characteristics, penetration behavior, penetration depth, tangential tension

## 1. Introduction

Cheese is a food product made from fermented milk that is consumed globally, [1]. Cheeses have evolved uniquely depending on climate and region, resulting in the development of over 1,000 cheese varieties, which can be grouped based on moisture content into categories such as hard, semi-hard, and soft cheeses, [2]. Cheese can be a soft, semi-hard, hard, or extra-hard product, either matured or fresh, and may be covered with a wax crust, infused with aromatic herbs, while the whey/casein protein ratio does not exceed that of milk, [3]; from the category

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of soft cheeses, fungal-flora cheeses are also included.

Moldy cheese is increasingly consumed, thus raising interest in the scientific analysis of their physicochemical and organoleptic characteristics across various types and origins. This sort of cheese is one of the foods obtained from fermented milk, characterized by its multitude of flavors and different textures. The most knownen cheeses for their taste, aroma, as well as their appearance, namely for the blue-green mold veins within the paste or for the white mold on the surface, are Roquefort and Gorgonzola, Brie and Camembert, respectivelly.

Soft cheeses are characterized by a high water content, short maturation period, and reduced shelf life. Due to their soft, smooth consistency and pleasant taste with a specific aroma, the production of these cheeses has expanded in recent times, with the number of varieties continuously increasing worldwide, [4].

Mold-ripening is an ancient cheese-making method, and there are two categories of cheese matured with the help of mold: surface-ripened cheese (such as Camembert and Brie) and blue-veined cheese (such as Roquefort and Gorgonzola), [5]. Blue mold cheeses (using *Penicillium roqueforti*) and white mold cheeses (using *Penicillium camemberti*) share the characteristic of mold growth during maturation, but the methods used for their production and the process of achieving distinctive flavors and textures different considerably from each other, [6]. Roquefort cheese belongs to the category of "blue veined cheese" or simply "blue cheese", due to the development of the *Penicillium roqueforti* mold in the cavities within the cheese paste [7].

Camembert cheese is characterized by the presence of a white rind formed by the growth of *Penicillium camemberti* mold, which gives it unique aroma and flavor characteristics, [8,9]. The most important stages in the technological process of cheese production are milk reception, heat treatment, milk standardization, coagulation, cutting and processing of the curd, draining, pressing, salting, and maturation, [10]. During the maturation process, the cheese curd initially appears white, crumbly, and tasteless, but gradually transforms into a creamy, elastic, yellowish-white texture with distinct taste and aroma characteristic of each variety, [11]. Maturation represents the most important technological step in cheese production, involving a multitude of biochemical changes that determine the quality of the cheese, texture and its physical characteristics. Maturation consists of three phases: pre-maturation, the maturation or primary fermentation, when flavor substances begin to develop, and final maturation, the phase during which the taste and aroma of the cheese are mainly defined, [2].

The maturation stage must be carefully monitored to produce cheesewith desired quality at minimal cost and with the highest acceptance from consumers. The organoleptic properties of cheese are mainly determined by the complex changes that occur during maturation. The degree of maturation plays a significant role in the development of cheese flavor due to the complex modifications of the chemical composition. Assessing cheese maturation is a difficult task, requiring the use of multiple methods to effectively study the biochemical changes that occur during this complex process, mainly from the perspective of improving flavor and accelerating the maturation. However, the successful implementation of this objective in the cheese industry is challenging, [1]. Attributes of cheese texture, such as hardness, brittleness, and elasticity, are largely linked to its mechanical properties, such as deformation upon rupture, penetration resistance, and Young's modulus.

Korolczuk and Mahaut [12] determined the tangential tensions during cone penetration on samples of acidified cheese (with protein content ranging from 6.6% to 10.4% and fat/total solids ranging from 40% to 55%), depending on the cone angle, at various penetration speeds, observing a Bingham-type behavior of the analyzed cheeses. It was also found that the tangential tension was proportional to the penetration speed and inversely proportional to the cosine of the cone angle. The determined value of tangential tension ranged from 0.2 to 5 kPa for intact samples and was 2 to 5 times lower for samples taken from cheese packaging and transferred to the testing penetrometer, indicating a change in cheese texture during handling.

The viscosity of cheese (Gouda and Cheddar) ranges between $10^7$-$10^8$ poises, shear stiffness between $10^4$-$10^5$ Pa, and relaxation/recovery time between 200-500 seconds at room temperature [13]. Additionally, the cheese exhibited a normal viscoelastic behavior in terms of rheology over narrow temperature intervals. The value of the cheese's elasticity/stiffness modulus was approximately $2\times10^4$ Pa at 29°C and remained constant regardless of the angle or weight of the cone in penetration tests using a cone penetrometer.

