A Review Regarding the Evolution of Ultrasound Technique and the Impact on Selecting Animals for Carcass Meat Quality

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Abstract

This review come to underline the great potential of the ultrasound technique that developed year by year with the evolution of meat market industry and become more sensitive to the human consumers. In Romania the ultrasound technique was the first time used *in vivo* at sheep to improve meat evaluation. Classical method implies time consuming and complicated approach by cutting the carcasses to obtain commercial yield, slaughtering yield, dressing percentage and meat – bone ratio. Ultrasound parameters obtained at *Longissimus Dorsi* muscle in Romanian local breed Teleorman Black Had showed a great potential for meat production. High correlations were found between muscle depth with eye muscle area (0.71, 0.76) and eye muscle perimeter (0.90, 0.85), also with body weight at birth (0.40, 0.54) and at weaning age (0.55, 0.67). Eye muscle area at Romanian lambs was situated in the limits known for ultrasound meat carcass quality. The research investigations continued with a comparative study between non – invasive ultrasound with classical methods using linear regression models to estimate meat production without sacrifice the lambs and keeping them for reproduction. Ultrasound application were used with very good results at Romanian Carpatina goats with ultrasound measurements situated within the limits known by the scientific literature. For both species the ultrasounds measurements showed that one – measurement is enough to estimate meat quantity for a better carcass evaluation. That why ultrasound method is recommended to be an efficient and easy to use method to classify the individuals designed for carcass meat quality. Also, ultrasound show as the opportunities that must be embraced by the animal breeders and farmers to maximize the genetic progress in order to select the best individuals design for meat production. The ultimate goal of the livestock and meat industry is to have an accurate and objective measurement method for assessing the economically important traits of meat quality, and to determine the value and merit of the carcass while the animal is still alive.

Keywords: ultrasound, non- invasive, meat evaluation, carcass quality

1. Introduction

Classical methods of investigation to discover the meat characteristics was to slaughter the animals, to measure dressing percentage, meat bone ration, and commercial cuts. These procedures were very laborious complicated and expensive to, and after slaughter the animals could no longer been used for reproduction. Non – invasive techniques appears, and one of them was ultrasound for estimating carcass composition, or meat traits such as real – time ultrasound (RTU), computed tomography (CT), magnetic resonance imaging (MRI), dual – energy X – ray absorptiometry (DXA), whole – body 40 K counting, total body electrical conductivity (TOBEC), dilution techniques, bioelectrical impedance and neutron activation analysis [1]. More and more, non – invasive procedures are chosen to make discoveries and obtain similar results with classical methods of investigation, or even better than those. The ultimate goal of the livestock and meat industry is to have an accurate and objective

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measurement method for assessing the economically important traits of meat quality, and to determine the value and merit of the carcass while the animal is still alive [2-4]. Ultrasonic evaluation is an objective method of predicting the carcass components of live animals within reasonable accuracy levels and is also an accurate measurement tool of fat thickness over the ribeye area in *Longissimus Dorsi* muscle [5, 6].

Human health is one of the most important criteria when we try to improve the quality of meat for the consumers. Over the years many researchers were fascinated to develop methods that helps farmers and breeder to improve the evaluation of the animals' design for meat production. Their results were reflected first in the quantity of meat, improved by prolificacy, with very good females which have multiple qualities like good abilities for motherhood and very nutritive milk designated to nourish the offspring, and to obtain high average daily gain. The quality of meat was also improved in time by selecting the best individuals with very good characteristics to deposit lean meat and small fat quantities. The refinement of the meat improvement comes also with the taste offered by meat flavors and its composition which gives the ability to be cooked and prepared. Taking account of this requirement, in the field of meat quality, evolution of modern approaching was done, and ultrasound summarize these necessities.

2. The evolution of the ultrasound technique for *in vivo* evaluation in animal word

Many researchers used in their studies as an investigation procedure, ultrasound, because afterwards, they have in mind to keep the best individuals for reproduction and not to lose them after slaughter. Firstly, ultrasound was successfully used in the field of medicine, giving answer to the questions rapidly and with great results, and this way the diagnoses of disease and other physiological states were established in time to hill, or to help the patient. Animals beneficiated of this technique in United State of America in 1956 with studies undertaken by *Tample et al.*, how estimated the fat layer in cattle [7]. Three year later, *Stouffer et al., (1959),* made a study on cattle in beef rib eye *Longissimus Dorsi* muscle [8]. The same author continuing his investigations by ultrasound, made a comparison between A – mode and B – mode in pigs, cattle and sheep [9]. In B – mode, the brightness of the dots is proportional to the amplitude of the echoes. The display consists of time traces running vertically (top to bottom) to indicate depth of the tissue analyzed. One of the big limitations of B – mode mechanical scanners for animal investigations was the movements made by the animal, causing inconstancy and inaccuracy of the pictures taken with low repeatability of measurements [10-12].

