GUTIERREZ JOSÉ DE FREITAS ASSIS

DETERMINAÇÃO DE PESO, COMPOSIÇÃO CORPORAL E CARACTERÍSTICAS DE CARCAÇA EM BOVINOS NELORE COM USO DE CÂMERA INFRAVERMELHO

Dissertação apresentada à Universidade Federal de Viçosa, como parte das exigências do Programa de Pós-Graduação em Zootecnia, para obtenção do título de *Magister Scientiae*.

VIÇOSA
MINAS GERAIS – BRASIL
2017

Ficha catalográfica preparada pela Biblioteca Central da Universidade Federal de Viçosa - Câmpus Viçosa

T

A848d
2017

Assis, Gutierrez José de Freitas, 1992-
Determinação de peso, composição corporal e características de carcaça em bovinos nelore com uso de câmera infravermelho / Gutierrez José de Freitas Assis. – Viçosa, MG, 2017.
viii, 60f. : il. (algumas color.) ; 29 cm.

Orientador: Mário Luiz Chizzotti.
Dissertação (mestrado) - Universidade Federal de Viçosa.
Inclui bibliografia.

1. Nelore (Bovino) - Pesos e medidas. 2. Composição corporal. 3. Processamento de imagens - Técnicas digitais. I. Universidade Federal de Viçosa. Departamento de Zootecnia. Programa de Pós-graduação em Zootecnia. II. Título.

CDD 22 ed. 636.291

GUTIERREZ JOSÉ DE FREITAS ASSIS

DETERMINAÇÃO DE PESO, COMPOSIÇÃO CORPORAL E CARACTERÍSTICAS DE CARCAÇA EM BOVINOS NELORE COM USO DE CÂMERA INFRAVERMELHO

Dissertação apresentada à Universidade Federal de Viçosa, como parte das exigências do Programa de Pós-Graduação em Zootecnia, para obtenção do título de *Magister Scientiae*.

APROVADA: 23 de junho de 2017.

Francisco de Assis de Carvalho Pinto

Fabyano Fonseca e Silva
(Coorientador)

Mário Luiz Chizzotti
(Orientador)

A Deus, por ser essencial em minha vida, aos meus familiares e amigos por sempre me incentivarem a seguir novos caminhos.

Dedico.

AGRADECIMENTOS

Primeiramente agradeço à Deus por ter permitido que eu alcançasse mais esta vitória.

À Universidade Federal de Viçosa, por minha formação, e em especial ao Departamento de Zootecnia, pela realização deste curso.

À Comissão de Aperfeiçoamento de Pessoal do Nível Superior (CAPES), pela concessão da bolsa.

Ao prof. Mário Luiz Chizzotti, pela excelente orientação, amizade, ensinamentos e apoio durante esses anos de convivência.

Aos funcionários do DZO pela ajuda sempre que necessária e em especial a Nataniel Máximo (Pum) e Daniel (Niel).

Aos amigos, estagiários e bolsistas de iniciação científica, pela grande amizade, apoio e por todas as discussões que contribuíram para o desenvolvimento deste trabalho.

Ao André Mendes, sem o qual desenvolvimento deste trabalho seria extremamente complicado.

Aos meus irmãos, Débora e Joubert, que sempre me aturaram em meus momentos de estresse e dificuldade.

Aos meus pais, Ilidio e Eunice, que sempre estiveram ao meu lado me incentivando a novos desafios.

Por fim, meus sinceros agradecimentos a todos que participaram de maneira direita ou indireta da execução e conclusão deste trabalho. Obrigado!

SUMMARY

CHAPTER 1 - **Use of infrared camera for weight prediction and body composition of cattle**

CHAPTER 2 - **Use of infrared camera in the grading and classification of cattle carcasses**

ABSTRACT

ASSIS, Gutierrez José de Freitas, M.Sc., Universidade Federal de Viçosa, June, 2017. **Determination of weight, body composition and carcass characteristics in Nellore cattle using infrared câmera**. Adviser: Mário Luiz Chizzotti. Co-advisers: Fabyano Fonseca e Silva and Sebastião de Campos Valadares Filho.

Researches that seek to develop and use technologies to predict weight, body and carcass composition in vivo, as well as to predict the physical and chemical components of carcasses are still scarce. Therefore, the objective in this work is to develop equations of weight prediction, body composition and carcasses from biometric measurements obtained by infrared image analysis of Nellore cattle. The experiment was conducted out at the Zootecnia Department of the Universidade Federal de Viçosa. Sixty Nellore steers were used, with age and initial mean weight of 8 ± 0.3 months and 276 ± 24 kg, respectively. The animals were weighed every 28 days and, concomitantly, the back images were collected to obtain the body parameters. To obtain the images, an infrared sensor synchronized with MATrix LABoratory software was used. The animals were slaughtered at three different times, at the beginning of the experiment, with 380 kg and 480 kg of body weight. After slaughter, the carcass was split longitudinally and cooled to 4 ° C for 24 hours. Subsequently, carcasses were weighed, and rib eye area (REA) and back fat thickness (BFT) were measured between the 12th and 13th rib of the carcass. Then images of the left half carcasses were collected. An image of each carcass was chosen to obtain the biometric parameters to be analyzed. Then, the section between the 9th and 11th ribs was removed for indirect estimation of the chemical and physical composition of the carcass. All statistical procedures were performed using the SAS 9.0 software (Statistical Analysis System Institute, Inc.). The Least Absolute Shrinkage and Selection Operator regression was used to select the most relevant variables to predict the carcass weight and composition and later, the REG procedure was used to calculate the P-value of selected variables in GLMSELECT. The area of the dorsal plane, volume, dorsal height, abdomen width and body length were the biometric measurements that presented the best fit to estimate body weight ($r^2 = 0.88$). The equations, including the biometric measurements, presented coefficients of determination of 0.32, 0.45 and 0.62 for the percentages of muscle, bone and fat in the carcasses. When the variables were expressed in units of mass, they presented determination coefficients of 0.99, 0.99 and 0.84 for the amounts of muscle, bone and fat in the carcasses. The equations estimated crude protein ($r^2 = 0.20$), ethereal extract ($r^2 = 0.99$) and water ($r^2 = 0.49$), as well as crude protein ($r^2 = 0.99$), extract Ethereal ($r^2 = 0.99$) and water ($r^2 = 0.99$) of the empty body. Regarding the carcass characteristics, the biometric parameters were the best option to estimate the muscle tissue and fat in the carcasses in units of mass, since measurements are performed at intervals and not only in specific regions as in traditional parameters (REA and BFT). The developed equations presented higher coefficients of determination (R^2) when compared with the equations generated by the traditional parameters. The R^2 of the best predictive equations was: Considering only area parameters, muscle (kg): 96%, fat (kg): 59%, ethereal extract (kg): 62% and 97% for crude protein (kg). Considering the simultaneous inclusion of area and volume parameters, muscle (kg): 96%, fat (kg): 98%, ethereal extract (kg): 98% and crude protein (kg): 88%. Considering the sum of the different sections, muscle (kg): 100%, fat (kg): 98%, ethereal extract (kg): 21% and crude protein (kg): 99%. For the traditional parameters, the following R^2 were obtained: Muscle (kg): 96%, Fat (kg): 0.53, ethereal extract (kg): 0.53and crude protein (kg): 75%. In light of the obtained results, this study presents a promising alternative to evaluate the feasibility of the use of image analysis as a tool to evaluate the characteristics related to animal body conformation and yields of cuts, besides providing for the producers and the Information that can be used to direct the animals and consequently the meat to specific markets.

RESUMO

ASSIS, Gutierrez José de Freitas, M.Sc., Universidade Federal de Viçosa, junho de 2017. **Determinação de peso, composição corporal e características de carcaça em bovinos nelore com uso de câmera infravermelho.** Orientador: Mário Luiz Chizzotti. Coorientadores: Fabyano Fonseca e Silva e Sebastião de Campos Valadares Filho.

Pesquisas que buscam o desenvolvimento e a utilização de tecnologias para predizer peso, composição corporal e de carcaça in vivo, assim como para predizer os componentes físicos e químicos das carcaças ainda são escassos. Portanto, o objetivo neste trabalho é desenvolver equações de predição de peso, composição corporal e de carcaças a partir de mensurações biométricas obtidas por análise de imagens infravermelho de bovinos Nelore. O experimento foi conduzido no Departamento de Zootecnia da Universidade Federal de Viçosa. Sessenta novilhos Nelore foram utilizados, com idade e peso médio inicial de 8 ± 0,3 meses e 276 ± 24 kg, respectivamente. Os animais foram pesados a cada 28 dias e concomitantemente coletou-se imagens do dorso, a partir das quais os parâmetros corporais a serem analisados foram obtidos. Para capturar as imagens, utilizou-se um sensor infravermelho sincronizado com o software MATrix LABoratory. Os animais foram abatidos em três momentos diferentes, no início do experimento, com 380 kg e 480 kg de peso corporal. Após o abate, a carcaça foi dividida longitudinalmente e arrefecida a 4ºC por 24 horas. Posteriormente, as carcaças arrefecidas foram pesadas, e a área dos olhos do lombo (AOL) e a espessura da gordura subcutânea (EGS) foram mensuradas entre a 12ª e a 13ª costela da carcaça. Em seguida coletou-se imagens das meias carcaças esquerdas. Uma imagem de cada carcaça foi escolhida para obter os parâmetros biométricos a serem analisados. A seção entre a 9ª e 11ª costelas foi removida para estimação indireta da composição química e física da carcaça. Todos os procedimentos estatísticos foram realizados utilizando o software SAS 9.0 (Statistical Analysis System Institute, Inc.). A regressão Least Absolute Shrinkage and Selection Operator foi utilizada para selecionar as variáveis mais relevantes para prever o peso e a composição da carcaça e posteriormente, o procedimento REG foi utilizado para calcular o P-valor das variáveis selecionadas no GLMSELECT. A área do plano dorsal, volume, altura dorsal, largura do abdômen e o comprimento do corpo foram as medidas biométricas que apresentaram o melhor ajuste para estimar o peso corporal ($r^2 = 0,88$). As equações, incluindo as medidas biométricas, apresentaram coeficientes de determinação de 0,32, 0,45 e 0,62 para as porcentagens de músculo, osso e gordura nas carcaças.

Quando as variáveis foram expressas em unidades de massa, apresentaram coeficientes de determinação de 0,99, 0,99 e 0,84 para as quantidades de músculo, osso e gordura nas carcaças. As equações estimaram as porcentagens de proteína bruta ($r^2 = 0,20$), extrato etéreo ($r^2 = 0,99$) e água ($r^2 = 0,49$) e também as quantidades de proteína bruta ($r^2 = 0,99$), extrato etéreo ($r^2 = 0,99$) e água ($r^2 = 0,99$) do corpo vazio. Em relação as características de carcaça, os parâmetros biométricos foram a melhor opção para estimar em unidades de massa o tecido muscular e a gordura nas carcaças, uma vez que as medidas são realizadas em intervalos e não apenas em regiões específicas como nos parâmetros tradicionais (AOL e EGS). As equações desenvolvidas apresentaram maiores coeficientes de determinação (R^2) quando comparados com as equações geradas pelos parâmetros tradicionais. O R^2 das melhores equações preditivas foi: Considerando apenas parâmetros de área, músculo (kg): 96%, gordura (kg): 59%, extrato etereo (kg): 62% e 97% para proteína bruta. Considerando a inclusão simultânea de parâmetros de área e volume, músculo (kg): 96%, gordura (kg): 98%, extrato etereo (kg): 98% e proteína bruta (kg): 88%. Considerando a soma das diferentes seções, músculo (kg): 100%, gordura (kg): 98%, extrato etereo (kg): 21% e proteína bruta (kg): 99%. Para os parâmetros tradicionais, obtiveram-se os seguintes R^2: Muscle (kg): 96%, Gordura (kg): 0,53, extrato etereo (kg): 0,53 e proteína bruta (kg): 75%. Frente aos resultados obtidos, este estudo apresenta-se como uma alternativa promissora para se avaliar a viabilidade do uso da análise de imagens como ferramenta para se avaliar característica relacionadas com conformação do corpo animal e rendimentos de cortes, além de proporcionar para os produtores e para a indústria frigorifica informações que poderão ser utilizadas para direcionar os animais e consequentemente a carne para mercados específicos.

General Introduction

In recent years, the demand for food has increased and, consequently, Brazilian livestock sector has developed as well. At the same time, there was intensification on looking for production models that are more efficient, economically viable and environmentally sustainable. In this context, Brazilian livestock farming has been developed on different production systems (intensive, extensive and semi-intensive). In order to establish measures that can improve animal performance, it is necessary to understand the peculiarities of each of these production systems, as well as the suitability of this to consumer market.

The use of Technologies suchas modeling techniques, image monitoring, and sensors, can improve the scientific-technological work, in order to improve the research accuracy and promote the development of specialized systems for making decisions (PANDORFI et al., 2012) within farm. Currently, there are systems capable of monitoring behavior and, provide more accurate data of the individual animal performance, mainly for dairy cows, swine and chickens. However, the control and monitoring of the production systems are relatively new and less developed when compared to systems used in medicine.

In beef cattle, the adoption of these systems would help in identifying the slaughter moment and, consequently, it would allow to improve the production per area, reduce the production costs and food waste as animals already finalized are not retained in the farm. In addition, te use of this type of technology would allow the production of heavy and standardized carcasses. It would also help in determination of the ideal spot for replacement heifers, since weight gain and changes in the animal's physical shape (body score) would be monitored and considered on making decision. Thus, body weight is the most important characteristic in the production systems due to it is easy to obtain and its high correlation with body composition (LAWRENCE & FOWLER, 2002).

Body weight is a parameter for production systems management, its knowledge allows to evaluate the growth, the nutritional state, adjust the amount of feed, administer properly medicaments and establish the market value. However, considering that beef cattle in Brazil is produced, mainly by small producers that usually do not have much technology and investment in infrastructure, the control of animal performance by periodic weighing becomes complicated and, sometimes, impracticable (ABREU et al., 2015). Thus, a way to overcome this limitation is through estimating animal's weight by using body measurements, called biometry (SOUZA et al., 2007).

The knowledge of the biometric measures allows the control development of the animals and, consequently, the control of production efficiency, thus, avoiding the inappropriate use of available resources. The advantages of biometry using are the easy way to obtain and the low cost of measurements. However, these systems have limitation that lead to measurement errors, which are associated with problems of reference points identification, due to excessive movement, changes in posture and muscle toning (FISHER et al., 1975), decreasing the data accuracy. The advancement of technology alowed the use of cameras associated with image processing programs as an efficient tool to the evaluation of biometric characteristics, requiring only few seconds in front the câmera to allow the image capture and, later, the characteristic measurements. However, research in this field still scarce.

Currently, the use of images in body composition evaluation in farm is limited to those generated by ultrasound apparatus. However, the use of new technologies, such as video image analysis, are under studying. Among these new technologies, infrared spectroscopy in the visible and near region (SILVA, 2012) and infrared thermography, are alternatives to evaluate the impact of environmental factors, promoting health and well-being animal welfare (ROBERTO, 2014). Infrared thermography can be defined as a non-invasive technique of body thermal mapping, from the infrared radiation emitted by the body surface (ROBERTO, 2014). Thus, based in infrared images, it is possible to detect disturbances in the peripheral blood circulation and correlate them with metabolism (EDDY et al., 2001; FERREIRA et al., 2011), reproductive behavior (SCOLARI et al.,2009) and diseases (RAINWATER-LOVETT et al., 2009).

