This paper studies and compares the results from different methods to evaluate ultrasonic velocity \( U/V \) of travelling waves during the coagulation process of renneted milk. Two transducers separated by a distance \( d \) were used in pulse-echo (P-E) mode. For the proposal, one of the transducers acted as a mirror which reflected the ultrasound waves. The measurement of the time of flight \( TOF \) was always done from the beginning of the transmitter pulse to: (a) the beginning, (b) the time of maximum value of voltage and (c) the time of minimum value of voltage of each wave train belonging to the 1\(^{st} \), 2\(^{nd} \) and 3\(^{rd} \) echoes in the receiver's A-scan. From the known distances \( s \) that are travelled by the waves and the aforementioned TOFs between consecutive echoes, two different values of \( U/V \) were calculated as: (1) averages and (2) fits by linear regressions. Moreover, by means of Fourier transformation \( FFT \), the influence of a periodic excitation (multiple echoes) allowed us to determine (3) the length of period, i.e. another measurement of \( TOF \) via cepstrum and consequently, another \( U/V \) value.

I. INTRODUCTION

II. MATERIALS AND METHODS

Getting \( U/V \) via \( TOF \).

\[
\begin{align*}
    v_{0j} &= \frac{2d}{t_{1j} - t_{00}} \\
    v_j &= \frac{2d}{t_{i+1j} - t_{ij}} \\
    v_j &= \{v_{0j}, v_{1j}, v_{2j}\} \\
    s &= v_j \cdot t_{ij}
\end{align*}
\]

Getting \( U/V \) via cepstrum

By means of the so-called cepstrum method the spectrum could be smoothed as well as the length of period be determined directly. The cepstrum arose by a \( FFT \) of the logarithmized spectrum. As you can see in the example, which shows the cepstrum created from \( FFT \), one reads directly from the first maximum a periodic time of flight \( t \).

\[
v = \frac{2d}{t}
\]

III. RESULTS AND DISCUSSION

For the four raw milks measured, the values of the velocity \( v \) obtained with the V318 transducer in pulse-echo mode were: \((1530\pm20)\) m/s, \((1410\pm40)\) m/s, \((1438\pm18)\) m/s and \((1432\pm17)\) m/s.

The results computed by the methods which velocities were obtained from all echoes \( (v_O, v_M, v_m, v'_O, v'_M, v'_m) \) are illustrated graphically in the figure for one of the four raw sheep milks. The location of mean values is represented by the point, and errors by the bars. According to the figure, one can't infer a greater accuracy of results produced by any method. In fact, no significant differences were determined between the discussed methods. Therefore, it seems insignificant whether the determination of velocities by a method involves values corresponding to the points where the signal line intersects the “zero” level or time values corresponding to the maximum or minimum values of voltage. Nevertheless, error values suggest that cepstrum analysis is a more precise method, as with the other methods, the error bars are either wider or equal to any particular milk only. In this regard, it should be noted that the higher relative velocity errors corresponded to \( v_O, v'_O, v_M, v'_M \) and \( v_m, v'_m \).

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