The mechanical properties of cheese are directly linked to its composition, especially to the fat and dry matter content. For example, hard cheese typically has a high dry matter content, which also leads to an increased perception of hardness and firmness, [14]. Among the factors influencing proteolysis and the generation of flavor compounds, contributing to differences in cheese aroma between producers, an important role is played by the maturation period, as it significantly influences the degree of proteolysis. As storage time increases, the degree of proteolysis also increases, and the cheese texture tends to become brittle instead of ductile over time. Extended maturation periods are associated with the development of a bitter taste due to increased formation of bitter peptides. These peptides are often derived from specific regions of β-casein. The degree of bitterness varies depending on both the maturation period and the cheese type

For example, white brined cheese is preferably matured for less than 90 days to prevent bitterness, [15, 16]. The development environment for mold in cheeses is heterogeneous, with pH, salt, and water activity (aw) among the most important parameters. The maturation temperature is typically between 8 and 15°C, depending on the cheese variety. The distribution of $O_2$, $CO_2$, NaCl, and the changes that occur during maturation have a significant impact on the growth, spatial distribution, and biochemical activity of various microorganisms present in cheese, thus affecting the mechanical properties and, consequently, the quality of the final product. Therefore, understanding the texture at different stages of maturation and in different areas of the cheese, such as the core versus the rind, is essential for building realistic model systems, understanding the dynamics of microbial populations, and optimizing and monitoring cheese quality, [4]. Additionally, packaging is crucial for matured cheeses, as it serves to halt maturation and stop the growth of undesirable microorganisms. However, packaging for blue mold cheese must allow cheese maturation and not hinder the activity of bacteria that play a role in preserving and developing cheese qualities throughout the storage period [17]. The packaging must be designed to allow the release of excess $CO_2$ and $H_2O$ and the supply of oxygen for microorganisms.

In the manufacturing process, cheese- is subjected to mechanical operations, including those occurring after setting and maturation. Therefore, by injecting Cheddar cheese with a specially prepared sodium citrate solution, the authors of the study [20] aimed to determine its effect on the cheese structure. Injection with citrate increased the sodium content from 0.63 to 0.93%, but had no effect on the pH, which remained around 5.2. The same authors [21] injected Cheddar cheese samples with a 20% w/w solution of glucono-delta-lactone, and after 40 days of storage at 4°C, they observed a decrease in cheese pH from 5.3 in the non-injected cheese to 4.7.

Studies on the tangential tension of cheese have been conducted by various researchers as well, in works [22-25], where the authors found that the coefficient of friction with the contact surface affects the relaxation behavior of tensions. For acid cheese samples with 12–39% total solids, the tangential tension had values of 0.3–14 kPa, while the non-relaxing tension represented 10–30% of the initial tension levels.

By injecting specific solutions into different categories of cheese, modified characteristics of the cheese can be achieved, which can lead to either longer shelf life, improved taste, or even better organoleptic properties.

The paper presents the results of penetration tests with cones and needles of different diameters for four categories of soft cheese at maturation, purchased from the Romanian food market.

The purpose of the study was to determine the penetration behavior of mold cheese (such as Camembert, Brie, Dorblu, and Roquefort) using cones and needles, during maturation, and to verify the logarithmic-type variation law of the shear stress limit for the analyzed cases.

## 2. Materials and methods

The manual penetrometer measures the force required to penetrate the products, thus determining their hardness (mechanical resistance to penetration). The penetration method allows for multiple measurements per cheese sample and, therefore, enables statistical analysis. The paper presents the results of the experimental texture evaluation for four types of cheeses (Camembert, Brie, Dorblu, and Roquefort), using the penetrometer equipped with needles and cones of various shapes and sizes. The cheese was purchased from a major retail chain and are exclusively made from cow's milk. The Camembert, Dorblu, and Brie cheese varieties were manufactured and matured in Poland, while the Roquefort cheese was produced in Germany.

Nine measurements were conducted for each cheese sample at 30-second intervals, from the edge towards the center, with the fifth measurement being taken at the center of the sample. The penetration depth was measured in penetrometric units, where 1 u.p. equals 0.1 mm. The method of determining penetration resistance is used to assess the quality of cheeses. The semi-automatic penetrometer with a cone measures the depth of penetration of the cheeses under the action of the own weight of the penetration plunger to determine hardness (mechanical resistance to penetration / yield strength), [18, 19].

The first cone used in the experiments had a tip angle of 19 degrees and a mass of 72.32 g. The second cone had a tip angle of 90 degrees and a mass of 53.81 g. The needles used had a diameter of 1 mm and a mass of 41.48 g, while the base diameter of 4 mm with a mass of 41.45 g, as can be seen in Fig. 1.

a)

b)


c)


d)

Fig. 1. The cheese samples and penetration points from the experiments were as follows:
a. Dorblu cheese; b.Brie cheese; c.Camembert cheese; d.Roquefort cheese;

The resistance of cheese to penetration with a needle or cone is an important index in assessing the mechanical properties of cheese, and the methods are described in international standards for testing various semi-solid materials such as fruits, cheese, biscuits, dough [18], etc. In the experiments, a semi-automatic penetrometer SDM Apparechi Scientifici Torino was used, equipped with cones and needles, which are used for the determination of the compactness, hardness, consistency of samples, for solid and semi-solid matrices, etc.