Image Processing

During the past few years, computer systems have developed rapidly and, this technological evolution has made computer apparatuses become smaller with a greater multimedia resources and affordable costs. Image processing systems have also been modernized, which were previously analog and are gradually being replaced by digital methods. Digital image processing (DIP) is more versatile, reliable, accurate and simplier to implement than analogue systems (SILVESTRE, 2005).

Image Processing is a technique for multidimensional data analysis, which allows manipulating and processing images to obtain information and improve the visual characteristics of the image (ALVES, 2013). Thus, the DIP has been improved and its applications permeate almost all branches of human activity, such as: biology, cartography, meteorology, geology, among others, and it has also been used in medicine and in agriculture (ALVES, 2013).

According to Albuquerque et al. (2000), image processing system can be broadly divided into the following steps: Out-of-image processing, image acquisition, image enhancement, segmentation of information, parameterization (magnitudes on each "object": area, perimeter, shape, structural description, topology, etc.), quantitative recognition and analysis. These various interconnected steps along with the types of sensors will determine the final image quality and the measurement in the images.

The use of new capture devices such as 3-D cameras, take images and videos has become simpler and more realistic than previous systems. The 3-D capture devices provide depth maps, which are images that contain depth values associated in each pixel, which allows to the object-related movements estimation (MACEDO & SOUZA, 2012) and development of models that are capable of reconstructing an object or different areas of object.

In light of the foregoing, the proposed study aims at the use of image processing techniques with the objective of developing equations of weight prediction, body composition and carcasses from biometric measurements obtained by infrared image analysis.

References

ABREU, B. A., MAGALHÃES, C. J., DUAYER, E., MACHADO, S. H. M., & Silva, D. A. (2015). Variação da medida torácica obtida com a fita métrica tradicional com fator de correção e com a fita de pesagem para bovinos. Acta Biomédica Brasiliensia, 6(2), 42-48.

DE ALBUQUERQUE, M. P., DE ALBUQUERQUE, M. P. (2000). Processamento de imagens: métodos e análises. Centro Brasileiro de PesquisasFısicas MCT.

ALVES; N. M. E. A equação do calor aplicada ao processamento de imagens. Universidade Federal de Minas Gerais. (2013). 50p. Dissertação (Especialista em Matemática). Disponivel em: http://www.mat.ufmg.br/~pgmat/monografias/Monografia_NataliaMoreira.pdf

EDDY, A.L.; HOOGMED, V.L.M.; SNYDER, J.R. (2001). The role of termography in the management of equine lameness. The Veterinary Journal, Davis. 162, 172-181.

FERREIRA, V.M.O.S.; FRANCISCO, N.S.; BELLONI, M.; AGUIRRE, G.M.Z.; CALDARA, F.R.; NÄÄS, I.A.; GARCIA, R.G.; ALMEIDA PAZ, I.C.L.; POLYCARPO, G.V. (2011). Infrared termography applied to the evaluation of metabolic heat loss of chicks fed ith different energy densities. Brazilian Journal of Poultry Science.Campinas. 13 (2),113-118.

FISHER, A. V. (1975). The accuracy of some body measurements on live beef steers. Livestock Production Science, Amsterdam, 2, 357-366.

LAWRENCE, T. L. J.; FOWLER, V. R. (2002). Growth of farm animals. Wallingford: CAB International, 368.

Macedo, M. C.F., Souza, A. C. S. (2012). Reconstrução de Modelos 3-D em tempo real utilizando Kinect e GPU.

PANDORFI, H.; ALMEIDA, G. L. P.; GUISELINI, C. (2012). Zootecnia de precisão: princípios básicos e atualidades na suinocultura1. Rev. Bras. Saúde Prod. Anim., Salvador, 13 (2):.558-568. http://www.rbspa.ufba.br ISSN 1519 9940

RAINWATER-LOVETT K., PACHECO J.M., PACKER C., RODRIGUEZ L.L. (2009). Detection of foot-and-mouth disease virus infected cattle using infrared thermography. Veterinary Journal,180 (3):317-24.

ROBERTO, J. V. B.; SOUZA, B. B. (2014). Utilização da termografia de infravermelho na medicina veterinária e na produção animal. Journal of Animal Behaviour and Biometeorology. 2: 73-84.

SCOLARI S., EVANS R., KNOX R., TAMASSIA M., CLARK S. (2009). Determination of the relationship between vulvar skin temperatures and time of ovulation in swine using digital infrared thermography. ReproductionandFertility, Urbana. 22: 178–178.

SILVA, S. D. L. (2012). Ultrassonografia em tempo real, análise de vídeo imagem e infravermelho como ferramentas para determinação da qualidade da carne bovina. Tese de Doutorado. Universidade de São Paulo.

SILVESTRE, A. P. C. (2005). Restauração de imagens digitais utilizando algoritmo de lucyrichardson. Monografia apresentada para obtenção do título de Bacharel em Engenharia da Computação. Disponível em:http://repositorio.uniceub.br/handle/123456789/3265?mode=full&submit_simple=Mostrar+registro+completo+do+item

SOUZA, S. F., R. G. COSTA, K. T. RESENDE, I. A. M.A. TEIXEIRA, E. P. CAVALCANTI FILHO, R. M. FERREIRA, E M. E. F. OLIVEIRA. (2007). Avaliação das curvas de crescimento de caprinos das raças Saanen e 7/8 Boer durante a fase de aleitamento. Mem. Reunião Anual da Sociedade Brasileira de Zootecnia 44:127.

Chapter 1

Use of infrared camera for weight prediction and body composition of cattle

G. J. F. Assis[*] [1], A. L.C. Mendes[*], D. E. F. Assis[*], G. B. Carneiro[*], A. M. Corrêa[*], L. H. P. Silva[*], M. M. Estrada[*], F. A. C. Pinto[*], F. F. Silva[*], S. C. Valadares Filho[*], M. L. Chizzotti[*] [1].

[*] Department of Animal Science, Universidade Federal de Viçosa, Viçosa, Minas Gerais, Brazil, 36.570-000.

[1] Corresponding authors. Email: gutierrez.assis@ufv.br ; mariochizzotti@gmail.com

ABSTRACT: Technologies that estimate animal body weight from biometric measurements are still scarce, however, the development and adoption of this system would have a lower cost than the conventional scale. Therefore, the objective of this study was to develop equations to predict weight and body composition of cattle from biometric measurements obtained by infrared image analysis. The experiment was conducted at the Animal Science Department of the Federal University of Viçosa. Sixty Nellore bulls were used, with age and initial mean weight of 8 ± 0.3 months and 276 ± 24 kg, respectively. The animals were weighed every 28 days and concomitantly collected dorsum images from which the body parameters to be analyzed were obtained. Subsequently, rib eye area (REA) and back fat thickness (BFT) were measured by ultrasonography. To obtain the images the Kinect® sensor synchronized with the MATrix LABoratory software was used. The animals were slaughtered at three different times, at the beginning of the experiment, at 380 kg and at 480 kg body weight. After slaughter, the carcass was divided lengthwise and cooled at 4ºC for 24 hours. Then, the section between the 9th and 11th ribs was removed for indirect estimation of the chemical and physical composition of the carcass. All statistical procedures were performed using the SAS 9.0 software (Statistical Analysis System Institute, Inc.). The Least Absolute Shrinkage and Selection Operator regression was used to select the most relevant variables to predict the carcass weight and composition and later, the REG procedure was used to calculate the P-value of selected variables in GLMSELECT. The area of the dorsal plane, volume, total height, abdomen and rump width and body length were the biometric measurements that presented the best fit to estimate body weight ($r^2 = 0.88$). Equations including the biometric measurements had coefficients of determination of 0.32, 0.45 and 0.62 for the percentages of muscle, bone and fat in the carcasses. When the variables were expressed in units of mass, they had coefficients of determination of 0.99, 0.99 and 0.84 for the amounts of muscle, bone and fat in the carcasses. The equations estimated crude protein percentages ($r^2 = 0.20$), ethereal extract ($r^2 = 0.99$), and water ($r^2 = 0.49$) and the amounts of crude protein ($r^2 = 0.99$), ethereal extract ($r^2 = 0.99$), and water ($r^2 = 0.99$) of the empty body. The results indicate the possibility of weight prediction and body composition by image analysis with good precision.

Key words: biometrics, cattle, image processing, sensor.

Introduction

Body weight is the most interesting characteristic in production systems due to its ease of production and good correlation with body composition (LAWRENCE & FOWLER, 2002). In this sense, the knowledge of weight gain allows monitoring the development of the animals and consequently adjust nutritional management, evaluate food efficiency, administer exact doses of drugs and define the point of slaughter of the animals. Considering, however, that cattle breeding in Brazil is mainly developed by small producers that usually have little technology and low investment in infrastructure, the performance control from the periodic weighing of the animals becomes complicated and sometimes unfeasible (ABREU et al., 2015). One way to overcome this obstacle is to use a technique that can estimate the live weight of the animal through measurements of its body, called biometry (SOUZA et al., 2007). Therefore, the objectives of this study were to develop equations to predict weight and body composition of cattle from biometric measurements obtained in infrared images, aiming to improve management practices and zootechnical control.

Material and Methods

All animal procedures were approved by Ethics Committee on the Use of Production Animals of Universidade Federal de Viçosa, protocol number 066/2016, and followed established standards for humane care and use.

Local and animal

The experiment was conducted at the Animal Laboratory of the Department of Animal Science of the Federal University of Viçosa (Viçosa, Minas Gerais, Brazil), located at latitude 20º 45 '14 "south and longitude 42º 52' 55" west and at an altitude of 648m. The experimental confinement used is composed of six collective bays, each capable of holding up to six animals, with concrete floor and with an area of 45 m² per bay, with 12 m² of covered area in the trough region, providing an area of 7.5 square meters per animal. All bays are equipped with GrowSafe® feed system and a water cooler that provides continuous water to animals.

Sixty Nellore bulls were used, with mean age of 8 ± 0.3 months and initial mean live weight of 300 ± 24 kg. The experiment lasted 230 days and was divided into initial adaptation (30 days) and growth phase. Initially, all animals were weighed, identified, adapted to diets and were treated for internal and external parasites. After the initial 30 days of adaptation, twelve animals were randomly selected and slaughtered, composing the group of reference animals. The forty-eight animals remaining were weighed after 14 hours of fasting and randomly distributed in the bays, remaining confined until reaching an average of 380 kg body weight, where twelve animals were randomly selected to be slaughtered. The other animals were slaughtered when they reached an average of 480 kg of body weight.

The confined animals received a diet formulated according to BR-CORTE (VALADARES FILHO et al., 2010), for average daily gain of 1.25 kg. The diet consisted of 40% maize silage based on dry matter (DM) and 60% concentrate formulated with corn meal, soybean meal, urea / ammonium sulfate, dicalcium phosphate, common salt and micro mineral mixture.

During the experimental period, the animals were weighed every 28 days to calculate the average daily gain (ADG), using an electronic scale of the Coimma brand, model B-01 (Dracena, São Paulo, Brazil), with a minimum capacity of 10 kg, maximum of 1.500 kg and accuracy of 0.5 kg and concomitantly images were collected from the animal's back.

Subsequent to the collection of images, the rib eye area (REA), in cm², and back fat thickness (BFT), in mm, were measured by ultrasonic images. The images were collected between the 12th and 13th ribs, transversal to the *Longissimus lombarum* muscle. The fat thickness was measured in the middle distal third of the loin eye area. Other images were obtained in the croup between the bony protuberances of the ileum and ischium, where fat thickness measurements were obtained on the *gluteus biceps* and depth of the rump. The equipment used was a veterinary ultrasound model Aloka 500 with linear housing transducer with 17.2 cm and frequency of 3.5 MHz. The measurements of REA and BFT occurred in the image generated by the ultrasound, with the aid of operational tools of the equipment.

Image acquisition

Kinect sensor (model 1473, Microsoft Corp., Redmond, Washington, USA) was used to acquire the images. The sensor was positioned in the maneuvering corral at a height of 2.70 meters parallel to the ground (Figure 1). Images infrared (640x480 pixels) of each of the animals were captured for approximately 15 seconds. To reduce light interference, the device was installed in an enclosed and insulated location relative to the external environment.

The Kinect sensor was synchronized with MATLAB software (The MathWorks Inc., Natick, Massachusetts, USA). The treatments of the images and measurements automatically performed in MATLAB.

The image was segmented with the aid of the regionprops function, which allowed obtaining the region corresponding to the animal. From this, a line was drawn following the cervical spine of the animal. Another line was drawn connecting the ventral angles of the scapulae in order to eliminate the anterior part of the animal and to standardize the images (Figure 2). The anterior part of the body, region of the head, has been removed because it is a region that suffers great variation of positioning.

Kinect® device

Kinect® (Microsoft, USA) is a device composed of an RGB (red–green–blue) camera and a depth sensor (laser infrared projector and an infrared camera) that allows the scanning of the environment in three dimensions.

To obtain distances, the Kinect emits an infrared signal and receives the signal reflected from the surface of the objects by its infrared receiver. The infrared camera captures the image of these points and calculates the distance value for the pixels in the image. The distance value is obtained in relation to the plane in which the Kinect is and the object.

The infrared camera has a resolution of 640x480 pixels and can generate an image stream of 30 frames per second. The field of view of the depth sensor is 57º horizontally and 43º vertically (CORRÊA, 2015) and can be operated between 0,8 m and 4,0 m of distance.

Body parameters evaluated

In the collected images, the physical evaluated variables were: Dorsal height (H), Abdomen height (AH), height of dorsal length (LH), thorax height (TH), rump height (RH), dorsal plane area (DPA), thorax width (TW), abdomen width (AW), rump width (RW), dorsal length (BL) and body volume (BV). Measurements of width and length were made by crossing a straight line for each measurement (Figure 3) and counting the number of pixels in the line.

The heights were estimated as the difference between the distance from the sensor to the ground and from the sensor to the back of the animal, in mm.

The dorsal height was defined as the mean of all dorsal points and calculated by the distance difference measured by Kinect®.

Abdomen height, measured at the intersection of abdomen width and dorsal length line.

Height of dorsal length, measured at the mean point of the dorsal lenght line, as the difference between the sensor and the ground and from the sensor to the back of the animal.

Thorax height, measured at the point where the lines used to measure the thorax width and dorsal length intersect.

Rump height, measured at the point where the lines used to measure the rump width and dorsal length intersect.

The area of the dorsal plane was obtained from a line connecting the ventral angles of the scapulae, DPA being considered the image before the line (Figure 4).

Thorax width, diameter measured caudal to the scapulas, in pixels. Abdomen width, the widest diameter of the abdomen, in pixels. Rump width, distance between the major trochanters of the femurs, in pixels and dorsal length, a line in the sagittal plane, from the shoulder to the tail base, in pixel.

Body volume was considered as a block, formed by the projection of animal back to the ground, in pixels (Figure 5).

