Dielectric Properties of Uncooked Chicken Breast Muscles from Ten to One Thousand Eight Hundred Megahertz


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ABSTRACT
The dielectric properties, consisting of the dielectric constant ($\varepsilon'$) and loss factor ($\varepsilon''$), were measured with an open-ended coaxial-line probe and impedance analyzer for uncooked broiler breast muscle pectoralis major and pectoralis minor, deboned at 2- and 24-h postmortem, over the frequency range from 10 to 1,800 MHz at temperatures ranging from 5 to 85°C. The dielectric property profiles of chicken breast muscle are dependent upon the radio-wave and microwave frequencies and temperature. Increasing frequency from 10 to 1,800 MHz results in decreasing values of the dielectric constant and loss factor regardless of temperature in this range, chicken breast muscle type, or deboning time. However, the response to temperature varies with the frequency, muscle type, and deboning time. There are no differences in the dielectric constant and loss factor values at frequencies of 26 or 1,800 MHz between samples deboned at 2- and at 24-h postmortem. However, the muscle type significantly affects the average values of the dielectric constant and loss factor, with pectoralis minor having significantly higher average values. Both the deboning time and muscle type significantly affect the average values of the loss tangent ($\tan \delta = \varepsilon'' / \varepsilon'$) at 26 and 1,800 MHz, with pectoralis minor having higher values than pectoralis major and 2-h samples having higher values than 24-h samples. Our quality measurements also show there are significant differences in chicken meat quality characteristics, including color, pH, drip loss, water holding capacity, and texture (Warner-Bratzler shear force value) between the different muscle types and between different deboning times in the same test. These results suggest that there is a probable potential for using dielectric property measurements to assess the quality of chicken meat.

Key words: chicken, deboning time, pectoralis, dielectric constant, dielectric loss factor

INTRODUCTION
Dielectric properties and permittivity in this article imply the relative complex permittivity (i.e., the permittivity of a material relative to free space, which is expressed as $\varepsilon = \varepsilon' - j \varepsilon''$, where $\varepsilon'$ is the dielectric constant and $\varepsilon''$ is the dielectric loss factor). The dielectric constant is associated with the capacity for energy storage in the electric field in a material. It also influences the amount of electromagnetic energy reflected from a product material or transmitted into the product material. The dielectric loss factor describes how well a material absorbs energy from electric fields and converts that energy into heat. Both properties are affected by the frequency of the electromagnetic fields, temperature, material density, food composition (Nelson, 1991; Kent et al., 2000; Nelson and Datta, 2001), and the state of foods, such as maturity (Nelson et al., 1995) and frozen vs. fresh products (Hall et al., 1994).

Dielectric properties have shown potential uses for meat quality and meat composition measurements. Zhukov et al. (1985) reported that the values of dielectric characteristics depended on the ratio between free and bound water of minced fish products. Kauffmann et al. (1986) used dielectric spectroscopy to measure water-holding capacity of porcine muscle. Pfuetzner et al. (1985) used dielectric loss factor to identify pale soft exudative (PSE) meat and found that PSE muscles had much greater dielectric loss factor values. They concluded that the dielectric loss factor was suitable for use in detection of the PSE defect of pork meat (Pfuetzner and Rapp, 1988). Chizzolini et al. (1993) evaluated various techniques to objectively measure pork quality and showed that dielectric loss factor seems to be specifically suited for PSE diagnosis. Fiala and Honikel (1995) reported that dielectric loss factor changed considerably during the aging of beef and may be of value for assessment of the degree of aging. Hall et al. (1994) demonstrated that at frequencies from 10 to 20 GHz, fresh pork
exhibited different dielectric properties than frozen and thawed pork. Both responses differed from that of PSE pork. Recently, Kent et al. have published several reports on using a combination of dielectric properties and principal component analysis to successfully predict the quality differences and shelf life of various meats and meat products, including harvest seasons of Atlantic hake (Kent et al., 2005), freshness of cod over storage (Kent et al., 2004a,b), composition (protein and salt), and added water in pork products (Kent et al., 2001, 2002), and poultry meat (Kent and Anderson, 1996, Kent et al., 2001). In addition, the changes in dielectric properties of fish skin and fish muscle are closely related to spoilage rates and have been used as quality indicators since 1970 (Burt et al., 1976; Storey and Mills, 1976). Lougovois et al. (2003) recently reported that dielectric measurements were consistent with sensory assessment of freshness quality of gilthead sea bream and concluded that dielectric methods provided a unique tool for quality assessment of fish meat.