The penetrometer stand consists of:

- a vertical shaft for maintaining and guiding the penetration of the object;
- a horizontal base;
- a device to ensure that the penetrating object is vertical;
- a device to check if the base is horizontal;
- a device for retaining and releasing the penetrating object;
- a scale indicating the penetration depth, graduated in tenths of millimeters;

The penetration object, made of suitable material, has a smooth surface and is characterized by its shape, size, and mass. The diagram of the penetrometer and the experiment are presented in Figures 2a and 2b, while the Figures 2c and 2d showthe geometric dimensions of two of the penetration objects.

The cheese sample was placed on the fixed plate of the apparatus, and the position of the sample was adjusted so that the tip of the cone was tangent to its surface. The automatic penetration time counter was set for 30 seconds. The start button of the apparatus was pressed, and the penetration depth (in penetrometric units) was read after the above mentioned test time. Nine determinations were made for each sample (repeating the experiment twice) (Figure 3), and the obtained results were centralized in a measurement table (Table 1).

Given that the depth at which the cone penetrates under its own weight can be associated with the texture hardness or consistency of the cheese, at the equilibrium state of the cone, corresponding to the maximum penetration depth, the following relationship can be written:

$$P = k_a \cdot h_{max}^2 \cdot \tau_c \tag{1}$$

where P is the pressing force (weight of the cone), in N; $h_{max}$ – the maximum depth of cone penetration, in m; $\tau_c$ – the cheese yield stress (firmness), in Pa; $k_\alpha$ – the cone constant, which depends solely on the cone's tip angle α.

$$k_\alpha = \frac{\left(\cos\frac{\alpha}{2}\right)^3}{\pi \sin\frac{\alpha}{2}} \tag{2}$$

