THESIS

Breeding Objectives and Economic Indexes for Hereford, Braford and Aberdeen Angus cattle raised in Southern Brazil.

Rodrigo Fagundes da Costa

Pelotas, 2018

Rodrigo Fagundes da Costa

Breeding Objectives and Economic Indexes for Hereford, Braford and Aberdeen Angus cattle raised in Southern Brazil.

Thesis presented to the Postgraduate Program in Animal Science of the Federal University of Pelotas, as a partial requirement to obtain a Doctor in Sciences (area of knowledge: Animal breeding).

Advisor: PhD. Fernando Flores Cardoso

Co-Advisors: Dr. Marcos Jun-Iti Yokoo

Dra. Arione Augusti Boligon

Pelotas/RS, 2018

Universidade Federal de Pelotas / Sistema de Bibliotecas
Catalogação na Publicação

C837b Costa, Rodrigo Fagundes da

Objetivos de Seleção e Índices Econômicos para as raças Hereford, Braford e Aberdeen Angus Criadas no Sul do Brasil / Rodrigo Fagundes da Costa ; Fernando Flores Cardoso, orientador ; Marcos Jun-Iti Yokoo, Arione Augusti Boligon, coorientadores. — Pelotas, 2018.

120 f.

Tese (Doutorado) — Programa de Pós-Graduação em Zootecnia, Faculdade de Agronomia Eliseu Maciel, Universidade Federal de Pelotas, 2018.

1. Índice de carcaça. 2. Índice econômico. 3. Melhoramento genético animal. 4. Modelos bio-econômicos. 5. Resistência ao carrapato. I. Cardoso, Fernando Flores, orient. II. Yokoo, Marcos Jun-Iti, coorient. III. Boligon, Arione Augusti, coorient. IV. Título.

CDD : 636.2

Elaborada por Gabriela Machado Lopes CRB: 10/1842

Banca Examinadora:

Fernando Flores Cardoso
Veterinarian, PhD Researcher Embrapa Pecuária Sul

Marcos Jun – Iti Yokoo
Zootechnist, Dr. Researcher Embrapa Pecuária Sul

Arione Augusti Boligon
Zootechnist, Dra. Profesor UFPel.

Jose Braccini Neto
Zootechnist, Dr. Profesor UFRGS

Nelson José Laurino Dionello
Agronomist, Dr. Profesor PPGZ/UFPel

Acknowledgments

To the Federal University of Pelotas and to its Post Graduate Program in Animal Science, for the opportunity to carry out the studies.

To the Coordination for the Improvement of Higher Education Personnel (CAPES) for the provision of the scholarship during the doctorate (process 88882.156956/2017-01) and during the sandwich doctorate held in Australia (process 88881.136013/2016-01).

To Embrapa Pecuária Sul, for the opportunity offered the availability of physical, financial and human resources.

To all the colleagues of the Laboratory of Bioinformatics and Genomic Statistics (Labegen) for the privileged work environment provided.

I am grateful for the support of the Brazilian Hereford and Braford Association (ABHB) and the Beef Cattle Improvement Program (PROMEBO) for assistance in this work.

To the researcher Ph.D. Fernando Flores Cardoso, for guiding not only the work developed, but the way and the attitudes to be taken to achieve personal and professional fulfillment and to the researcher Dr. Marcos Jun-Iti Yokoo, for the co-advisor during the master's and doctor's degree, assisting both in the elaboration and in the resolution of the diverse questions that emerged during the elaboration of the present work.

To the researchers Ph.D. Michael MacNeil and Ph.D. Julius van der Werf for accepting to participate in this project and for having contributed so much to the elevation of the quality of the present work, and of the ones that are still to come.

To my family for the support granted during my studies and in all moments.

To my fiancée, Candida, for all the moments we spent together and the unconditional support given over all these years.

To God for life, and all opportunities granted.

Resumo

COSTA, Rodrigo Fagundes. **Objetivos de Seleção e Índices Econômicos para as raças Hereford, Braford e Aberdeen Angus Criadas no Sul do Brasil**. 2018. Tese (Doutorado) – Programa de Pós-Graduação em Zootecnia. Universidade Federal de Pelotas, Pelotas.