In the United States, poultry meat consumption has been growing very rapidly at the expense of red meat in the past 2 decades, especially boneless, skinless chicken breast meat and marinated (water-added) poultry products. Quality, including taste, freshness, and tenderness, has been the major aspect of consumer satisfaction with chicken meat (Hayman, 2004). However, little has been attempted in assessing and monitoring chicken meat quality, including PSE meat, water holding capacity, and texture quality during aging, with rapid, nondestructive instrument methods in the poultry industry (Swatland, 1999). Permittivity measurements have indicated potential for assessing meat quality nondestructively, but measurements on chicken meat have been limited to frequencies from 100 to 2,500 MHz and temperatures from 2 to 40°C. The objective of this study was to determine dielectric property profiles of fresh chicken breast muscle at frequencies from 10 to 1,800 MHz at temperatures from 5 to 85°C and to study the effect of postmortem aging time and chicken breast muscle types on the measured dielectric properties.

**Materials and Methods**

**Chicken Samples**

Broiler carcasses (average weight 1,554 ± 223 g) were obtained from a local processing plant immediately after the flow-through, paddle-type chiller. The carcasses were placed in a cooler and transported to the laboratory within 20 min, and carcass temperature was 3 to 4°C on arrival. Muscles from the right breast half were removed from carcasses at the early postmortem stage (for the 2-h group) within 15 to 25 min of arrival at the laboratory (Liu et al., 2004), whereas the other breast half was left on the carcass with normal attachment to the skeletal restraints (intact). The carcass with the left half breast was then placed in a Ziploc freezer bag and stored at 1 to 2°C until 22 h later (for 24-h group) for deboning. The breast muscles deboned at 2-h postmortem were placed in Ziploc bags and stored in the same refrigerator for 22 h before use. The entire study was replicated 4 times and completed in 5 wk.

**Quality Measurements**

Color and pH measurements were performed on chicken breast muscle, pectoralis major and pectoralis minor, after deboning. Surface color measurements (L*, a*, and b* values) were carried out with a Minolta spectrophotometer CM-2600d (Konica Minolta, Ramsey, NJ) with settings of illuminant C, specular component excluded, and an 8-mm aperture. Surface areas were selected that were free from obvious defects (bruises, discolorations, hemorrhages, or any other conditions that might have prevented uniform color readings). One measurement was taken on the bone side of the fillet. Each measurement was the result of 3 averaged readings by the spectrophotometer. The pH of chicken fillets was determined with a Sentron model 201 pH meter (Sentron, Gig Harbor, WA) and a piercing probe (Lance FET Tip) at the cranial end (wing end) of breast fillets after deboning. Between measurements, the probe tip was cleaned with a toothbrush and rinsed with deionized water.

Moisture content was measured by the AOAC method (AOAC, 1990). Five grams of minced meat was dried in an aluminum pan at 100°C for 18 h. The sample was weighed after being cooled to room temperature in a desiccator.

Drip loss was determined essentially as described by Rasmussen and Anderson (1996). Chicken breast muscle samples were cut with a cork borer at a right angle to the muscle fiber direction. Samples were suspended in a cone-shaped centrifuge tube with lid to avoid evaporation. The drip loss was expressed as the weight loss in percent of initial sample weight over 48 h at 4 to 6°C.

Water-holding capacity (WHC) was determined by a method similar to that developed by Wardlaw et al. (1973). The minced meat sample (10 g) and 15 mL of 0.6 M NaCl solution were placed into a 50-mL centrifuge tube and mixed with a Vortex mixer for 1 min. The tube was then refrigerated at 4°C for 15 min before being centrifuged at 4°C at 3,000 × g for 15 min. The WHC (%) was determined by the formula

\[
\text{WHC} = 100 \times \frac{(W_{\text{pellet}} - W_{\text{raw}})}{W_{\text{raw}}}
\]

where W represents sample weight, pellet refers to the solid material at the bottom of the tube after centrifugation, and raw refers to the chicken meat sample used for the analysis.