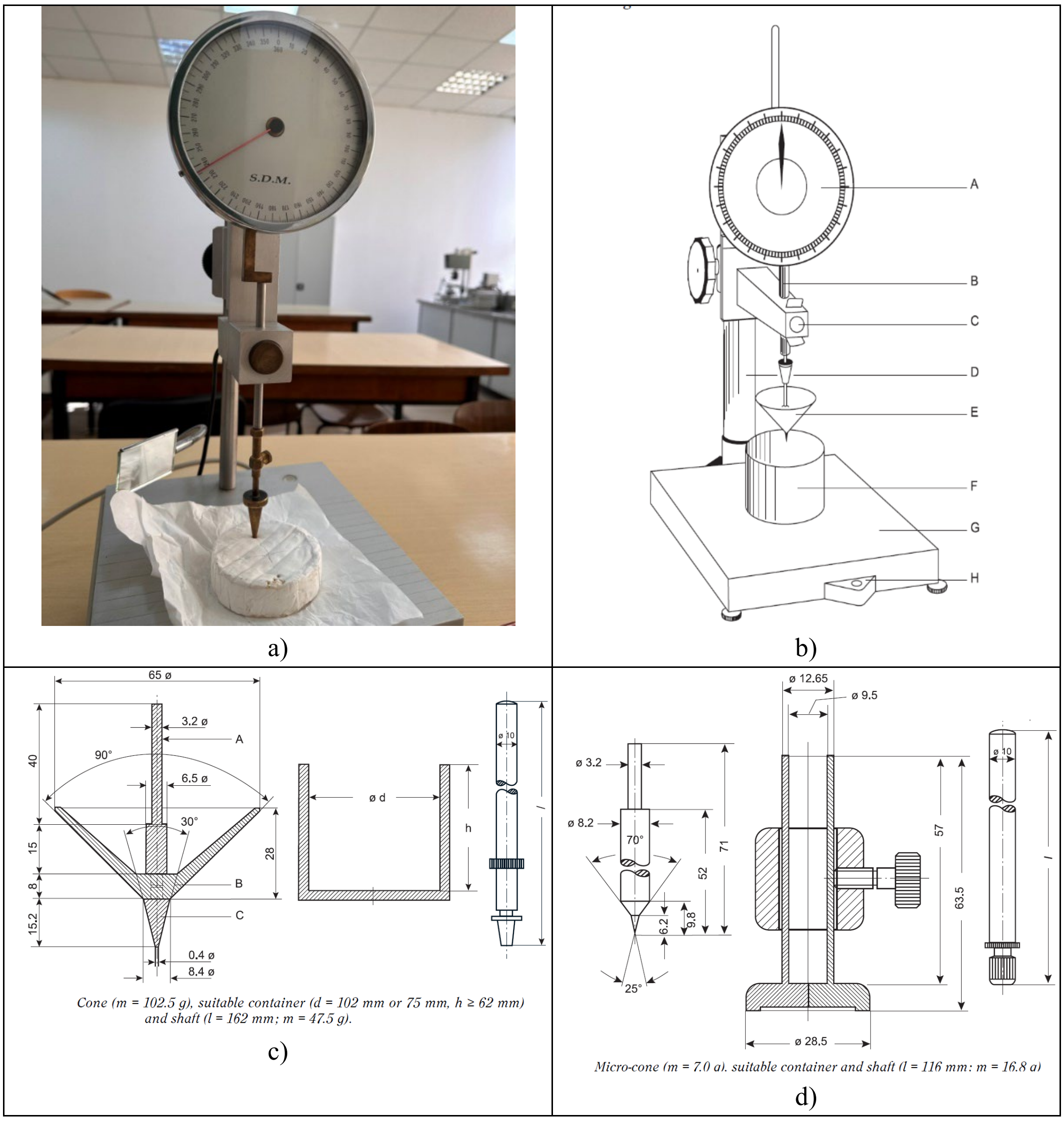



Fig. 2. The diagram of the semi-automatic penetrometer with a cone, [18]
A.display screen; B.cone shaft; C.shaft release button; D.stand; E.penetrometer cone (needle); F.container for viscous samples; G.penetrometer mass; H.bubble level


Fig. 3. Aspects regarding the geometric shape and masses of the cones and needles used in the penetration experiments of the analyzed cheese samples

From equations (1) and (2), the yield limit of each analyzed cheese category can be determined.

For a given cone with the tip angle $\alpha$ and its own weight $P$ (including the attaching rod), the maximum penetration depth $h_{max}$ is dependent solely on the yield stress, $\tau_c$, therefore $h_{max}$ becomes a parameter of cheese hardness.

However, analyzing the relationship in reverse, the yield stress of the material depends on the pressing force and the cone angle, with different values depending on these factors.

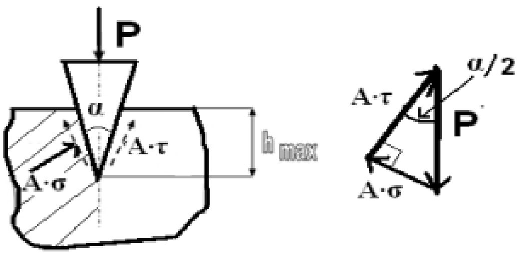



Fig. 4. The force diagram acting on the material samples, [18]

Thus, the yield limit of the material samples subjected to cone penetration can be determined using the relationship (3):

$$\tau_C = \frac{P}{k_\alpha \cdot h_{max}^2} \quad (3)$$

Using the determined masses of the needles and cones used in the experiments, their weights (in N) are determined, representing the acting force *P*, each cone having a different shape coefficient $k_\alpha$.

The yield point is defined as the point where an increase in deformation is observed with a decrease or no change in force (stress) on the stress-strain or force-deformation curve, particularly in food products but not limited to them.

**3. Results and discussions**

The experimental tests conducted are useful for characterizing cheese in terms of how closely it behaves like a solid or a liquid. The results obtained in the experiments regarding the variation of the maximum penetration depth depending on the testing point are presented in Table 1. The precision of the method determined by statistical examination of the results is as follows:

- Repeatability at a temperature of 25°C - the difference between two test results obtained by the same operator with the same apparatus under constant operating conditions on identical test material would exceed, in the long-term, normal and correct operation of the testing method, only in one case out of twenty, the following value:

$$Repeatability = 1.72 \cdot (10^{0.00524\ (x\_med)}) \quad (4)$$

- Reproducibility at a temperature of 25°C - the difference between two unique and independent results obtained by different operators working in different laboratories on identical test material would exceed, in the long-term, normal and correct operation of the testing method, only in one case out of twenty, the following value:

$$Reproducibility = 4.81 \cdot (100.00442\ (x\_med)) \quad (5)$$

No general statement can be made about the deviation of this testing method because the results cannot be compared with an accepted reference material.

Examining the data from Table 1 and the curves from Figure 5, in relation to the experimental points, shows that for the four types of cheese investigated, the experimental data could be described by concave or convex curves. Additionally, the data presented in Table 1 reveal a significant difference between the penetration depth values for the four types of penetration objects (cones or needles) used in the experiment. It is crucial to understand if the cheese is subjected to significant deformation outside the viscoelastic range.

*Table 1*

**Depth of penetration for the four types of cheese, in penetrometric units (p.u.), for the nine measurement points on each sample**