Slaughter procedure

At the end of the experimental period the animals were fasted for 16 hours and slaughtered by cerebral concussion and jugular section for total exsanguination followed by washing of the gastrointestinal tract (including rumen, reticulum, omasum, abomasum, small intestine, and large intestines). The heart, lungs, liver, spleen, kidneys, internal fat, diaphragm, mesentery, tail, trachea, esophagus, reproductive tract, gastrointestinal tract (after washing), head, leather, paws, blood and carcass were weighed to evaluate the weight of body (EBW).

After slaughter, the carcass of each animal was divided lengthwise into two halves which were weighed for evaluation of the warm carcass yield and then cooled in a cold room at 4 ° C for approximately 24 hours. The cooled carcasses were weighed for evaluation of the cold carcass yield and carcass length, rib eye area (REA) and back fat thickness (BFT), were measured between 12th and 13th rib of the carcass.

Subsequently, the section comprising of the 9th to 11th ribs (section HH) was removed from the left half carcass according to the methodology described by Hankins and Howe (1946), for indirect estimation of the chemical composition of the carcass. In order to estimate the physical composition of the carcass, the equations proposed by Marcondes et al., (2012) were used.

Laboratory tests

Muscle, fat and bone tissue samples obtained from section HH were lyophilized for 72 hours to quantify partial dry fatty matter. Subsequently, these samples were partially degreased by successive washes with petroleum ether, according to method number 920.39 (AOAC, 1990). After partial degreasing, the samples were ground in a ball mill for quantification of dry matter (DM, AOAC, 1990, method number 930.15), mineral matter (MM, AOAC, 1990, method number 924.05), crude protein, AOAC, 1990, method number 984.13) and ethereal extract (EE, AOAC, 1990, method number 920.39). The fat removed in the partial degreasing was added to the ethereal extract content to quantify the total fat content in the carcass.

Statistical analysis

All statistical procedures were performed using SAS 9.0 software (Statistical Analysis System Institute, Inc.). The LASSO (Least Absolute Shrinkage and Selection Operator) regression (TIBSHIRANI, 1996) was used to select the most relevant variables to predict the body weight and physical and chemical composition of carcasses. It is indicated for situations involving larger number of correlated independent variables (HANS, 2009) as observed in the present study. Under a matrix notation, the used model is given by: $\mathbf{y} = \mathbf{X\beta} + \mathbf{e}$, where $\mathbf{y} = \left[y_i \right], \mathbf{X} = \left[x_{ij} \right], \boldsymbol{\beta} = \left[\beta_j \right]$ and $\boldsymbol{\varepsilon} = \left[e_i \right]$. In summary, the LASSO is a penalized least squares procedure that minimizes the residual sum squared subject to the non-differentiable constraint expressed in terms of the norm of the coefficients, being the estimator given by: $\hat{\boldsymbol{\beta}}_L = \arg\min_\beta (\hat{\mathbf{y}} - \mathbf{X\beta})'(\hat{\mathbf{y}} - \mathbf{X\beta}) + \lambda \sum_{j=1}^{1000} | \beta_j |$. The intensity of the penalization (shrinkage of regression coefficients toward zero) is given by the regularization parameter (λ). This method was implemented thought GLMSELECT procedure of SAS® (SAS Inst. Inc., Cary, NC) software assuming initially all the biometric variables. After that, the REG procedure was used to calculate the P-value of selected variables in GLMSELECT.

Results and Discussion

Table 1 shows the descriptive statistics of the data collected during this experiment. There is a great amplitude between the maximum and minimum values found for each variable, because of the different weights of slaughter, which allowed to correlate biometric measurements in animals of different body compositions.

Table 2 shows the correlation coefficients and P-value between body weight (BW), biometric measurements and carcass composition.

As shown in table 2, the correlations between subcutaneous fat thickness (BFT) and biometric parameters presented significant correlations ($P < 0.05$), except the different heights of the animal body (thorax, abdomen, rump and lenght) that presented correlations with values close to zero and not significant ($P > 0.20$).

Biometric measurements presented correlations with weight. The correlations between body weight and dorsal length ($r^2 = 0.77$) and rump width ($r^2 = 0.87$) were high and significant ($P < 0.01$). The correlations between the different heights in the animal body and body weight were predominantly non-significant ($P > 0.20$, Table 2).

The body weight showed significant correlations ($P < 0.01$) with the physical and chemical composition of the carcass, which indicates association between these parameters (Table 2). The correlations found between the biometric measurements and the muscle (kg), fat (kg) and bones (kg) of the carcass were significant ($P < 0.01$). When analyzing the physical composition of the carcass expressed as a percentage, were verified negative correlations and significant ($P < 0.01$), except for fat (%), that presented a significant correlation ($P < 0.01$), and positive.

The correlation between dorsal length and chemical and physical composition of carcasses expressed in mass units and percentage were significant ($P < 0.05$), indicating a strong interaction between this body measurement and the carcass composition (Table 2).

In view of the strong correlations between the evaluated parameters, regression analyzes of the variables whose correlations were significant ($P < 0.20$) and with biological explanation were performed. Table 3 presents the model to estimate the body weight of animals and their respective determination coefficient.

In the model selected to predict body weight (BW), all variables were significant ($P < 0.05$), providing equation with high coefficient of determination ($r^2 = 0.88$) indicating that biometric measurements are intimately related to variations in live weight. It is important to note that body volume was negatively associated with body weight and presented contribution to the estimate. Fernandes et al. (2010) and Puputunga et al. (2015) found strong correlations between body volume and weight.

Table 4 presents the different models to estimate the physical components of carcasses and their respective coefficients of determination. Body weight was the most important variable to predict the physical components of the carcass, and the other variables were used to better fit the equations.

The knowledge of the biometric measures allows to estimate the carcass yield, this is an indirect indicator, that must be carefully evaluated, of the amount of meat that the carcass can to produce. Yield is influenced by several factors, the most important being pre-slaughter feeding and the fasting period, as these may influence biometrics, especially the area and volume of the body because to ruminal filling. Therefore, it is possible to know the carcass yield before slaughter without the use of scales ($r^2 = 0.25$) as is shown in table 4.

The equation developed to predict BFT is shown in Table 4. The equation presented a coefficient of determination from 0.31. In contrast, De Paula et al. (2013), working with the predicting carcass and body fat composition using biometric measurements of grazing beef cattle found coefficients of determination for the estimation of BFT ranging from 0.57 to 0.96. This difference can be explained by the variability of the fat content in the carcasses since the deposition of this depends on several factors, including race, sex, age and maturity (TEDESCHI et al., 2004, BONILHA et al., 2011).

The equations of estimates of the chemical composition of the carcass show that the percentages of water ($r^2 = 0.67$) and ethereal extract ($r^2 = 0.70$) and the amounts of water ($r^2 = 0.78$), ethereal extract ($r^2 = 0.99$) and crude protein ($r^2 = 0.99$), presented high values for the determination coefficients (Table 5). Same behavior was observed for the equations of the empty body, which show that the percentages of water ($r^2 = 0.49$) and ethereal extract ($r^2 = 0.99$) and the amounts of water ($r^2 = 0.99$), ethereal extract ($r^2 = 0.99$) and crude protein ($r^2 = 0.99$), presented high values for the determination coefficients (Table 6).

The percentage of crude protein was the most difficult chemical variable to predict. The equations adjusted to estimate the percentage of crude protein in the carcass as a function of the biometric measurements in the animal body did not present an adjusted appropriate and it was not possible to generate a prediction equation. The equation for estimating the percentage of crude protein in the empty body presented determination coefficients from $r^2 = 0.20$. This limitation has also been reported in other studies, Henrique et al. (1999) and Alleoni et al. (2000) found no equations capable of accurately estimating protein percentages in the body of the animals as a function of the concentration of this element in the cut of section 9th-11th ribs bovine.

Considering the results, a 3D camera can function as a tool to obtain the weight and body composition of Nelore cattle. The camera can be placed in a feeding station or drinking troughs allowing a greater number of images to be collected, and through the analysis of these, administrative decisions are made. The technological advance allowed the improvement of the image processing techniques and also the development of cameras with wider angles that allow the collection of images in low heights, with quality and without the interference of the external luminosity.

In order for current cameras to collect data so that it is possible to measure body weight and composition, they should be placed quite high, being the height of the bays being a limitation, however, the greatest limitation is the sensitivity that the cameras present in relation to luminosity. The external luminosity is captured by the camera generating noises that can hinder the measurements, leading to errors of interpretation, because the biometric parameters can not be correctly delimited. In order to perform the measurements more properly, we must take into account the sources of variation, understand how they influence the values of the analyzed parameters and from these improve the calibration of the software and the apparatus used.

Conclusions

The correlations between the biometric measurements and the body composition of the animal, as well as the coefficients of determination indicate that the equations generated can be used to estimate the live weight and body composition of Nellore cattle.

References

ABREU, B. A., MAGALHÃES, C. J., DUAYER, E., MACHADO, S. H. M., & Silva, D. A. (2015). Variação da medida torácica obtida com a fita métrica tradicional com fator de correção e com a fita de pesagem para bovinos. Acta Biomédica Brasiliensia, 6(2), 42-48.

ALLEONI, G.F.; LEME, P.R.; BOIN, C. et al. (2000). Equações de estimativa da composição química corporal de novilhos Nelore, ¾ Nelore x ¼ Canchim e ¾ Nelore x ¼ Caracu a partir da composição química do corte da 10a costela. In: Reunião Annual da Sociedade Brasileira de Zootecnia, 37. Viçosa, MG. Anais.Viçosa: Sociedade Brasileira de Zootecnia, 436.

ANDRIGHETTO, C., JORGE, A. M., CERVIERI, R. D. C., CUCKI, T. O., RODRIGUES, É., ARRIGONIi, M. D. B. (2009). Relação entre medidas ultrassônicas e da carcaça de bubalinos Murrah abatidos em diferentes períodos de confinamento. Revista Brasileira de Zootecnia, 38(9), 1762-1768.

ASSOCIATION OF OFFICIAL ANALYSIS CHEMISTS. (1990). Official methods of analysis.15th ed. Arlington, 1094.

BONILHA, S. F. M., L. O. TEDESCHI, I. U. PACKER, A. G. RAZOOK, R. F. NARDON, L. A. FIQUEIREDO, and G. F. ALLEONI. (2011). Chemical composition of whole body and carcass of Bos indicus and tropically adapted Bos taurus breeds. J. Anim. Sci. 89:2859–2866

CORRÊA, P. B. P. Estimação da massa corporal de bovinos por meio de sensor de profundidade. (2015). 50p. Dissertação (Mestrado em Zootecnia) – Universidade Federal de Viçosa.

DE PAULA, N. F., TEDESCHI, L. O., PAULINO, M. F., FERNANDES, H. J., & and FONSECA, M. A. (2013). Predicting carcass and body fat composition using biometric measurements of grazing beef cattle. Journal of animal science, 91(7), 3341-3351.

FERNANDES, H. J., L. O. TEDESCHI, M. F. PAULINO, and L. M. PAIVA. (2010). Determination of carcass and body fat compositions of grazing crossbred bulls using body measurements. J. Anim. Sci. 88:1442–1453. doi:10.2527/jas.2009-1919

HANKINS, O. G., & HOWE., P. E. (1946). Estimation of the composition of beef carcasses and cuts. Washington, DC: USDA Technical Bulletin 926.

HANS, C. (2009). Bayesian lasso regression. Biometrika 96, 835–845.

HENRIQUE, W.; LEME, P.R.; LANNA, D.P.D. et al. (1999). Equações para a estimativa da composição química corporal de tourinhos Santa Gertrudis a partir do corte da 9-10-11a costelas. In: REUNIÃO ANUAL DA SOCIEDADE BRASILEIRA DE ZOOTECNIA, 36., Porto Alegre. Anais ... Porto Alegre: Sociedade Brasileira de Zootecnia, 1999. p.352.

LAWRENCE, T. L. J.; FOWLER, V. R. (2002) Growth of farm animals. Wallingford: CAB International,368.

MARCONDES, M.I.; TEDESCHI, L.O.; VALADARES FILHO, S.C.; CHIZZOTTI, M.L. (2012). Prediction of physical and chemical body compositions of purebred and crossbred Nellore cattle using the composition of a rib section. Journal of animal science. 90(4):1280-1290.

PUPUTUNGA, U., L. HAKIM, G. CIPTADI, and H. F. N. LAPIAN. (2015). Application of body volume formula for predicting live weight in Ongole crossbred cows. Int. J. Livest. Prod. 6(3):35–40. Doi:10.5897/IJLP2014.0243

SOUZA, S. F., COSTA, R. G., RESENDE, K. T., TEIXEIRA, I. A. M. A., CAVALCANTI FILHO, E. P., FERREIRA, R. M., & OLIVEIRA, M. E. F. (2007). Avaliação das curvas de crescimento de caprinos das raças Saanen e 7/8 Boer durante a fase de aleitamento. Mem. Reunião Anual da Sociedade Brasileira de Zootecnia, 44, 127.

TEDESCHI, L. O., D. G. FOX, and P. J. GUIROY. (2004). A decision support system to improve individual cattle management. 1. A mechanistic, dynamic model for animal growth. Agric. Syst. 79:171–204.

TIBSHIRANI, R. (1996). Regression shrinkage and selection via the LASSO. J. Royal Stat. Soc. B 58, 267–288.

VALADARES FILHO, S.C.; MARCONDES, M.I.; CHIZZOTTI, M.L.; PAULINO, P.V.R. (2010). Exigências nutricionais de zebuínos puros e cruzados-BR CORTE. 2nd ed. Viçosa-MG: Suprme Gráfica LTDA.