Resumo: A definição dos objetivos de seleção (**BG**) deve ser o primeiro passo na elaboração de um programa de melhoramento genético, uma vez que essa definição guiará as direções a serem tomadas no programa de avaliação genética. A definição correta é determinante para o melhoramento genético efetivo, onde os BG devem ser ponderados de acordo com sua relevância econômica, dada por seus valores econômicos e pelo tempo e frequência que serão expressos nas próximas gerações. Os objetivos deste estudo foram desenvolver um modelo bioeconômico para um típico sistema de produção de ciclo completo no sul do Brasil baseado nas raças Hereford ou Braford, considerando características de sobrevivência/adaptação, fertilidade/longevidade, carcaça, e de crescimento, que permita definir os objetivos de seleção e estimar seus respectivos valores econômicos, para então, desenvolver um índice econômicos de seleção que maximize a lucratrividade, combinando as características de sobrevivência/adaptação (resistência ao carrapato), reprodução (habilidade de permanência), e características de carcaça e crescimento (peso ao desmame direto e materno, peso maduro das vacas, área de olho de lombo e gordura subcutânea) em sistemas típicos de produção de bovinos de corte em ciclo completo no Sul do Brasil, utilizando as raças Hereford ou Braford; e identificar os objetivos de seleção através de um modelo bioeconômico relacionado às características de carcaça para melhorar a qualidade da carcaça de animais Aberdeen Angus participantes do Programa de Avaliação Genética Promebo. Os objetivos de seleção e seus valores econômicos utilizados nos três índices desenvolvidos foram estimados por meio de modelos bioeconômicos. No sistema de produção típico de ciclo completo do sul do Brasil, as características que influenciaram o lucro foram peso ao desmame direto e materno, contagem de carrapatos, peso maduro das vacas, gordura subcutânea, área de olho de lombo, ganho pós-desmame, ganho final e habilidade de permanência. A adoção dos índices econômicos desenvolvidos para o Programa PampaPlus permitirá aumentar a fertilidade dos animais e a adaptação do rebanho ao parasitismo de carrapatos, aumentando a rentabilidade dos sistemas produtivos do sul do Brasil, que historicamente apresentam sérios problemas relacionados à baixa taxa reprodutiva e com parasitismo por carrapato. A importância relativa e a resposta de seleção dos objetivos de seleção para as raças Hereford e Braford foram semelhantes, indicando que os mesmos critérios e um índice econômico com pesos similares podem ser usados para ambas as raças no programa de melhoramento PampaPlus. O modelo bioeconômico de carcaça desenvolvido para o Programa de Avaliação Genética do Promebo foi capaz de identificar quais características biológicas relacionadas às carcaças dos animais deveriam ser melhoradas para alcançar maior lucratividade, sendo elas o peso final dos animais, a área de olho de lombo, a gordura subcutânea e a porcentagem de gordura intramuscular. O índice econômico de carcaça deverá ser adotado pelo Programa de Avaliação Genética Promebo, pois a nova ponderação dos critérios de seleção resultará em maior retorno econômico aos sistemas de produção que utilizam a raça Aberdeen Angus quando comparados aos índices empíricos previamente utilizados neste programa de avaliação genética.

Palavras-chaves – Índice de carcaça, índice econômico, Melhoramento genético animal, modelos bio-econômicos, resistência ao carrapato.

Abstract

COSTA, Rodrigo Fagundes. **Breeding Objectives and Economic Indexes for Hereford, Braford and Aberdeen Angus Breed raised in Southern Brazil**. 2018. Thesis (Doctor) – Post Graduation Program in Zootechny. Federal University of Pelotas, Pelotas.

Abstract: The definition of the breeding goals (**BG**) should be the first step in the elaboration of a genetic improvement program, since this definition will guide the directions that the genetic evaluation program will take. The correct definition is determinant for effective genetic improvement, where the BG must be weighted according to their economic relevance given by their economic values and for the time and frequency that they will be expressed on the next generations. The aims of this study were to develop a bioeconomic model for a typical beef cattle full cycle production system in Southern Brazil using Hereford or Braford breeds considering survival/adaptation, fertility/longevity, carcass and growth traits, that allows define breeding goals and estimating economic values to develop an economic selection index that maximize the profit and combines survival/adaptation (tick resistance), reproduction (stayability) and carcass and growth traits (direct and maternal weaning weight, mature cow weight, ribeye muscle area and subcutaneous fat) in a typical full cycle beef cattle production systems in Southern Brazil using Hereford or Braford breeds; and to identify the breeding goals through a bio-economic model related to carcass traits to improve the carcass quality of the Aberdeen Angus herds participating in the Promebo Genetic Evaluation Program. The breeding goals and its economic values used in the three indexes developed were estimated through bioeconomic models. In the full cycle production system of Southern Brazil the traits that affected the profit were weaning weight direct and maternal, tick count, mature cow weight, subcutaneous backfat, ribeye muscle area, post weaning gain, final gain and stayability. Adoption of the developed economic indexes in PampaPlus Program will allow to increase the fertility of the animals and the adaptation of the herd to tick parasitism, increasing the profitability of the productive systems of southern Brazil, which historically have had serious problems related to the low reproductive rates and with tick parasitism. The relative importance and selection response of the breeding goals for Hereford and Braford were similar, indicating that the same criteria and an economic index with similar weights can be used for both breeds in PampaPlus breeding program. The developed carcass bioeconomic model for Promebo Genetic Evaluation Program was able to identify which biological traits related to the carcasses of the animals should be improved to achieve greater profitability, being them the final weight of the animals, ribeye muscle area, subcutaneous fat and percentage of intramuscular fat. The carcass economic index was adopted by the Promebo Genetic Evaluation Program and the new weighting of the selection criteria will result in a higher economic return to the production systems that use the Aberdeen Angus breed when compared to the empirical indexes previously used in this genetic evaluation program.