For cook loss and Warner-Bratzler (WB) shear force measurements, the caudal portion, two-thirds of the pectoralis major, was cut and vacuum-bagged in a polymeric bag (Seal-a-Meal, The Holmes Group, El Paso, TX). The fresh samples were cooked in a Henny Penny MCS-6 combi oven (Henny Penny Corp., Eaton, OH) at 85°C (185°F) with the tender steam setting to reach an internal temperature of 78°C. The internal temperatures were checked in the thickest part of each fillet by a hand-held digital thermome-
Cook loss (%) was calculated as follows:

\[ \text{cook loss} = 100 - 100 \times \left( \frac{W_{\text{cooked}}}{W_{\text{raw}}} \right) \]

For the WB shear force measurement, room temperature samples were sheared perpendicular to the longitudinal orientation of the muscle fibers by a TA-XTPlus Texture Analyzer (Stable Micro Systems, Surrey, UK) fitted with a 30-kg load cell and Texture Exponent 32 version 2,0,5,0 software. A TA-7 WB shear type blade was used. Test settings included a button type trigger, 55 mm travel distance, 4 mm per second test speed, and calibration return distance of 1 mm. Maximum force measured to cut the strips was expressed in kilograms. For each cooked fillet, 1 strip was sheared in 2 locations and heights at each shear point were recorded. The average of the 2 maximum forces for each strip was used for data analysis (Liu et al., 2004).

**Dielectric Property Measurements**

**Dielectric Spectroscopy Method.** The electrical measurements necessary for dielectric property determination were obtained with a Hewlett-Packard (Palo Alto, CA) 85070B open-ended coaxial-line probe, a Hewlett-Packard 4291A Impedance/Material Analyzer, and a temperature-controlled stainless steel sample cup and water jacket assembly designed and built for use with the 85070B probe (Nelson, 2003). Dielectric properties (dielectric constant and loss factor) were calculated with Agilent Technologies 85070D Dielectric Probe Kit Software, modified for use with the HP 4291A Analyzer by Innovative Measurement Solutions, which provided dielectric property values from the reflection coefficient of the material in contact with the active tip of the probe. Settings were made to provide measurements at 51 frequencies on a logarithmic scale from 10 MHz to 1.8 GHz. The 4291A Analyzer was calibrated with an open, short, and matched load prior to the calibration of the open-ended coaxial-line probe with measurements on air, a short-circuit block, and glass-distilled water at 25°C. A personal computer was used to control the system and record resulting data (Nelson, 2003).

**Measurement Procedures.** Chicken breast muscle samples were cut with a 21-mm cork borer at a right angle to the muscle fiber direction. The surfaces of the chicken breast meat cylindrical samples were removed by using a razor blade to provide a smooth surface. Samples were about 1 cm high, and weights averaged 3.3 g. The cylinder was inserted into the sample cup with the skin side of the meat samples up facing the probe, and the muscle fiber direction of the sample was parallel to the axis of the probe. The sample cup and water jacket assembly was raised to bring the sample into firm contact with the open-ended coaxial-line probe for the permittivity measurements (Nelson, 2003). The sample was allowed to come into temperature equilibrium with the circulating water at 5°C before the first permittivity measurement to be recorded was triggered (the water temperature in the circulator had been lowered to 5°C by the addition of crushed ice). After the initial measurement, permittivity measurements were taken at 10 or 20°C intervals up to 85°C. After the circulator raised the water temperature to the target value, a subsequent period of 3 min. was provided for the sample to equilibrate to the new temperature. The entire measurement sequence was completed in about 60 min.

**Statistics**

The measurements of quality characteristics were analyzed by the paired t-test for the main effects, deboning time and muscle type (Microsoft Excel, 2003). In the statistical model, the measurements (such as pH) of pectoralis major and pectoralis minor, deboned 2-h postmortem were combined and paired with those of the muscles deboned 24-h postmortem from the same bird but different sides to test deboning time effect. The same model was used for the muscle effect, except for the comparison, which was made by combining the measurements of 2-h deboned pectoralis major and 24-h deboned pectoralis major and pairing them with those of pectoralis minor muscles from the same bird and the same side of the breast. Dielectric property data were analyzed by the GLM with SPSS 9.0 software package (SPSS Inc., 1999). The null hypothesis (H₀) implied no difference in the measurement means between deboning times or between types of muscles. The statistical significance selected for Type I or alpha error (rejection of H₀) was \( P < 0.05 \).