Table 1: Descriptive statistics of data collected during this experiment

Variable	N	Mean	Std Dev	Minimum	Maximum
Body weight (kg)	238	393.55	73.56	157.00	552.00
Hot carcass weight (kg)	104	252.23	50.61	83.87	347.93
Back fat thickness (mm)	216	4.34	1.66	0.25	10.30
Dorsal area (pixels)	180	94135	14570	40342	127525
Body volume (pixels)	180	13966173	2404821	51838679	203645351
Dorsal height (mm)	148	121.872	5.89	108.78	141.68
Thorax width (pixel)	190	174.288	31.55	102.70	499.22
Thorax height (mm)	190	1469	344.94	638.00	2406
Abdomen width (pixel)	190	220.49	25.46	138.65	276.85
Abdomen height (mm)	190	1489	331.20	606.00	2352
Rump width (pixel)	190	198.42	19.30	132.83	245.47
Rump height (mm)	190	1373	377.03	23.19	2501
Dorsal length (pixels)	190	491.88	41.90	319.26	612.32
Height of dorsal length(mm)	190	1182	158.93	549.00	1565
Muscle (%)	104	64.58	1.54	60.18	68.70
Bones (%)	104	18.22	2.25	14.22	26.55
Fat (%)	104	17.19	3.39	7.32	24.88
Muscle (kg)	104	160.58	30.87	58.19	220.97
Bones kg)	104	44.56	7.24	21.94	61.79
Fat (kg)	104	44.04	13.81	8.00	77.01
Crude Protein carcass	104	19.92	1.36	16.56	22.92
Ether extract carcass (%)	104	19.53	3.13	11.47	27.60
Water carcass (%)	104	55.84	2.160	51.53	61.68
Crude Protein EBW (%)	104	19.10	1.06	15.98	21.33
Ether extract EBW (%)	104	20.81	3.80	11.24	30.77
Water EBW (%)	104	63.13	4.20	52.79	73.85
Crude Protein carcass (kg)	104	49.83	9.67	20.20	70.05
Ether extract carcass (kg)	104	50.20	14.75	11.47	84.60
Water carcass (kg)	104	139.57	24.99	54.37	186.12
Crude Protein EBW (kg)	104	74.92	13.64	31.68	97.62
Ether extract EBW (kg)	104	83.87	25.38	19.48	144.85
Water EBW (kg)	104	246.65	41.66	107.08	329.04

Table 2: Correlation coefficients and P-value (above the diagonal) between body weight (BW), biometric measurements and carcass composition.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	-	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.3582	<0.0001	0.1894	<0.0001	0.2246	<0.0001	0.2906	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
2	0.5647	-	<0.0001	<0.0001	0.0007	0.0001	0.9388	<0.0001	0.8164	<0.0001	0.6965	<0.0001	0.7378	<0.0001	<0.0001	<0.0001	<0.0001	0.0008	<0.0001	0.0020	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
3	0.8820	0.4043	-	<0.0001	<0.0001	<0.0001	0.3391	<0.0001	0.3680	<0.0001	0.2865	<0.0001	0.2012	0.3097	0.2383	<0.0001	0.0008	0.4118	0.2326	0.6345	0.2143	<0.0001	0.0005	<0.0001	0.0009
4	0.8101	0.3504	0.9735	-	<0.0001	<0.0001	0.9356	<0.0001	0.0850	<0.0001	0.7443	<0.0001	0.0121	0.7659	0.7619	0.0002	0.0404	0.5879	0.8257	0.7194	0.7947	0.0004	0.0367	0.0001	0.0449
5	0.7433	0.2940	0.7785	0.7609	-	<0.0001	0.7103	<0.0001	0.6522	<0.0001	0.3178	<0.0001	0.3558	0.2734	0.7023	0.0007	0.0527	0.2528	0.3608	0.4212	0.3945	0.0004	0.0217	<0.0001	0.0159
6	0.6636	0.2953	0.5950	0.5593	0.5561	-	0.1814	<0.0001	0.4149	<0.0001	0.2351	<0.0001	0.6830	0.3249	0.0468	0.0003	0.0054	0.1892	0.0456	0.2177	0.0495	0.0006	0.0034	0.0002	0.0034
7	0.0681	-0.0060	0.0724	-0.0061	0.0311	0.0973	-	0.39	0.0104	0.1035	0.0014	0.6529	0.2235	0.7144	0.8788	0.9421	0.9236	0.9822	0.9975	0.7508	0.9881	0.8970	0.9969	0.9717	0.9576
8	0.8834	0.4532	0.8652	0.8152	0.6119	0.5782	0.0624	-	0.2757	<0.0001	0.1156	<0.0001	0.3711	0.0025	<0.0001	<0.0001	<0.0001	0.0105	<0.0001	0.0038	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
9	-0.0971	-0.0183	-0.0682	-0.1301	-0.0377	-0.0594	0.1855	-0.0794	-	0.1372	0.0034	0.7757	0.4912	0.8017	0.3870	0.0278	0.1827	0.4397	0.9318	0.6423	0.8967	0.0335	0.3352	0.0164	0.3616
10	0.8760	0.4737	0.8418	0.8088	0.7145	0.6086	0.1184	0.8356	-0.1082	-	0.0712	<0.0001	0.2974	0.0084	<0.0001	<0.0001	<0.0001	0.0071	<0.0001	0.0091	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
11	0.0899	0.0308	0.0807	0.0247	0.0835	0.0865	0.2297	0.1145	0.2113	0.1311	-	0.4222	0.1923	0.7902	0.9729	0.5386	0.7309	0.7836	0.9862	0.5551	0.9657	0.4965	0.7611	0.5086	0.8769
12	0.7756	0.4063	0.7967	0.8109	0.6870	0.6104	-0.0328	0.7121	-0.0208	0.7663	0.0585	-	0.1855	0.3160	0.0460	<0.0001	0.0009	0.0146	0.1086	0.0291	0.1178	<0.0001	0.0006	<0.0001	0.0012
13	-0.0783	0.0265	-0.0968	-0.1888	-0.0772	-0.0298	0.0887	-0.0652	0.0502	-0.0759	-0.0950	-0.0964	-	0.3129	0.8530	0.0407	0.6172	0.1986	0.5075	0.4202	0.4988	0.1037	0.6363	0.0701	0.7412
14	-0.5113	-0.5031	-0.1567	-0.0461	-0.1822	-0.1406	0.0525	-0.4146	0.0360	-0.3650	-0.0382	-0.1432	-0.1441	-	<0.0001	0.0001	<0.0001	0.1855	<0.0001	0.0035	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
15	0.7302	0.6478	0.1815	0.0470	0.0640	0.2797	0.0218	0.6272	-0.1237	0.5913	0.00488	0.2806	0.0266	-0.8432	-	<0.0001	<0.0001	0.0029	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
16	0.9702	0.5169	0.6864	0.5383	0.5249	0.4894	0.0104	0.8090	-0.3081	0.8341	0.0881	0.6879	-0.2876	-0.3702	0.6516	-	<0.0001	<0.0001	<0.0001	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
17	0.8889	0.6342	0.4867	0.3102	0.3167	0.3843	0.0137	0.7531	-0.1895	0.7214	0.0493	0.4519	-0.0716	-0.7530	0.9314	0.8477	-	0.0010	<0.0001	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
18	-0.4510	-0.3242	0.1268	0.0839	0.1901	-0.1868	-0.0032	-0.3552	0.1106	-0.3725	0.0394	-0.3402	0.1830	0.1308	-0.2890	-0.4276	-0.3171	-	0.0085	<0.0001	0.0092	0.2476	0.0009	0.1484	0.0027
19	0.6989	0.5922	0.1836	0.0341	0.1524	0.2811	-0.0004	0.5977	0.0122	0.5742	-0.0024	0.2273	0.0949	-0.7931	0.9385	0.6178	0.8926	-0.2567	-	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
20	-0.4512	-0.3002	0.0736	0.0557	0.1343	-0.1756	0.0458	-0.3977	0.0666	-0.3617	0.0845	-0.3057	0.1153	0.2838	-0.3737	-0.3691	-0.3648	0.9469	-0.3800	-	<0.0001	0.3727	<0.0001	0.2483	<0.0001
21	0.6958	0.5719	0.1909	0.0403	0.1421	0.2765	-0.0021	0.5992	0.0186	0.5684	-0.0061	0.2217	0.0969	-0.7897	0.9342	0.6105	0.8886	-0.2541	0.9986	-0.3862	-	<0.0001	<0.0001	<0.0001	<0.0001
22	0.9295	0.5133	0.6717	0.5085	0.5445	0.4653	0.0185	0.7989	-0.2983	0.8107	0.0974	0.6210	-0.2305	-0.4648	0.7086	0.9353	0.8743	-0.1143	0.6747	-0.0883	0.6677	-	<0.0001	<0.0001	<0.0001
23	0.8989	0.6086	0.5001	0.3159	0.3712	0.4023	0.0005	0.7646	-0.1377	0.7430	0.0436	0.4659	-0.0678	-0.6928	0.8878	0.8650	0.9803	-0.3219	0.9126	-0.3755	0.9096	0.8831	-	<0.0001	<0.0001
24	0.9377	0.4898	0.6971	0.5444	0.6234	0.4984	0.0051	0.7906	-0.3345	0.8211	0.0947	0.6538	-0.2557	-0.4427	0.6712	0.9442	0.8485	-0.1427	0.6397	-.01142	0.6319	0.9911	0.8596	-	<0.0001
25	0.8823	0.5783	0.4838	0.3038	0.3884	0.4028	-0.0076	0.7501	-0.1304	0.7254	0.022	0.4404	-0.0473	-0.7260	0.8935	0.8252	0.9688	-0.2913	0.9337	-0.3792	0.9340	0.8561	0.9913	0.8390	-

1 =Body weight (kg), 2= Back fat thickness (mm), 3= Dorsal plane area (pixels), 4= Body volume (pixels), 5= Dorsal height (mm), 6= Thorax width (pixels), 7= Thorax height (mm), 8=Abdomen width (pixels), 9=Abdomen height (mm), 10= Rump width (pixels), 11= Rump height (mm), 12=Dorsal length (pixels), 13=Height of dorsal length (mm),14=Muscle (%), 15=Fat(%), 16=Muscle (Kg), 17=Fat(Kg), 18= Crude protein carcass (%), 19=Extract etereo carcass (%), 20=Crude protein in empty body (%), 21=Ether extract in the empty body (%), 22= Crude protein carcass (Kg), 23=Extract etereo carcass (Kg), 24=Crude protein in empty body (Kg), 25=Ether extract in the empty body (Kg).

Table 3: Equation for prediction of body weight of animals and their respective determination coefficient.

Equations	Intercept	DPA (Pixels)	Volume (Pixels)	Dorsal height (mm)	A W (Pixels)	Rump Width (Pixel)	Dorsal length (Pixel)	R²
Body weight (kg)	-312.91 (<0.0001)	0.00568 (<0.0001)	-0.000002 (<0.0001)	1.13 (0.0240)	0.65 (0.0003)	0.75 (0.0003)	0.21 (0.0099)	0.88

DPA: Dorsal plane area (pixels), AW: Abdomen Width (Pixel), R²: Determination coefficient.

Table 4: Equations for prediction physical components of bovine carcasses.

Equations	Intercept	B W (kg)	DPA (Pixels)	Volume (Pixels)	Dorsal height (mm)	A W (Pixels)	Rump Width (Pixel)	Dorsal length (Pixel)	LH (mm)	R^2
Carcass yield (%)	71.55 (0.001)		0.000168 (0.076)	-6.81E-8 (0.167)	-0.164 (0.015)		0.00148 (0.037)			0.25
BFT (mm)	-0.68 (0.188)	0.0127 (0.001)								0.31
Muscle (%)	74.18 (0.001)	-0.0118 (0.001)							-0.00369 (0.0201)	0.32
Bone (%)	9.99 (0.0337)		-0.00030 (0.001)	1.32E-7 (0.0005)	0.0947 (0.041)			0.01416 (0.080)		0.45
Fat (%)	16.22 (0.0002)	0.0439 (0.001)						-0.0350 (0.0019)		0.62
Muscle (kg)		0.379 (0.001)								0.99
Bone (kg)		0.0809 (0.001)				-0.0649 (0.0538)	0.00231 (0.039)	0.0431 (0.0009)		0.99
Fat (kg)	14.80 (0.157)	0.186 (0.001)						-0.0990 (0.0007)		0.84

BW: Body weight (kg), BFT: Back fat thickness (mm), DPA: Dorsal plane area (pixels), AW: Abdomen Width (Pixel), Volume: Body Volume (pixels), LH: Height of dorsal length (mm), R^2: Determination coefficient.

Table 5: Equations for predicting chemical components of bovine carcasses.

Equations	Intercept	B W (kg)	APD (Pixels)	Body volume (Pixels)	Dorsal height (mm)	A H (mm)	Rump height (mm)	Rump width (Pixels)	Dorsal length (Pixels)	LH (mm)	R^2
EEcp (%)	8.95	0.0437				0.0025			-0.0309	0.00301	0.70
	(0.116)	(0.001)				(0.0043)			(0.0022)	(0.194)	
Water Cp (%)	69.77	-0.0277			-0.0596			0.0375		-0.0021	0.67
	(0.001)	(0.001)			(0.181)			(0.113)		(0.125)	
CPc (kg)		0.0475	0.000842	-3.76E-7							0.99
		(0.062)	(0.0056)	(0.0077)							
EEc (kg)		0.210				0.00780			-0.1023		0.99
		(0.001)				(0.0003)			(0.001)		
Water C (kg)	42.45	0.243			-0.5262		0.00427	0.260			0.78
	(0.113)	(0.001)			(0.094)		(0.187)	(0.092)			

BW: Body weight (kg), APD: Dorsal area (pixels), LH: Height of dorsal length (mm), A H: Abdomen height (mm), EEcp (%): Ether extract carcass (%), Water Cp (%): Water carcass (%), CPc (kg): Crude Protein carcass (kg), EEc (kg): Ether extract carcass (kg), Water C (kg): Water carcass (kg), R^2: Determination coefficient.

Table 6: Equations for predicting chemical components of the empty body

Equations	Intercept	B W (kg)	DPA (Pixels)	Body volume (pixels)	Dorsal height (mm)	A H (mm)	Rump height (mm)	Dorsal length (Pixel)	LH (mm)	R²
CP EBW (%)	21.64	-0.0060								0.20
	(0.001)	(0.001)								
EE EBW (%)		0.0515				0.00327		-0.0273	0.00613	0.99
		(0.001)				(0.0022)		(0.0003)	(0.0018)	
Water EBW (%)	71.17	-0.0490			0.189	-0.0035			-0.0048	0.49
	(0.001)	(0.002)			(0.048)	(0.0191)			(0.1546)	
CP EBW (kg)		0.0746	0.00114	-4.87E-7						0.99
		(0.046)	(0.0099)	(0.017)						
EE EBW (kg)		0.267	0.00167	-7.60E-7		0.0141	-0.0056	-0.199		0.99
		(0.002)	(0.118)	(0.116)		(0.008)	(0.145)	(0.0004)		
Water EBW (kg)		0.341			1.004	-0.0155				0.99
		(0.001)			(0.0007)	(0.0503)				

BW: Body weight (kg), DPA: Dorsal plane area (pixels), A H: Abdomen height (mm), LH: Height of dorsal length (mm), CP EBW (%): Crude Protein EBW (%), EE EBW (%): Ether extract EBW (%), Water EBW (%): Water EBW (%), CP EBW (kg): Crude Protein EBW (kg), EE EBW (kg): Ether extract EBW (kg), Water EBW (kg), R²: Determination coefficient.