Keywords - animal breeding, bioeconomic models, carcass index, economic index, tick resistance.

Table of Contents

List of Figures

List of tables

217

1. Introduction

Brazil has had a significant position in world beef trade, with the largest commercial beef herd in the world in 2016, comprised of 219.1 million heads (ABIEC, 2017). This is due to its low cost of production and its extensive area intended for beef cattle.

However, to achieve greater competitiveness and new markets, some aspects still need to be improved, such as the health status of the Brazilian herd, the management in the farms and mainly, the productive ability of the animals.

Animal production can be increased by altering environmental conditions such as management, nutrition, and sanity, or by genetic improvement, which occurs more slowly but cumulatively and permanently across generations when are identified and reproduced superior animals with traits of economic importance, increasing the herd frequency of favorable genes (Cardellino and Rovira, 1987; Lôbo et al., 1999).

In spite of the recognition of their contributions to national livestock breeding, the existing animal breeding programs present an evident deficiency in the characterization of the breeding goals, that is, determining the direction that selection must follow in order to maximize the economic return of the activity (Formigoni, 2002).

The revenues and costs are directly related to the phenotype of animals, which is the combination of genotype and environment effects (P=G + E) (Falconer, 1981).

Over the years, the genetic evaluation programs have based their selection criteria on traits of ponderal performance neglecting those related to reproductive and adaptation to the environment, even though these are important aspects in the evaluation of the productive systems, presenting more economical return than the other growth and carcass traits (Newman et al. (1992); Macneil et al. (1994); Phocas et al. (1998).

The permanent objective of a beef farmer should be to produce meat, using sustainable natural and financial resources, such as the environment (e.g., land, air, water, fauna), work (e.g., on the farm, feedlot, and industry), and animal welfare, and these factor expand the range of traits to be considered in breeding programs, making selection decisions increasingly complex (Garrick & Golden, 2009).

Thus, the farmer should be concerned with selecting animals for several traits, taking into account their economic contribution to the productive system, and the genetic relationship to the other characteristics to be selected, and for this, the most efficient way is the selection through indices, which allows the selection of multiple traits at the same time (Hazel, 1943).

For a long time, selection through indexes was performed using empirical weights for selection criteria that is, without prior identification of the characteristics that have economic importance, and the actual financial contribution that each selection objective had in the index used. This has limited the wide use of selection indexes by producers (Golden et al., 2000).

Currently, many genetic improvement programs have developed selection indexes with weights based on the economic values of each breeding goal, as ANCP Breeding Program, that giving greater focus on traits that maximize the economic return of the activity (Lôbo et al. 2018).

In this way, the definition of the breeding goals should be the first step in the elaboration of a genetic improvement program (Urioste et al., 2000), since this definition will guide the directions that the genetic evaluation program will take , that is, what productive characteristics should be selected (Garrick & Golden, 2009).

These breeding goals should reflect the economic and production conditions in the environments in which the animals are raised. The vast environmental management, and commercialization variability of beef cattle production, makes it almost impossible to define a general selection objective, even for a single breed (Wolfová et al., 2005).

For this purpose, the use of bio-economic models that seek to reproduce the conditions found in the field have been adopted for the correct definition of breeding goals. Such modeling allows to simulate the environmental and market variations, being the most efficient way to calculate the economic values of each breeding goal (Pravia, 2010).

2. Hypothesis

Through the phenotypic data of the Hereford and Braford cattle population of the PampaPlus Genetic Evaluation Program and local farm survey data, it is possible to develop bio-economic models to identify the breeding goals for a full-cycle production system typical of southern Brazil.

The use of an economic selection index for the PampaPlus Genetic Evaluation Program will bring different weights compared the current empirical selection indices used in this program resulting in greater economic benefit.

Through the phenotypic data of the Aberdeen Angus cattle population of the Promebo Genetic Evaluation Program and beef cattle slaughter market data, it is possible to develop bio-economic models that allow identifying the breeding goals that have an impact on the value of carcasses destined to premium quality markets in Southern Brazil.

The substitution of the empirical index used in the Promebo Genetic Evaluation Program by an economic carcass index allows to increase the quality of the animal carcasses and consequently increase the profitability of farms that use the genetics of animals derived from this selection index.

