A TRIBO ACOUSTICAL APPROACH TO EVALUATE THE SWEETNESS *IN VIVO* OF THE HUMAN SKIN

Frédéric Flamand
LTDS, Ecole Centrale de Lyon, 36 avenue Guy de Collongue 69134 Ecully cedex
Hassan Zahouani
LTDS, Ecole Centrale de Lyon, 36 avenue Guy de Collongue 69134 Ecully cedex
Rosario Toscano
LTDS, Ecole Nationale d'Ingénieurs de Saint-Etienne, 58 rue Jean Parot 42023 Saint-Etienne

Abstract :

Human skin is a very complex tissue consisting of several distinct layers and components. Hence it exhibits complex material behaviour. The mechanical properties of the skin are of importance for various cosmetic and clinical applications. The sweetness of the skin is also an important notion, but have not received more attention in the scientific community. However, the possibility of evaluating the sweetness of skin after a cosmetic treatment is an important practical issue. This paper presents an effective method to evaluate the subjective notion of the sweetness of the skin, which is also strongly correlated with the age. The major difficulty resides in the exploitation of a measurable quantities related to the subjective quality of sweetness. In this work is showed that the acoustical signal obtained during a cutaneous friction, is relevant to evaluate the sweetness of skin. The major contribution of our work is the realization of a tribo-acoustics sensor with an original treatment to assess in vivo the skin sweetness.

Key words: human skin, sweetness, tribo-acoustics, fuzzy relation.

1 Introduction

The skin is a highly organized, stratified structure consisting of three main layers, called the epidermis, dermis and hypodermis [1]. The most obvious functions of the skin are to protect the body by preventing the loss of fluid and the penetration of undesirable substances by the impermeability of the epidermis and by cushioning it against mechanical shocks, mostly by the dermis [2]. Less obvious, but of equal importance is the immunological response to foreign materials mediated by the Langerhans cells. Within the skin are organs with sensory functions : they detect stimuli of touch, pressure, heat, cold and pain [3]. The skin also play an essential role in social communication by its appearance, its feel and smell. The study of its mechanical properties is consequently an essential subject embracing the fields of the dermatology and the beauty care. However, despite its great practical importance, little effort has been made to quantify the sweetness of the skin.

The objective of this work is to provide an approach making it possible to evaluate the subjective notion of the sweetness of the skin, which is also strongly correlated with the age. The major difficulty resides in the exploitation of a measurable quantity related to the subjective quality of sweetness of the skin. To this end, it is possible to adopt an approach purely mechanist. A large variety of mechanical experiments have been performed on the skin in the past such as tensile tests, torsion, suction, indentometry [4], [5] etc. However, it appear that the mechanical properties of the human skin differ among subjects and with circumstances, such as the relative humidity of the environnement, the wetness of the skin, the direction of the applied load, age, and even the season of the year [6]. Due to the large variability of the mechanical properties of the skin, it appears that a purely mechanistic approach is not well adapted for a good evaluation of the subjective quality of sweetness. Obviously, the sweetness of the skin is closely related with the roughness of the stratum corneum which is the most superficial layer of the epidermis. For our purpose, an appealing idea is to exploit the acoustical signal obtained during a cutaneous friction. Indeed, this information is closely related with the roughness of the surface, thus a correct interpretation of this information leads to an adequate evaluation of the sweetness.

The major contribution of our work is the realization of a tribo-acoustics sensor with an original treatment to assess in vivo the skin sweetness. This work is divided into four sections. In section 2 is presented the prototype of tribo-acoustics sensor and is showed that the acoustical signal obtained during a cutaneous friction, is relevant to evaluate the sweetness of skin. In section 3 is presented an original treatment of the acoustical signal permitting an evaluation of the sweetness of the skin for a given reference level. Section 4 conclude this paper.

2 The tribo-acoustics sensor

The tribo-acoustics sensor (see figure 1) is a prototype which associates tribology and study of the sound radiation. This system was developed with the aim of collecting, *in vivo*, on any body site, the sound emission obtained during a cutaneous friction.