**RESULTS AND DISCUSSION**

**Quality Characteristics of Chicken Breast Muscles**

Quality characteristics of the chicken breast muscles, pectoralis major and pectoralis minor, used for the permittivity measurements are summarized in Table 1. These include CIE (Commission Internationale de l’Eclairage) values for lightness \( (L^*) \), redness \( (a^*) \), and yellowness \( (b^*) \), pH, moisture content (%), drip loss (%), WHC (%), cook loss (pectoralis major only), and WB shear force value (pectoralis major only) with \( P \)-values for statistical significance for the main effects (deboning time and muscle types).

The average of \( L^* \) values of 2-h pectoralis major muscles is 54.9 with a range from 51.3 to 58.4. The average of \( L^* \) values of 2-h pectoralis minor is 53.0 with a range from 48.8 to 57.1. The average of \( L^* \) values of 24-h pectoralis major muscles is 59.3 with a range from 54.3 to 67.3, and the average of \( L^* \) values of 24-h pectoralis minor is 56.5 with a range from 53.6 to 59.0. The paired t-test reveals significant differences \( (P\text{-value} < 0.05) \) for deboning time and muscle type. The \( L^* \) value of the pectoralis minor is significantly lower than the \( L^* \) value of pectoralis major, indicating that pectoralis minor is darker than pectoralis major. The \( L^* \) value of the 2-h samples is significantly lower than the \( L^* \) value of 24-h samples, indicating that...
Deboning time (h)  

| Measurement | P. major | P. minor | P. major | P. minor | P-value | Muscle type  
|------------|----------|----------|----------|----------|---------|--------------  
| L*         | 54.9 ± 0.8 | 53.0 ± 0.9 | 59.3 ± 1.4 | 56.5 ± 0.8 | <0.01 | 0.03  
| a*         | 0.17 ± 0.27 | 0.15 ± 0.27 | –0.32 ± 0.26 | 0.31 ± 0.15 | 0.51 | 0.22  
| b*         | 12.8 ± 0.7 | 12.0 ± 0.6 | 12.1 ± 0.5 | 12.8 ± 0.6 | 0.93 | 0.90  
| pH         | 6.03 ± 0.04 | 6.20 ± 0.02 | 5.84 ± 0.07 | 6.05 ± 0.06 | <0.01 | <0.01  
| Moisture (%) | 75.7 ± 0.1 | 76.2 ± 0.1 | 75.9 ± 0.2 | 76.1 ± 0.1 | 0.37 | 0.04  
| Drip loss² | 2.86 ± 0.47 | 2.72 ± 0.60 | 3.08 ± 0.61 | 1.71 ± 0.52 | 0.68 | 0.01  
| WHC³       | 24.6 ± 5.6 | 74.2 ± 17.0 | 34.2 ± 5.7 | 87.7 ± 14.5 | <0.01 | <0.01  
| Cook loss¹ | 15.8 ± 0.6 | —*       | 16.6 ± 0.4 | —       | 0.23 | NA  
| WB shear force (kg) | 11.4 ± 1.2 | —       | 3.5 ± 0.3 | —       | <0.01 | NA  

¹Average of at least 8 measurements with at least 8 different chicken pectoralis major (P. major) fillets or pectoralis minor (P. minor) muscles from 4 independent replications.  
²Calculation of drip loss with the formula: drip loss = \[(W_{drips}/W_{raw})\] × 100.  
³Calculation of water holding capacity (WHC) with the formula: WHC = \[(W_{pellet} - W_{raw})/W_{raw}\] × 100.  
*Not measured because of the limited availability of raw materials.

The range of average pH values of chicken breast muscle is from 5.8 of 24-h pectoralis major to 6.2 of 2-h pectoralis major. The pH of 2-h samples is significantly higher than that of 24-h samples, and the pH of pectoralis minor is significantly higher than pectoralis major.

The range of average moisture content (%) of chicken breast muscle is from 75.7 (2-h pectoralis major) to 76.2 (2-h pectoralis minor). There is no difference between the deboning times; however, the moisture content of pectoralis minor is significantly higher than pectoralis major. The overall average drip loss is 2.47% with a range from the average 1.71 (24-h pectoralis minor) to the average 3.08 (24-h pectoralis major). The drip loss of pectoralis major is significantly higher than that of pectoralis minor. No statistical significance is noted between the 2 deboning times. The WHC is significantly different for the chicken breast muscle types and deboning times, with pectoralis minor having significantly higher WHC than pectoralis major and with the WHC of 24-h samples being significantly higher than 2-h samples. The average cook loss of pectoralis major used in our test is 16.2, and no difference exists between the 2-h samples and the 24-h samples. However, WB shear force values of the 2-h deboned pectoralis major (11.4 kg) are significantly higher than the 24-h deboned pectoralis major (3.5 kg).