3. Objectives

The present study was developed with the objective of developing bio-economic models that make it possible to identify the biological traits that impact the profitability of productive systems and to estimate their respective economic values, and later to develop weighted selection indices in the most profitable manner, according to the following specific objectives:

1) Develop a new bio-economic models for a full-cycle production system herd-based of Hereford and Braford breeds, that allow identify the biological traits that affect the profitability of the system and estimate its economic values;

2) Develop economic indexes to be implemented in the PampaPlus Genetic Evaluation Program, which weigh the breeding goals in the most profitable way;

3) To develop a bio-economic models that allow estimating economic values for carcass traits of Aberdeen Angus animals;

4) Develop an economic carcass index to be implemented in the Promebo Genetic Evaluation Program, which weigh the breeding goals in the most profitable way.

/

4. Literature review

4.1 Selection Index Theory

Most breeders of Brazilian herds have commonly adopted for many years as the main method of selection the choice of animals through one or few traits, usually growth traits. Garrick (2005) which can be explained by the rapid response to the selection when working with only one trait, ignoring the others. However, considering only one trait is not an adequate criterion to represent the economic merit of an animal, since the selection based on it can lead to the development of economically unsatisfactory animals, either by not considering other traits of economic importance or by negative correlated response on other characteristics that were not considered as a breeding goal (Enns, 2007).

In other cases, the breeders select through indexes, taking into account several traits of economic importance, but does it in a subjective way, that is, without a good scientific support (Resende et al., 1990).

Selection indices have been proposed in plant and animal breeding programs as the main way of selecting multiple quantitative traits simultaneously, first described by Smith (1936) and later by Hazel (1943) that introduced the approach to help producers improve more than one trait at the same time. Afterward, the approach was named as a selection index.

The theory of selection indexes is based on the fact that each individual has a global genetic value that is peculiar to him (Hazel & Lush 1942). Hazel defined the concept as aggregate genotype: the sum of the product of the genetic value and the economic value for several traits, Aggregate genotypes are a way to amalgamate information for different traits into a single value that represents the breeding objective. The equation for aggregate genotype (H) is defined as follows:

$$H = a_i G_i + \cdots + a_n G_n \tag{4.1}$$

where H is aggregate genotypes, a represent economic value, G is genetic value and n is the number of traits in the objective. In animal breeding, the breeding values (EBV) are usually used as "G" value in the equation. Then the equation becomes:

$$H = a_i EBV_i + \cdots + a_n EBV_n \tag{4.2}$$

Statistical methods and computation tools are used to calculate the EBV. In Hazel's articles, selection index defined as the sum of product of every traits' record value and coefficient as follows:

$$I = \sum_{i=1}^{n} b_i X_i \tag{4.3}$$

where I represents index, b are index weights and X is the information (phenotype, EBV, etc) used for selection. Equation (4.1) includes traits in breeding objective, while Equation (4.3) includes traits in the selection criteria. In the two equations (4.1, 4.3), the traits can be the same, or they can be different depending on available information. However, in most situations, the economically important traits are difficult to record, thus the breeding objectives and selection criteria are not the same (Dekkers et al., 2004).

The correlation between the phenotypic value, I, and the genetic value, H, corresponds to (Lin 1978):

$$r(I, H) = \frac{COV(I,H)}{\sigma_I \times \sigma_H} \tag{4.4}$$

where COV (I, H) is the covariance between the phenotypic value and the genetic value and, σ_I^2 and σ_H^2 are the variance of these respective values. The b_i coefficients must be determined so that the correlation *r*(I, H) would be maximal.

The index-based selection, considering several traits in relation to other methods is considered the most efficient methodology for the improvement of multiple characteristics simultaneously, where the superiority of index selection grows with the number of characteristics involved, and when the relative importance of traits become similar, has been amply demonstrated (Hazel & Lush 1942; Bourdon,1998). This recognized superiority has made the great majority of Brazilian beef breeding programs nowadays adopt indexes as the main selection tool.

4.2 Breeding Goals

For the definition of the breeding goals, it is necessary to identify the characteristics that must be improved genetically due to its direct impact on the economic benefit of the production system considered. These traits may be the pregnancy rate, weaning weight, growth, carcass weight, etc., and their relative importance, given by its economic value, will depend on the production system and price relationships at the date considered (Soares de Lima et al., 2011).

The traits that must be included as breeding goals can be related in the following categories: 1) survival/ adaptation; 2) fertility/longevity; 3) food consumption; 4) products and 5) non-food costs. It is possible to adopt as a rule that the characters that affect survival are the most economically important since the death of cows and calves represents totally lost production units that had production costs (Bourdon & Golden, 2000).

Fertility and longevity traits come next because they influence the number of units produced and the proportion of units in the different product categories. Increased fertility, for example, would result in increased sales of calves and a reduced rate of cull cows. The next traits in relative importance would be those related to the consumption of food, as mature size and residual feed intake, and a final product, as carcass traits. Finally, there would be traits not related to feeding costs (Bourdon & Golden, 2000).

