Texture analysis for milk coagulation process monitoring

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RÉSUMÉ. La coagulation du lait est un processus au cours duquel le lait qui est liquide devient solide et visqueux. C'est la première et la plus importante étape dans l'industrie du fromage. Parmi les méthodes, couramment utilisées pour contrôler le processus de coagulation du lait, on peut citer la méthode d'ultrason. Cette méthode permet de suivre en ligne de la coagulation, mais elle ne donne pas d'informations sur la manière avec laquelle a lieu cette coagulation et comment elle se propage en volume. En effet, cette coagulation peut être homogène et / ou en amas, ce qui aura des conséquences sur la qualité de la fabrication des produits laitiers. Pour cela nous avons utilisé l'analyse de texture pour suivre le processus de la coagulation en volume. Un certain nombre de paramètres pertinents ont été trouvé. Ils peuvent être utilisés pour quantifier l'homogénéité et la finesse du processus de coagulation du lait.

ABSTRACT. The coagulation of milk is a process during which the milk that is liquid becomes a strong viscous. It is the first and most important stage in cheese industry. Among the methods more used to control the process of the milk coagulation, it is necessary to mention the ultrasonic sound method. This method permits followed it on-line of the coagulation but doesn't give some information on the manner with which takes place the coagulation and how propagates itself in volume. This coagulation can be homogeneous and or in heap what will have some consequences on the quality of the dairy product manufacture as cheese. For it we used the scan to follow the process of the coagulation in volume and the analysis of texture.

A certain number of texture parameters have been found pertinently. Its can use to quantify homogeneity and the fineness of the process of milk's coagulation.

MOTS-CLÉS : coagulation du lait, image d'échographie, Analyse de texture.

KEYWORDS: coagulation of milk, ultrasonic sound method, texture analysis..

1. INTRODUCTION

Milk coagulation using rennet involves three stages: enzymatic hydrolyse, aggregation and gelation. The coagulation time marks the end point of the enzymatic phase and the start of the aggregation. This time is an essential parameter in the cheese-making industry because it can be used for the evaluation of the cutting time, that is the time at which the curd is cut.

Electrical, thermal, optical, viscometric and ultrasonic methods have been used to control on line the milk coagulation [1-6]. Moreover, some researchers have used echography to observe the coagulation [7]. This coagulation can be homogeneous and or in heap what will have some consequences on the quality of the dairy product manufacture as cheese. For it we used the scan to follow the process of the coagulation in volume and the analysis of texture.

The objective of the work was to use the texture analysis to find applicable parameters to quantify the homogeneity and fineness in order to understand better the coagulation process.

2. EXPERIMENTAL SET-UP.

A small rectangular chamber (80mm x 42mm x 25mm) with a capacity of 84ml was designed and constructed for the ultrasonic and temperature characterisation of the coagulation processes (Figure 1). This chamber is included into a block made of alumina loaded epoxy resin. The walls of the chamber consist of two Plexiglas windows, 2mm thick, for visual evaluation.

The chamber has an acoustic window made of a thin plastic sheet in the upper part to couple a 2.5 Mhz phase array probe connected with an AU4 Idea echograph –Esaote-. The entire chamber was introduced into a temperature controlled water bath at 35.00ºC.

The experimental procedure was as follows [8]:

1. The cell was introduced into the bath to attain the bath temperature. The array probe, protected into a surgical glove was coupled to the acoustic window
2. The milk was introduced carefully by gravity into the chamber to avoid introducing air. The milk was left to attain the bath temperature before proceeding with next step.
3. The rennet was prepared and mixed in 3 cc of milk at the cell temperature and introduced by gravity into the milk cavity.

4. The echographic image, the ultrasonic temporal traces from the transducers and the temperature from the thermocouples were recorded continuously from the initial time of step 1.

In this work several experiments with different rennet concentration were performed. The results are equivalent occurring with a time lag proportional to the rennet concentration used.

3. ECHOGRAPHIC RESULTS

Figure 2 shows an image of the coagulation process. These images correspond to the second step -only milk-, the introduction of the rennet, the milk before forming the gel and the final gel structure respectively.

The images were first digitalized from the original videotape and analysed with texture analysis.

