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Use of metallic nanoparticles for characterization of muscle tissue by electrical impedance spectroscopy (EIS)

Uso de nanopartículas metálicas para la caracterización del tejido muscular mediante espectroscopia de impedancia eléctrica (EIS)

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Abstract

Objectives. The electrical impedance spectroscopy (EIS) is relatively new technique used in medicine. The main problems that should be solved are its low resolution and that it fails to distinguish between tissue types, so some kind of the contrast should be applied. Magnetical nanoparticles have been used for imaging and other medical applications. For that reason, our research group decided to analyse the changes of electrical properties of chicken muscle tissue caused by three different types of metal nanoparticles at 50KHz. Methodology. Bio-Logic Science Instruments SP-150 was used as EIS device. Three different particles were analysed: two types of nanomagnetite (NM1 and NM2) and one of Gold particles (GNP). NM1 and NM2 samples were synthetized by coprecipitation and combustion method, respectively. GNP were synthetized by Turkevich method. Nanoparticles were characterized by SEM and RAMAN spectroscopy. Four needles were placed in each chicken breast to connect the EIS device. Measurements were obtained from each chicken breast at basal stage and after being injected with nanoparticles. Data was analyzed by bode graphics (module and phase). Contribution. The major changes of electrical properties of tissue were evidenced by using NM1 and GNP.

Magnetite, Gold nanoparticles, Electrical impedance

Resumen

Objetivos. La espectroscopia de impedancia eléctrica (EIS) es una técnica utilizada en medicina. Los principales problemas que deben resolverse son su baja resolución y el no poder distinguir entre los tipos de tejido, por lo tanto, se necesita aplicar un medio de contraste. Las nanopartículas magnéticas se han usado en imagenología y otras aplicaciones médicas. Por esa razón, nuestro grupo de investigación decidió analizar los cambios en las propiedades eléctricas del tejido muscular del pollo causados por tres tipos diferentes de nanopartículas metálicas a 50KHz. Metodología. Bio-Logic Science Instruments SP-150 se utilizó como dispositivo EIS. Se analizaron tres partículas: dos de nanomagnetita (NM1 y NM2) y una de oro (GNP). Las muestras de NM1 y NM2 se sintetizaron por los métodos de coprecipitación y de combustión, respectivamente. El GNP se sintetizó mediante el método de Turkevich. Las nanopartículas se caracterizaron por SEM y espectroscopia RAMAN. Se colocaron cuatro agujas en cada pechuga de pollo para conectar el dispositivo. Las mediciones se obtuvieron de cada pechuga de pollo antes y después de ser inyectadas con nanopartículas. Los datos fueron analizados por gráficos de Bode (módulo y fase). Las diferencias más significativas se muestran usando las partículas NM1 Y GNP. Contribución. Los principales cambios en las propiedades eléctricas en el tejido se evidenciaron mediante el uso de NM1 y GNP.

Magnetita, Nanopartículas de oro, Impedancia eléctrica

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Introduction

The electrical impedance spectroscopy (EIS) is a versatile technique that consist in injection of an electrical current and detection of potential and *vice versa*. Applications of this technique include but are not limited to materials characterization, exploration of cavities in constructions, transmission lines and medicine.

Medical application of EIS is based on the fact that it allows to characterize the electrical properties of tissues by detecting volume changes and the variations of cellular structure. Electrical current used for this purpose is very small and undetected for human body (less then 1mA), also electrical impedance equipment is relatively cheap and can be produced as portable devices.

The main problem that should be solved in order to establish EIS as a reliable medical procedure is its low resolution and it fails to distinguish between tissue types, so some kind of the contrast should be applied.

Magnetic nanoparticles provide a multifunctional platform for scientific and clinical applications, such as biosensors, protein and cell separation systems and magnetic carriers for hyperthermia and tissue specific drug delivery. For instance, nanomagnetite was assessed as imaging contrast for magnetic resonance tomography with good results and as an agent for magnetically guided drug delivery. In other hand, the gold nanoparticles also have shown promising results in targeted drug delivery, imaging, photothermal and photodynamic therapy.

Taking into account that metallic nanoparticles possess electrical properties different from living tissue our research group decided to assess them in EIS measurements. In this work, changes of the parameters of impedance vector (module and phase) in three chicken breasts under the influence of three different nano-particles (two samples of nanomagnetite synthetized by two different methods and one sample of nanogold particles synthesised by precipitation method) were assessed. At this work we present the results at 50 KHz frequency, of interest at our group, at which a change in the cellular structure can be detected.