In a general way, we can classify the breeding goals into growth, reproductive, survival/adaptation and carcass traits.

4.3 Selection criteria

It is important to distinguish between the traits included in the breeding goals and the traits used as selection criteria. In the first case, the traits that are economically important, that is, related to the farms' revenues and expenses should appear. In the selection criteria, they should preferably be those that can be easily measured with low cost and earlier in the life of the animals, in addition to presenting medium to high heritability estimates, contribute and are correlated to the breeding goals (Queiroz et al. , 2005).

Economically important, but difficult to evaluate, expensive or problematic traits can be replaced in the index by indicator characters to which they are genetically correlated (Brigham, 2011).

After defining the objectives, the breeding goals and/or the selection criteria will be chosen, from which the predictions of the breeding values of the individuals will be made. The characteristics considered in the breeding goals are the basis for the formulation of the profit function from which economic weights are derived (Vercesi Filho, 1998).

The following are the main sets of traits considered economically important within beef cattle production systems:

4.3.1 Growth Traits

Due to the ease of measurement, growth characteristics were the first to be used in genetic breeding programs (Pravia, 2000). Usually, these characteristics are related to the weight at certain moments in the life of the animals, such as at birth, weaning and eighteen months old and mature cow weight (Teixeira, 2013).

The weight of the animal at birth is extremely important information, as it portrays the prenatal growth of the animal, being the earliest information about the individual. It is partly determined by the individual's genetic ability for prenatal growth and maternal intrauterine environment (Newman et al., 1987).

The use of this measure in breeding programs is important mainly for European breeds, aiming to reduce or eliminate problems with dystocia, although it has a positive correlation with postnatal growth (Bergmann, 1998).

Weaning weight measurement (WW) is used to identify the growth potential of the animal, together with the cow's maternal ability (Graser & Tier, 1988), and should be adjusted for the standard age of 205 days in order to the comparison between group members.

In calf-crop production systems, WW is determinant on the profitability, since it is precisely at this moment that the animals are marketed, where the value paid per calf is per kilogram of live weight. In general, WW is a trait that presents an intermediate but positive economic value, justifying the selection for this characteristic (Laske et al., 2012).

According to Rosa et al. (2013), the weight at eighteen months is a measure that reflects the individual's ability to gain weight in the post-weaning period, with less residual maternal effect, thus expressing the true quality of the animal in growing and gaining weight. However, according to Brumatti et al. (2011), this weight presents higher economic value than WW and inferior economic value to the reproductive traits.

Teixeira (2013) found a direct heritability of 0.13 for the weight at eighteen months of the population evaluated by PampaPlus, indicating that there was moderate genetic variability to adopt this characteristic as a selection criteria.

Mature cow weight (MCW) is highly important in production systems and should be considered in genetic breeding programs, since when it is increased, it causes several impacts on the herd, such as the increase in carcass weight, which is positive, since it increases the revenue of the system. However, when increasing MCW, herd feeding requirements also increase, resulting in an increase in the cost of production (Bullock et al., 1993; Jorge Jr et al., 2007; Laske et al., 2012).

For Caprio (2000), the increase of the weight of the females is not accompanied, in the same proportion, by the increase in the weight of the calves, suggesting economic losses for cows with large body size.

Ortiz Peña et al. (2008) considered the maintenance cost as a function of mature weight and estimated dry matter consumption and included this component in a productive efficiency index, aiming to increase productivity without increasing costs and without a possible negative correlated fertility response of cows due to the increase in mature weight.

Exton et al. (2000) and Euclides Filho (2001) affirm that there is a positive correlation between mature cow size and feed consumption, and Lanna (1997) mentions that if food resources are inadequate (in quantity and quality), smaller individuals have productive advantages over larger ones, since, at lower nutritional levels, smaller cows present a higher rate of conception, compensating for the lower weight of the weaned calf.

4.3.2 Fertility and longevity Traits

Effective reproduction can be defined as the ability for one generation to produce enough healthy offspring capable of perpetuating the species (Foote, 2003). In livestock species, this need is also combined with production of a product for human use/consumption. In the case of beef cattle, sufficient levels of reproduction can maintain herd size, but there is still a need for improved reproductive efficiency (Boldt, 2017).

The performance of animals within the system is fundamental to maximize meat production, making birth the most important reproductive event in a production system by the generation of a new offspring (Neves et al., 1999).

Currently a beef female is considered reproductively efficient when more than 50 to 60% of cattle conceive each service is achieved (Parkinson, 2004) and beef females at the first calve are two years olds and subsequently maintain a 365-d calving interval each successive year. Failing to maintain this interval and then to rebreed is a major cause for culling decisions in beef cattle systems (Snelling, 1994). While in most cow/calf systems, primary emphasis is put on management practices to improve reproduction, little selection pressure has been applied to the measures of reproductive performance (Boldt, 2017).

