

ULTRASONIC DETERMINATION OF A MEAT-BASED PRODUCT COMPOSITION

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ABSTRACT

The use of ultrasonics as an analytical technique to estimate the composition of a fermented meat-based product (sobrassada) was assessed. The ultrasonic velocity temperature dependence allowed the determination of fat, moisture and protein+others contents by measuring the ultrasonic velocity in the meat-based product at 4 and 12°C using a semiempirical equation. The explained variance was 95.8% for protein + others, 96.8% for fat and 95.7% for moisture. The results obtained show the feasibility of using ultrasonic velocity measurement to assess, in a rapid and non-destructively way, the composition of a meat-based product.

INTRODUCTION

The chemical composition of meat-based products has a large influence on its nutritional value, functional properties, sensory quality, storage conditions and commercial value constituting one of the major quality attributes. Thus, its knowledge is of great importance for quality control, not only for producers but also for retailers and consumers.

Low-intensity ultrasound can be used to provide information about the physicochemical properties of many foods (Mulet, Benedito, Bon and Rosselló, 1999). Ultrasound has advantages over other traditional analytical techniques because measurements are rapid, nondestructive, precise, fully automated and might be performed either in a laboratory or on-line (McClements, 1995; Abouelkaram et al., 2000).

Recent studies have shown that the ultrasonic velocity in fish tissue, chicken and raw meat mixtures can be related to its composition (solids nonfat, moisture and fat content) using semiempirical equations (Ghaedian, Decker and McClements, 1997; Ghaedian, Coupland, Decker and McClements, 1998; Chanamai and McClements, 1999; Benedito, Cárcel, Rosselló and Mulet, 2001).

The ultrasonic properties of a multicomponent material can be described to a first approximation by the following relationship (eq.1) (Ghaedian, Decker and McClements, 1997) where Φ_j and v_j are, respectively, the mass percentage and ultrasonic velocity in component j :

$$\frac{100}{v^2} = \sum_{j=1}^n \frac{\Phi_j}{v_j^2} \quad (1)$$

The objective of this study was to examine the relationship between the ultrasonic velocity measured on a meat-based product (sobrassada de Mallorca) at different temperatures and its chemical composition and, thus, assess whether ultrasound could be used as an useful technique to determine the overall composition of this type of products.

MATERIALS AND METHODS

Meat-based products used in this study (sobrassada) were manufactured at the island of Mallorca (Spain) by a local factory following the methodology suggested by the Protected Geographical Indication (PGI) for the “Sobrassada de Mallorca”. Sobrassada is composed by a mixture of lean pork meat, white fat, paprika and salt.

The meat ingredients were kneaded until particle size of 4 mm was achieved and then mixed with the other ingredients. Afterwards, the mince was filled into artificial casings (25 10^{-2} m of long, 7.5 10^{-2} m of diameter and 2.68 10^{-12} g/Pa-s-m of permeability at 12°C and 75% of relative humidity) and ripened at 14°C and 70% of relative humidity. In order to obtain samples with different composition, sobrassada samples were elaborated by using different proportions of meat and white fat.

All samples of sobrassada were analyzed in triplicate for moisture, fat and protein contents according to the official methods (ISO R-1442, ISO R-1443 and ISO R-937, respectively).

Measurements of ultrasonic velocity at 4 and 12°C were carried out by using the experimental set-up described previously by Benedito et al. (2001) which consisted of a couple of narrow-band ultrasonic transducers (1 MHz, 0.75” crystal diameter, A314S-SU Model, Panametrics, Waltham, MA), a pulser-receiver (Toneburst Computer Controlled, Model PR5000-HP, Matec Instruments, Northborough, MA) and a digital storage oscilloscope (Tektronix TM TDS 420, Tektronix Inc., Wilsonville, OR) linked to a personal computer using GPIB interface. To compute the time of flight for a sample, five acquisitions were performed and averaged. All analyses were performed in duplicate on two different samples without removing the casing.

RESULTS AND DISCUSSION

Results obtained in the chemical composition measurements and ultrasonic velocity at 4 and 12°C for the 16 samples analyzed are shown in table 1. As it can be observed in this table, mean values of composition, ranged from 43.1 to 67.1 % (wm) for fat content, from 19.6 to 37.2 % (wm) for moisture content and from 5.0 to 10.5 % (wm) for protein content.