First equipment of 3D ultrasound scanner was presented by *Szabo et al., (2004*) in his work and was used from 1987 [13]. Ones with the evolution of meat industry how grew up and evolved beautifully, *Busk et al., (1984*) mention in his study, the first real time ultrasound application for carcass traits evaluation in breeding programs for pigs, cattle and sheep, which take place in 1976 [14].

Real Time Ultrasound systems evolved and improved, coming with very good capture of pictures quality and this way traced the end of the mechanical B – scanners, which disappeared until 1980 [15, 13]. RTU systems are based on the B – mode technique and use multiple – crystal transducers to display an image on the screen that is constantly updated. There are studies where are explained the functioning principle by which the pictures are recorded and how the frame must be displayed in 30 milliseconds and that way to update the image information at real – time frame rates [16].

In recent years, RTU has become a crucial tool in many routine carcass evaluations for animal production, and offers the advantage of providing data not only on carcass traits but also on a multitude of meat and fat deposits, which are similar to or even superior to those provided by more expensive imaging tools. The features of the ultrasound equipment, combined with the possibility of differentiating tissues and organs in the image, form the basis of the huge success that this technique has achieved in medicine and in animal science.

3. Ultrasound meat evaluation in Romania

In Romania the ultrasound technique was the first time used *in vivo* at sheep to improve meat evaluation [17]. Classical method implies time consuming and complicated approach by cutting the carcasses to obtain commercial yield, slaughtering yield, dressing percentage and meat – bone ratio. That why are losing the best individuals selected for meat qualities. Ultrasound parameters measured in two points at *Longissimus Dorsi* muscle in Teleorman Black Had lambs expressed a great potential for meat production, with high correlations between muscle depth with eye muscle area (0.71, 0.76) and eye muscle perimeter (0.90, 0.85), and also with body weight at birth (0.40, 0.54) and 3.5 month age (0.55, 0.67). Eye muscle area on Teleorman Black Head lambs was situated in the limits known for ultrasound meat carcass quality [18]. A comparative study between non – invasive ultrasound with classical methods for improving carcass sheep evaluation on Teleorman Black Head lambs was accomplished, using models that combine body and ultrasound measurements which gives important information in estimating meat production on carcass lambs, without sacrifice them and keeping the best individuals for reproduction [19]. The studies continued with the ultrasound obtained in Carpatina goats for the first time in Romania with ultrasound parameters situated within the limits known by the scientific literature [20, 21]. The ultrasounds measurements show that one – measurement is enough to estimate meat quantity for Carpatina goats in both categories, young and adults for a better carcass evaluation. That is why ultrasound method is recommended for its efficiency and easiness utilization in classifying the individuals designed for carcass meat quality.

4. Factor influencing the ultrasound measurements for animal meat evaluation

There are many factors affecting and influencing the ultrasound measurements and studies were conducted to determine eye muscle *Longissimus lumborum*, a muscle that gives information about animal carcass. This subject has been addressed in research to improve the meat quality. The waning weight at Kivircik (26.8 kg at 125 day) lambs was moment when by ultrasound a few parameters were recorded like depth, width and area of eye muscle and the thickness of fat covering Longissimus muscle at the cross sectional area between the 12 and 13 ribs from Kivircik lambs. Weaning weight was significantly affected by flock, sex and birth type of lambs except dam age. Lamb age as a covariate on weaning weight was not a significant effect. The lamb sex was found only to be a significant variable for muscle depth. Age of dam and the birth type of lamb were not significant sources of variation for the ultrasonic measurements. All phenotypic correlations within ultrasonic criteria and weaning weights of lambs, were significant and correlation coefficients ranged between 0.36 and 0.85 [22]. Same meat market particularities are explained about the decision when the lambs could be sold at weaning or a short time thereafter by the breeders in Western Anatolia, and in Aylin province. It is extremely difficult to take measurements on carcasses in these regions as lambs are mainly marketed or slaughtered as small groups or individually and abattoirs do not record any measurements on carcasses characteristics. In this situation, information on body composition of lambs can be obtained practically by ultrasonic measurements on live animals [22]. When combined in a breeding program with lamb weaning or market weights, these measurements will provide a way to increase both meat yield and the quality of Kivircik lambs [22].