| Product | Camembert | | | | Brie | | | | Dorblu | | | | Roquefort | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cone | Cone | | Needle | | Cone | | Needle | | Cone | | Needle | | Cone | | Needle | |
| | 19° | 90° | 2° | 6.35° | 19° | 90° | 2° | 6.35° | 19° | 90° | 2° | 6.35° | 19° | 90° | 2° | 6.35° |
| $h_{max}$ (p.u.) | 130 | 83 | 175 | 199 | 128 | 80 | 160 | 180 | 155 | 132 | 190 | 225 | 166 | 120 | 180 | 215 |
| | 134 | 95 | 180 | 205 | 135 | 82 | 175 | 192 | 140 | 128 | 186 | 222 | 150 | 118 | 175 | 212 |
| | 145 | 98 | 188 | 215 | 140 | 96 | 182 | 198 | 135 | 120 | 175 | 218 | 146 | 115 | 168 | 205 |
| | 155 | 105 | 195 | 224 | 148 | 105 | 185 | 206 | 120 | 108 | 170 | 210 | 130 | 108 | 160 | 198 |
| | 175 | 120 | 202 | 230 | 155 | 115 | 190 | 215 | 116 | 96 | 165 | 200 | 126 | 105 | 155 | 190 |
| | 165 | 99 | 194 | 225 | 145 | 98 | 186 | 202 | 122 | 110 | 172 | 208 | 135 | 110 | 164 | 200 |
| | 154 | 95 | 186 | 215 | 140 | 90 | 180 | 196 | 136 | 115 | 180 | 215 | 140 | 115 | 170 | 205 |
| | 142 | 84 | 178 | 204 | 132 | 85 | 172 | 190 | 140 | 126 | 186 | 218 | 145 | 118 | 178 | 215 |
| | 138 | 80 | 170 | 200 | 125 | 78 | 165 | 185 | 153 | 130 | 192 | 220 | 150 | 122 | 180 | 218 |
| $h_{max\_med}$ | 148.7 | 95.4 | 185.3 | 213.0 | 138.7 | 92.1 | 177.2 | 196.0 | 135.2 | 118.3 | 179.6 | 215.1 | 143.1 | 114.6 | 170.0 | 206.4 |
| $\sigma_{hmax}$ | 14.85 | 12.44 | 10.48 | 11.58 | 9.72 | 12.46 | 10.06 | 10.78 | 13.83 | 12.06 | 9.54 | 7.83 | 12.10 | 5.75 | 9.04 | 9.34 |
| *Repet25* | 10.34 | 5.44 | 16.09 | 22.47 | 9.17 | 5.23 | 14.59 | 18.30 | 8.79 | 7.17 | 15.01 | 23.05 | 9.67 | 6.85 | 13.38 | 20.76 |
| *Reprod25* | 26.50 | 16.15 | 33.91 | 39.61 | 24.52 | 15.52 | 32.25 | 36.10 | 23.84 | 20.54 | 32.73 | 40.05 | 25.40 | 19.81 | 30.79 | 38.25 |
| $\tau_c$ (Mpa) | $1.77 \cdot 10^{-3}$ | 0.037 | $7.6 \cdot 10^{-5}$ | $0.2 \cdot 10^{-4}$ | $0.2 \cdot 10^{-3}$ | 0.040 | $8.3 \cdot 10^{-5}$ | $0.27\ 10^{-4}$ | 0.002 | 0.024 | $8.0 \cdot 10^{-5}$ | $0.23 \cdot 10^{-4}$ | 0.002 | 0.026 | $9.0 \cdot 10^{-5}$ | $0.25 \cdot 10^{-4}$ |

For cheese with white mold, the penetration depth is much smaller than for cheeses with green mold, even though all cheeses are made from cow's milk. The cones used for penetration demonstrate that cheese with white mold is less matured and have a softer texture compared to cheese with green mold, where the penetration depth reaches up to 225 p.u. For the same type of cheese, the penetration depth varies over time for the four penetration objects used.

The curves exhibit a concave shape for Camembert and Brie cheeses with all types of needles or cones used, showing a smaller penetration depth at the edges of the sample and a larger one at the margins. On the contrary, for Dorblu and Roquefort cheese, the curves have a convex shape, with smaller penetration depths at the central points. However, a regression analysis with a quadratic polynomial equation cannot be performed because the measurement points are represented on the horizontal axis. Nevertheless, it can be stated that the analyzed samples have different consistency at the marginal points compared to the central measurement points, without reference to their structure.

Using the values presented in Figure 3 for the masses of the cones and needles used in the experiments (together with the attaching rod and holding system), the penetration forces (weights) of these were determined as follows: $P_1$=0.7232 N, $P_2$=0.5381 N, $P_3$=0.4148 N, $P_4$=0.4145 N.

Also, knowing the penetration cone angles, their shape coefficients $k_\alpha$ have been calculated, and their values are presented at the beginning of Table 2 ($k_\alpha$=1.8503, $k_\alpha$=0.1592). The yield point $\tau_c$ for the four types of cheeses (1.8 kPa