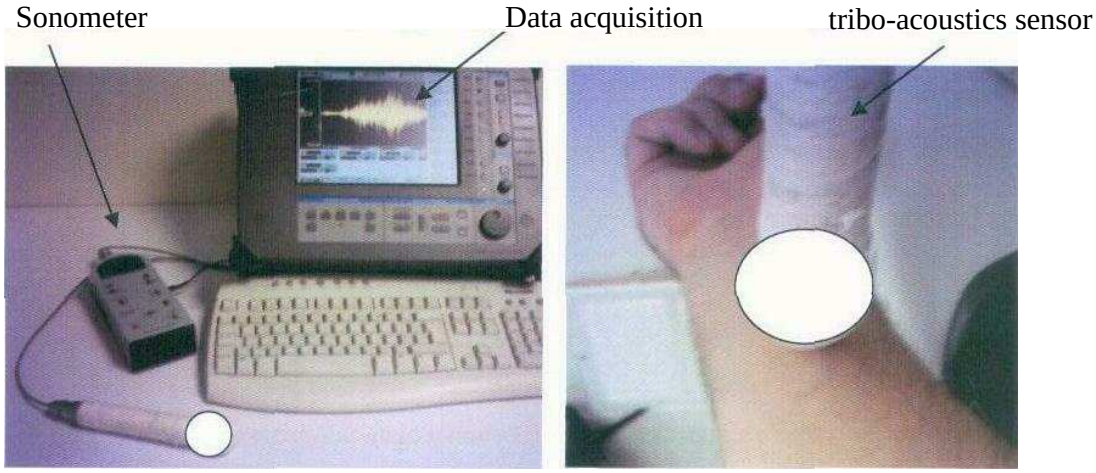

Fig. 1: *the tribo-acoustics sensor.*

Figure 2 shows the global structure of the measurement system. We have a microphone 1/2 inch (size of the membrane) Bruel & Kjaer of a sensitivity of 50mV/dB in a steel pipeline (length = 150 mm and diameter = 30 mm) in such a way that the head of acquisition rests in a nitrocellulose cavity of a diameter of 40 mm for a thickness of 1 mm perfectly separated from outside. Thus, the silicone sheath isolates the cavity of measurement while foam - without acoustic modes - absorbs the vibrations being able to interfere in the environment of the room of measurement. This device of a strong sensitivity (457mV/Pa), allows the recording of the noise of friction resulting from a rectilinear motion of the acoustical sensor on the skin. The obtained data are then transferred on numerical support in order to interpret easily the measure.