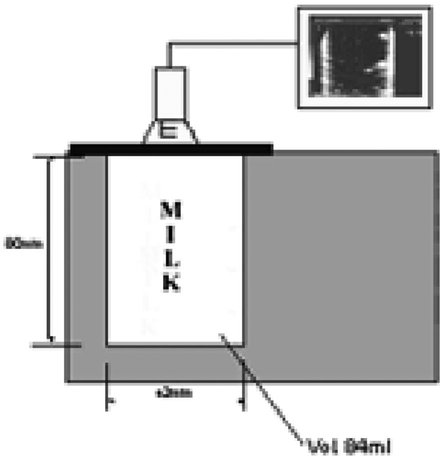

Figure 1- *Scheme of the experimental set-up, showing the milk cavity and the echographic probe*

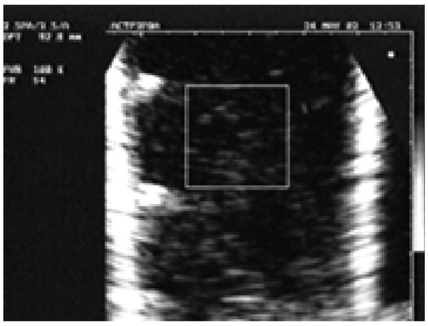

Figure 2- *Example of milk's coagulation image. In the upper left image, the areas used to perform the analysis are marked*

4. TEXTURE ANALYSIS

The co-occurrence matrices approach has been considered in this work for the description of a statistical model of the texture encoded within the decomposed subimages. It captures second-order gray-level information, which is mostly related to the human perception and discrimination of textures. For a coarse texture these matrices tend to have higher values near the main diagonal whereas for a fine texture the values are scattered. The cooccurrence matrices encode the gray level spatial dependence based on the estimation of the second-order joint-conditional probability density function f(i,j,d,), which is computed by counting all pairs of pixels at distance having gray levels and at a given direction. The angular displacement is usually included in the range of the values $\{0,\pi/4,\pi/2,3\pi/2\}$

This study concentrates on textural analysis based on gray-level co-occurrence matrice. Sub-image of size 72x72 pixels were cropped as ROIs from each echographic image of milk coagulation. As quantitative indicators of echographic image (texture description) we use Harralick and structural texture features. Table 1 show Harralick texture and structural texture features were computed from the co-occurrence matrix corresponding to a one-pixel separation d(1,0) in fours directions (0°, 45°, 90° and 135°). These features are statistical nature and not require any image pre-processing.

Abbrev	Feature name	Definition
CONTR	Texture Contrast	$\sum_i \sum_j \lvert i-j \rvert C_{\vec{d}}(i,j)$
IDM	Texture Homogeneity	$\sum_i \sum_j \frac{C_{\vec{d}}(i,j)}{\lvert i-j \rvert + 1}$
ENR	Uniformity of energy	$\sum_i \sum_j (C_{\vec{d}}(i,j))^2$
SRE	Short run length emphasis	$\frac{\sum_i \sum_L C_{\vec{d}}(i,L) * L^{-1}}{\sum_i \sum_L C_{\vec{d}}(i,L)}$
LRE	Long run length emphasis	$\frac{\sum_i \sum_L C_{\vec{d}}(i,L) * L^{2}}{\sum_i \sum_L C_{\vec{d}}(i,L)}$

Table 1 - *Description of Haralick and structural texture features and their abbreviations used in the text*

Statistical evaluation was performed using CPA analysis computed on 30 images oder to find some pertinents parameters linked to homogenous milk caogulation proce: We chose three parameters of textures; it is SRE, IDM and LRE. They seem to be link to the homogeneity. Figure 4-a and figure 5-b shows Projection image's parameter values on a plan representative by the most important two factors

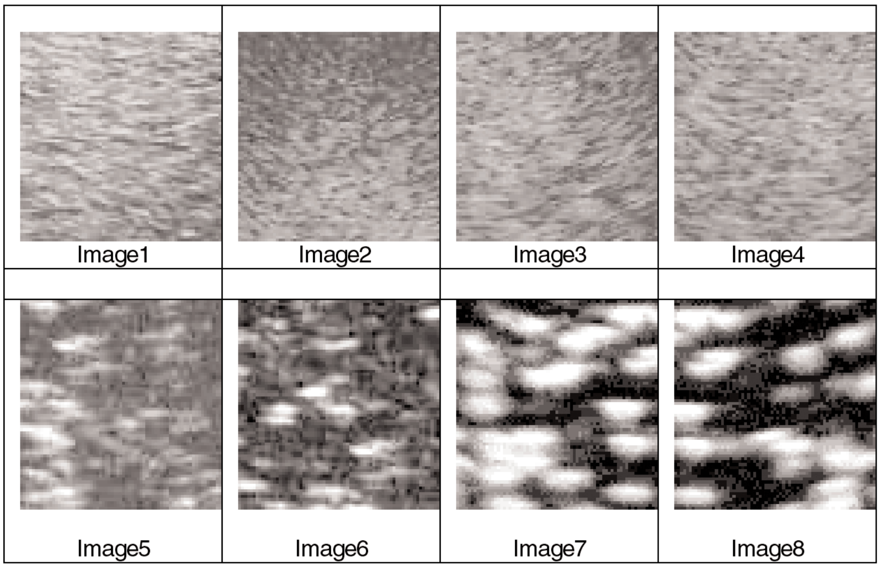

Figure 3 - *Milk coagulation image ordering from the most homogeneous image to the less homogeneous image*