A research investigation describes computer tomography (CT) used to improve carcass composition and conformation in Scottish Blackface sheep accomplished after 5 years of selection with an index specially **designed for both composition and conformation** [23]. This CT index responded with genetic progress equivalent to 0.11 phenotypic standard deviations per year. Heritability for the index and for the component traits of average CT-assessed muscle area, ultrasonic muscle depth and ultrasonic fat depth were 0.41, 0.38, 0.41 and 0.30, respectively [23]. The index was positively genetically correlated with ultrasonic muscle depth and carcass weight and negatively genetically correlated with fat class. The genetic and phenotypic correlations among ultrasonic measurements were positive and moderate. Selection made with this CT index improved conformation and decreasing fat class of the carcass. Equivalent selection on live weight at ultrasound scanning would improve carcass and slaughter weight, and total price received, by the breeders and farmers with a slight impact on conformation score [23]. *Pena et al., 2005* explained that sex primarily affected the quantity of all types of fat deposits and there are factors with a great impact in meat quality investigated on Segurena lambs (effects of sex, slaughter weight and carcass weight) on carcass quality traits [24]. This allowed to classify the slaughtered animals with a hot carcass weight below 20 kg assigned to class B, and those greater than 22 kg to class C. Carcass weight had a significant influence on "non-carcass" components, dressing percentage, subjective carcass conformation, fat deposits, carcass fatness, bone and most carcass measurements. Sex had a significant effect on age at slaughter, "non-carcass" components, rib measurements, dressing percentage, fat deposits, and neck and shoulder percentage. As the weight increased, the carcass measurements also increased. While improving the conformation indices of the carcass, leg and dressing percentages, neither the commercial cuts of the animal nor tissue composition was significantly affected [24]. First approach of the ultrasound was adopted by *Nam-Deuk et al., 1998* to investigate the principal factors in determining beef quality grades for carcass meat classification with amount and distribution of intramuscular fat percentage (IMFAT) [25]. Texture analysis was applied to ultrasound B-mode images from ribeye muscle of live beef cattle to predict its IMFAT. Wavelet transform (WT) was used for multi resolution texture analysis and second-order statistics using a gray-level co-occurrence matrix (GLCM) technique. The models used ultrasonic images and linear regression methods to improve quality evaluation in live animals for IMFAT prediction [25]. First approach of the ultrasound in Romania was accomplished using a non – linear multiple regression equations developed by *Lazar et al, 2016*, with very high precision coefficients, suggesting that one ultrasound measurements might be used for estimating meat production [19]. The same author found the best estimations of the carcass and half carcass meat amount using three ultrasound parameters (depth, eye muscle area and perimeter of LD muscle) were obtained to improve the evaluation of sheep selected for carcass meat quality. Second approach was made by the same author using ultrasound parameters in Carpatina goats in Romania and observed that were situated within the limits known by the scientific literature [20]. The ultrasounds measurements show that one – point measurement is enough to estimate the meat quality for Carpatina goats in both categories, young and adults for a better meat carcass evaluation using ultrasound measurement [20]. *Lazar et al., 2017 r*ecommend it as an efficient and easy to use method in order to classify the individuals designed for goat meat production [20]. Using the same technique, a similar study was done by *Ghita et al., (2017)* to evaluate lambs carcass quality of two local breeds Palas Merino and Palas Meat Breed [21]. Very good parameter resulted on live animals after ultrasound investigation was done for depth muscle, eye muscle area, muscle perimeter on *Longissimus Dorsi* muscle and the thickness of the subcutaneous fat layer. Both local breeds mentioned above had the LD muscle characteristics analyzed and compared with another local breed Teleorman Black Head, with the same body weight, and Palas Meat Breed had the best performance, with potential for improvements of meat quality in Romanian local sheep breeds [21].

5. The **Ultrasound and Video Imaging Analysis equipment used to improve the meat quality evaluation in different animal breeds** evolved and the first references and research appeared in cattle (table 1) followed by sheep (table 2), pigs (table 3) and goats (table 4). Ultrasound proved to be a very efficient and non-harmful procedure for animal welfare with very good premises for research area of meat quality improvements in beef cattle, pig, sheep and goat. For the beginning meat market industry had some uncertainties about the usefulness of ultrasound method and evolving studies come to underline that pig data obtained by ultrasound are very important in practical conditions with application in carcass classification. *Houghton et al*., *1992* affirmed that exist ultrasound data variation for sheep, in fat depth and muscle area of the lambs, but the ultrasound equipment evolved since then and the data consistency was more precise and ultrasound become useful for meat market lamb industry [26]. Ultrasound is frequently used in beef cattle industry to measure fat depth and 12th rib *longissimus* eye muscle area. Ultrasound information presented by *Houghton et al., 1992* for cattle is sufficient and accurate for being used to determine the exact moment when is appropriate to slaughter cattle with the indication of the body composition end point [26]. These ultrasound data should give the producers the impulse to have confidence in ultrasonic measurements of loin eye area and to develop new model equations comprehensive and able to describe meat carcass quality in real time.