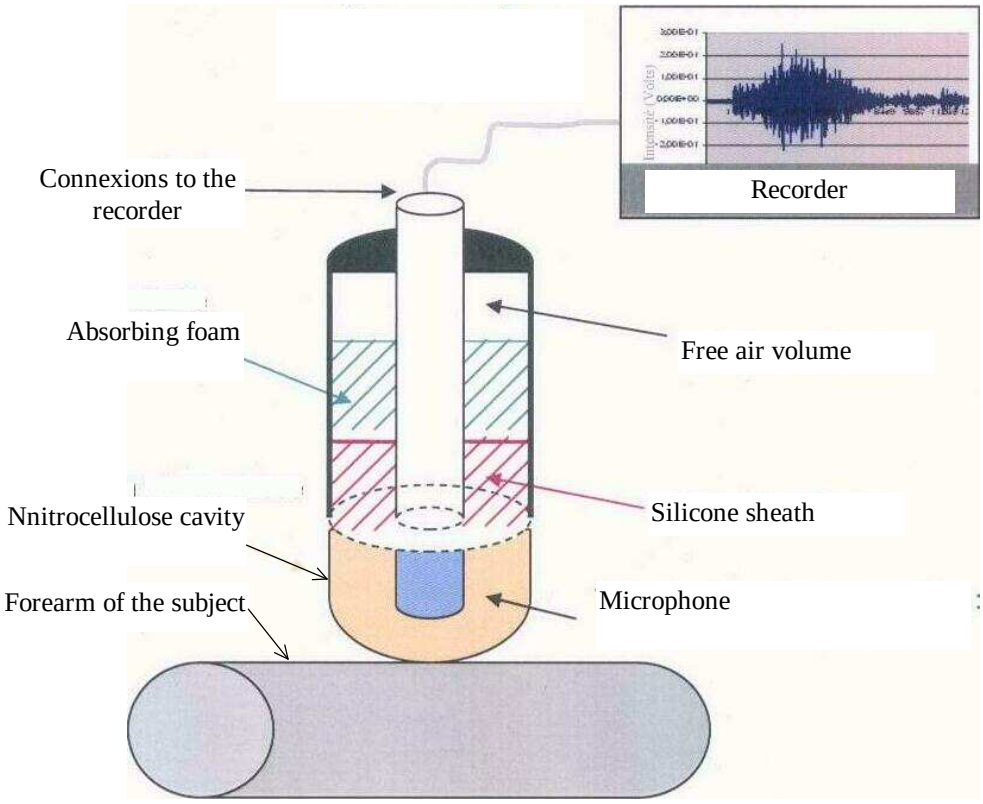

Fig. 2: *global structure of the measurement system.*

3 Application to the evaluation of the sweetness of skin

The feeling of cutaneous sweetness is a very subjective concept which requires to be quantified. It is usual to take as reference for this notion the skin of the very young children. In order to highlight a possible correlation between the age of the subject and the intensity of the resulting acoustical signal, we have compared the average intensity for three age groups: 5-7 years, 20-30 years and 50-60 years. It appears that the intensity of the acoustical signal is systematically lower for the very young subject (5-7 years) compared with the obtained results for the other age groups (20-30 and 50-60 years) and this for any explored cutaneous

zone [7]. This experiment suggest a possible relation between a low noise level and a strong sweetness. In addition, following the work of EL Cussler & al. [8], the feeling of sweetness for a given surface, can be represented using the following relation:

$$Feeling\ of\ sweetness \propto (diameter\ of\ the\ grain\ of\ surface)^{-1.5} \quad (1)$$

According to this relation, the feeling of sweetness is an increasing function of the fineness of the grain of surface. In the case of the young subjects, the size of the corneocytes is lower than 800 and exceeds the 1000 beyond 50 years. Consequently, in the child, the roughness of surface due to the corneocytes or the overlapping of corneocytes will be lower and thus will be equivalent to an increased sweetness. In conclusion, the sweetness of the skin is closely related on the size and the arrangement of the corneocytes which depends on the age of the individual. In addition, the intensity of the acoustical signal is also strongly related on the age and thus to the feeling of sweetness. We can then postulate the existence of a relation of the following form:

$$Feeling\ of\ sweetness = f(Intensity\ of\ the\ acoustical\ signal) \quad (2)$$

Where f is a decreasing function which can be determined from experimental data. We propose to introduce a scale of sweetness of the skin based on three age groups: 5-7 years, 20-30 years and 50-60 years. The membership to one of these classes is determined starting from an appropriate evaluation of the acoustical signal. Let $x(t)$ be the acoustical signal, its intensity at the time t is defined as $x^2(t)$, this intensity can also be represented in an equivalent manner by $I(t) = \sqrt{x^2(t)} = |x(t)|$. It is convenient to introduce an appropriate measure or norm of this signal in order to classifies different categories of age and thus of sweetness . We define de norm of the signal as follows

$$\|I\| = \sqrt{m^2 + \sigma^2} \quad (3)$$

with

$$m = \frac{1}{T}\int_0^T I(t)dt, \quad \sigma = \sqrt{\frac{1}{T}\int_0^T (I(t) - m)^2 dt} \quad (4)$$

where m reflect the average intensity of the acoustical signals and σ its standard deviation. With this norm, it is now possible to compare different acoustical signal and thus to introduce different level of softness. The softness level is an unknown concept which must be learned from various experiments realised on various subjects of different ages. The problem is then to find a classification function based on input-output data. Our objective is to "train" a prototype function in such a way that is a good approximation to the unknown target function.