The ultrasonic velocity decreased with the temperature of the sample. As an example, the ultrasonic velocity measured in five samples with different composition at two different temperatures (4 and 12°C) has been represented vs the sample fat content in figure 1. As it can be seen in this figure, ultrasonic velocity decreased with the increase in fat content being higher the slope (in absolute value) of the representation at 12°C.

In this study, it is considered that the sobrassada is formed by three different constituents: fat, water and protein+others. Based on equation 1, the ultrasonic velocity of a meat-based product can be calculated by the following equation (eq. 2):

$$\frac{100}{v^2} = \frac{\Phi_f}{v_f^2} + \frac{\Phi_w}{v_w^2} + \frac{\Phi_{p+o}}{v_{p+o}^2} \quad (2)$$

where v is the ultrasonic velocity and v_f , v_w and v_{p+o} are the ultrasonic velocities in fat, water and protein+others, respectively. Moreover, Φ_f , Φ_w and Φ_{p+o} are the percentages of fat, water and protein+others (wm), respectively.

Table 1. Mean and standard deviation of fat, moisture and protein contents (% wm) and ultrasonic velocity (m/s) at 4 and 12°C.

sample	fat % wm	moisture % wm	protein % wm	v(4°C) (m/s)	v(12°C) (m/s)
1	43.1 ± 0.6	35.8 ± 0.5	11.0 ± 0.1	1635.0 ± 0.7	1617.0 ± 2.6
2	43.9 ± 0.2	37.2 ± 0.7	9.3 ± 0.3	1624.5 ± 1.2	1607.5 ± 2.0
3	46.3 ± 0.6	31.7 ± 0.3	10.2 ± 0.1	1649.0 ± 1.1	1625.3 ± 2.2
4	48.3 ± 0.3	32.5 ± 0.3	10.5 ± 0.2	1630.3 ± 1.3	1609.3 ± 3.6
5	48.7 ± 0.7	34.2 ± 0.2	9.7 ± 0.1	1619.6 ± 1.0	1599.1 ± 0.7
6	49.8 ± 0.3	31.9 ± 0.3	9.9 ± 0.1	1627.4 ± 2.1	1605.9 ± 1.4
7	50.8 ± 0.2	30.2 ± 0.2	9.5 ± 0.3	1636.8 ± 1.9	1609.6 ± 2.2
8	52.8 ± 0.4	29.4 ± 0.2	9.3 ± 0.2	1630.4 ± 1.7	1603.8 ± 1.4
9	54.5 ± 0.6	28.0 ± 0.3	9.0 ± 0.2	1630.4 ± 3.3	1603.8 ± 1.4
10	57.6 ± 0.5	26.5 ± 0.2	8.4 ± 0.3	1626.6 ± 1.2	1594.7 ± 2.0
11	58.6 ± 0.7	24.9 ± 0.2	8.0 ± 0.3	1629.3 ± 0.8	1597.9 ± 1.9
12	62.4 ± 0.6	23.8 ± 0.7	6.6 ± 0.2	1623.4 ± 0.5	1593.1 ± 1.1
13	61.5 ± 0.4	25.1 ± 0.2	5.9 ± 0.4	1613.9 ± 2.0	1584.8 ± 1.3
14	61.8 ± 0.6	22.5 ± 0.4	6.5 ± 0.3	1624.1 ± 1.9	1592.2 ± 1.4
15	63.2 ± 0.5	20.4 ± 0.4	8.0 ± 0.3	1631.7 ± 1.5	1595.4 ± 1.3
16	67.1 ± 0.9	19.6 ± 0.8	5.0 ± 0.5	1625.5 ± 0.9	1588.5 ± 3.3