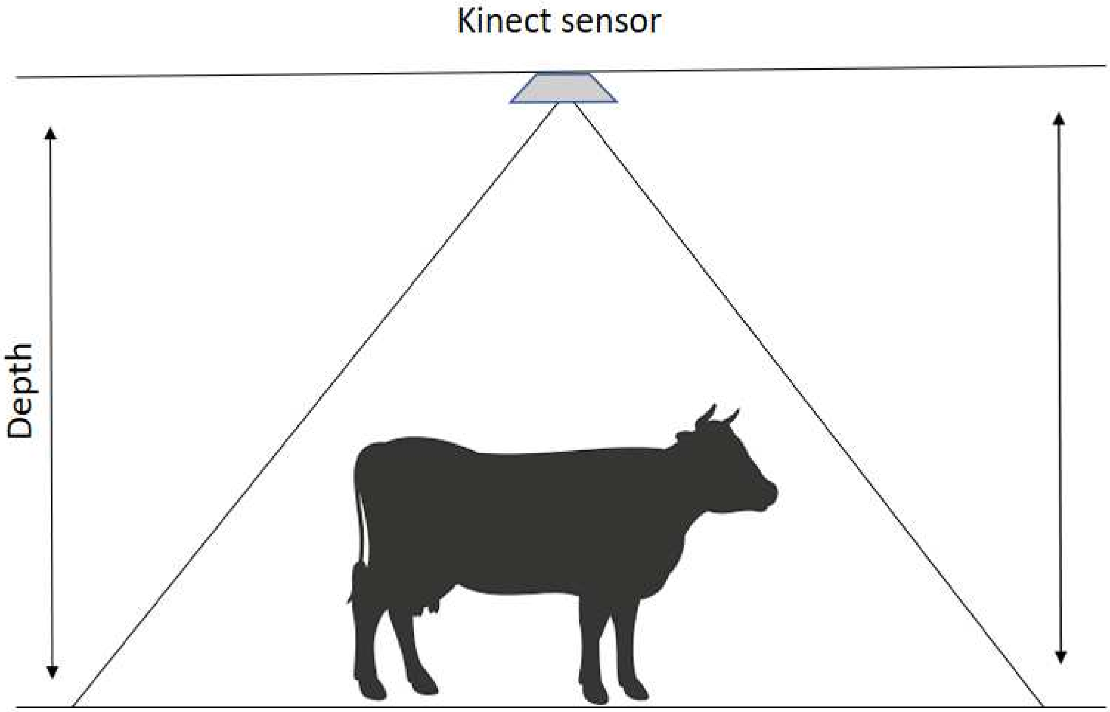

Figure 1: Image acquisition scheme of the animal's dorso.

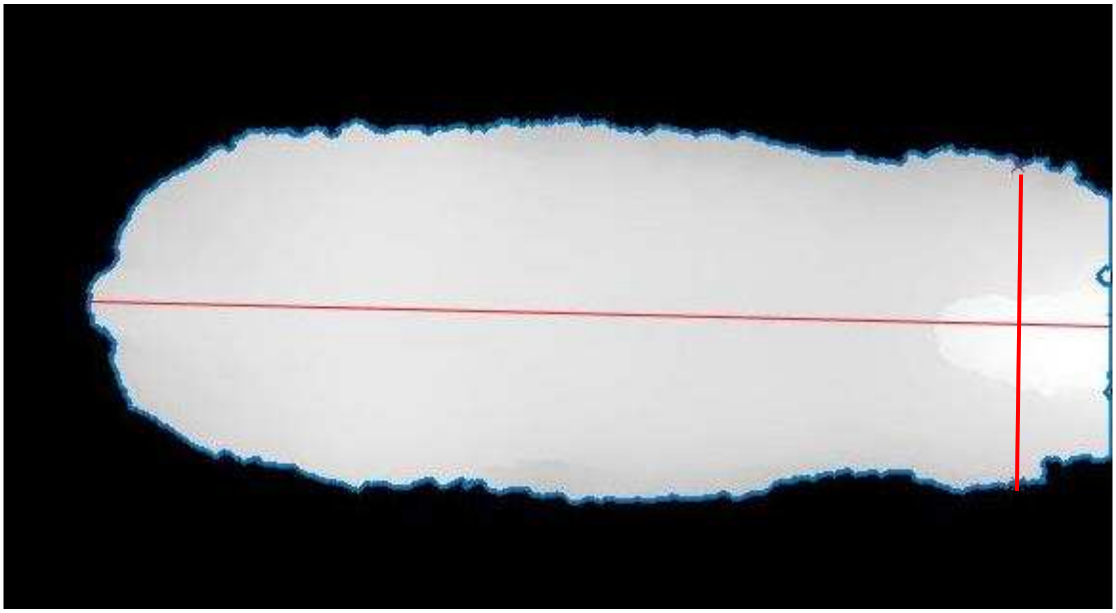

Figure 2: Image obtained after contour line treatment and exclusion errors.

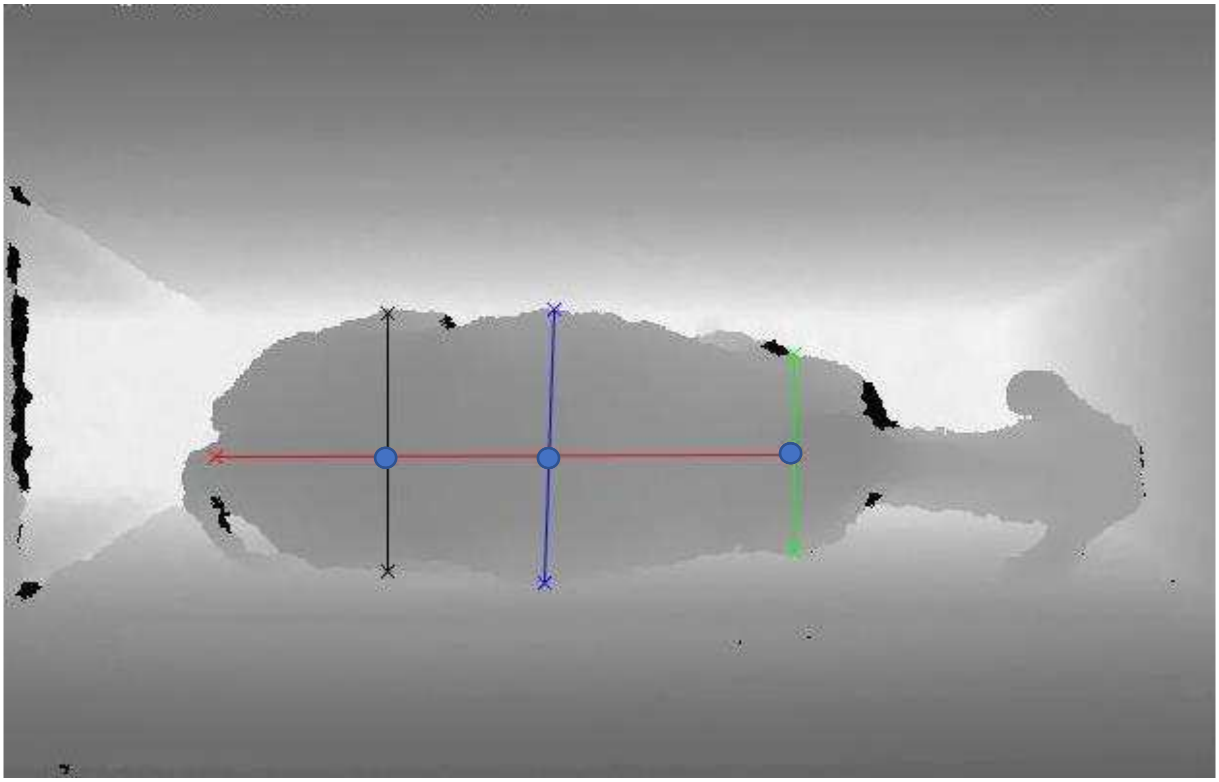

Figure 3: Illustration of the measurements obtained by image analysis, thorax width (green line), abdomen width (blue line), width of rump (black line), dorsal length (red line) and height (blue circle).

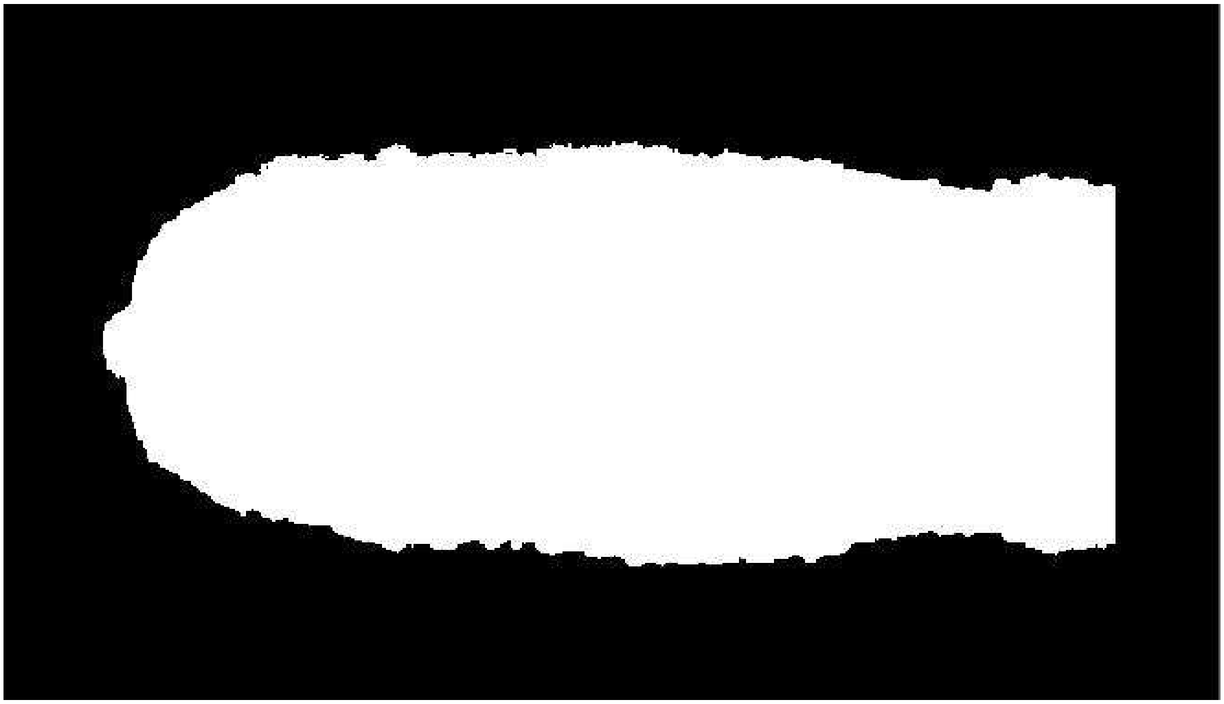

Figure 4: Representation of the dorsal plane area (DPA).

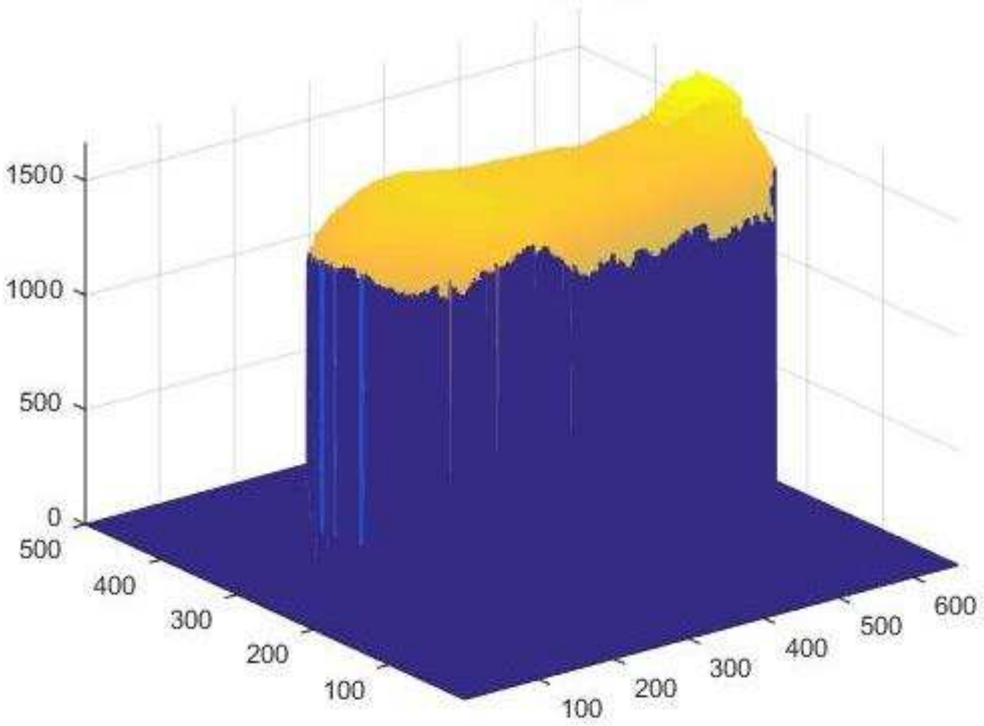

Figure 5: Projection of the animal's back to the ground.

Chapter 2

Use of infrared camera in the grading and classification of cattle carcasses

G. J. F. Assis[*1], A. L.C. Mendes[*], D. E. F. Assis[*], G. B. Carneiro[*], A. M. Corrêa[*], L. H. P. Silva[*], M. M. Estrada[*], F. A. C. Pinto[*], F. F. Silva[*], S. C. Valadares Filho[*], M. L. Chizzotti[*1].

[*] Department of Animal Science, Universidade Federal de Viçosa, Viçosa, Minas Gerais, Brazil, 36.570-000.

[1] Corresponding authors. Email: gutierrez.assis@ufv.br ; mariochizzotti@gmail.com

ABSTRACT: The grading and classification of bovine carcasses in Brazil are carried out subjectively, and the objective of this work was to estimate the physical and chemical composition of bovine carcasses through the analysis of infrared camera images. The experiment was conducted at the Animal Laboratory of the Department of Animal Science of the Federal University of Viçosa. Thirty-five Nellore bulls were used, with a mean age of 14 ± 0.3 months and a mean weight of 437 ± 47kg. The animals were slaughtered and the carcass was divided lengthwise and cooled at 4 ° C for 24 hours. Subsequently the cooled carcasses were weighed, and the loin eye area (REA) and back fat thickness (BFT), were measured between 12th and 13th rib of the carcass. Later, a sensor synchronized with MATrix LABoratory software was used to capture images on the left half carcasses. An image of each carcass was chosen to obtain the biometric parameters to be analyzed. All statistical procedures were performed using the SAS 9.0 software (Statistical Analysis System Institute, Inc.). All statistical procedures were performed using the SAS 9.0 software (Statistical Analysis System Institute, Inc.). The Least Absolute Shrinkage and Selection Operator regression was used to select the most relevant variables to predict physical and chemical composition and later, the REG procedure was used to calculate the P-value of selected variables in GLMSELECT. The biometric parameters were the best option to predict muscle tissue and fat in the carcasses with good precision, since the measurements are performed at intervals and not only in specific regions as in traditional parameters (rib eye area and back fat thicknes). The developed equations presented higher coefficients of determination (R^2) than the equations generated by the traditional parameters. The R^2 of the best predictive equations were: Considering only area, muscle (kg): 96%, fat (kg): 59%, ether extract (kg): 62% and 97% for crude protein (kg). Considering the simultaneous inclusion of area and volume parameters, muscle (kg): 96%, fat (kg): 98%, ether extract (kg): 98% and crude protein (kg): 88%. Considering the sum of the different sections, muscle (kg): 100%, fat (kg): 98%, ether extract (kg): 21% and crude protein (kg): 99%. For the traditional parameters, the following R^2 were obtained: Muscle (kg): 96%, Fat (kg): 0.53, ether extract (kg): 0.53 and crude protein (kg): 75%. The use of images to grading and classification of carcasses has shown promising technique, but further studies are needed to increase the accuracy of this technique.

Key words: biometrics, precision, prediction

Introduction

The classification and grading of carcasses allows the slaughterhouses to assure the quality of the products produced, since they can infer about the quantitative and qualitative attributes of the meat and consequently direct the meat to different consumer markets, increasing value to the final product. However, the processes of classification and grading in Brazil are generally carried out in a subjective way, which implies different quality standards and impossibility of hierarchizing meat from different slaughterhouses, since the evaluation criteria vary according to the evaluator. In this sense, tools are necessary that allow the slaughterhouses to objectively evaluate the carcasses and estimate the yield of boned cuts. Therefore, the objective of this work was to estimate the physical and chemical composition of bovine carcasses through the analysis of infrared camera images.