Table 1. Ultrasound and Video Imaging Analysis equipment used in the meat quality evaluation in cattle

Author	Ultrasound method	Equipment
Giaretta et al., 2018 [27]	Assessment of muscle *Longissimus thoracis et lumborum* marbling by image analysis and relationships between meat quality parameters	Video Image Analysis (VIA),
Hernabdez et al., 2016 [28]	The subcutaneous fat thickness and the *Longissimus dorsi* muscle area were determined 24 h *pre-mortem* ultrasound	Real-time ultrasound equipment Pie Medical 100 B-mode, with a 6/8 MHz linear probe
Ribeiro et al., 2015 [29]	Real-time ultrasound and carcass measurements to estimate total internal fat in beef cattle over different breed types	Ultrasound Guidelines Council field-certified technician using an Aloka 500V instrument with a 17-cm, 3.5-MHz probe (Aloka Co. Ltd., Wallingford, CT).
Silva et al., 2006 [30]	Assessment of muscle *Longissimus thoracis et lumborum i*ntramuscular fat by ultrasonography and image analysis	Aloka SSD 500V real time scanner (Tokyo, Japan) 7.5 MHz linear probe. The RTU scanner was connected to a video camera (Sony DCR-HC96E, Tokyo, Japan)
Speidel et al., 2007 [31]	Eye muscle area on *Longissimus Dorsi*	Ultrasound equipment used by Red Angus Association of America
Naum-Deuk et al., 1998 [25]	Ultrasound Image Texture Analysis for Characterizing Intramuscular Fat Content of Live Beef Cattle	(Aloka 500V by Corrometrics Medical Systems, Inc., Wallingford, CT) with a 17 cm, 3.5 MHz linear probe

Table 2. Ultrasound and Video Imaging Analysis equipment used in the meat quality evaluation in sheep

Author	Ultrasound method	Equipment
Orman et al., 2018 [32]	Fat thickness in different ages and body weight in lambs	Dynamic Imaging MCV Concept model 7.5 MHz
Lazar et al., 2016 [19]	Estimation of meat amount by non-linear multiple regression equations using *in vivo* and carcass measurements on Teleorman Black Head lambs	Echo Blaster 64 with LV 7.5 65/64 probe (TELEMED ultrasound medical systems, Lithuania). Ultrasound images were recorded and analyzed with Echo Wave II 1.32, software
Morais et al., 2016 [33]	Models predict the proportion of bone, muscle, and fat in ewe, lamb carcasses by *in vivo* measurements of the 9^{th}, 11^{th}, 12^{th} rib	Áquila Veterinário, Pie Medical (Nutricell, Campinas, São Paulo, Brazil), with linear transductor with a frequency of 6.0/8.0 MHz and 7 cm
Agamy et al., 2015 [34]	Carcass characteristics in lambs for prediction equations to determine carcass weight components by ultrasound	Scanner 100LC Pie Medical company, Maestricht, Netherlands, 8 MHz
Hadhami Hajji et al., 2015 [35]	*In vivo* fat and muscle weight prediction for lambs from fat- and thin-tailed breeds by real-time ultrasonography	Real-time ultrasound Falco vet, B-mode, with 3.5 MHz and 12 cm linear transducer, depth was 5 cm with a 3.5 MHz probe
Hosseini et al., 2014 [36]	Real-time Ultrasonography in Assessing Carcass Traits in Torki-Ghashghaii Sheep Scanned for backfat thickness, *longissimus dorsi* muscle depth, width and area	Pie Medical Falco 100, B mode real-time ultrasound machine with an 8 MHz linear probe and a 6.8 cm length (Pie Medical, Netherlands)
Ripoll et al., 2010 [37]	Estimation of carcass composition by ultrasound measurements in 4 anatomical locations of 3 commercial categories of lamb	Aloka SSD-900 with a multi frequency electronic linear array probe of 7.5 MHz (5 to 10 MHz) with a 62-mm width (UST 5710-7.5, Aloka Spain, Madrid, Spain)
Emenheiser et al., 2010 [38]	Validation of Live Animal Ultrasonic Measurements of Body Composition in Market Lambs, Images of *Longissimus* area and fat between 12^{th} and 13^{th} ribs	Aloka 500 ultrasound machines (Corometrics Medical Systems, Wallingford, CT) equipped with 11-cm, 3.5 MHz probe
Emenheiser et al., 2009 [39]	Use of ultrasound technology in the genetic improvement of U.S. lamb composition in *Longissimus Dorsi* muscle between 12^{th} and 13^{th} ribs	Aloka 500 ultrasound machines (Corometrics Medical Systems; Wallingford, CT) equipped with 12.5cm, 3.5mHz transducers
Leeds et al., 2007 [40]	Ultrasound estimates of loin muscle measures and backfat thickness augment live animal prediction of weights of subprimal cuts in sheep	Aloka SSD-500V (Corometrics Medical Systems, Wallingford, CT) with a 3.5-MHz, 14.5-cm linear array transducer and standoff
Silva et al., 2005 [41]	Estimation in vivo of the body and carcass chemical composition of growing lambs by real-time ultrasonography	500-V real-time ultrasound with a 7.5-MHz probe combined with image analysis

