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Application of ultrasounds to determine carrot juice properties

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Abstract: *Application of ultrasounds to determine carrot juice properties*. The purpose of the study was to determine the possible influence of the properties of raw material used to prepare carrot juice on the speed and attenuation coefficients of ultrasonic waves. Wave velocity and solid phase concentration dependencies are described using a linear model. This dependence was used to evaluate the properties of carrot juice from various sources and after the thermal processing of the prepared juice. The results show that not only the temperature or the solid phase concentration affect the velocity of sound or attenuation coefficient, but it can also be a conditions or time of storage and thermal processing of juice.

Key words: ultrasounds, carrot juice, product properties

INTRODUCTION

Testing of biological materials using indirect methods may be subject to considerable error if not taken into account all factors that could affect the measured values. In the case of puree juice, the relationship between the speed of sound and the temperature or solid phase concentration is described by Abu-Jdayil et al. [2007]. This work did not evaluate the properties of raw material used in juice production. Various soil factors, fertilization or cultivation methods, as well as different conditions and storage time, may affect the properties of the raw material so that the finished product will also be affected.

In the case of ultrasonic measurements of fruit juices and fruit purées, the largest influence has the dispersed phase in the form of solid particles [He and Zheng 2001]. It affects both the wave velocity and the attenuation coefficient. The size, shape and physical properties of these particles, and their parameters can vary depending on the used raw material and all of them are significant [Mougin et al. 2003].

The purpose of this work was to determine the influence of the origin of the raw material, the thermal processing of the product, the concentration and temperature of the carrot juice on the ultrasonic wave velocity and the attenuation coefficient.

MATERIAL AND METHODS

The study was divided into four stages, which were performed independently. The influence of the following factors on the wave velocity and attenuation coefficients was investigated: temperature and concentration of juice (I), thermal processing (II), source of carrot (III), juice storage (IV).

The carrot juice used for the study was prepared from carrots purchased at the market and made with the use of juicer (Zelmer ZJE1200W). At each stage, the raw material for testing could have come from another production batch where the storage conditions affect to it before buying. During the study, which included the origin of carrots (III), the purchase was made at various suppliers. Measurements were made immediately after the juice was prepared so that it was not necessary to store it. Only during the stage where its properties were tested in time (IV), the samples were stored in refrigerator (4°C) and room temperature. Different concentrations of juices for testing the effect of the solid phase concentration on the wave velocity were obtained by diluting the prepared juice with distilled water twice. The concentrations obtained are 8.2, 4.1 and 2.1%.

Ultrasonic measurements were taken with the use of an OPBOX ultrasonic defectoscope (Optel, Poland) and the head generated a longitudinal wave with frequency of 1 MHz using echo technique. The measurements were performed at 25°C, and for the study to determine the effect of temperature (I) in addition to 30° and 35°C.

Measurements taking into account the effect of heat treatment on juice properties were made for juices: fresh, pasteurized, boiled, frozen and made from blanched carrots. All measurements were made at the same temperature (after naturally chilled) and for frozen juice after 24 h in the freezer (–17°C).

After the test, each sample of the juice was dried at 95°C to determine the proportion of dry matter.

RESULTS AND DISCUSION

During the study, some samples of juice had a very high attenuation coefficient, which made it impossible to carry out measurements immediately after placing the sample in the measuring chamber. Statistical analysis showed that the change in velocity due to sedimentation was not important in the period of 15 min. In contrast, the differences in the values of the damping coefficient were statistically significant in the first minute of measurement Dickinson and McClements [1995].

First, measurements were made to estimate the relationship between the wave velocity and the juice temperature at every concentrations (Fig.). Values from empirical measurements were used to construct a model based on a linear function. The coefficients of this model and R^2 are shown in the graph. Because of the small range of concentrations, the proposed equations describe this relationship with a high approximation. However, it is clearly noticeable that the wave velocity increases with both increasing temperature and increasing concentration of the dispersed phase. Based on the directional coefficients of the model, it can be observed that the increase in temperature by one degree caused a speed increase in the range of from 0.88 to 0.96 $m \cdot s^{-1}$. The attenuation coefficient values increase as the concentration of the dispersed phase increases regardless of the juice temperature. But because of

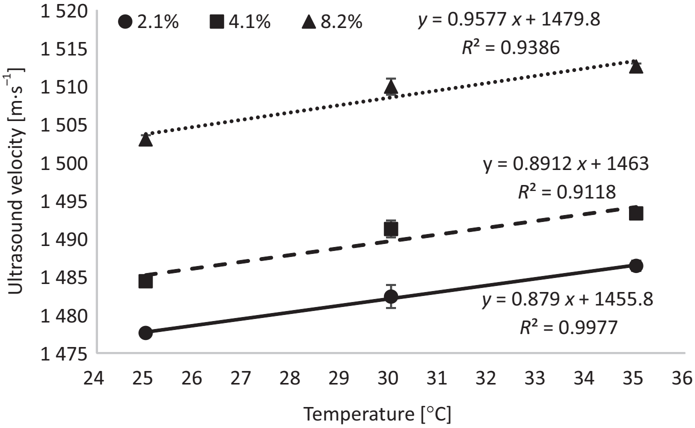

FIGURE. The relationship between velocity of wave propagation and temperature at different concentrations of carrot juice

too few repetition, measured attenuation coefficients cannot been used to develop the model. The nature of changes of the speed of sound as well as the attenuation coefficient is in line with the tests performed by Kubo et al. [2015].