Material and Methods

All animal procedures were approved by Ethics Committee on the Use of Production Animals of Universidade Federal de Viçosa, protocol number 066/2016, and followed established standards for humane care and use.

Local, animal and Slaughter

The experiment was conducted in the experimental confinement of the Department of Animal Science of the Universidade Federal de Viçosa, in Viçosa (MG), from July to January to 2016.

Thirty-five Nellore bulls were used, with a mean age of 14 ± 0.3 months and weight of 437 ± 47kg. The animals were subjected to fasting for solids for 16 hours and then slaughtered by concussion followed by jugular section for complete exsanguination.

The animals were slaughtered and the carcass was divided lengthwise and cooled at 4 ° C for 24 hours. Subsequently the cooled carcasses were weighed, and the loin eye area (REA) and back fat thickness (BFT) were measured between 12th and 13 th rib of the carcass.

The left half-carcass was used to obtain the images. The carcasses were suspended by the Tenderstretch method and were images collected from the lateral view and dorsal view of the carcass. Subsequently, the section comprising of the 9th to 11th ribs (section HH) was collected according to the methodology described by Hankins and Howe (1946), for indirect estimation of the chemical composition of the carcass. The physical composition of the carcass was estimated by the equations proposed by Marcondes et al. (2012).

Image acquisition

For the determination of the images was used the sensor Kinect (model 1473, Microsoft Corp., Redmond, Washington, USA). The sensor was positioned at a height of 1.50 meters in relation to ground and distance of 3.80 meters from the carcass. Image infrared (640x480 pixels) of each carcass were captured for approximately 15 seconds. The Kinect sensor was synchronized with the MATLAB software (The MathWorks Inc., Natick, Massachusetts, USA; MatLab, 2015). The image was segmented with the aid of the regionprops function, which allowed obtaining the region corresponding to the carcass. The treatments of the images and all the measurements were performed in an automated way with the support of MatLab software operating tools.

Kinect® device

Kinect® (Microsoft, USA) is a device composed of an RGB (red–green–blue) camera and a depth sensor (laser infrared projector and an infrared camera) that allows the scanning of the environment in three dimensions.

To obtain distances, the Kinect emits an infrared signal and receives the signal reflected from the surface of the objects by its infrared receiver. The infrared camera captures the image of these points and calculates the distance value for the pixels in the image. The distance value is obtained in relation to the plane in which the Kinect is and the object.

The infrared camera has a resolution of 640x480 pixels and can generate an image stream of 30 frames per second. The field of view of the depth sensor is 57º horizontally and 43º vertically (CORRÊA, 2015) and can be operated between 0,8 m and 4,0 m of distance.

Body parameters evaluated

The following biometric parameters were measured in the images: Carcass dorsal area (CDA), carcass dorsal volume (CDVOL), carcass dorsal length (CDL), carcass dorsal height (CDH) and carcass average dorsal height (CADH) in the dorsal view of the carcass. From the lateral view of the carcass it was accessed the carcass lateral area (CLA), carcass lateral volume (CLVOL), carcass lateral length (CLL), carcass lateral height (CLH) and carcass average dorsal height (CADH).

The images were segmented into fifteen sections (Figure 1) and the following variables were obtained: Section area (AS), section volume (VOLS), section height (HS) and section average height (HMS) for both images, lateral view and dorsal view.

We also obtained variables consisting of the sum of the different sections. Dorsal view: Sum of areas dorsal of section 2 to 13, sum of areas dorsal of section 6 to 12, sum of heights dorsal of section 2 to 13, sum of heights dorsal of section 6 to 12, sum of the average heights dorsal of sections 2 to 13, sum of the average heights dorsal of sections 6 to 12. Lateral view: sum of areas from sections 2 to 13, sum of areas from sections 6 to 12, sum of heights of sections 2 to 13, sum of heights of section 6 to 12, sum of the average heights of Sections 2 to 13, sum of the average heights of Sections 6 to 12. The sums constituted from sections 6-12 and 2-13 were measured to eliminate the ends of the carcass, since this is extremely variable.

Carcass lateral height, measured from a plane parallel to the sagittal line to the value of the mean point obtained by the average of the points most prominent on the surface of the carcass, in mm.

Carcass dorsal height, measured from a plane parallel to the ventral region to the value of the mean point obtained by the average of the points most prominent on the carcass dorsal surface, in mm.

Carcass average lateral height, measured from a plane parallel to the sagittal line to the value of the mean point obtained by the average of all points on the carcass surface, in mm.

Carcass average dorsal height, measured from a plane parallel to the ventral region to the value of the mean point obtained by the average of all points on the carcass dorsal surface, in mm.

Height lateral of the section, measured from a plane parallel to the sagittal line to the value of the mean point obtained by the average of the most prominent points in the section, in mm.

Height dorsal of the section, measured from a plane parallel to the ventral region to the value of the mean point obtained by the average of the most prominent points in the section, in mm.

Average lateral height of the section, measured from a plane parallel to the sagittal line to the value of the mean point obtained by the average of all points on the surface of the section, in mm.

Average dorsal height of the section, measured from a plane parallel to the ventral region to the value of the mean point obtained by the average of all points on the surface of the section, in mm.

Length of the carcass, a line on the surface of the carcass, from the 4th cervical vertebra to the base of the tail, in cm.

Carcass lateral area, amount of two-dimensional space present in the frame, in pixels

Carcass lateral volume, considered as a block, formed by the projection of the surface of the carcass to the plane parallel to the sagittal line, in pixels.

Carcass volume dorsal, considered as a block, formed by the projection of the back to the plane parallel to the ventral, in pixels.

Laboratory tests

Muscle, fat and bone tissue samples obtained from section HH were lyophilized for 72 hours to quantify partial dry fatty matter. Subsequently, these samples were partially degreased by successive washes with petroleum ether, according to method number 920.39 (AOAC, 1990). After partial degreasing, the samples were ground in a ball mill for quantification of dry matter (DM, AOAC, 1990, method number 930.15), mineral matter (MM, AOAC, 1990, method number 924.05), crude protein, AOAC, 1990, method number 984.13) and ethereal extract (EE, AOAC, 1990, method number 920.39). The fat removed in the partial degreasing was added to the ethereal extract content to quantify the total fat content in the carcass.

The following chemical variables were measured: the quantities in kilograms of crude protein in the carcass (CP kg) and ethereal extract in the carcass (EE kg). the following the physicists were measured: the amounts of muscle (kg muscle) and fat in the carcass (kg fat).

Statistical analysis

All statistical procedures were performed using SAS 9.0 softwares (Statistical Analysis System Institute, Inc.). The LASSO (Least Absolute Shrinkage and Selection Operator) regression (TIBSHIRANI, 1996) was used to select the most relevant variables to predict the physical and chemical composition of carcasses. It is indicated for situations involving larger number of correlated independent variables (HANS, 2009) as observed in the present study. Under a matrix notation, the used model is given by: $\mathbf{y} = \mathbf{X}\boldsymbol{\beta} + \mathbf{e}$, where $\mathbf{y} = \left[\mathrm{y_i}\right], \mathbf{X} = \left[\mathrm{x_{ij}}\right], \boldsymbol{\beta} = \left[\beta_\mathrm{j}\right]$ and $\boldsymbol{\varepsilon} = \left[\mathrm{e_i}\right]$. In summary, the LASSO is a penalized least squares procedure that minimizes the residual sum squared subject to the non-differentiable constraint expressed in terms of the norm of the coefficients, being the estimator given by: $\hat{\boldsymbol{\beta}}_\mathrm{L} = \arg\min_\beta (\hat{\mathbf{y}} - \mathbf{X}\boldsymbol{\beta})'(\hat{\mathbf{y}} - \mathbf{X}\boldsymbol{\beta}) + \lambda \sum_{\mathrm{j}=1}^{1000} |\beta_\mathrm{j}|$. The intensity of the penalization (shrinkage of regression coefficients toward zero) is given by the regularization parameter (λ). This method was implemented thought GLMSELECT procedure of SAS$^{®}$ (SAS Inst. Inc., Cary, NC) software assuming initially all the biometric variables, REA, BFT and weight. After that, the REG procedure was used to calculate the P-value of selected variables in GLMSELECT.

Results and Discussion

The descriptive statistics of the characteristics evaluated in the carcasses and in the images, are presented in table 1

The correlations between weight, muscle, fat and the different sections of area and volume obtained in the carcasses are presented in table 2. The studied variables, in general, presented significant correlation ($P<0,20$) with the weight of the carcass, this because they express the size of the carcass and consequently the yield of meat cuts after boning.

The correlations involving the physical composition of the carcasses exemplify the influence of this on the different sections. There was no significant correlation between muscle and fat ($P >0.20$) with sections 1,2,9,12 and 13 as shown in table 2, indicate out that such sections are extremely variable. Sections 4, 5, 6, 7, 8,10, 11 and 14 showed significant correlations ($P<0.20$), except for correlations between the fat and volume of sections 4 and 10, and the correlation between muscle and volume of Section 7. This shows a tendency of measures such as area, vary of conformation, interacting with the changes in the body composition of the animals, being able to be effective measures and auxiliary of the weight to obtain better estimates of the variables related to the composition (MONTEIRO, 2015)

Analyzing table 3, which shows the correlations between weight, muscle and fat with the biometric parameters (area and volume) of the carcass dorsal view, we observed a greater number of significant correlations ($P<0.20$), compared to Correlations between weight, muscle and fat with the biometric parameters (area and volume) of the carcass lateral view (table 2), indicating that the carcass back is a better option to estimate the physical components of the carcass.

Due to the correlations, equations were developed to analyze which characteristics could be more interesting for estimate the physical and chemical components of the carcass. The rib eye area (REA) and back fat thickness (BFT) are the parameters traditionally used to predict the meat yield after boning (LUCHIARI FILHO, 2000; SILVA et al., 2006). However, in order to obtain these parameters, is necessary to divide the carcass between the 12th and 13th ribs, damaging muscles of high commercial value, which hinders the adoption of this system by some slaughterhouses. Table 4 presents the different models to estimate the carcass components and their respective determination coefficients when considering the traditional variables.

Contrary to expectations, REA was not included in the prediction model (Table 4). The variables carcass weight and BFT ($P < 0.20$) were important for the prediction of the amount of muscle, probably the animal reached the moment of slaughter and ceased the body growth, consequently REA also stopped the growth, thus the BFT becomes the most important variable in determination of the amount of muscle tissue (SUGUISAWA et al., 2006).The results of our study involving a small sample exemplify that the traditionary parameters have a limited performance to correctly estimate the crude protein (kg) of the carcasses ($R^2 = 0.75$), this limitation has not been reported in other studies. Campeneere et al. (1999) based only on empty body weight (EBW) found coefficients of determination for protein 0.99.

The traditional parameters presented correlation of 0.96 with the proportion of carcass muscles, being these correlations higher than those reported by Suguisawa et al. (2006) when working with Ultrasonography to predict the carcass composition of young bovines that found determination coefficients of 0.86.

Table 4 shows also the components of the regression equations to estimate fat amounts, the variables determinants were carcass weight and BFT. The equation for estimating the amount of fat obtained a coefficient of determination from 0.53, which is less than those reported by Campeneere et al. (1999) and Greiner et al. (2003) who found coefficient of determination for fat estimates of 0.78 and 0.89 respectively.

Previous studies also showed a significant correlation between traditional parameters (REA and BFT) and carcass traits (SILVA et al., 2003, TAROUCO et al., 2005), but the reliability of predictions obtained from these variables are limited, these are point estimates and subject to measurement errors. A scenario to exemplify this would be a carcass with developed musculature and a slightly increased fat content, compared to another carcass that presents a limited muscularity and a high fat content, both representing characteristics of completely different carcasses, but, by traditional parameters, they can present the same values of muscle and fat prediction because to measurement errors. Therefore, the accuracy of the traditional parameters to estimate physical and chemical composition is limited, especially for carcasses in the intermediate intervals.

This study exemplifies limitations in the use of traditional parameters, however is important to emphasize that these parameters are not worthless and can continue to be used to identify extremes, carcass with developed musculature and high contents fat and carcass with limited musculature and low fat. Fortunately, adjusting predictions with area and volume parameters overcomes the limitations of using traditional parameters. The, studies were performed out on a small sample of carcasses, but this fact did not limit that we had carcasses of different physical and chemical compositions, allowing the equations to are probably applicable in all carcasses. Our study is one of the first reports to describe the performance of the biometric parameters to estimate carcass characteristics. It is evident that these parameters are superior when compared with the traditional parameters, since they consider different sections of areas, volumes and heights without the need to make cuts in the carcasses.

In fact, our found that the interaction between biometric parameters correlated better than the traditional parameters. The simultaneous inclusion of area and volume parameters (table 5) showed to perform better in predicting fat (kg), ether extract (kg) and crude protein (kg, figure 2).

The equations adjusted to estimate the proportion of muscle, fat, crude protein and ethereal extract in the carcass with only the area parameters and the equations for prediction of physical and chemical components of bovine carcasses considering sums of sections are shown in tables 6 and 7, respectively.

The equations to estimate the tissue composition of the carcass from the non-traditional parameters showed good fit to the linear model adopted. The equations related to the muscular quantity presented determination coefficients of 96% when only the parameters of the area were considered and 100% when the sum of the parameters was used. The equation that estimates the amount of fat in the carcass depending only on the area obtained a coefficient of determination of 59%, lower than the coefficient of determination found by the equation that considers the simultaneous inclusion of area and volume and superior the equation that considers the traditional paramentros (Tables 4 and 5).

The coefficient of determination obtained for the equations adjusted by the area to estimate crude protein and ethereal extract was 97% and 62%, respectively. For the equations adjusted by the sums (Table 7) the determination coefficients were 99% and 21% for the crude protein and ethereal extract respectively. We observe the high coefficients of determination of the equations to predict muscle and crude protein (CP kg), in the first instance this instigates us to consider such equations as the best to predict such parameters, however the number of variables necessary to carry out the predictions becomes a limitation, making us consider such equations inappropriate to be used in the field due to the probability of measurement errors in some of these variables.

Only regressions with components expressed in kg are reported in this study, since they were always superior to equations with components quoted in percentages.

Conclusions

The use of images represents promising alternative in the classification and grading of bovine carcasses. The equations generated from the biometric measurements obtained by image analysis allow to estimate the amount muscle, crude protein and ether extract in the carcasses. The system also allows to estimate the amounts of fat, although this is a very variable tissue in the carcass. But more studies are necessary to increase the precision of this technique.

References

ANDRIGHETTO, C., JORGE, A. M., CERVIERI, R. D. C., CUCKI, T. O., RODRIGUES, É., ARRIGONIi, M. D. B. (2009). Relação entre medidas ultrassônicas e da carcaça de bubalinos Murrah abatidos em diferentes períodos de confinamento. Revista Brasileira de Zootecnia, 38(9), 1762-1768.

ASSOCIATION OF OFFICIAL ANALYSIS CHEMISTS. Official methods of analysis.15th ed. Arlington, 1990. 1094 p.

