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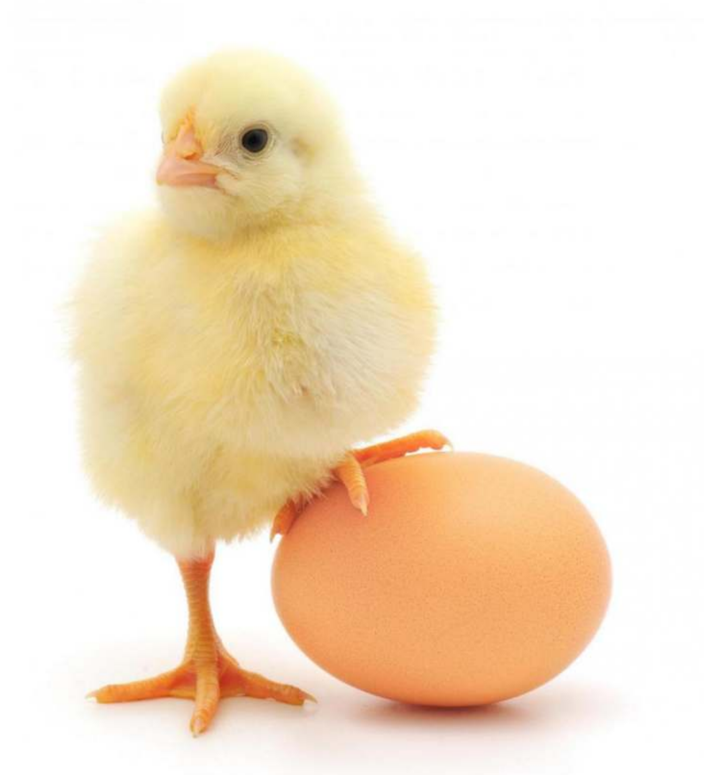

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The Use of Dielectric Spectroscopy as a Tool for Predicting Meat Quality in Poultry

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Abstract: Interest in Dielectric Spectroscopy (DS) has increased due to its potential use to predict meat quality in real time. We investigated the potential of using DS to predict meat quality characteristics such us pH, color, Water Holding Capacity (WHC), cook loss and drip loss in *Pectoralis* (*P.*) major muscle in broiler chicken. Dielectric properties were obtained utilizing a Hewlett-Packard 85070E open-ended coaxial-line probe and an N5230C PNA L-Network Analyzer through a flexible coaxial cable. Measurements were collected at 501 frequencies on a logarithmic scale from 200 MHZ to 50 GHz. The relationship between the quality measurements and the DP which included the dielectric constant, the dielectric loss factor and the dielectric loss tangent were determined using Pearson correlation. Low correlations were obtained between the dielectric constant and the dielectric loss factor and the quality parameters measured. However, the loss tangent showed a more promising relationship with the quality parameters at frequencies between 14 and 19 GHz. The results indicate the potential for utilizing DS as a tool for predicting of meat quality related to pH and color.

Key words: Poultry, meat quality, dielectric spectroscopy, frequency

INTRODUCTION

Spectroscopy has become a popular method for analyzing qualitative characteristics in food due to a decrease in cost, improvement in equipment design and data-analysis methodology. Advantages of using spectroscopy include rapid data acquisition with minimal sample preparation; the opportunity for simultaneous determination of several quality parameters; and the ability to replace expensive and slower reference techniques (Brøndum *et al.*, 2000a).

Interest in Dielectric Spectroscopy (DS) and the Dielectric Properties (DP) of food materials are related to their potential in sensing certain quality characteristics (Nelson and Trabelsi, 2009). Dielectric properties of foods are the electrical properties which strongly influence the temperature distribution of food during Radio Frequency (RF) and Microwave Heating (MW) (Metaxas and Meredith, 1983). The dielectric constant and loss factor are the critical properties that indicate the degree of polarization of the dielectric field and thereby determine the microwave energy absorption in the material (Tanaka *et al.*, 2000). Radio frequency electric fields can easily penetrate food materials and their interactions with the DP of the food materials can be correlated with quality characteristics. This provides a rapid nondestructive instrument that can be used to assess food quality measurements (Nelson and Trabelsi, 2009). The ability to predict real-time meat quality has great commercial potential, especially for Water-holding Capacity (WHC) which ultimately increases yield (Swatland, 2002).

Most research involving DS and poultry has focused on DP as they relate to added ingredients or the composition of different foods at frequencies ranging from as low 10 MHZ to 20 GHz. Limited information exists on the relationship between poultry breast meat quality and its DP. Castro-Giraldez *et al.* (2011) found that DS could potentially be used to determine key biochemical markers of meat quality. The objective of this study was to examine the potential use of DS as a tool for identifying specific quality parameters such as WHC, pH and color.

