Ultrasound parameters of porcine back fat with relation to structure and composition

T. Koch[1*], S. Brand[2], L. Sannachi[2], K. Raum[2], P. Freudenreich[3], M. Wicke[1] & D. Mörlein[1]
[1]Institute of Animal Breeding and Genetics, University of Goettingen, Germany.
[2]Orthopedical Clinic – Q-Bam group, University of Halle-Wittenberg, Germany.
[3]Federal research institute of nutrition and food (MRI), Kulmbach, Germany.
*E-mail: tkoch@gwdg.de.

Abstract

Numerous studies indicate relationships of muscle structure and composition with meat quality. One major advantage of ultrasound is that sound propagation through tissue is non invasive. Therefore, ultrasound technology potentially provides the opportunity for non destructive prediction of meat quality. Previous investigations using spectral analysis of ultrasound echo signals to predict intramuscular fat content of porcine longissimus muscle were promising but yet not satisfying (Mörlein et al., 2005). Principal mechanisms of ultrasound backscatter in muscle tissue remain unclear. In the current study back fat layers of 27 pork carcasses were investigated by scanning acoustic microscopy. Experiments included data acquisition from all three fat layers and the skin. To our knowledge acoustic investigation on the individual fat layers were performed for the first time. Parameter estimates (sound velocity, attenuation) showed significant variations between the fat layer nearest to the muscle and the two outer layers. Furthermore, the fatty acid composition was significantly correlated with thickness, sound velocity, and attenuation of the individual fat layers.

Introduction

The intramuscular fat content (IMF) of pork loin is widely regarded as an important parameter influencing its sensory characteristics. Since ultrasound technology is non destructive, fast and cost effective, it has repeatedly been investigated to predict IMF or marbling score in living animals and carcasses. Spectral analysis of ultrasonic echo signals has become one of the prominent tools for quantitative characterization and differentiation of soft tissue in medical research. In a previous study a conventional diagnostic ultrasound device working in B-mode was successfully used to acquire echo signals from the longissimus muscle in pig carcasses. Spectral analysis and multivariate modelling was performed to predict the IMF of the loin muscle and yielded average prediction errors of ~ 0.4 % IMF (Mörlein et al., 2005). However, principal scattering mechanisms of ultrasound in muscle tissue remained unclear. Additionaly, while muscle tissue is targeted non invasively through the back fat layer, the characteristics of all intermediate materials and their impact on the sound propagation have to be evaluated.

In several studies differences of the fatty acid composition of the outer and inner porcine subcutaneous backfat layers were investigated. The fatty acid profile, i.e. the amount of saturated fatty acids and unsaturated fatty acids is largely affected by breed and diet, and impacts on its technological quality, e.g. solidity and oxidative stability (DAVANEL *et al.*, 1999; ESTÉVEZ *et al.*, 2003; WOOD *et al.*, 2004; DAZA *et al.*, 2007; WHITTINGTON *et al.*, 1986). It is expected that the chemical composition of the back fat also affects the ultrasound propagation properties. NINOLES *et al.*, 2007 reported increased ultrasound velocitiy due to an increased proportion of saturated fatty acids. As for attenuation, no data related to back fat properties have been published yet.

Thus, the goal of this study was to analyse the relationship of acoustic parameters (sound velocity and acoustic attenuation) and compositional parameters of the porcine back fat.

Materials and methods

At a commercial abattoir, 27 carcasses were selected according to their body weight and lean meat proportion. Carcass weight and lean meat percentage ranged from 81 to 112 kg and 47 to 62 %, respectively. Samples were obtained from the longissimus muscle at the 13th/14th rib including skin and the backfat layer. The ultrasonic data acquisition was performed using a custom made scanning acoustic microscope (SAM) equipped with a 10 MHz central frequency transducer (V311, PANAMETRICS, Waltham, USA). The SAM consisted of a pulser-receiver unit (5900PR, PANAMETRICS, Waltham, USA), a x-y-z-scan stage including a motion controller (MICOS, Eschbach, Germany) and a computer containing an 8-bit analogue-to-digital converter (ADC) (8500, GaGe, Lockport, USA). Scanning of the intact bulk back fat sample and the individual layers was performed parallel to the sample surface with the sample placed in a custom made multi-chamber-holder made of stainless-steel. For coupling of the acoustic waves the sample and the transducer were submerged in degassed phosphate-buffered-saline (PBS; 1539 m/s) at 38°C. For estimating sound velocity and acoustic attenuation ultrasonic echo signals were analysed using a custom made MATLAB (The Mathworks, Natick, USA) software. For determination of the fatty acid composition, melted fat of the outer and middle fat layer was methylated. Fatty acid methyl esters were analysed using a HP 6890 gas chromatograph. The statistical analysis was performed with the program SAS 9.1 (SAS Institute, Cary, USA). For comparison of the individual layers ANOVA was accomplished using PROC GLM. Correlations of acoustic parameters and fatty acid traits were computed using PROC CORR.

Results and discussion

Table 1 shows mean values and variations of carcass traits and fatty acid profile. A considerable variation of the carcass traits was realized due to the selection at slaughter. Muscle thickness (FM) and fat thickness (SM) ranged from 47 to 74mm and 11 to 26mm, respectively. Fatty acids were summed to groups of saturated fatty acids (SFA), monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA).