Image n°	SRE	LRE	IDM	ENR	CONTR
1	0.9830	1.0566	11.8201	137.199	25.5651
2	0.9811	1.0601	11.8359	137.199	20.4442
3	0.9816	1.0597	11.8332	137.199	20.7506
4	0.9798	1.0650	11.8328	137.199	21.2013
5	0.9156	1.4671	11.897	137.202	21.3647
6	0.9247	1.4042	11.8923	137.201	18.5202
7	0.8066	2.8784	12.0312	137.422	25.5948
8	0.7874	3.1295	12.0426	137.753	23.0806

Table 2- *The average value of the Harralick and structural texture features calculate on images below over directions 0°, 30°, 45°, 90°, and 135°*

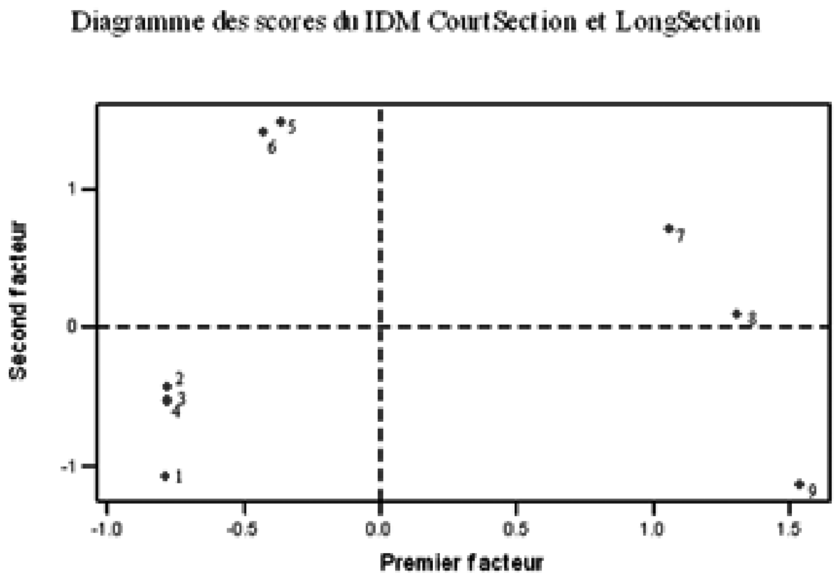

Figure 4-a *Projection image's parameter's values on a plan representative by the most important two factors*

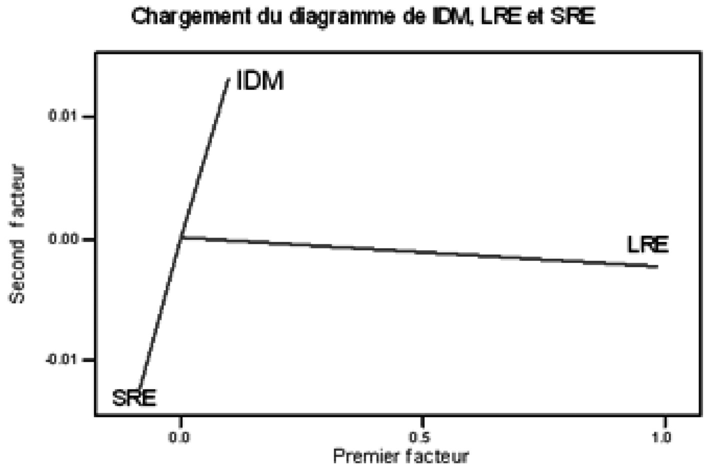

Figure 4-b *Projection image's parameter's values on a plan representative by the most important two factors*

5. DISCUSSION AND RESULTS

We can observe that the fine and homogeneous images (images 1, 2, 3 and 4) can be described by the SRE parameters and IDM. Indeed if the process of milk coagulation performed in a fine manner the probability to have the short sections, in gray level, is important and therefore we have a great value of SRE parameter. On the other hand if the process of milk's coagulation performed in heap, the probability to have the long sections is important and therefore the value of SRE is low. Concerning the homogeneity of the process milk's coagulation the IDM parameter seems to be very sensitive to this aspect, in other words more the value of this parameter is low more the image is homogeneous.

For images 7 and 8, we note that the process of coagulation occurs in heap and this because of the quantity of rennet or temperature relatively high. The parameter texture LRE provides interesting results for this type of coagulation.

We can conclude that more the value of the SRE parameter is great and IDM is low more the process of milk coagulation performed in a fine and homogeneous manner. Certainly, these are primary results; we need more experience to have knowledge of the reproducibility and robustness of these results.

6. Bibliographie

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