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Understanding the effect of pulsed electric fields on thermostability of connective tissue isolated from beef pectoralis muscle using a model system

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ABSTRACT

Brisket is a low value/tough meat cut that contains a large amount of connective tissue. Conversion of collagen into gelatin during heating reduces the toughness of the connective tissue however this conversion is slow at low cooking temperatures (around 60 °C). The objective of this project was to determine the ability of pulsed electric field (PEF) processing to reduce the thermal stability of connective tissue. To achieve this, a novel model system was designed in which connective tissue obtained from beef *deep pectotalis* muscle (brisket) was exposed to PEF at combinations of electric field strength (1.0 and 1.5 kV/cm) and specific energy (50 and 100 kJ/kg) within an agar matrix at electrical conductivities representing the electrical conductivity found in brisket. Differential scanning calorimetry showed that PEF treatment significantly ($p < 0.05$) decreased the denaturation temperature of connective tissue compared to untreated samples. Increasing electric field strength and the specific energy increased the Ringer soluble collagen fraction. PEF treated samples showed higher solubilization compared to the untreated samples at both 60 °C and 70 °C in heat solubility test. SEM examination of PEF treated (at 1.5 kV/cm and 100 kJ/kg) and untreated samples revealed that PEF appeared to increase the porosity of the connective tissue structure. These finding suggest that PEF processing is a technology that could be used to improve the tenderness and decrease the cooking time of collagen rich, meat cuts.

1. Introduction

The tenderness of meat within a carcass varies widely and only a few meat cuts are usually classified as prime grilling cuts. Some meat cuts are naturally tough owing to the presence of higher levels of intramuscular connective tissue in muscles that are worked regularly (Baldwin, 2012; Lawrie & Ledward, 2006). Tough meat cuts have a lower monetary value than tender meat cuts and better utilization of lower value cuts will result in benefits to both the meat industry and to consumers. Brisket is a meat cut, obtained from the breast or lower chest of animal, it contains a high amount of connective tissue and is generally considered to be a tough meat cut.

Intramuscular connective tissue primarily consists of collagen and elastin fibers as a composite network wrapped in a matrix of proteoglycans. The morphology, composition, and amount of connective tissue present is dependent on muscle type, species, breed and animal age (Purslow, 2005) and its impact on meat toughness is dependent on its composition, distribution, and mechanical and thermal stability properties (Brooks & Savell, 2004). The toughness of connective tissue can be reduced by long cooking times, which convert the collagen into gelatin with small changes in the thermal stability of the connective tissue having a considerable impact on cooking times (Purslow, 2005).

The potential of non-thermal emerging technologies to improve the tenderness of meat, is currently of interest, owing to their ability to physical disrupt the muscle structure, and enhance the denaturation and solubilization of meat proteins (Warner et al., 2017). Pulsed electric field (PEF) processing has the ability to induce microstructural changes in meat, which can change its functional properties and quality through the collective impact of electroporation and subsequent activation of proteolysis process (Lee, Joo, & Ryu, 2010). In addition, the increased fragmentation of myofibrils that occurs due to PEF treatment facilitates meat tenderization (Bekhit, Van de Ven, Suwandy, Fahri, & Hopkins, 2014). The positive effects of PEF on improving meat tenderness have been reported for *Semitendinosus* (outside round), *Semimembranosus* (Inside round), *Longissimus thoracis* (Rib-eye), *Triceps brachii* (Chuck) meat cuts (Arroyo, Lascorz, O'Dowd, Arimi, & Lyng, 2015; Bekhit et al., 2014; Faridnia et al., 2015). However, there has been very little research reported on the effectiveness of PEF to tenderize low value/tough meat cuts. The current study was designed to determine the impact of PEF on the thermal stability of connective tissue and therefore the potential of PEF to reduce cooking time, required to tenderize tough meat cuts, especially at the lower