The next step was to make measurements for juices subjected to various thermal treatments. Table 1 shows the results of these measurements. Note that for the prepared juice that has been divided into individual samples, the dry matter content values change after the treatment (e.g. water loss during boiling). For both boiled and pasteurized juice there was a clear delamination where most of the solid phase fell to the bottom. In the production of vegetable juices, homogenization is carried out to avoid solid phase deposition in such a way [Jarczyk and Płocharski 2010].

Measurements of the attenuation coefficient for fresh and boiled juices were difficult because of its high value. After 5 min of sedimentation there was possibility to make the measurements. Therefore the real attenuation coefficient values are higher than shown.

Since each sample of juice had a different solid phase content, the adjusted

TABLE 1. Properties of carrot juices subjected to various treatments

Product	Dry matter content [%]	Speed of sound [m·s^{-1}]	Attenuation coefficient [Np·m^{-1}]	Adjusted speed of sound [m·s^{-1}]
Fresh juice	9.54	1 492.4	>0.084	1 508.317
Boiled juice	10.28	1 493.7	>0.079	1 511.436
Pasteurized juice	9.96	1 492	0.041	1 510.087
Frozen juice	10.34	1 494.7	0.035	1 511.689
Fresh juice from blanched carrots	8.85	1 491.8	0.026	1 505.408

wave velocity is calculated on the basis of the linear model based on the measurements from the first stage. It describes the relationship between the concentration of the solid phase and the ultrasound velocity at 25°C. The equation of this model is $V = 4.216 \cdot f + 1{,}468.1$, where V is the adjusted speed of sound, and f is the solid phase concentration. The adjusted speed of sound allows you to compensate the differences in values, due to varying solid phase concentrations, and realistically compare wave velocity.

Especially noteworthy is the juice made from blanched carrots. Apart from the fact that the juice was clearly lighter than the others [Jabbar et al. 2014], it was characterized by the lowest solid phase concentration, the lowest wave velocity and the lowest attenuation coefficient.

By acquiring material for research from unknown source we do not have any information about its production or method or time of storage. Table 2 shows the results of the measurements of juices made from carrots obtained from various independent suppliers. Again due to differences in solid phase concentrations, the adjusted speed of sound was determined. On the basis of this, it can be seen that not only the concentration of the solid phase can influence to the velocity of sound. It can be seen that the attenuation coefficient increase as the concentration increases, as confirmed by previous studies, but does not exclude the existence of another factor influencing its value.

Fresh juices that have not been pasteurized should be drunk in one day. However, these highly processed and pasteurized can be stored for many months, and when opened should be consumed within 24 h. During storage harmful substances can appear in juice, in this situation it should not be consumed. Ultrasonic measurements have not clearly determined the relationship between storage time and ultrasound velocity or attenuation coefficient. Only bubbles of gas appearing inside the juice causing an increase of the attenuation coefficient, sometimes making it impossible to measure.

CONCLUSIONS

1. Ultrasound velocity changes with the change of temperature and solid phase concentration. In the studied range of temperatures and concentrations, the nature of these changes is very well described by linear model. The attenuation coefficient increases

TABLE 2. Characteristics of juice obtained from carrots from different sources

Sample number	Dry matter content [%]	Speed of sound [$m \cdot s^{-1}$]	Adjusted speed of sound [$m \cdot s^{-1}$]	Attenuation coefficient [$Np \cdot m^{-1}$]
1	7.1	1 507.1	1 498.0	0.129
2	7.5	1 500.5	1 499.9	0.139
3	8.0	1 504.6	1 501.7	0.196
4	8.0	1 504.3	1 501.9	0.160
5	9.7	1 509.8	1 509.1	0.168

with increasing concentration, but the nature of these changes is not clear and require more study with more replications.

2. The heat treated juice does not significantly affect the propagation speed of the wave. The only change was observed for the juice that was prepared from the blanched carrots.
3. The properties of carrot juice made from carrot obtained from different sources in individual cases were different. This may indicate the influence of other factors on the measured values than the temperature or concentration of the juice.
4. No significant changes in wave velocity were observed during storage, and the nature of the change in attenuation coefficient was ambiguous.

The results obtained after their enlargement are the basis for the development of a rapid method of evaluating the properties of carrot juice using ultrasonic waves.

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Streszczenie: *Badania ultradźwiękowe właściwości soku marchwiowego***.** Celem badań było określenie, czy na prędkość i współczynniki tłumienia fali ultradźwiękowej mogą wpływać właściwości surowca wykorzystanego do przygotowania soku marchwiowego. Zależności prędkości fali od temperatury i stężenia fazy stałej opisano z użyciem modelu liniowego. Zależność ta została wykorzystana przy ocenie właściwości soku pochodzącego z marchwi z różnych źródeł oraz po przeprowadzeniu obróbki termicznej przygotowanego soku. Uzyskane wyniki wskazują, że na prędkość fali czy współczynnik tłumienia wpływa nie tylko temperatura lub stężenie fazy stałej, ale może to być także sposób bądź czas przechowywania, a także przeprowadzona obróbka.

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