These results demonstrate that there are significant differences in quality characteristics among the samples used in this study, such as color, pH, moisture, drip loss, WHC, and WB shear force values. For example, the 24-h samples have lower pH, lighter color (higher L* value), higher WHC and lower WB shear force (pectoralis major) than the 2-h samples. Pectoralis minor has darker color, higher pH, higher moisture, lower drip loss, and higher WHC compared with pectoralis major. The quality measurements also show that the samples used in our test have the typical meat quality characteristics associated with 2 different deboning times as expected. The significant pH
DIELECTRIC PROPERTIES OF CHICKEN BREAST MUSCLES

Figure 1. Frequency and temperature dependence of permittivity of pectoralis major muscle deboned at 2 h postmortem. (A) Dielectric constant; (B) dielectric loss factor (mean ± SD).

Dielectric Properties of Chicken Breast Muscles

The dielectric property profiles of chicken breast muscles with frequency and temperature are shown in Figures 1 to 6 (mean ± SD, average of 5 to 8 data points). The dielectric constant and loss factor show monotonic decreases in value as frequency increases from 10 to 1,800 MHz regardless of deboning time and muscle type (Figures 1, 2, 3, and 4). At frequencies below 100 MHz, the dielectric constant and loss factor increase regularly with temperature up to about 65°C. Above that temperature, the dielectric behavior is less consistent. Also, at frequencies above about 200 MHz, the temperature coefficient of the dielectric constant changes from positive to negative. The effect of temperature also depends on the muscle type and deboning time (Figure 1, 2, 3, and 4). For example, the value for the dielectric constant of pectoralis major peaks at 75°C at lower frequencies (from 10 to 200 MHz), and then decreases as temperature continues to increase (Figures 1A and 3A). However, the dielectric constant for pectoralis minor increases monotonically from 5 to 85°C (Figures 2A

Figure 2. Frequency and temperature dependence of permittivity of pectoralis minor muscles deboned at 2 h postmortem. (A) Dielectric constant; (B) dielectric loss factor (mean ± SD).

decrease in muscle (pectoralis major) and reduced pH associated with the increase in color lightness during postmortem have been widely observed in meat research (Lyon et al., 1985; Fletcher, 1999a,b). The changes result from biochemical processes. The ATP concentration declines and lactic acid accumulates because of glycolysis (reduced pH of muscle and therefore lighter color) within the muscle cell as rigor mortis develops (Cornforth, 1994; Lyon and Buhr, 1999). Another well-known change in deboning chicken breast muscle meat during postmortem is the WB shear force value. Xiong et al. (2006) reported that average WB shear force value for chicken pectoralis major meat deboned at 24-h postmortem was 4.40 kg compared with 10 kg for 2- to 2.5-h samples. Lyon and Lyon (1990) found that the average WB shear force value for chicken pectoralis major meat deboned at 24-h postmortem was 3.22 kg, whereas it was 9.53 kg for 2-h pectoralis major samples. Our pH, color, and WB shear force results of pectoralis major are consistent with these previous reports.
Figure 3. Frequency and temperature dependence of permittivity of pectoralis major muscles deboned at 24 h postmortem. (A) Dielectric constant; (B) dielectric loss factor (mean ± SD).

Figure 4. Frequency and temperature dependence of permittivity of pectoralis minor muscles deboned at 24 h postmortem. (A) Dielectric constant; (B) dielectric loss factor (mean ± SD).

and 4A), for both deboning times. For the dielectric loss factor, the value of 2-h pectoralis major peaks at 65°C (Figure 1B); however, the value of 24-h pectoralis major peaks at 75°C (Figure 3B). The value of 2-h pectoralis minor peaks at 75°C (Figure 2B), whereas the value of 24-h pectoralis minor continues to increase at 85°C (Figure 4B).