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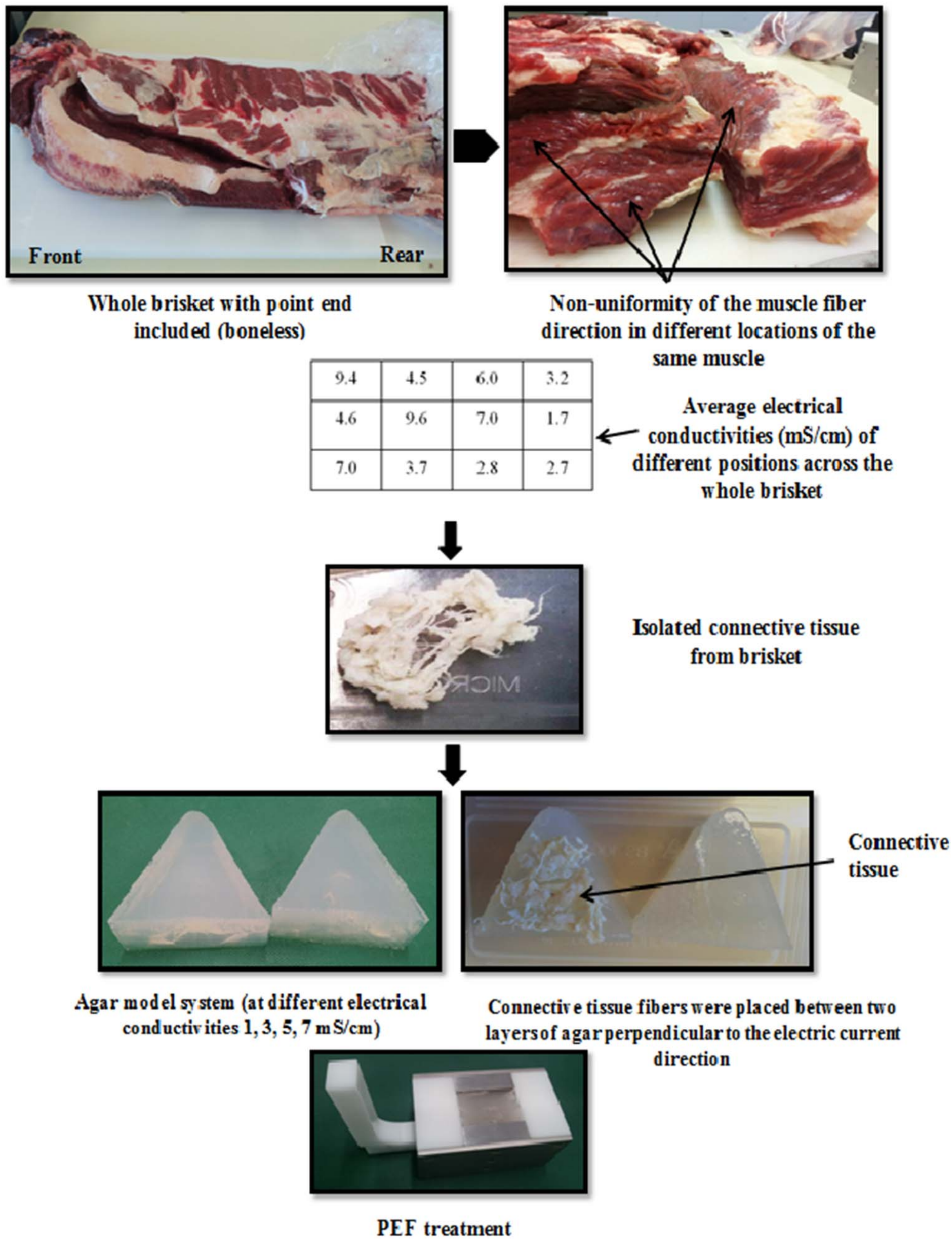

Fig. 1. The schematic representation of isolation of connective tissue, development of agar model system, and PEF treatment.

temperatures commonly used in sous vide cooking.

One of the major parameters responsible for the effectiveness of PEF on meat is the electrical conductivity of the meat. Brisket contains differing levels of protein, fat, muscle tissue and collagen and these fractions have different electrical and topological properties and the effect of PEF on such a multicomponent system is complex (Alahakoon, Faridnia, Bremer, Silcock, & Oey, 2016; Lebovka, Bazhal, & Vorobiev, 2001). In addition, in brisket muscle fiber orientation is highly variable from the top to bottom and front to rear of the cut which also impacts on electrical conductivity (Mahapatra, Jones, Nguyen, & Kannan, 2010) (Fig. 1).

When low conductivity fat is surrounded by high conductivity muscle tissues in meat, the electrical current moves through the more conductive medium and bypasses the lower conductivity fat. These alternative current paths can result in a voltage drop and a reduction in the electrical field strength (Sarang, Sastry, & Knipe, 2008). Similarly, connective tissue networks act as an electrochemical pathway for the conduction of electrical current (Shirsat, Lyng, Brunton, & McKenna, 2004) and their disruption due to changes in fiber orientation reduce electrical conductivity.

To date studies on the impact of PEF on complex samples such as brisket have not be carried out and there is no data on the relative impact of PEF against the different fractions in the meat. It is however, extremely challenging to study the impact of PEF on collagen *in vivo* owing to the interactions that occur between the collagen and the muscle fibers. To simplify the experimental system, PEF treatment was carried out on collagen which had been isolated from brisket and placed between pairs of agar blocks which had electrical conductivities of either 1, 3, 5 or 7 mS/cm, which reflects the range of electrical conductivities found in brisket. The impact of PEF on the connective tissue was subsequently determined by differential scanning calorimetry (DSC), scanning electron microscopy (SEM), estimation of the amount of Ringer soluble collagen (heat labile fraction) and by measuring the heat solubility of collagen at different temperature and time combinations.