MATERIALS AND METHODS

Sample collection: We used the Arkansas randombred chicken population for this study. The population is a random mating broiler control line. At 6 wk of age, the chickens were slaughtered and chilled at 4°C overnight prior to deboning. *Pectoralis* Muscle Weight (PMW) was measured during deboning. *Pectoralis* Muscle Yield (PMY) was calculated as percent PMW of body weight at 6 wk of age. The average PMW and body weight were 190 and 1682 g, respectively. The deboned samples were collected and put on ice prior to analysis.

Color and pH measurements: L* values were determined on the right ventral *P. major* using a Minolta Chroma Meter CR-410, Osaka, Japan. Color

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measurements were made on the medial portion of the filet void of any color defects such as bruises, blood spots or discolorations. Color values were reported as the average value of triplicate measurements. The pH measurements were performed with a spear tip Hannah pH meter (Hannah Instruments, Van Nuys, CA) designed for meat samples.

Water Holding Capacity (WHC): WHC was determined as described by Barbut (1993) with some minor modifications. All skin and visible fat were removed from the breast meat. Approximately 75 to 100 grams of the medial portion of the breast meat was chopped for approximately 20 seconds in a small chopper to mince the meat. A 10 g aliquot of the chopped muscle was mixed with 16 ml of 0.6 M NaCl and then incubated for 30 min at 4°C. Samples were then centrifuged at 7000 g at 4°C for 15 min using a tabletop Sorvall Legend XTR (Thermo Scientific, Waltham, MA 02451, USA) and the supernatant was decanted. WHC was defined as the portion of fluid retained by the sample:

$$\frac{16\ \text{ml} - (\text{amt of decanted superatant})}{16\ \text{ml}} \times 100 = \text{WHC}\ (\%)$$

Cooking Yield (CY): After weighing pellet and tube, the cap was loosely recapped and cooked for 20 min at 80°C in a water bath (Cole Parmer, Niles, IL, 60714 USA). The juices were poured off and thoroughly drained before weighing. Cooking yield (CY) was calculated as the weight (Wt) of the pellet and tube after cooking divided by the initial weight of the pellet and tube multiplied by 100:

$$CY = [(Wt_{\text{pellet and tube after cooking}}) / (Wt_{\text{pellet and tube before cooking}})] * 100$$

Dielectric properties measurement: Dielectric properties were obtained utilizing a Hewlett-Packard 85070E open-ended coaxial-line probe and an N5230C PNA - L- Vector Network Analyzer connected through a flexible coaxial cable. Measurements were collected at 501 frequencies on a logarithmic scale from 200 MHZ to 50 GHz. Prior to sample measurements, the open-ended coaxial-line probe connected to the analyzer was calibrated with measurements on air, a short-circuit block and glass-distilled water at 25°C. The dielectric constant and loss factor were calculated with Agilent Technologies 85070E Dielectric Probe Kit Software.

Measurement procedures: Samples were measured utilizing a stainless steel sample cup. A 1.5-cm long cylindrical shaped sample was cut with a 21 mm diameter cork borer from the chicken breast meat and then inserted into the stainless steel cup. The stainless steel cup was 19-mm in diameter and 19-mm in depth. A razor blade was utilized to provide a smooth surface to the cored samples. The average sample weight was approximately 3g. Samples were measured in the stainless steel sample cup with a pressure gage attached to it to ensure constant pressure for all meat samples. The sample cup was raised until the coaxial-line probe came into contact with the sample and a pressure of 25+/- 5 psi was applied. All measurements were performed in triplicate on meat samples equilibrated to room temperature.

Statistical analysis: The Pearson Product Moment Correlation Coefficients were determined to see if any of the quality parameters measured had any significant relationships with the dielectric properties of the meat (Qiao *et al*., 2001) (Microsoft Excel, 2007).

RESULTS AND DISCUSSION

Correlations among quality parameters: The relationship between pH and meat quality has been reported in previous studies (Allen *et al*., 1998; Qiao *et al*., 2001, 2002). A rapid pH decline and a low ultimate pH are associated with the development of low WHC, excessive drip loss and possible denaturation (loss of functionality and water binding) (Huff-Lonergan and Lonergan, 2005). For this study, several quality parameters and the DP of poultry breast meat were measured. Data were analyzed to determine the relationships among the parameters and the dielectric properties of the samples. The Pearson correlation coefficients were determined to identify relationships among the quality parameters and subsequently between the pH, color (L*), WHC and cooked yield and DP. Figure 1-3 show the correlations between the quality parameters. Color (L*) was found to negatively correlate with pH with a correlation coefficient of -0.65. Water holding capacity and cook yield showed positive correlations with the pH (0.52 and 0.59, respectively). These relationships are similar to what has been reported in the literature (Allen *et al*., 1998; Qiao *et al*., 2001, 2002).