The response to temperature is further shown in Figures 5 and 6, where the permittivity values of 4 different chicken breast muscle samples at frequencies of 26 and 1,800 MHz are plotted against temperature as examples. At 26 MHz, the dielectric constant of pectoralis minor increases monotonically as temperature increases from 5 to 85°C; however, the value of pectoralis major (2-h postmortem) reaches the peak at 75°C (Figure 5A). At 1,800 MHz, the dielectric constant decreases as the temperature increases for both deboning times and both muscle types (Figure 6A). For the dielectric loss factor at 26 MHz, the value of pectoralis major increases linearly as the temperature increases and reaches the maximum at 65°C at both deboning times; however, the value of pectoralis minor continues to increases linearly after 65°C and reaches the maximum at 75°C (Figure 6A). At 1,800 MHz, although the dielectric loss factor shows similar peak values to those at 26 MHz, the increasing trend is quadratic instead of linear as the temperature increases before reaching the maximum value (Figure 6B).

Food materials have shown similar frequency- and temperature-dependent patterns for permittivity spectra. Tran and Stuchly (1987) showed that with uncooked chicken meat, the dielectric constant and loss factor values decreased with increasing frequency from 100 to 2,500 MHz, and the response to temperature change depended on the frequencies. Nelson (2003) reported that the permittivity spectra of fresh fruits and vegetables depended on frequency and temperature. For these fruits and vegetables, the dielectric constant and loss factor decreased as frequency increased from 10 to 1,800 MHz at all temperatures from 5 to 95°C. However, the dielectric response at the higher temperatures was different for different commodities. The frequency-dependence of the permittivity depends more on ionic conduction at the lower frequencies and on dipolar relaxation at the higher frequencies, and the differences in response to temperature were attributed to differences in tissue structure and the nature of water binding to constituents in the materials.
The effect of deboning time and muscle type on the dielectric property values, including dielectric constant, dielectric loss factor, and loss tangent (tan δ = ε″/ε′), is presented in Table 2 for frequencies of 26 and 1,800 MHz. For the statistical analysis, the dielectric property values were averaged over all measurements on each muscle type and deboning time and all 6 temperatures, and the mean values are shown in Table 2. Statistical analysis shows that although there is no significant effect by deboning time, pectoralis minor muscle has significantly higher average values for both the dielectric constant and loss factor than pectoralis major at both frequencies. Both deboning time and muscle type have a significant effect on the loss tangent values regardless of frequency, with the 2-h deboned muscle having higher average values than the 24-h deboned muscle and with pectoralis minor having higher average values than pectoralis major. Our quality measurements (Table 1) show the muscle types have a significant effect on moisture content and drip loss, deboning time has a significant effect on WB shear force values, and the muscle type and deboning time have significant effects on chicken meat color (L* value), pH, and WHC.

These results suggest that it is possible to use dielectric property or permittivity measurement to assess differences in chicken meat muscle types, deboning time, and quality. For example, it may be possible to use average values of either dielectric constant or dielectric loss factor to predict the moisture content or drip loss of chicken breast meat. The loss tangent values could be used to indicate the difference in WHC or WB shear force values.

**Conclusions**

The dielectric property profiles of uncooked chicken breast muscle, pectoralis minor and pectoralis major deboned at 2-h and 24-h postmortem time, are dependent upon frequency and temperature. Increasing frequency from 10 to 1,800 MHz results in decreasing values of the dielectric constant and loss factor regardless of temperature, chicken breast muscle, and deboning time. However, the response to temperature from 5 to 85°C varies with the frequency, muscle type, and deboning time. There is no difference in the dielectric constants and loss factors at 26 or 1,800 MHz between 2 deboning times. However, muscle type significantly affects the average values of the...
dielectric constant and loss factor, with pectoralis minor values being significantly higher. Both deboning time and muscle type significantly affects the average value of the loss tangent at both 26 and 1,800 MHz, with 2-h samples having significantly higher values than 24-h samples and with pectoralis minor having significantly higher values than pectoralis major. The deboning time, chicken breast muscle types, or both also significantly affect the quality characteristics such as color, pH, drip loss, WHC, and texture of the meat. These results suggest that there is potential to use dielectric property measurements to assess the quality of chicken meat.

REFERENCES

Nelson, S. O. 2003. Frequency- and temperature-dependent permittivities of fresh fruits and vegetables from 0.01 to 1.8 GHz. Trans. AESA 46:567–574.