Table 1. Carcass traits and fatty acid profile (n=27; mean value (Ø) and standard deviation (SD))

	Carcass traits				Fatty acids		
	Weight [kg]	lean [%]	fat [mm]	muscle [mm]	SFA [%]	MUFA [%]	PUFA [%]
Ø	94.97	54.14	61.89	19.14	39.96	45.69	14.32
SD	7.87	3.78	6.15	4.08	2.88	2.11	3.15

Weight: hot carcass weight; lean: lean meat percentage; muscle: muscle thickness; fat: fat thickness; SFA: saturated fatty acids; MUFA: mono-unsaturated fatty acids; PUFA: poly-unsaturated fatty acids

Estimated US parameters for the compound sample (all three layers and skin), the skin and the 3 individual fat layers are shown in Figure 1. The estimates for attenuation and speed of sound (sos) of the compound block are in accordance with data of earlier publications (GREENLEAF, 1986; NINOLES *et al.*, 2007). Skin showed a significantly higher speed of sound (1728 m/s) and attenuation (3.27 dB/(MHz*cm)) compared to the fat tissue. Significant differences were also obtained for speed of sound and attenuation between the inner layer (1466 m/s; 2.71 dB/(MHz*cm)) compared to the outer layer (1449 m/s; 1.75 dB/(MHz*cm)) and the middle layer (1449 m/s; 2.55 dB/(MHz*cm)). It has been shown that the inner fat layer contains less fat but more water (DAZA *et al.*, 2007) that probably causes the slightly higher sound velocity.

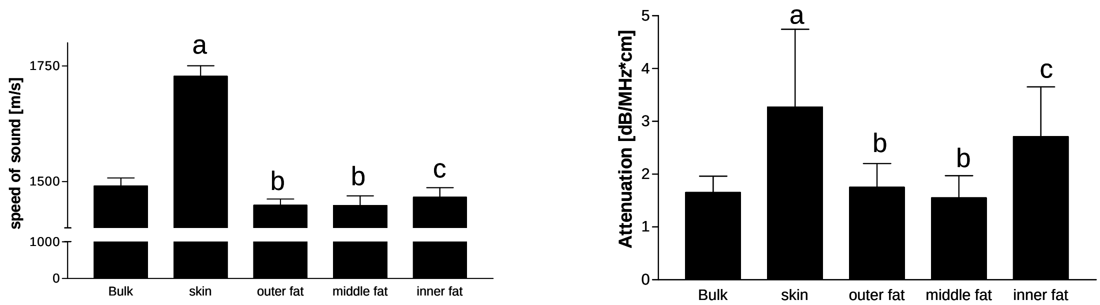

Figure 1. Speed of sound and attenuation with respect to back fat. a, b, c: different letters indicate significant differences between layers (P<0.05).

Table 2 shows the correlations of the acoustic parameters of the outer and middle fat layers and the fatty acid traits. As expected, fat thickness is highly correlated with the fatty acid content. Smaller fat thickness resulted in an increased amount of PUFA and a decrease in SFA. As for the outer fat layer, sound propagation is faster with a decreased amount of MUFA (r = -.54) and a higher amount of polyunsaturated fatty acids (r = .41). For the middle fat layer only slight correlations were found. Ninoles (2007) reported higher sound velocities in compound fat samples (without skin) with increased proportions of SFA. Both in the outer and the middle layer the attenuation corresponds to the amount of PUFA (r = .47 to .55).

Table 2. Correlations of acoustic parameters of outer and middle fat layer and fatty acid traits (n=27)

	outer fat layer			middle fat layer		
	SOS	d	α	SOS	d	α
SFA	-0.14	0.60 **	-0.36	0.24	0.51 **	-0.23
MUFA	-0.54 *	0.05	-0.27	-0.06	-0.10	-0.37
PUFA	0.41	-0.56 **	0.47 *	-0.21	-0.47 *	0.55 **

sos: speed of sound [m/s]; d: thickness [mm]; α: attenuation [dB/(MHz*cm)]
SFA: saturated fatty acids; MUFA: mono-unsaturated fatty acids; PUFA: poly-unsaturated fatty acids; Significance: * P < 0.05; ** P < 0.01

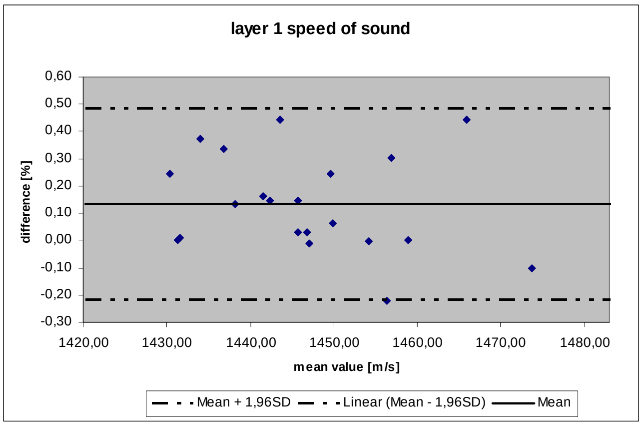

Figure 2. Comparability of the results of layer 1 sos after the analysis with 2 different users (n=27)
Mean: mean value; Mean +/-: Mean value +/- 1.96 standard deviation.

Figure 2 shows the relative differences vs. mean values of sound velocity comparing the data analysis by two different users. Obviously, the results are in general agreement for all measured ultrasound parameters and thus independent from the user.

Summary

In conclusion, for the first time speed of sound and acoustic attenuation are reported for individual layers of porcine back fat and skin. The results indicate no significant differences between the fat layers 1 and 2 but considerable different properties of layer 3, which is is probably due to its reduced fat content. The fatty acid composition showed a correspondence with the acoustic property estimates, which needs to be confirmed by further investigations.

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