Marination with kiwifruit powder followed by power ultrasound tenderizes porcine *M. biceps femoris*

A.S. Jørgensen, M. Christensen & P. Ertbjerg
Department of Food Science, University of Copenhagen, Rolighedsvej 30, DK-1958 Frederiksberg C, Denmark, E-mail: peer@life.ku.dk.

Abstract

Marination with kiwifruit protease (actindin) has been shown to tenderize beef and lamb muscles. Ultrasound treatment after actinidin injection may distribute the marinade more evenly and hence prove effective in the tenderization. The aim of the study was to investigate the combined effect of actinidin injection and subsequent ultrasound treatment on tenderness of pork. Warner-Bratzler (WB) shear test was performed on *biceps femoris* muscles injected with actinidin 24 hours post-mortem followed by ultrasound treatment in an ultrasound bath for 40 min. Samples were stored 2 days after injection before heat treatment and subsequent WB shear test. Initial yield (IY), peak force (PF) and final yield (FY) were determined from the WB force-deformation curves. Injection of actinidin resulted in decreased toughness. The combination of actinidin injection and subsequent ultrasound treatment resulted in a further decrease of the toughness. IY and FY decreased, suggesting that the treatments weakened both the myofibrillar and connective tissue component.

Introduction

Tenderness is one of the most important quality attributes affecting consumer satisfaction and positive perception of meat. Tenderness of meat is determined by two major components of the skeletal muscle: contractile tissue, which is largely the myofibrillar fraction, and the connective tissue fraction which determines the fixed background toughness.

Tenderness can be improved by marination with fruit extracts containing proteolytic enzymes. Actinidin is a plant thiol protease present in kiwi fruit. Some investigators have reported a meat tenderizing effect of kiwi fruit or isolated actinidin in beef (Lewis and Luh, 1988; Sugiyama et al., 2005) and in pork (Christensen et al., 2007). High power ultrasound might also have the potential to achieve desired meat tenderness (Jayasooriya et al., 2007) through cavitation related mechanisms such as high shear, pressure and temperature, which may cause physical and chemical disruption of the muscle structure. Until now, no investigators have examined the combined effect of kiwifruit marination and high power ultrasound on the tenderness of meat. However, a study has shown that damage to muscle structure caused by ultrasound can affect the moisture migration in meat (Cárcel et al., 2007). The objective of the current study was to investigate the combined effect of marination with kiwi fruit powder and high power ultrasound on tenderness of porcine *M. biceps femoris*.

Materials and methods

Six pigs were slaughtered at a commercial abattoir. *M. biceps femoris* were excised from the right and left side of each carcass 24 h after slaughter. Within each animal, muscle from one side was used as a control and muscle from the other side was injected with 0.83% kiwifruit powder, 9.3 % marinade powder consisting of maltodextrin and corn starch, and 89.9 % demineralised water to a 10 % weight increase and a final concentration of 0.075 % kiwifruit powder in muscle. After injection the muscles were divided into two pieces and vacuum-packed. One piece was used as a control and the other piece was ultrasonicated for 40 min in an ultrasound bath using both high and low frequency ultrasound at the same time (1 MHz, 150 W and 500 W, 25 kHz). Samples for Warner-Bratzler shear force measurements were vacuum packed and stored for 2 days at 2˚C. The samples (4.5 cm thick) were then heat treated for 60 min at 75˚C in circulating water, and subsequently cooled in ice water. Rectangular shaped blocks of 10mm x 10mm was cut along the fibre direction. Warner Bratzler shear force (N/cm^2) measurements were performed on an Instron testing machine mounted with a 100 N load cell and a triangular shear blade. Three single deformations were performed on each block using a cross-head speed of 50 mm/min. The mean value of each sample represents 12-15 WB force-deformation curves. Three parameters were measured: initial yield, peak force, and final yield.

Results

The Warner-Bratzler shear force measurements revealed a significant main effect of kiwifruit marinade and high power ultrasound on peak force ($P<0.05$ and $P<0.05$) and initial yield ($P<0.05$ and $P<0.05$), whereas only tendencies was found for final yield ($P=0.09$ and $P=0.11$) (Figure 1).