In other word, the problem is to interpret the quantities $\|I\|$ in term of sweetness which is a concept not well defined. In order to define this concept in an utile manner, the notion of fuzzy relation based on the fuzzy set theory can be used [9]. Indeed, the relation (2) can be seen as a fuzzy relation between fuzzy variables. According to our experiments, this fuzzy relation can be defined by the following fuzzy rules base :

$$\begin{cases} If \quad \|I\| \quad is \quad \tilde{\tilde{C}}_{5-7} \quad then \quad softness \quad is \quad b_{5-7} \\ If \quad \|I\| \quad is \quad \tilde{\tilde{C}}_{20-30} \quad then \quad softness \quad is \quad b_{20-30} \\ If \quad \|I\| \quad is \quad \tilde{\tilde{C}}_{50-60} \quad then \quad softness \quad is \quad b_{50-60} \end{cases} \tag{3}$$

where $\tilde{\tilde{C}}_{5-7}$, $\tilde{\tilde{C}}_{20-30}$ and $\tilde{\tilde{C}}_{50-60}$ are fuzzy sub-sets associated of the class 5-7 years, 20-30 years, and 50-60 years respectively. These fuzzy sets are defined by membership functions $\mu_{\tilde{\tilde{C}}_{5-7}}(\|I\|)$, $\mu_{\tilde{\tilde{C}}_{20-30}}(\|I\|)$ and $\mu_{\tilde{\tilde{C}}_{50-60}}(\|I\|)$. The parameters b are determined in accordance with the desired scale of softness. In accordance with de fuzzy set theory, the output y obtained by application of this fuzzy rule bases, is given by :

$$y = \frac{b_{5-7} \cdot \mu_{\tilde{\tilde{C}}_{5-7}}(\|I\|) + b_{20-30} \cdot \mu_{\tilde{\tilde{C}}_{20-30}}(\|I\|) + b_{50-60} \cdot \mu_{\tilde{\tilde{C}}_{50-60}}(\|I\|)}{\mu_{\tilde{\tilde{C}}_{5-7}}(\|I\|) + \mu_{\tilde{\tilde{C}}_{20-30}}(\|I\|) + \mu_{\tilde{\tilde{C}}_{50-60}}(\|I\|)} \tag{4}$$

The membership functions $\mu_{\tilde{\tilde{C}}_{5-7}}(\|I\|)$, $\mu_{\tilde{\tilde{C}}_{20-30}}(\|I\|)$ and $\mu_{\tilde{\tilde{C}}_{50-60}}(\|I\|)$ can be defined from the average value of $\|I\|$ for each class with the constraint to have a fuzzy partition (i.e. the sum of the membership function is equal to one). For triangular memberships functions, we obtain the results given in figure 3. The modal values are obtained according to tests carried out on avant-bras.

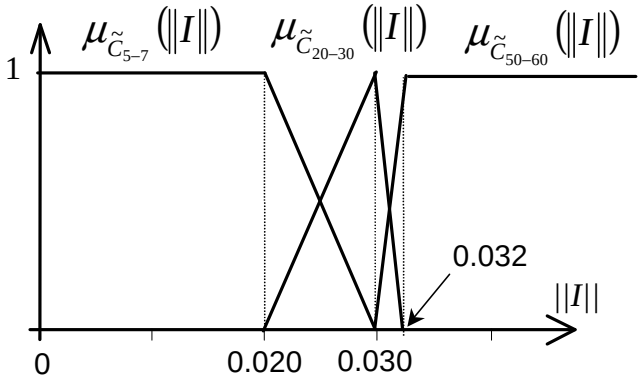

Fig. 3: *memberships functions.*

If we define y as a number which reflect the sweetness of the skin such that $y \in [0,1]$, the parameters are as follows :

$$b_{5-7} = 1, \quad b_{20-30} = \frac{1}{2}, \quad b_{50-60} = 0 \tag{4}$$

with these parameters, more y is close to 1, softer is the skin. With this parameterisation, figure 4 show the result obtained in term of quantitative sweetness vs. mean intensity of the acoustical signal.