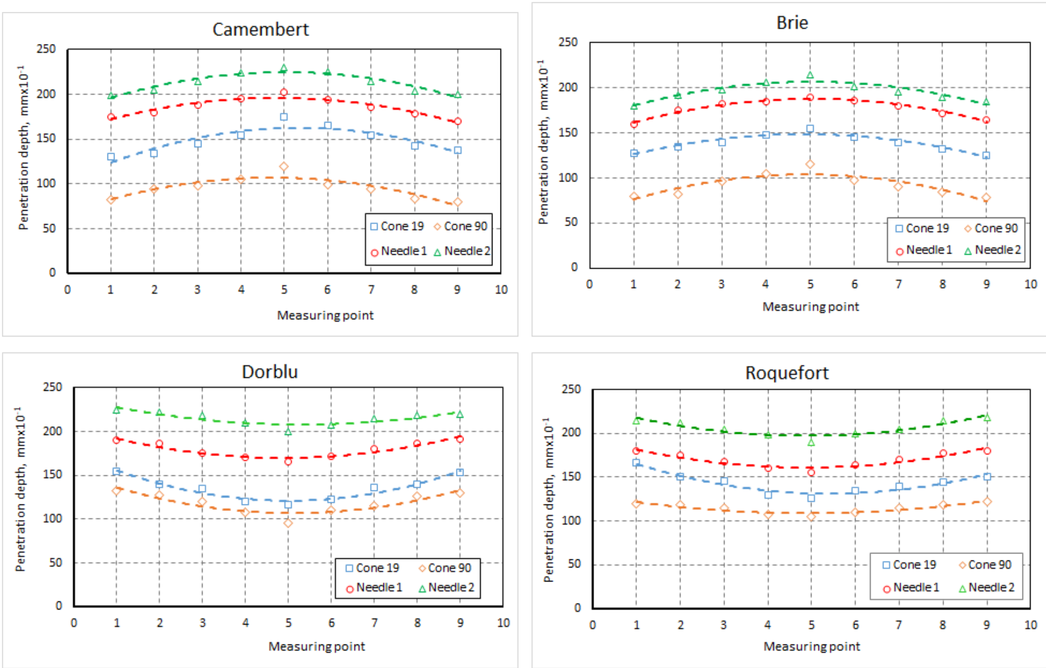



Fig. 5. The curves showing the variation of penetration depth h (in p.u.) in relation to the testing point, for the analyzed cheeses.

- Camembert; 2.0 kPa – Brie; 2.1 kPa – Dorblu; 1.9 kPa - Roquefort) The yield point τc for the four types of cheese, calculated with the average value of the penetration depth measured with the penetration cone with a tip angle of 19°, is in full agreement with the determinations made by Korolczuk et Mahaut [12]. Next, the values of the tangential stress τ were calculated for the two cones and the four cheese categories used in the experiment (Table 2).

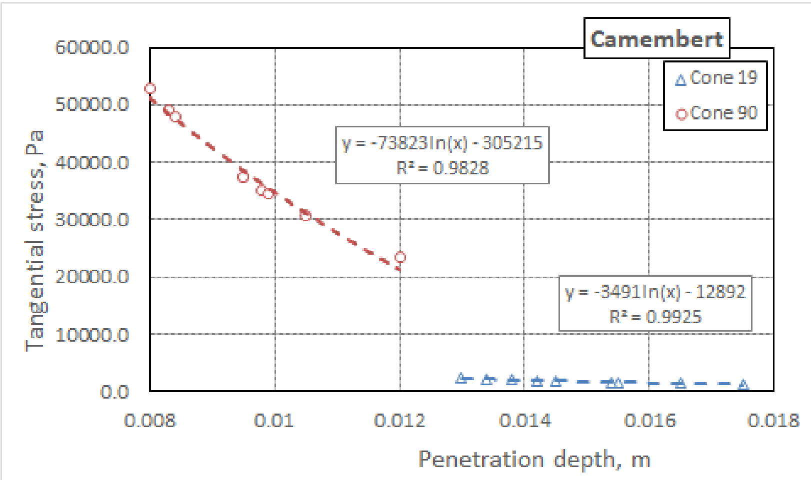
*Table 2*

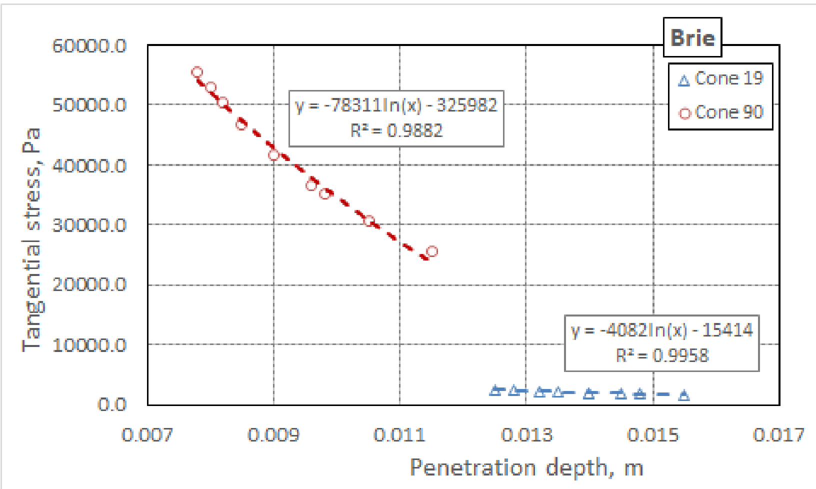
**Tangential stress for the four types of cheese, for the nine measurement points on each sample, in Pa**