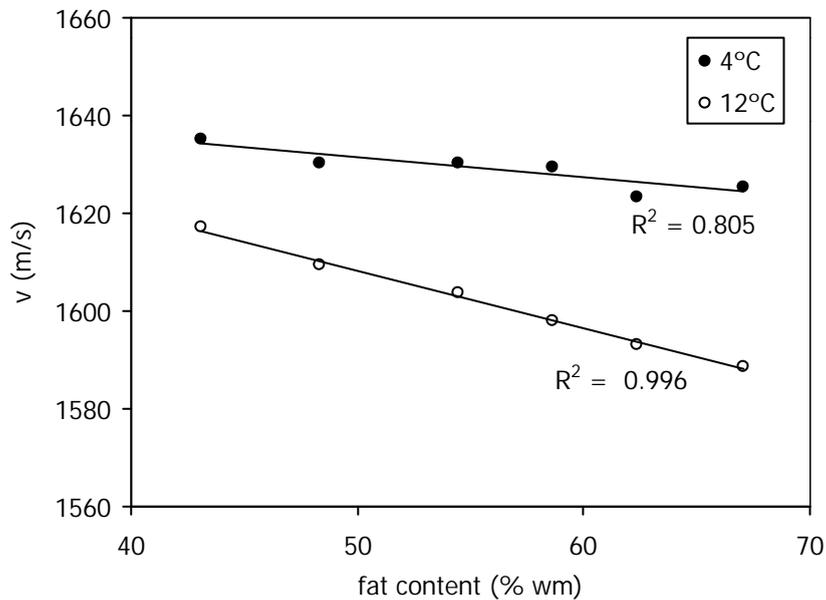


Figure 1. Influence of sobrassada fat composition on ultrasound velocity at 4 and 12°C.

The relationship between water and temperature (eq. 3) was taken from the literature (Kinsler, Frey, Coppens and Sanders, 1982). Further, the relationship between the ultrasonic velocity and temperature in fat was obtained by Benedito, Cárceles, Rosselló and Mulet (2001) from experiments carried out using vacuum dried pork fat (eq. 4).

$$v_w = 1403 + 5T - 0.06T^2 + 0.0003T^3 \quad (3)$$

$$v_f = -5.6076 T + 1651.7 \quad (4)$$

With the aim of establishing an equation relating v_{p+o} with temperature, the equations 2, 3, 4 and the experimental results obtained in the measurements of ultrasonic velocity and the experimental percentages of fat and water contents (table 1) were used to calculate the values of v_{p+o} at different temperatures (4 and 12°C). As an example, calculated v_{p+o} at 4 and 12°C has been represented versus the fat content in figure 2. As it can be inferred from this figure, calculated v_{p+o} decreased with temperature from 4 to 12°C in all samples. Furthermore, chemical composition influence was also observed decreasing the calculated figures for v_{p+o} when fat content increased and moisture and protein content decreased. Similar results were observed for the remaining samples.

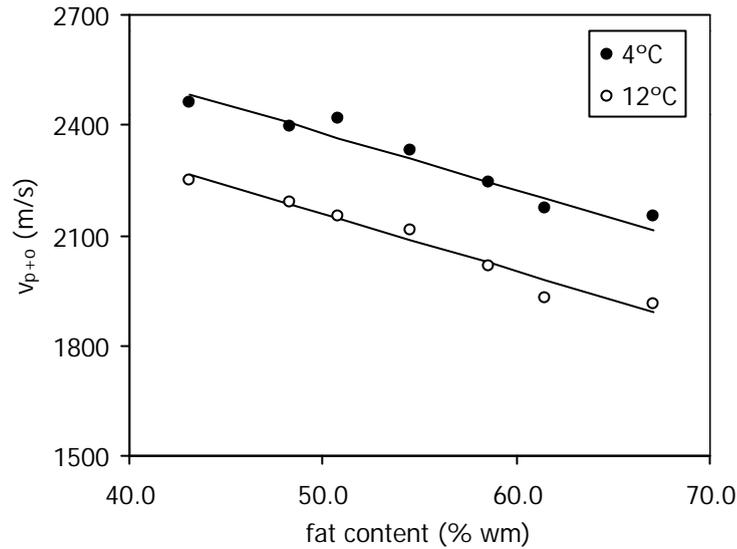


Figure 2. Influence of fat content (% wm) on ultrasound velocity of protein+others calculated for samples of sobrassada at 4 and 12°C.

From these results, it was concluded that, probably due to the fact that the protein proportion varies in “protein+others” among samples with different chemical composition, the ultrasonic velocity in protein+others not only depends on temperature but also on chemical composition. Thus, an empirical equation is proposed to relate the v_{p+o} with temperature and fat content (eq. 5).

$$v_{p+o} = a_1 + a_2 \Phi_f + a_3 T \quad (5)$$

In order to determine the parameters a_1 , a_2 and a_3 of equation 5, calculated values of v_{p+o} at 4 and 12°C through equations 2 to 4 for five samples with different chemical composition (samples 1, 4, 9, 13 and 16) were used. SOLVER, an optimization tool (GRG2 method) included in Microsoft Excel 7.0™ spreadsheet was used, obtaining equation 6, which provided the lowest sum of the square differences between the values calculated using equations 2 to 4 and those estimated using the proposed equation 6.

$$v_{p+o} = 3262.67 - 15.48 \Phi_f - 27.56 T \quad (6)$$

The percentage of explained variance obtained through the comparison of the calculated v_{p+o} through equations 2 to 4 and estimated v_{p+o} by using the equation 6 was 97.2%. As an example, estimated figures has been also represented in figure 2 vs temperature through continue lines for five different samples.