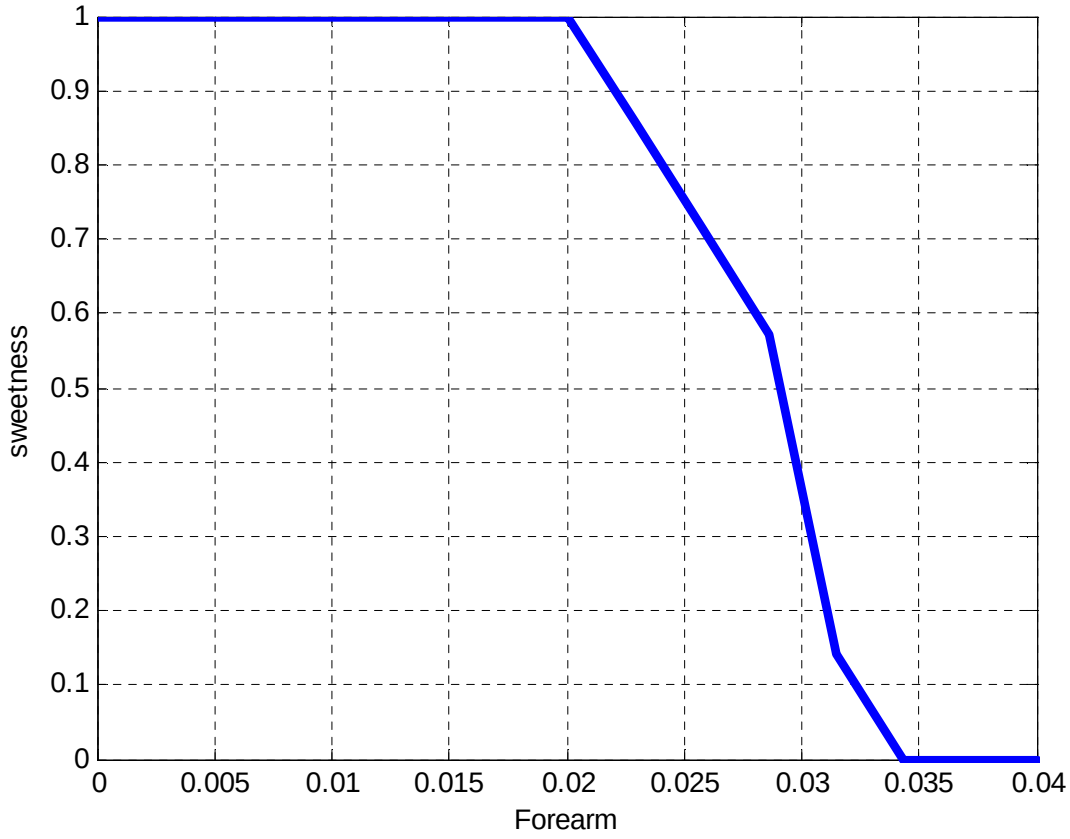

Fig. 3: *sweetness vs. mean intensity of the acoustical signal on the forearm.*

This function can then be used to evaluate the effectiveness of a given cosmetic product in term of sweetness.

3 Conclusion

In this paper was presented an original method to evaluate the subjective notion of the sweetness of the skin. The proposed approach exploits the acoustical signal obtained during a cutaneous friction. This acoustical signal is collected with a tribo acoustical sensor. The intensity of the signal thus obtained is strongly related with the age of the subject and can then be used to evaluate the sweetness of the skin. However, due to the subjective notion of the sweetness, a fuzzy treatment of an appropriate norm of the acoustical signal is realised in order to obtain a realistic evaluation of the sweetness of the human skin.

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