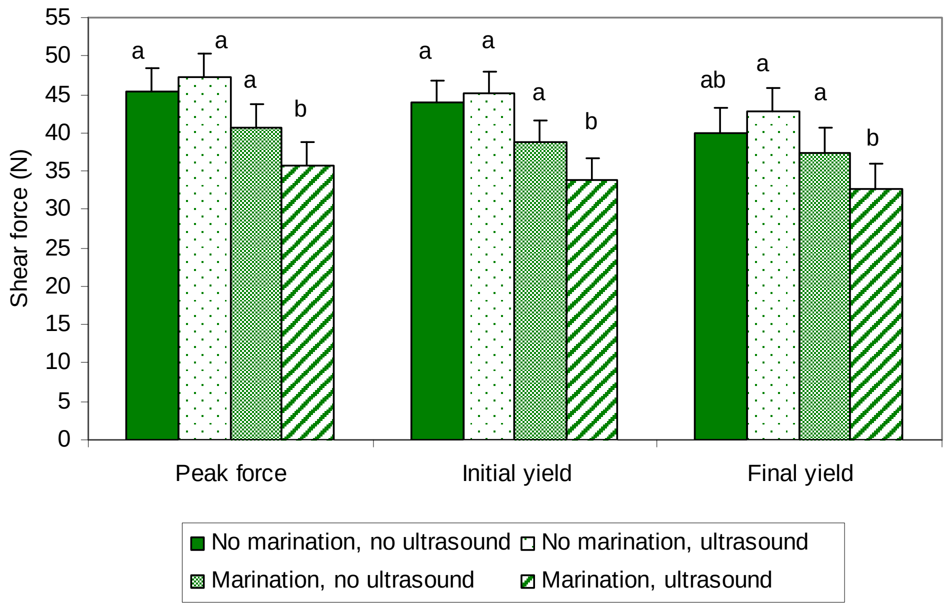

Figure 1. Warner-Bratzler peak force, initial yield, and final yield. Measurement of shear force was conducted on samples stored for two days after kiwifruit marination and ultrasonication. Columns represent least squares means and error bars are SEM (n=6).[a-b]Within traits, columns (treatments) with the same letter are not significantly different (P>0.05).

A tendency towards an interaction between kiwifruit marinade and ultrasound was found for all three WB characteristics ($P \leq 0.11$). Ultrasonication of the unmarinated meat did not result in decreased peak force. Combining kiwifruit marination and ultrasonication resulted in a significant decrease of peak force and initial yield compared to control (no marination, no ultrasonication), whereas final yield only tended ($P=0.06$) to decrease.

Discussion

Ultrasonication of unmarinated meat did not decrease the peak force. The lacking effect of high power ultrasound is in compliance with the findings of several other investigators, who reported no significant increase in tenderness of beef (Lyng et al., 1998a; Got et al., 1999) and lamb (Lyng et al., 1998b) after different ultrasound treatments. In contrast to these findings, Dickens et al. (1991), Smith et al. (1991), and Jayasooriya et al. (2007) reported positive effects on beef tenderness caused by high power ultrasound treatments. Since the *biceps femoris* muscle has a high level of connective tissue, the tenderness improvement caused by ultrasonication may have been masked by high levels of collagen or the ultrasound treatment intensity and duration employed may have been too low to produce significant cellular disruption leading to increased tenderness. The high frequency applied may have resulted in difficulties in bubble formation and inertial cavitation resulting in less cellular disruption. The thickness of the muscle samples (half muscles) may also have affected the effect of ultrasonication.

Injection of kiwifruit marinade followed by ultrasonication of the meat led to a significant decrease in peak force and hence more tender meat. The reason for the increased tenderness is unclear, but one possibility is that ultrasonication may led to a better distribution of the kiwifruit marinade in the meat: Ultrasonication has earlier been shown to affect the mechanisms of moisture migration in meat (Cárcel et al., 2007), and ultrasonic disruption of the muscle tissue caused by cavitation may for example have increased the gaps between muscle fibres and the connective tissue allowing more rapid moisture movement. Thermal denaturation of myofibrillar proteins caused by the heat generated during ultrasound may also have affected the mechanisms of moisture migration (Jayasooria et al., 2007). Cárcel et al. (2007) found a net increase in

NaCl and water of porcine longissimus dorsi samples caused by ultrasound treatment during salt brining. The authors suggested that the surrounding brine might have made it easier for the ultrasonic waves to act on the meat surface; cavitation near the solid surface may have produced microjets that hit the solid. These microjets could result in microinjection of brine into the meat samples, and this could explain the observed net increase. In the current study the kiwifruit marinade was injected into the meat prior to ultrasonication, but leaked marinade present in the vacuum packaging of the meat samples may have resulted in formation of microjets hitting the meat surface causing microinjection of the marinade during ultrasonication. However, microjets may also have been generated inside the meat samples due to cavitation and thus, may have resulted in a better distribution of the marinade. The tenderizing effect may also be explained by a higher effect of the ultrasonication caused by the injected marinade; samples injected with kiwifruit marinade had higher moisture contents, and thus bubble formation and cavitation may have been easier generated and more pronounced in marinated samples, resulting in more cellular disruption and thereby increased tenderness.

Besides the peak force, initial yield and final yield was measured, and the two latter parameters were taken as an indication of the myofibrillar and connective tissue components of tenderness, respectively. Similar effects and tendencies of treatments were seen for initial yield and final yield as for peak force. However, in contrast to peak force and initial yield, no significant effect between control meat (no marinade, no ultrasound) and marinated and ultrasonicated meat was found for final yield. The results therefore indicate that the myofibrillar component of meat is affected by the combined effect of kiwifruit marinade and ultrasound whereas the effect on the connective tissue component is less clear.

Conclusions

The combination of kiwifruit marinade and subsequent ultrasonication resulted in increased tenderness of pork *M. biceps femoris*. Initial yield and peak force decreased and final yield tended to decrease, suggesting that the treatments weakened both the myofibrillar and connective tissue component.

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