Ultrasonic composition assessment

Using equation 2 at two different temperatures (T_1 and T_2) and taking into account that the sum of the components of the product in percentage is 100, the following three-equation system was obtained:

$$\frac{100}{V_{T_1}^2} = \frac{\Phi_f}{V_{f_{T_1}}^2} + \frac{\Phi_w}{V_{w_{T_1}}^2} + \frac{\Phi_{p+o}}{V_{p+o_{T_2}}^2} \quad (7)$$

$$\frac{100}{V_{T_2}^2} = \frac{\Phi_f}{V_{f_{T_2}}^2} + \frac{\Phi_w}{V_{w_{T_2}}^2} + \frac{\Phi_{p+o}}{V_{p+o_{T_2}}^2} \quad (8)$$

$$\Phi_f + \Phi_w + \Phi_{p+o} = 100 \quad (9)$$

With the aim to estimate the chemical composition of the sobrassada samples, fat, moisture and protein+others contents, equations representative of v_w , v_f and v_{p+o} (eqs. 3, 4 and 6) and the results obtained in the measurements of ultrasonic velocity at 4 and 12°C for samples 1 to 16 were considered. Thus, Φ_w , Φ_f and Φ_{p+o} were estimated for each sobrassada sample. Figure 3 shows the comparison between the estimated composition (fat, moisture and protein+others contents) and the experimental values. As it can be observed in this figure, there was a close fit between both estimated and experimental data.

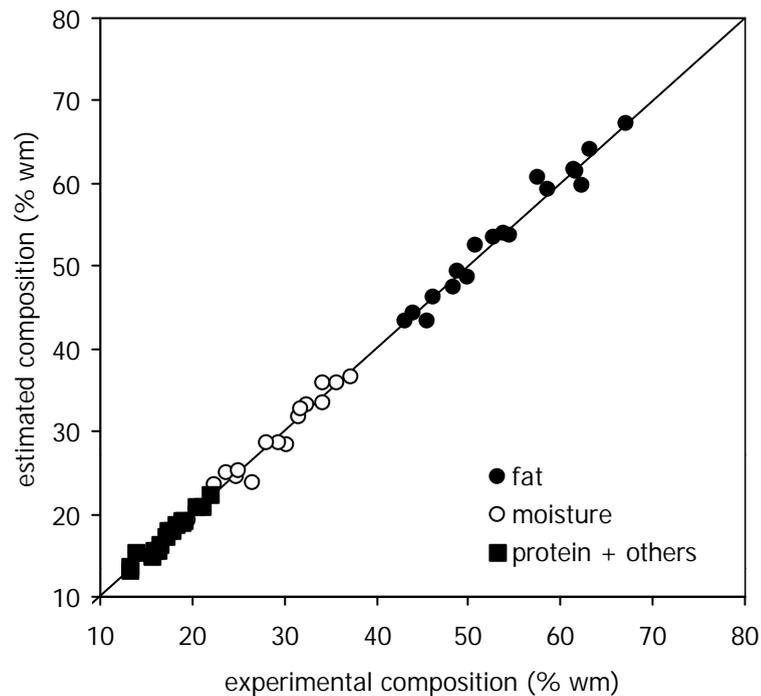


Figure 3. Estimated vs experimental composition of sobrassada samples: fat, moisture and protein+others contents (% wm).

In order to mathematically evaluate the accuracy of the simulation obtained using the proposed method to determine the chemical composition of a meat-based product, the percentage of explained variance (eq. 10) was computed by using the standard deviation of the sample (S_y) and the corresponding estimation (S_{yx}).

$$\%var = \frac{S_{yx}^2}{S_y^2} \cdot 100 \quad (10)$$

The explained variances obtained by comparison of the estimated composition and the experimental one were satisfactory, of 96.8% for the fat content, 95.7% for the moisture content and 95.8 % for the protein+others content.

CONCLUSIONS

On the one hand, the ultrasonic properties of a meat-based product depended on composition and temperature. Furthermore, the semiempirical equations proposed in this study accurately predicted fat, water and protein+others contents of a meat-based product (sobrassada) from ultrasonic velocity measurements at two different temperatures.

Although this study was carried out by using a typical meat product from Spain, the obtained results pointed out that a non-destructive technique of ultrasounds could be used to accurately estimate the chemical composition of any meat-based product.

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