An improved reproductive rate provides more replacements to choose from which can boost selection intensity of replacements and in turn increase rate of genetic change.

For many years most Brazilian genetic evaluation programs use only the scrotal circumference as selection criteria for reproductive purposes, as indicative of sexual precocity, because it is easily measured, potentially associated with fertility, and would have favorable genetic correlations with other reproductive and growth traits (McCosker et al., 1990; Bergmann, 1997; Gressler et al., 1998).

The effectiveness of the scrotal circumference as the only reproductive criteria is questionable. Studies such as Evans et al. (1999) and Doyle et al. (2000) did not identify a relevant genetic correlation between scrotal circumference and pregnancy probability in the Hereford and Angus breeds, respectively.

Although reproductive traits have a high economic impact, their inclusion within breeding programs has been restricted due to the difficulty of their registration, low heritability associated with reproductive performance traits (<0.30), to the low number of phenotypes collected because several of these characteristics are restricted by sex, and finally to the time needed to collect phenotypes, since in cases such as stayability, for example, the collection of this phenotype can take up to eight years (Koots et al., 1994; Cammack et al., 2009).

Stayability is defined as the period the cow produces in a herd, which is a longevity trait. Another definition of stayability is the probability a cow will remain in the herd until six years of age given she first calved as a two year old (Brigham et al., 2006). The stayability record is binary observation for dams enough to have had the required number of calves, coded as 1 (success) and 0 (failure). Because the dam needs to be old enough to have complete records, other indicators can be utilized (days to calving, calving interval, etc.) which are correlated with stayability (Golden et al., 2000).

4.3.3 Survival/adaptation Traits

The growth traits were the first to be collected and selected in the genetic evaluation programs, due to their ease of measurement. However, several authors reported that the selection just for growth and productive traits for many years could reflect negatively on reproduction and survival traits, as related in pig (Chen et al. 2003; Arango et al. 2005) and dairy cattle (Berry et al., 2014; Carthy et al. 2016).

Animals with good adaptation to the environment, resistant to diseases, insects, parasites and without problems of calving are easier to survive in regions of variable climate and/or poor pasture. According to Mezzadri (2007), the rusticity acquired over the years may provide cattle with less food requirement and greater resistance to parasites, in addition to increasing the longevity of the breeders.

According to Grisi et al. (2014) the main parasite that causes major economic damages is the gastrointestinal nematodes followed by ticks (Boophilus microplus), horn fly (Haematobia irritans), Dermatobia hominis larvae (Dermatobia hominis), myiasis (Cochliomyia hominivorax) and stable fly (Stomoxys calcitrans).

These authors reported that the economic losses resulting from infestations by gastrointestinal nematodes represent in Brazil an impact of $ 7.11 billion per year. In this loss are included expenses with chemical controls, labor, facilities, equipment, weight losses, and milk.

The method described by Gordon & Whitlock (1939) to evaluate the degree of gastrointestinal infestation and sanity of the herd, a laboratory technique called egg count per gram of feces, is used. According to Coppieters et al. (2009), the heritability for egg numbers of nematodes per gram of feces in dairy cows is 0.21, being considered sufficient for genetic selection.

Several animal health problems observed in cattle production in tropical and subtropical regions are directly and indirectly caused by the Rhipicephalus (Boophilus) microplus tick (Cardoso, 2015). Tick can affect directly the chemical costs, average daily gain, mainly in younger animal categories, could reduce the growth, weight losses and eventually animal deaths (Jonsson, 2006).

Annually estimated beef and dairy production losses in Brazil due to ticks could potentially reach over 3 billion dollars (Grisi et al., 2014).

Thus the selection against tick using the tick count trait is an option to select animals more resistant to this parasite. Cardoso et al. (2015) observe moderately accuracy values for genomic predictions for tick load in Braford cattle, indicating that genomic predictions could be used as a practical tool to improve genetic resistance to ticks.

4.3.4 Carcass Traits

Nowadays the expansion of the beef market are closely associated with meat quality, mainly the characteristics tenderness, which is highly valued by consumers (Paz & Luchiari Filho, 2000; Magnabosco et al., 2006).

In this sense, the emerging demand for organoleptic quality and food safety of beef has modified the meat market, where cuts of meat presented in trademarks that have proven origin and come from animals with racial standard recognized for having different quality, has received added value, causing slaughterhouses to establish compliance specification standards in the purchase of the animals, attributing bonuses to the producers (Ferraz & Felício, 2010; Barcellos & Oaigen, 2014).

Aiming to occupy this growing market niche, several breeders' associations from many countries have implemented genetic evaluation programs that include the genetic improvement of carcass traits (BIF, 2002), searching for earlier and heavier animals with higher yields of carcass, greater marbling, and with sufficient subcutaneous fat finishing to preserve meat during the postmortem period (Magnabosco et al. 2006).