BAILEY, C.; JENSEN, J.; BECH ANDERSEN, B. (1986). Ultrasonics scanning and body measurements for predicting composition and muscle distribution in young Holstein x Friesian bulls. Journal of Animal Science. 63, 1337-1346.

CAMPENEERE, S. DE, FIEMS, L.O., VAN DE VOORDE, G., VANACKER, J.M., BOUCQUE, CH.V., DEMEYER, D.I., (1999). Meat Science. Estimation of chemical carcass composition from 8th rib characteristics with Belgian blue double-muscled bulls. 51 (1), 27 - 33

CORRÊA, P. B. P. Estimação da massa corporal de bovinos por meio de sensor de profundidade. (2015). 50. Dissertação (Mestrado em Zootecnia) – Universidade Federal de Viçosa.

GREINER, S.P.; ROUSE, G.H.; WILSON, D.E. (2003) The relationship between ultrasound measurements and carcass fat thickness and longissimus muscle area in beef cattle. Journal of Animal Science.81, 676-682.

HANKINS, O. G., & HOWE., P. E. (1946). Estimation of the composition of beef carcasses and cuts. Washington, DC: USDA Technical Bulletin 926.

HANS, C. (2009). Bayesian lasso regression. Biometrika 96, 835–845.

LUCHIARI FILHO, A. (2000). Pecuária da carne bovina. Nova Odessa: Limbife – Laboratório de Análises de Carne. 140.

MARCONDES, M.I.; TEDESCHI, L.O.; VALADARES FILHO, S.C.; CHIZZOTTI, M.L. (2012). Prediction of physical and chemical body compositions of purebred and crossbred Nellore cattle using the composition of a rib section. Journal of animal science, 90(4): 1280-90.

MONTEIRO, G. R. Uso de câmera de infravermelho para predizer peso, composição corporal e de carcaça em bovinos Nelore e Angus. (2015). 40 p. Dissertação (mestrado acadêmico) –Universidade Federal de Lavras.

SILVA, S. L., LEME, P. R., PUTRINO, S. M. U., MARTELLO, L. S. U., LIMA, C. G. D., LANNA, D. P. D. (2003). Estimativa do peso e do rendimento de carcaça de tourinhos Brangus e Nelore, por medidas de ultra-sonografia. R. Bras. Zootec. 32 (5):1227-1235. ISSN 1806-9290. http://dx.doi.org/10.1590/S1516-35982003000500025

SILVA, S.L., LEME, P.R., PUTRINO, S.M., LANNA, D.P.D. (2006). Alterações nas características de carcaça de tourinhos Nelore, avaliados por ultra-som. Revista Brasileira de Zootecnia. 35 (2): 607-612.

TIBSHIRANI, R. (1996). Regression shrinkage and selection via the LASSO. J. Royal Stat. Soc. B 58, 267–288.

SUGUISAWA, L., MATTOS, W. R. S., SOUZA, A. A. D., SILVEIRA, A. C., OLIVEIRA, H. N. D., ARRIGONI, M. D. B., BURINI, D. C. M. (2006). Prediction of carcass composition of steers using ultrasound measurements. Revista Brasileira de Zootecnia, 35(1), 177-185.

TAROUCO, J. U., LOBATO, J. F. P., TAROUCO, A. K., & MASSIA, G. D. S. (2005). Relationship between ultrasound measurements and fat thickness or rib eye area in carcass of beef cattle. Revista Brasileira de Zootecnia, 34(6), 2074-2084

VALADARES FILHO, S.C.; MARCONDES, M.I.; CHIZZOTTI, M.L.; PAULINO, P.V.R. (2010). Exigências nutricionais de zebuínos puros e cruzados-BR CORTE. 2nd ed. Viçosa-MG: Suprme Gráfica LTDA.

Table 1: Descriptive statistics of the characteristics evaluated.

Variables	N	Mean	Standard deviation	Mínimum	Máximum
Carcass weight (kg)	33	135.46	14.10	110.90	170.70
Rib eye area (cm²)	33	74.41	8.17	58.89	93.48
Dorsal fat thickness (mm)	33	4.87	1.70	2.48	10.30
Muscle (kg)	33	86.93	9.21	70.79	110.66
Fat (kg)	33	24.70	4.60	17.79	37.16
Crude protein (kg)	33	53.64	5.23	43.76	67.31
Ether extract (kg)	33	56.41	10.00	38.93	84.60
Carcass lateral length (cm)	33	170.85	5.66	160.45	183.66
Carcass dorsal length (cm)	33	200.95	6.00	190.22	215.45
Carcass lateral area (pixels)	33	11566	826.65	9614	13063
Lateral area section1 (pixels)	33	360.24	137.90	170.02	693.85
Lateral area section2 (pixels)	33	774.82	185.36	526.63	1408
Lateral area section3 (pixels)	33	1106	160.60	833.58	1443
Lateral area section4 (pixels)	33	1056	193.66	712.65	1384
Lateral area section5 (pixels)	33	700.62	81.81	541.78	889.69
Lateral area section6 (pixels)	33	669.53	55.52	564.79	780.83
Lateral area section7 (pixels)	33	720.94	48.39	618.66	814.22
Lateral area section8 (pixels)	33	800.66	58.48	688.52	945.52
Lateral area section9 (pixels)	33	931.74	87.50	771.57	1153
Lateral area section10 (pixels)	33	1024	84.10	858.83	1231
Lateral area section11 (pixels)	33	974.12	82.88	804.96	1153
Lateral area section12 (pixels)	33	980.59	154.52	807.48	1611
Lateral area section13 (pixels)	33	1017	299.38	248.58	1541
Lateral area section14 (pixels)	33	361.27	226.65	160.48	1006
Lateral area section15 (pixels)	33	190.30	71.36	96.79	417.21
Carcass dorsal area (pixels)	33	5085	840.12	3740	6953
Area dorsal section1 (pixels)	33	137.36	70.60	62.78	346.58
Area dorsal section2 (pixels)	33	301.62	113.390	161.86	745.02
Area dorsal section3 (pixels)	33	316.84	107.164	178.85	748.59
Area dorsal section4 (pixels)	33	356.10	80.80	212.64	528.60
Area dorsal section5 (pixels)	33	393.08	83.36	283.28	623.71
Area dorsal section6 (pixels)	33	406.35	102.57	260.77	621.93
Area dorsal section7 (pixels)	33	351.46	82.75	200.46	497.70
Area dorsal section8 (pixels)	33	347.31	75.23	231.78	503.45
Area dorsal section9 (pixels)	33	368.33	76.685	235.74	551.05
Area dorsal section10 (pixels)	33	375.21	68.72	254.19	538.10
Area dorsal section11 (pixels)	33	354.54	74.09	210.31	523.45
Area dorsal section12 (pixels)	33	391.41	74.20	220.05	523.453

Area dorsal section13 (pixels)	33	409.45	63.13	233.44	519.70
Area dorsal section14 (pixels)	33	381.52	44.93	289.65	469.96
Area dorsal section15 (pixels)	33	313.03	536.19	126.09	3285
Carcass lateral volume (pixels)	31	29413939	4754197	19906962	38264649
Volume lateral section1 (pixels)	31	1192531	484274	457033	3050799
Volume lateral section2 (pixels)	31	2726588	836551	1636179	4639523
Volume lateral section 3 (pixels)	31	3800657	834813	2652190	5563032
Volume lateral section 4 (pixels)	31	3286843	762746	1943628	5986345
Volume lateral section 5 (pixels)	31	1939200	445044	1118223	3126001
Volume lateral section 6 (pixels)	31	1852703	377787	1164257	2704789
Volume lateral section7 (pixels)	31	1913521	351436	1283222	2770945
Volume lateral section8 (pixels)	31	1935439	342902	1417229	2877027
Volume lateral section9 (pixels)	31	2000801	360283	1466318	3110216
Volume lateral section10 (pixels)	31	2027200	356881	1388072	3049761
Volume lateral section11 (pixels)	31	1904654	356487	1261332	2839369
Volume lateral section12 (pixels)	31	1981237	301935	1421584	2721840
Volume lateral section13 (pixels)	31	1830489	561859	468657	2772023
Volume lateral section14 (pixels)	31	704181	529394	234797	2606828
Volume lateral section15 (pixels)	31	317895	212010	102395	1081348
Carcass dorsal volume (pixels)	33	27497451	12870125	9394508	71564318
Volume dorsal section1 (pixels)	33	812289	479930	289649	2373651
Volume dorsal section2 (pixels)	33	1947586	703153	817143	3458897
Volume dorsal section3 (pixels)	33	1965446	672451	728687	3813621
Volume dorsal section4 (pixels)	33	2183121	883972	818005	5299080
Volume dorsal section5 (pixels)	33	2541984	1085987	1180115	6782862
Volume dorsal section6 (pixels)	33	2507708	1202205	1057119	7876023
Volume dorsal section7 (pixels)	33	1912001	949399	616676	5277548
Volume dorsal section8 (pixels)	33	1800100	1019295	568995	5429378
Volume dorsal section9 (pixels)	33	1850893	1092742	552702	5755331
Volume dorsal section10 (pixels)	33	1838031	1023567	528864	5360777
Volume dorsal section11 (pixels)	33	1728034	1000847	450093	4991532
Volume dorsal section12 (pixels)	33	1860975	1108746	488144	5538208
Volume dorsal section13 (pixels)	33	1940131	1051884	581208	5232875
Volume dorsal section14 (pixels)	33	1710396	908637	529349	4432071
Volume dorsal section15 (pixels)	33	1135662	1408267	295427	8533065
Sum Lateral area section6_12 (pixels)	33	6102	477.94	5228	7241
Sum Lateral area section2_13 (pixels)	33	10757	811.01	9134	12517
Sum vol. lateral section6_12 (pixels)	31	13615555	2272787	10039697	19853165
Sum vol. lateral section2_13 (pixels)	31	27199332	4328730	18785296	36155966
Sum of heights of section 6_12 (mm)	33	2397	925.38	1686	5986
Sum of heights of section 2_13 (mm)	33	4510	1588	3344	10575

Carcass average height (mm)	33	286.72	131.32	193.71	804.00
Sum average height section 6_12 (mm)	33	1822	927.62	1166	5487
Sum average height section 2_13 (mm)	33	3475	1586	2332	9706
Sum area dorsal section6_12 (pixels)	33	2595	467.77	1875	3639
Sum area dorsal section2_13 (pixels)	33	4372	759.33	3166	5906
Sum vol. dorsal section6_12 (pixels)	33	13497741	7217330	4262592	38502970
Sum vol. dorsal section2_13 (pixels)	33	24076009	11193288	8387749	62733757
Carcass dorsal height (mm)	30	764.63	113.80	483.00	909.00
Sum height dorsal section6_12 (mm)	30	4006	705.45	2002	5030
Sum height dorsal section2_13 (mm)	30	7397	1206	4039	9103
Sum average height dorsal section 2_13	30	5881	1057	3205	7789

Table 2: Coefficients of correlations between carcass weight, muscle and fat with the biometric parameters (area and volume) of the lateral view of the carcass.

Variables	Area			Volume		
	Weight (kg)	Muscle (kg)	Fat (kg)	Weight (kg)	Muscle (kg)	Fat (kg)
Carcass lateral	0.65893 (<0.0001)	0.68245 (<0.0001)	0.25911 (0.1454)	0.25876 (0.1598)	0.25040 (0.1743)	0.14179 (0.4468)
Lateral section 1	0.00042 (0.9982)	-0.01290 (0.9432)	0.03761 (0.8354)	-0.1883 (0.3103)	-0.18899 (0.3086)	-0.14943 (0.4224)
Lateral section 2	0.02277 (0.8999)	0.00838 (0.9631)	0.01267 (0.9442)	-0.1617 (0.3846)	-0.16948 (0.3621)	-0.12046 (0.5186)
Lateral section 3	-0.02909 (0.8723)	0.01340 (0.9410)	-0.23480 (0.1884)	-0.1414 (0.4479)	-0.11175 (0.5495)	-0.26426 (0.1508)
Lateral section 4	0.60953 (0.0002)	0.62626 (<0.0001)	0.34158 (0.0517)	0.43376 (0.0148)	0.46661 (0.0081)	0.11869 (0.5248)
Lateral section 5	0.75216 (<0.0001)	0.76174 (<0.0001)	0.40916 (0.0181)	0.44597 (0.0119)	0.44988 (0.0111)	0.23729 (0.1987)
Lateral section 6	0.68520 (<0.0001)	0.67047 (<0.0001)	0.43451 (0.0115)	0.36821 (0.0415)	0.34666 (0.0561)	0.27581 (0.1331)
Lateral section 7	0.55023 (0.0009	0.54667 (0.0010)	0.27423 (0.1225)	0.26154 (0.1553)	0.23041 (0.2124)	0.24909 (0.1766)
Lateral section 8	0.38291 (0.0278)	0.38166 (0.0284)	0.19038 (0.2886)	0.26788 (0.1451)	0.22742 (0.2186)	0.29978 (0.1013)
Lateral section 9	0.15831 (0.3789)	0.19091 (0.2872)	-0.04488 (0.8041)	0.19603 (0.2906)	0.16978 (0.3612)	0.16616 (0.3717)
Lateral section 10	0.32505 (0.0649)	0.35257 (0.0442)	0.03002 (0.8683)	0.26559 (0.1487)	0.24696 (0.1805)	0.17687 (0.3412)
Lateral section 11	0.60055 (0.0002)	0.60544 (0.0002)	0.24182 (0.1752)	0.34597 (0.0566)	0.31641 (0.0829)	0.24434 (0.1853)
Lateral section 12	0.15633 (0.3850)	0.15752 (0.3813)	0.04776 (0.7918)	0.16354 (0.3794)	0.13802 (0.4590)	0.11074 (0.5531)
Lateral section 13	0.14132 (0.4327)	0.17817 (0.3212)	-0.11566 (0.5215)	0.20844 (0.2605)	0.22554 (0.2225)	0.05033 (0.7880)
Lateral section 14	0.45346 (0.0080)	0.43273 (0.0119)	0.41744 (0.0156)	0.42470 (0.0172)	0.38533 (0.0323)	0.46910 (0.0078)
Lateral section 15	0.18763 (0.2957)	0.15097 (0.4017)	0.21095 (0.2386)	0.20061 (0.2792)	0.17229 (0.3540)	0.26886 (0.1436)

Table 3: Coefficients of correlations between carcass weight, muscle and fat with the biometric parameters (area and volume) of the dorsal view of the carcass.