| Camembert | | Brie | | Dorblu | | Roquefort | |
|---|---|---|---|---|---|---|---|
| $k_\alpha$=1.8503 | $k_\alpha$=0.1592 | $k_\alpha$=1.8503 | $k_\alpha$=0.1592 | $k_\alpha$=1.8503 | $k_\alpha$=0.1592 | $k_\alpha$=1.8503 | $k_\alpha$=0.1592 |
| **19°** | **90°** | **19°** | **90°** | **19°** | **90°** | **19°** | **90°** |
| 2312.7 | 49079.5 | 2385.6 | 52829.5 | 1626.8 | 19404.8 | 1418.4 | 23479.8 |
| 2176.7 | 37463.6 | 2144.6 | 50283.9 | 1994.1 | 20636.5 | 1737.1 | 24282.4 |
| 1859.0 | 35205.0 | 1994.1 | 36687.1 | 2144.6 | 23479.8 | 1833.6 | 25565.9 |
| 1626.8 | 30667.5 | 1784.4 | 30667.5 | 2714.2 | 28987.4 | 2312.7 | 28987.4 |
| 1276.2 | 23479.8 | 1626.8 | 25565.9 | 2904.6 | 36687.1 | 2461.9 | 30667.5 |
| 1435.6 | 34497.4 | 1859.0 | 35205.0 | 2626.0 | 27942.9 | 2144.6 | 27942.9 |
| 1648.0 | 37463.6 | 1994.1 | 41741.8 | 2113.2 | 25565.9 | 1994.1 | 25565.9 |
| 1938.4 | 47917.9 | 2243.2 | 46797.1 | 1994.1 | 21296.8 | 1859.0 | 24282.4 |
| 2052.3 | 52829.5 | 2501.4 | 55573.4 | 1669.7 | 20006.4 | 1737.1 | 22716.3 |

Using the values of tangential stress and penetration depth, the graphs in Figure 6 were plotted. Regression analysis was performed in Microsoft Excel, with the logarithmic law showing a decreasing variation of tangential stress τ with increasing maximum penetration depth (depth recorded after 30 seconds of cone action).

It is also observed a very good correlation of the experimental data with the normal logarithmic law, appreciated by a high value of the correlation coefficient $R^2$ (>0.980), for all four types of cheese and the two penetration cones. The shear stress values τ as a function of the mass and type of penetration cone express that the quality, and respectively the firmness, of the cheese can be evaluated with sufficient accuracy using the penetrometer with a cone [12].



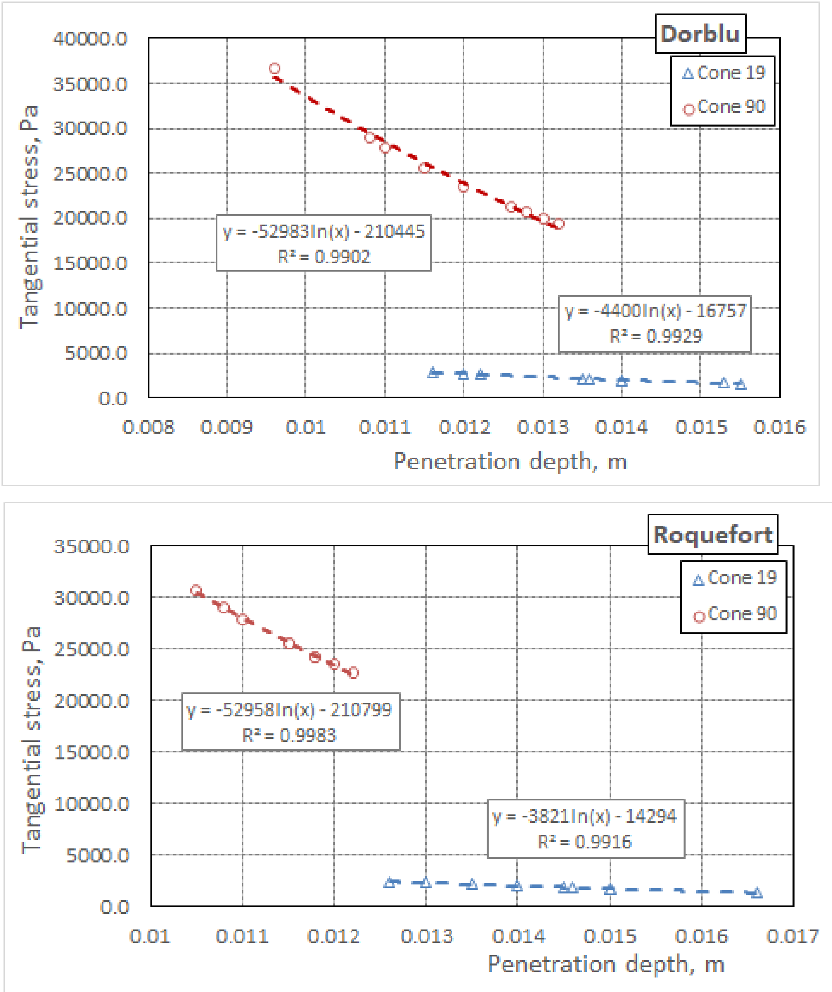



Fig. 6. The curves showing the variation of shear stress $\tau$ (Pa) vs. penetration depth $h$ (m), together with the regression curves using the logarithmic law.