Selection through ultrasound measurements can result in predictable genetic improvement for carcass characteristics. The ribeye muscle area (REA), measured through the technique of ultrasound on the muscle longissimus dorsi, is an indicator trait of the carcass yield and is associated with the final weight and the carcass weight (Moser et al., 1998).

The subcutaneous fat (FAT) is a selection criteria important to measure and improve the carcass fat cover, that is related to the quality of the carcass. Usually, this measure can be measured between the 12th-13th rib, at a point three-fourths of the distance from the medial end of the longissimus dorsi muscle or above the rump, as is a fat depot that is highly related to 12th-13th rib fat thickness (genetic correlation exceeding 0.70). This measurement can be beneficial when scanning very lean animals such as yearling bulls and can be used to improve the overall accuracy of external fat estimation (BIF, 2002)

The percentage of intramuscular fat (IMF), also measured by ultrasound in this muscle, is highly correlated with the amount of intramuscular fat in the carcass (Moser et al., 1998).

The economic values of these traits are dependent on the preference of the customer and accordingly to market.

4.4 Derive economic weight

With multiple trait selection, economic weights provides direction to the selection program (MacNeil et al., 1997). Finding the economic weight of each trait is the first step in framing the ideal toward which the breeder is to strive (Hazel & Lush, 1942). Two parts are involved with cumulative gene expression: marginal economic value and discounted gene expression (DGEs) (Ponzoni & Newman, 1989). The DGE are used to adjust economic values, and the economic weight is the product of economic value and DGE. Thus, in order to obtain economic weight, economic value and DGE are first required (Zeng, 2013).

4.5 Economic values

The economic values are necessary to ensure that the emphasis of selection is proportional to the economic importance of each of the characteristics in a breeding goal, and may vary in importance according to the productive system (Amer et al., 2001).

According to Zeng (2013), three ways are usually used to estimate economic value: The first is using regression of profit on related traits (Crews Jr et al., 2005). Second, is building a profit equation based on the production system and using partial derivatives of the profit equation to get the economic value (Ponzoni & Newman, 1989; Van Arendonk, 1991; MacNeil et al., 1994). Third, simulate the production system and combine the economic and biological information to build a bio-economic profit equation and then evaluate the impact of change in each production variable on profitability (Van Arendonk, 1985; Koots & Gibson, 1998; Tess & Kolstad, 2000). The simple profit equation approach may be adequate for simple production system while more complex system can be described by bio-economic model (Kluyts et al., 2004).

To estimates the economic values for complex production systems, first, a economic model was developed and a base profit calculated. After this, each breeding goal was increased in one unit without changing the other traits in separate simulations. The differences between profits observed in these latter simulations and profit from the baseline simulation divided by the number of dams were the economic value of the respective trait (MacNeil et al., 1994).

4.6 Bio-economic models

The determination of breeding goals the first part of the process requires that a bio-economic model must be developed that describes the productive process (Ponzoni & Newman, 1989; Cardellino, 1995).

According to Jorge Júnior et al. (2006), modeling is the main tool used to derive the economic values of traits of interest through the application of profit equations or bioeconomic models. Since these models are based on joint analyzes between the economic and productive aspects, relating costs, revenues, biological data and the management carried out in the farms and have been used to obtain economic values in production systems of beef cattle.

The first step of development of a bio-economic model is describing the production process in each situation of interest consists of the following stages (Ponzoni, 1988): 1) Specify the production system, herd production, and market; 2) Take inventory of income and expenses of the activity; 2) Determine the breeding goals, that is, the biological characteristics that constitute the revenues and expenses and therefore affect the profit of the system; 3) Derive the relative economic values of the traits identified in item 2).

However, according to Dijkhuizen et al. (1997), in the development of a bio-economic model, it is difficult to get complete availability of necessary information. Thus, the complexity of each model depends to a large extent on the availability and detail of the information collected.

Phocas et al. (1998) reported that it is difficult to compare the economic values of different breed and production systems, since the breeding goals may differ considerably according to the circumstances of production, where these circumstances can be defined as the set of factors that characterize each farm, which can cause significant differences in costs and revenues across production systems (Groen, 1989). Therefore, it should be emphasized that each bio-economic model represents the production system for which it was developed, not necessarily being useful to any other production system without adaptations (Campos, 2013).

In this way, as many factors influence the economy of beef cattle production, for the estimation of economic values for well-defined breeding goals, it is necessary to develop a specific model for each breed and production system, considering all the elements that affect the performance of farms, be they genetics used, nutrition and economic management (Jones et al., 2004).

4.7 Discounted genetic expressions

When a breeding program decides directs the selection for a group of traits, using a selection index, it is expected that some traits will express less than others because some traits will only manifest itself at the end of the animal's life cycle, as carcass weight, for example, and others will manifest in the beginning of life cycle, as birth weight or weaning weight, so the time is relevant for the decision of how much weight should be given in the selection process (Gibson & Wilton, 1998).