Variables	Area			Volume		
	Weight (kg)	Muscle (kg)	Fat (kg)	Weight (kg)	Muscle (kg)	Fat (kg)
Carcass dorsal	0.5413 (0.0011)	0.51963 (0.0019)	0.3809 (0.0287)	0.34744 (0.0476)	0.27744 (0.1180)	0.44237 (0.0099)
Dorsal section1	0.0208 (0.9082)	0.01836 (0.9192)	0.0186 (0.9179)	0.32805 (0.0623)	0.28212 (0.1117)	0.38500 (0.0269)
Dorsal section2	0.2104 (0.2397)	0.22087 (0.2168)	0.0904 (0.6166)	0.37534 (0.0314)	0.34172 (0.0516)	0.35005 (0.0458)
Dorsal section3	0.2936 (0.0972)	0.30709 (0.0821)	0.1209 (0.5026)	0.33680 (0.0553)	0.30792 (0.0813)	0.28077 (0.1135)
Dorsal section4	0.3390 (0.0536)	0.34653 (0.0482)	0.1832 (0.3074)	0.31908 (0.0703)	0.27096 (0.1272)	0.33806 (0.0543)
Dorsal section5	0.3496 (0.0461)	0.34711 (0.0478)	0.2230 (0.2122)	0.34708 (0.0478)	0.28568 (0.1070)	0.40487 (0.0194)
Dorsal section6	0.2735 (0.1234)	0.23835 (0.1816)	0.2760 (0.1200)	0.29936 (0.090)	0.22000 (0.2185)	0.4236 (0.0140)
Dorsal section7	0.3355 (0.0562)	0.29661 (0.0937)	0.35483 (0.0427)	0.29739 (0.0928)	0.21817 (0.2226)	0.45212 (0.0083)
Dorsal section8	0.5156 (0.0021)	0.46888 (0.0059)	0.4950 (0.0034)	0.34665 (0.0481)	0.26602 (0.1346)	0.50121 (0.0030)
Dorsal section9	0.6243 (0.0001)	0.57324 (0.0005)	0.5319 (0.0014)	0.36468 (0.0369)	0.28650 (0.1060)	0.49369 (0.0035)
Dorsal section10	0.6433 (<0,0001)	0.60086 (0.0002)	0.5039 (0.0028)	0.36834 (0.0349)	0.29173 (0.0995)	0.48482 (0.0042)
Dorsal section11	0.6099 (0.0002)	0.58319 (0.0004)	0.4225 (0.0143)	0.37878 (0.0297)	0.30697 (0.0823)	0.46515 (0.0064)
Dorsal section12	0.5822 (0.0004)	0.56259 (0.0007)	0.3804 (0.0290)	0.34034 (0.0526)	0.27203 (0.1257)	0.42693 (0.0132)
Dorsal section13	0.5480 (0.0010)	0.53324 (0.0014)	0.3470 (0.0478)	0.30083 (0.0889)	0.23445 (0.1891)	0.40200 (0.0204)
Dorsal section14	0.4304 (0.0124)	0.40810 (0.0184)	0.2722 (0.1253)	0.25028 (0.1601)	0.18220 (0.3102)	0.36791 (0.0352)
Dorsal section15	-0.2995 (0.0904)	-0.29444 (0.0963)	-0.2569 (0.1488)	-0.2616 (0.1414)	-0.27648 (0.1193)	-0.17092 (0.3416)

Table 4: Equations for prediction of physical and chemical components of bovine carcasses considering traditional parameters.

Equations	Intercept	Carcass Weight (kg)	BFT (mm)	R²
Muscle (kg)	1.15227 (0.7125)	0.65268 (<0.0001)	-0.54131 (0.0086)	0.963
Fat (kg)	-5.54912 (0.3247)	0.19199 (<0.0001)	0.87130 (<0.000166)	0.536
EE (kg)	-10.46714 (0.3916)	0.43290 (<0.0001)	1.69002 (0.0312)	0.533
CP (kg)	9.84852 (0.0349)	0.32329 (<0.0001)		0.758

BFT: Back fat thickness (mm), EE: Ether extract (kg), CP: Crude protein (kg), R²: Determination coefficient

Table 5: Equations for prediction of physical and chemical components of bovine carcasses considering the simultaneous inclusion of area and volume parameters.

Equations	Intercept	Carcass Weight (kg)	Dorsal length (cm)	Carcass lateral area (pixels)	Carcass dorsal volume (pixels)	THD (mm)	R^2
Muscle (kg)	18.731 (0.0971)	0.6103 (<0.0001)	-0.1408 (0.0274)	0.00119 (0.0403)			0.963
Fat (kg)		0.2814 (<0.0001)	0.0593 (0.2058)	-0.0021 (0.0373)			0.984
EE (kg)		0.596 (<0.0001)	0.1186 (0.2421)	-0.0041 (0.0650)			0.985
CP (kg)	-21.042 (0.0495)	0.2391 (<0.0001)		0.00396 (0.0009)	-5.12E-7 (0.0079)	0.01624 (0.0503)	0.883

THD: Carcass dorsal height (mm), EE: Ether extract (kg), CP: Crude protein (kg), R^2: Determination coefficient.

Table 6: Equations for prediction of physical and chemical components of bovine carcasses considering only area parameters.

Variables	Equations			
	Muscle (kg)	Fat (kg)	EE (kg)	CP (kg)
Intercept	-10.649 (0.0730)	11.488 (0.1703)	23.096 (0.1622)	43.13517 (<.0001)
Carcass weight (kg)	0.624 (<0.0001)	0.20331 (0.0004)	0.399 (0.0003)	0,39764 (<0,0001)
Area dorsal section1 (pixels)				0,0192 (0,0119)
Area dorsal section 2 (pixels)				-0,02212 (0,0097)
Area dorsal section 3 (pixels)				0,02141 (0,0107)
Area dorsal section 4 (pixels)				0,01661 (0,0845)
Area dorsal section 6 (pixels)				-0,01052 (0,0288)
Area dorsal section 8 (pixels)	-0.00934 (0.1601)	0.01639 (0.1266)	0.0569 (0.0049)	
Area dorsal section 9 (pixels)				0.05735 (0,0007)
Area dorsal section 10 (pixels)				-0.05587 (0,0063)
Area dorsal section 13 (pixels)				0.01305 (0,1992)
Lateral area section 1 (pixels)				-0,01363 (0,0189)
Lateral area section 2 (pixels)	-0.00605 (0.0441)	0.00702 (0.0819)		0.02404 (0,0005)
Lateral area section 3 (pixels)				0.00775 (0.0036)
Lateral area section 6 (pixels)	0.0164 (0.1786)			-0.06408 (0.0004)
Lateral area section 7 (pixels)				0.04739 (0.1266)
Lateral area section 8 (pixels)				-0.04179 (0.0914)
Lateral area section 9 (pixels)		-0.02291 (0.0132)		0.03994 (0.0074)
Lateral area section 10 (pixels)	0.02111 (0.0325)		-0.0396 (0.0141)	-0.11974 (<.0001)
Lateral area section 11 (pixels)	-0.01454 (0.2139)			0.05337 (0.0002)
Lateral area section 13 (pixels)	0.00250 (0.1445)	-0.00404 (0.0852)		
R^2	0.966	0.597	0.619	0.975

EE: Ether extract (kg), CP: Crude protein (kg), R^2: Determination coefficient.

Table 7: Equations for prediction of physical and chemical components of bovine carcasses considering sums of sections.

Variables	Equations			
	Muscle (kg)	Fat (kg)	EE (kg)	CP (kg)
Intercept			46.44574 (<0.0001)	56.6057 (0.1088)
Carcass weight (kg)	0.474 (<0.0001)	0.16403 (<0.0001)		0.25084 (0.0015)
Caracass latera length (cm)	-0.862 (0.0060)			0.32437 (0.0269)
Carcass dorsal length (cm)	0.3278 (0.101)			-0.44153 (0.0057)
Carcass lateral area (pixels)	0.0281 (0.0009)			0.01415 (0.0018)
Sum lateral area section6_12 (pixels)	-0.0198 (0.0093)			-0.01862 (0.0010)
Sum lateral area section2_13 (pixels)	-0.0126 (0.0035)			
Carcass lateral volume (pixels)	-0.0000078 (0.0014)			-0.0000027 (0.0283)
Sum Volume lateral section6_12 (pixels)	0.00001133 (0.0060)			0.00001033 (0.0011)
Sum Volume lateral section2_13 (pixels)	0.00000422 (0.0110)			-0.0000017 (0.0113)
Carcass lateral height (pixels)	0.03030 (0.0421)			-0.10329 (0.0004)
Sum average heights section6_12 (mm)	-0.09691 (0.0096)			-0.10434 (0.0007)
Sum height section 6_12 (mm)				-0.00690 (0.2174)
Sum height section 2_13 (mm)				0.04054 (0.0006)
Carcass average lateral height (mm)				0.26156 (0.0539)
Sum area dorsal section6_12 (pixels)				0.01172 (0.0051)
Sum area dorsal section2_13 (pixels)				0.00495 (0.0166)
Sum average height section 2_13 (pixels)	0.03203 (0.0301)			
Carcass dorsal area (pixels)	0.00938 (0.0161)			-0.02737 (0.0005)
Carcass dorsal Volume (pixels)	-0.0000104 (0.0038)			0.0000144 (0.0006)
Sum volume dorsal section6_12 (pixels)	-0.0000060 (0.0001)			-0.000014 (0.1780)
Sum volume dorsal section2_13 (pixels)	0.00001217 (0.0023)	1.045E-7 (0.0727)	4.139431E-7 (0.0066)	-0.0000144 (0.0005)
Carcass dorsal height (mm)	0.06224 (0.0069)			0.04929 (0.0036)

Sum height dorsal section6_12 (mm)	0.05740 (0.0032)			-0.02137 (0.0305)
Sum height dorsal section2_13 (mm)	-0.03897 (0.0034)			0.01686 (0.0187)
Sum average height dorsal section 2_13	-0.03897 (0.0079)			-0.01965 (0.0009)
R^2	1.00	0.983	0.214	0.998

EE: Ether extract (kg), CP: Crude protein (kg), R^2: Determination coefficient.

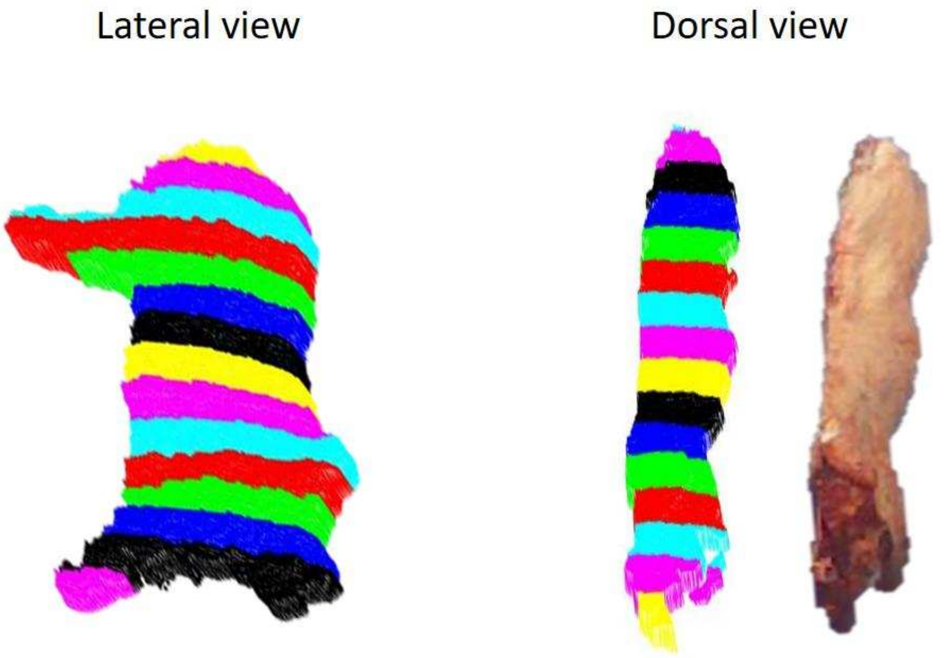

Figure 1: Fifteen carcass subdivisions for the determination of the area, volume, height section and average height of the sections.

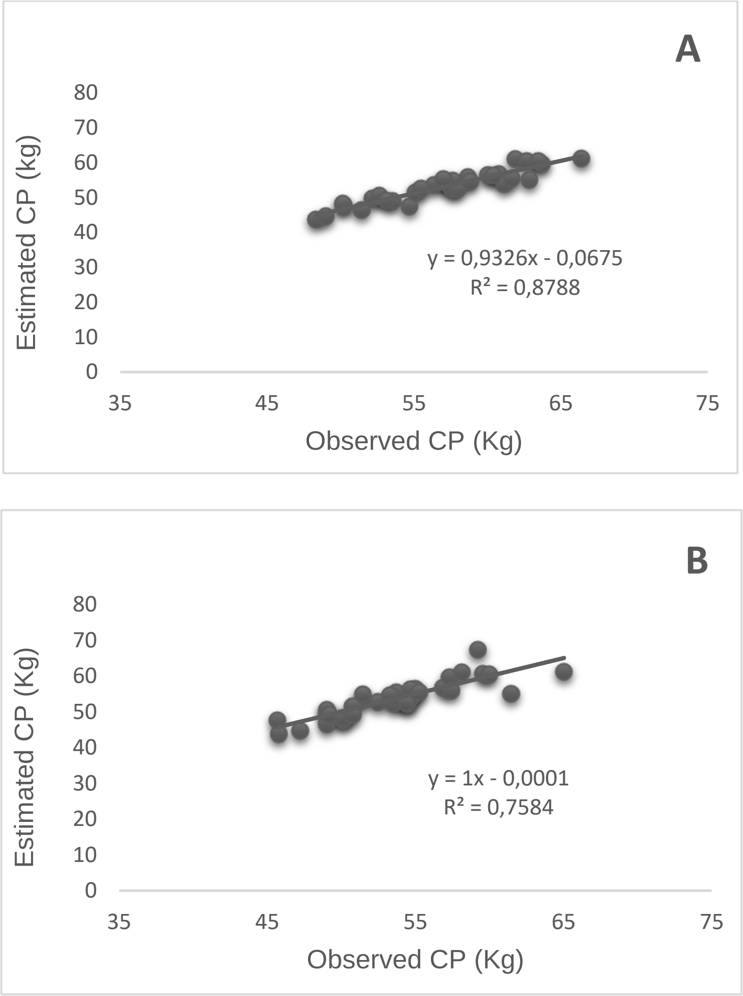

Figure 2: The relationship between crude protein CP (kg) observed and estimated by the simultaneous inclusion of area and volume parameters (A) and by traditional parameters (B).

General Conclusions

This research addressed the development of a segmentation methodology that allows the extraction of information regarding the animal body and carcass, and later the use of this information in prediction equations. The efficiency of a system for obtaining information by image analysis depends on aspects since capture to processing, being the quality of the images is an important factor in the process.

Considering the high costs to measure the weight and body composition of animals, biometric measurements of animal body and carcass using sensors and, posteriorly the image analysis, is an interesting alternative, easy to adopt and justifiable. In addition, the adoption of this new system would provide less animal manipulation thus, it can reduce stress and increase well-being. The correlations between the biometric measurements and the body composition of the animal, as well as the coefficients of determination indicate that the equations generated can be used to estimate the live weight and body composition of Nellore cattle. Considering the carcass characteristics, the use of images represents the promising alternative in the classification and grading of bovine carcasses. The equations generated from the biometric measurements obtained by image analysis allow to estimate the amount muscle, crude protein and ether extract in the carcasses. The system also allows to estimate the amounts of fat, although this is a very variable tissue in the carcass. Justifying the possible use of the system in slaughterhouses to perform the evaluation of the carcasses produced.

The results presented in this study are exclusive to Nellore cattle thus, new models have to be generated for using to other breeds, as the biometric characteristics will certainly defer between the different genetic groups.