Table 3. Ultrasound and Video Imaging Analysis equipment used in the meat quality evaluation in pigs

Author	Ultrasound method	Equipment
Forests et al., 1989 [42]	10 Rib fat, Last rib fat, Last lumbar fat, 10^{th} Rib fat, Longissimus muscle area	Technicare 210 DX
Lopez et al., 1987 [43]	10 Rib fat, Last rib fat, *Longissimus* muscle area	Technicare 210 DX
McLaren et al., 1989 [44]	10 Rib fat, Last rib fat, Back fat tickness	Technicare 210 DX
Turligton et al., 1990 [45]	First Rib fat, Last rib fat, Last lumbar fat, 10^{th} Rib fat, *Longissimus* muscle area	Technicare 210 DX

Table 4. Ultrasound and Video Imaging Analysis equipment used in the meat quality evaluation in goats

Author	Ultrasound method	Equipment
Lazar et al., 2017 [20]	Meat Quality Evaluation by Ultrasound in Carpatina Goat Breed (fat layer, muscle depth, eye muscle area, eye muscle perimeter in *Longissimus Dorsi)*	Echo Blaster 64 with LV 7.5 65/64 probe (TELEMED ultrasound medical systems, Lithuania). Echo Wave II 1.32, software
McGregor et al., 2016 [46]	Eye muscle depth, fat thickness in linear and regression models in goats	Advanced Livestock Services, Hamilton Victoria
Gomez et al., 2013 [47]	*Longissimus Dorsi* muscle measured between 12-13 ribs and 3^{rd} and 4^{th} sternabra	Ultrasound equipment
Stamper 2010 [48]	Linear and Ultrasound Measurements in Crossbred Goats as a Predictor of Live and Hot Carcass Weights	Ultrasound Scanner (Pie Medical 200 SLC, the Netherlands)
Teixeira et al., 2008 [5]	In vivo estimation of goat carcass composition and body fat partition by real-time ultrasonography	Ultrasound Toshiba Sonolayer ultrasound (SAC-32B,Toshiba Corp., Otawara, Japan with a 5-MHz probe and image analysis
Mesta et al., 2004 [49]	*Longissimus Dorsi* muscle	Aloka 500V
Stanisz et al., 2004 [50]	The live ultrasound measurements to assess slaughter value of meat-type male kids	Pie Medical 100LC device with an 8.0 MHz linear probe
Dhanda et al., 2003 [51]	Eye muscle area on *Longissimus Dorsi* 12-13 ribs	LI-COR portable meter LI-3000A
Dhanda et al., 1998 [3]	Eye muscle area in different crossbreed goats on *Longissimus Dorsi* muscle	Fiber Optic Probe VIA Video Imaging Analysis

6. Conclusions

First approach of the ultrasound in Romania was accomplished using a non – linear multiple regression equations with very high precision coefficients, suggesting that one ultrasound measurements might be used for estimating meat production. Classical methods of investigation to discover the meat characteristics was to slaughter the animals, to measure dressing percentage, meat bone ration, and commercial cuts. These procedures were very laborious complicated and expensive to, and after slaughter the animals could no longer been used for reproduction. This review come to underline the great potential of the ultrasound technique that developed year by year with the evolution of meat market industry and become more sensitive to the human consumers. Also, ultrasound show as the opportunities that must be embraced by the animal breeders and farmers to maximize the genetic progress in order to select the best individuals design for meat production.

Acknowledgements

This research was supported by funds from the National Research Project ADER 8.1.10 granted by the Romanian Ministry of Agriculture and Rural Development. The publication was supported by funds from the National Research Development Project Projects to finance excellence (PFE-Valorif) - 17/2018-2020 granted by the Romanian Ministry of Research and Innovation.

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