Methodology

For this work a Bio-Logic Science Instruments SP-150 was used as EIS device. Three chicken breasts were used, weighing 345.9 g, 349.5 g 270g. Each one was analyzed at basal state an under the influence of a specific nanoparticle.

Three types of nanoparticle were used: two nanomagnetite (NM1, NM2) synthetized by coprecipitation and combustion method, respectively; the NM1 particle, exhibited a hematite phase; a gold particle (GNP) synthetized by Turkevich method.

The nanomagnetite particles were characterized by SEM and Raman spectroscopy.

Four needles (38mm) were placed in each chicken breast to connect the EIS device.

Five measurements were obtained from each chicken breast at: I) basal stage II) after being injected with nanoparticles, the equipment setting is shown in Figure 1.

Figure 1 EIS device (left) connected to chicken breast at 1) basal stage and 2) after being injected with nanoparticles

The impedance measurements were made at 50 KHz and the mean value of the impedance-module an impedance-phase was calculated, for each chicken breast.

All the parameters of impedance vector were analyzed by Bode graphics (magnitude and phase).

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Results

The particle size of NM1 is 10-70 nm. Similarly, NM2 sample's particles were irregular in shape with size less than 100 nm. GNPs were colloidally suspended with size 10-50 nm. RAMAN spectra of synthetized nanoparticles are shown in Figure 2. It can be observed that nanomagnetite synthesized by two methods shows similar RAMAN spectra, so it can be concluded that this two samples possess similar composition.

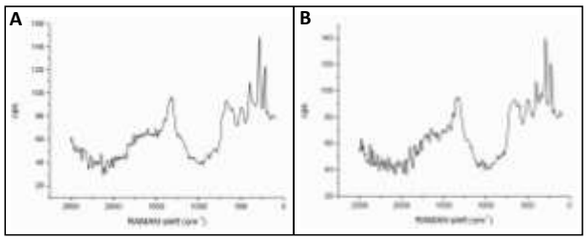

Figure 2 RAMAN spectra of used nanoparticles: A) NM1; B) NM2

The mean value of impedance-module and impedance-phase at basal stage and under the influence of the three nanoparticles were for breast 1 (NM1): 244.1Ω (-58.47°) and 147.5Ω (-47.8°), for breast 2 (NM2): 141.4Ω (-47.7°) and 138.9Ω (-47.6°), for breast 3 (GNP): 130.9Ω (-38.1°) and 132.9Ω (-39.1°), respectively.

Conclusions

The major changes of electrical properties of chicken breast were evidenced by using NM1 and GNP due to the particle size, NM1 phase condition, and Au conductivity. For the further evaluation of use of nanoparticles in EIS technique, they should be evaluated in other tissue types.

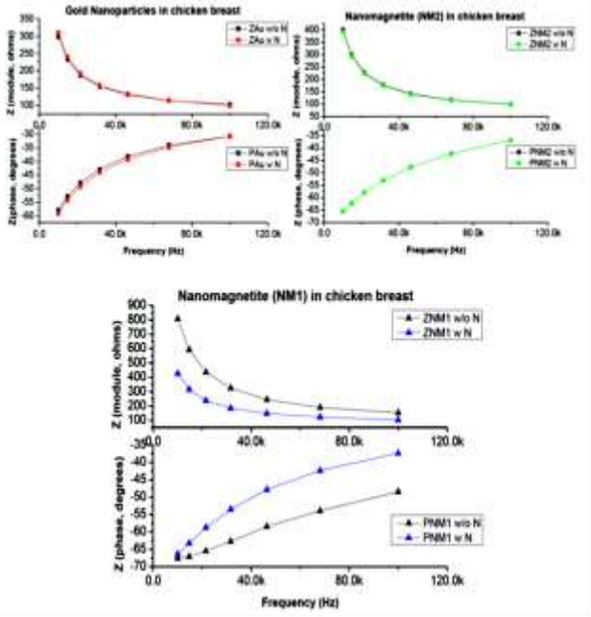

Figure 3 Graph of impedance vector (magnitude and phase) at 1) basal stage and 2) after being injected with nanoparticles (GNP, NM1, NM2)

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