Dielectric properties analysis: Dielectric properties were measured and correlated with the following quality parameters: WHC, L* and pH. The correlations between the dielectric properties and the measured quality parameters are shown in Table 1. Water holding

Table 1: Correlation coefficient and frequency (in parenthesis) between dielectric properties (DP) and pH, color (L*) and Water Holding Capacity (WHC)

DP[1]	pH	L*	WHC
ε'	-0.39	0.41	-0.38
	(21.2)	(2.7)	(12.5)
ε''	-0.46	0.46	-0.38
	(21.5)	(11.2)	(13.2)
ε''/ε''	-0.77	0.78	-0.67
	(14.5)	(17.5)	(18.8)

[1]ε'= dielectric constant; ε''= dielectric loss factor; ε''/ε''= dielectric loss tangent

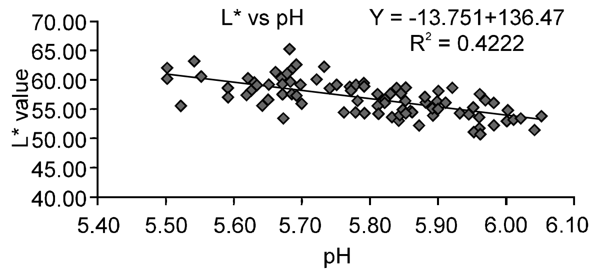

Fig. 1: Relationship between the color (L* value) and the pH of *Pectoralis major* muscle in broilers (N=90; Pearson Correlation = -0.65)

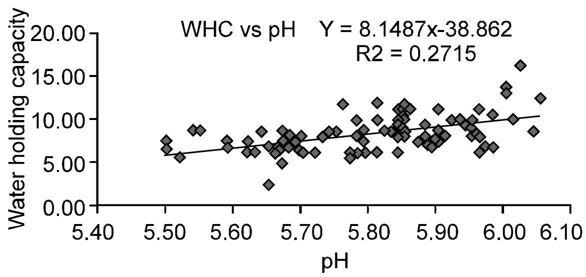

Fig. 2: Relationship between water holding capacity and the pH of *Pectoralis major* muscle in broilers (N = 92; Pearson Correlation = 0.52)

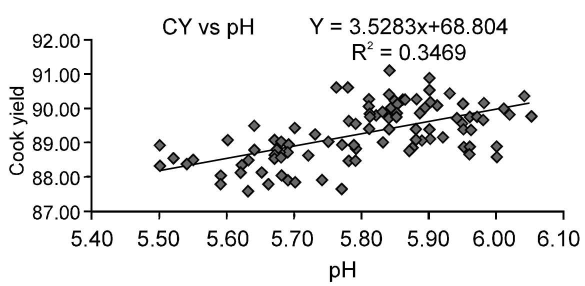

Fig. 3: Relationship between the Cooked Yield (CY) and the pH *Pectoralis major* muscle in broilers (N = 92; Pearson Correlation = 0.59)

capacity and pH both had negative correlations with the dielectric constant and dielectric loss factor while color showed a positive correlation with them. The correlation coefficients were not significantly high. Due to the low correlation coefficients between the dielectric properties (dielectric constant and dielectric loss factor) and the quality parameters, further analysis was conducted to examine a third dielectric property, the loss tangent. The loss tangent is defined as the ratio of a material's dielectric loss to its dielectric constant (Mudgett, 1995). The loss tangent indicates how well the material can be penetrated by an electrical field as well as how it dissipates electrical energy into heat (Singh, 2001). A subset of thirty samples was utilized to examine

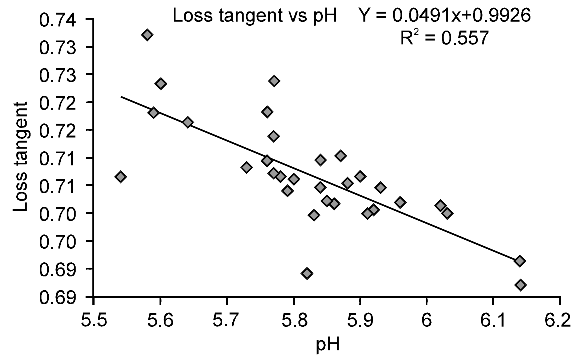

Fig. 4: Relationship between the loss tangent and pH of *Pectoralis major* muscle in broilers preselected for quality differences (N = 30; Pearson Correlation = -0.77)