From the analysis of Figure 6, it can be observed that the shear stress values are much higher when using cones with larger tip angles for all analyzed types of cheese, while for smaller tip angles of the penetration cones, the tangential stress has lower values, but the decreasing tendency with increasing penetration depth is preserved.

Values of 20–56 kPa of the shear stress of cheeses are noted overall for the 90° penetration cone, at low depths of penetration between 7.7–13.2 mm, while for the 19° penetration cone, the shear stress values are much lower, from 1.2 kPa to around 3 kPa, for higher penetration depths, between 11.5 and around 17.6 mm, comparable to those in [23-25]

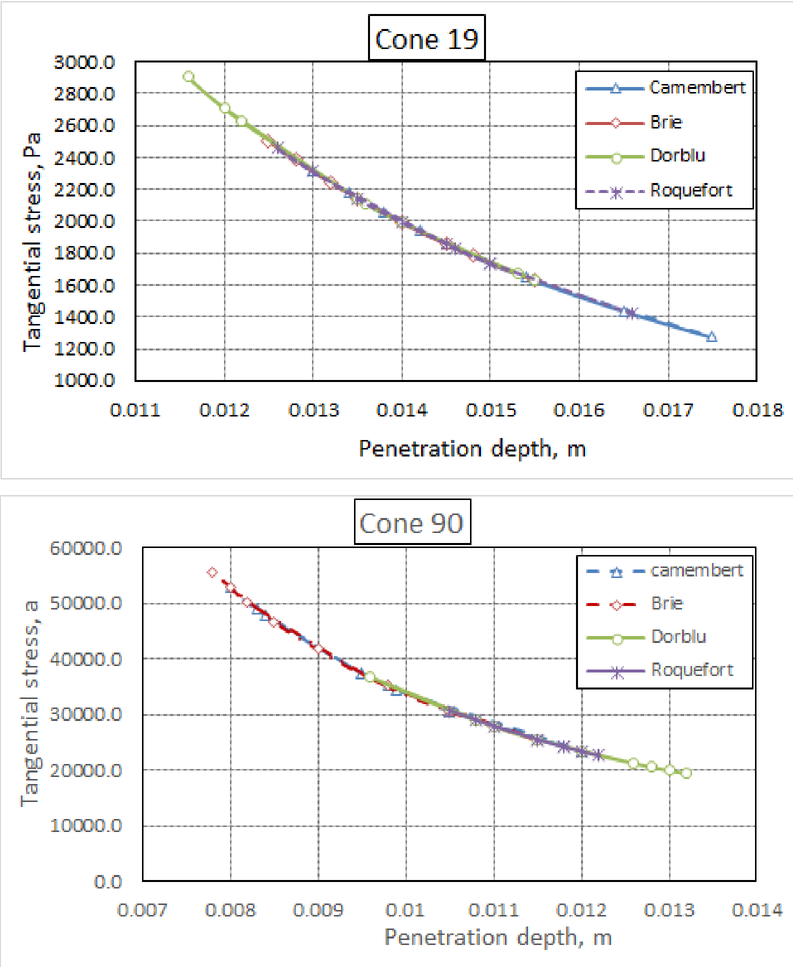



Fig. 7. The curves showing the variation of shear stress $\tau$ (Pa) vs. penetration depth h (m) for the two types of penetration cones

For the 19° penetration cone, the lowest tangential stress is observed for Camembert cheese and the highest for Dorblu cheese, while for the 90° penetration cone, it is the opposite: the lowest shear stress is found for Dorblu cheese and the highest for Brie cheese, as shown by the graphs in Figure 7 and the data in Table 2.

Interestingly, the experimental points regarding the variation of tangential stress with penetration depth, both for tests using the 19° penetration cone and for the 90° penetration cone, are arranged on the same logarithmic curve for all cheese samples (Camembert, Brie, Dorblu, Roquefort), with a correlation coefficient of over 98%, leading to the conclusion that mold-ripened cheeses have very similar firmness and consistency.

## 6. Conclusions

Many types of cheese undergo compression, shear, and kneading stresses during their manufacturing. After coagulation and whey drainage, processes such as molding, pressing, brine injection, or adding solutions are contributing to the development of specific characteristics in cheese. Mold cheese is produced by controlling the growth of mold strains, which can also be introduced through injection. Cheese behavior during processing can be studied through cutting, kneading, piercing, and penetration tests using various cones or needles, to gather information on penetration resistance, shear yield stress, and maximum penetration depth. The results of the tests performed in this work revealed that the four types of mold cheese studied exhibit similar behaviors when are subjected to penetration. Sharper cones resulted in lower tangential stress values but maintained the decreasing trend with increasing penetration depth. The results of these measurements represent useful information for manufacturers about the texture and firmness of cheese at different stages of ripeness.

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