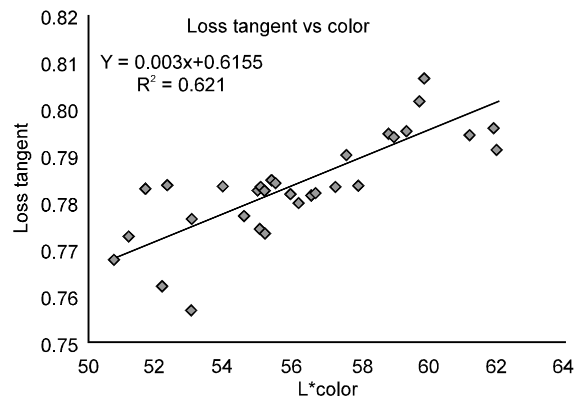

Fig. 5: Relationship between the loss tangent and color of *Pectoralis major* muscle in broilers preselected for quality differences (N=30; Pearson Correlation = 0.78)

the relationship between the loss tangent and the quality parameters. Samples were preselected for pH and color extremes to determine whether DS could potentially be used for sensing differences in poultry meat quality. Qiao *et al*. (2001) found that lighter-than-normal meat was associated with low pH, high moisture, low emulsion capacity and low water holding capacity. Our results showed much higher correlations between the quality parameters and the dielectric loss tangent than those between the dielectric constant and dielectric loss factor independently (Fig. 4-6).

The correlation coefficients reported between the quality parameters and the loss tangents were found to be the greatest between the frequencies of 14 to 19 (Table 1). This frequency range is consistent with the findings of Mashimo *et al*. (1987). Their research confirmed the existence of two Debye absorption peaks around 20 GHz and 100 MHZ in several biological materials and attributed the peaks to be associated with free and

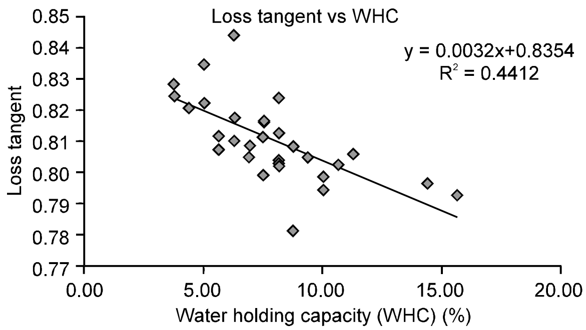

Fig. 6: Relationship between the loss tangent and Water Holding Capacity (WHC) of *Pectoralis major* muscle in broilers preselected for quality differences (N=30; Pearson Correlation = -0.67)

bound water, respectively. Water constitutes approximately 75% of muscle and exists in three forms: bound, immobilized and free. Bound water is tightly bound to muscle proteins and remains bound despite the amount of physical force exerted upon the muscle. It can account for 4 to 5 percent of the water in muscle. Immobilized water is located between the thick and thin filaments. It accounts for approximately 10-15% of the water in the muscle and it is dependent upon the amount of physical force exerted upon the muscle. The remaining water exists as free water which is located in the extracellular spaces of the muscle and held loosely by capillary forces. This water is easily lost when any type of force is applied (Aberle *et al.*, 2001; Hui, 2006; Lawrie, 1998).

Nelson and Trabelsi (2009) states that the moisture or water content is the dominant factor affecting the DP of foods and their interaction with Radio Frequency (RF) and microwave electric fields. Although the dielectric behavior of foods when exposed to such fields is heavily dependent upon frequency and temperature, it is also highly influenced by moisture content and the degree of water binding within the food materials (Nelson and Trabelsi, 2009). Water-holding capacity and water-binding capacity are critical attributes in meat quality (Bianchi *et al.*, 2005).

Conclusions: Low correlations were found between the dielectric constant and the dielectric loss factor and the quality parameters measured. However, the loss tangent showed a more promising relationship with the quality parameters at frequencies between 14 and 19 GHz. Previous literature has shown that a strong relationship exists between muscle pH, color and functional properties of meat. It has also been reported that extremes in lightness and darkness in breast meat color can be a possible indicator of meat functionality (Qiao *et al.*, 2001). The data reported here shows a potential for DS to be used as a predictor of meat quality especially, pH and color. Further research involving classification of samples and modeling should be done to determine the full extent of the use of dielectric spectroscopy as a tool for sensing meat quality.

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