On this way, the discounted expressions models could adjust the economic values through coefficients calculated that take into account the frequency and the time that a trait needs to be expressed, considering animal life cycle, as selecting traits that resulting in more rapid changes in the profit could give more economic benefit compared to traits that take longer to be expressed (McClintock & Cunningham, 1974; Borg, 2004).

The principle of discounted gene flow has historically been used in animal breeding and genetic fields (Ponzoni & Newman, 1989; Amer, 1999; Jiang et al., 1999; Berry et al., 2006). Ponzoni and Newman (1989) indicated that since the discounted gene flow method takes into account both the frequency and the time of expression of traits, it should be the preferred method used in the estimation of economic values for beef cattle.

4.8 Economic Indexes using expected progeny differences (EPD)

The concept of combining genetic evaluation and economics is not new, as it was first introduced by Hazel & Lush (1942) and Hazel (1943), however, for a long time was rarely used by farmers and their genetic evaluation programs, which only provided the results of the genetic evaluation to the producers and allowed each individual farmer to weigh each trait in the way that they believe it was the best (Bourdon, 1998).

However, in the last decade, the development and implementation of economic indexes have become a trend, since they allow producers to scale the economic contribution of the use of each sire on their farms.

The economic index (I) could be applied using phenotypic or genetic information and this differ in the information used to calculate the b.

MacNeil et al. (1997) demonstrated how to calculate the vector (b) of weighting coefficients for each source of information in the index using the equation:

$$b = P^{-1}Gv \tag{4.4}$$

Where: **P** is a n x n matrix of the phenotypic (co)variances among the n traits measured and available as selection criteria, **G** is a n x m matrix of the genetic (co)variances among the n selection criteria and m objective traits, and **v** is a m x 1 vector of economic values for objective traits.

Bourdon (1998) pointed out two serious drawbacks in applying index weighting factors to phenotypic values for an individual. First, this method lacks accuracy because it does not incorporate information on relatives. Second, it is biased because genetic differences among contemporary groups are not accounted for.

These issues can be overcome by using genetic predictions derived from best linear unbiased prediction (BLUP) instead of individual phenotypic performance (Ochsner, 2016). Henderson (1963) demonstrated that if genetic predictions derived from multitrait BLUP are available for all traits in the breeding objective, genetic predictions can simply be substituted for true breeding values when calculating the aggregate genotype.

Schneeberger et al. (1992) presented the models needed to compute index weights for the more likely case in which traits in the breeding goal differ from those for which genetic predictions are available. The equation to estimate index coefficients to be applied to EPD is:

$$\mathbf{b} = \mathbf{G}_{11}^{-1} \times \mathbf{G}_{12} \times \mathbf{v} \tag{4.5}$$

Where: $\mathbf{G}_{11}^{-1}$ is the inverse of genetic (co)variance matrix between the selection criteria in the indexes, $\mathbf{G}_{12}$ is the genetic covariance matrix between the selection criteria and breeding goals, and $\mathbf{v}$ is the vector of economic values for the breeding goals.

4.9 Literature Cited

Amer, P. 1999. Economic accounting of numbers of expressions and delays in sheep genetic improvement. New Zealand Journal of Agricultural Research 42(3): 325-336.

Amer, P. R., Simm, G., Keane, M. G., Diskin, M. G., and Wickham, B. W. 2001. Breeding objectives for beef cattle in Ireland. Livest. Production Sci. 67 223–239.

Arango, J., I. Misztal, S. Tsuruta, M. Culbertson, and W. Herring. 2005. Threshold-linear estimation of genetic parameters for farrowing mortality, litter size, and test performance of Large White sows. J. Anim. Sci. 83:499–506.

Barcellos, J. O. J., & Oaigen, R. P. 2014. Cadeia produtiva da carne bovina e os sistemas de produção na bovinocultura de corte. In: OAIGEN, R. P. (Coord.). Gestão na bovinocultura de corte. Guaíba: Agrolivros. P. 21-43.

Bergmann, J. A. G., Quirino, C. R., Vale Filho, V. R., Andrade, V. J., and Fonseca, C. G. 1997. Herdabilidades e correlações genéticas entre medições testiculares e características espermáticas em touros Nelore. Arch. Latinoam. Prod. Anim., v.5, supl. 1, p. 473-475.

Bergmann, J. A. G. 1998. Indicadores de precocidade sexual em bovinos de corte. In: Congresso Brasileiro das Raças Zebuínas,3; 1998, Uberaba, Anais do... Uberaba, p.145-155.

Berry, D., F. Madalena, A. Cromie and P. Amer. 2006. Cumulative discounted expressions of dairy and beef traits in cattle production systems. Livestock Science 99(2): 159-174.

Berry, D. P., & R. D. Evans. 2014. Genetics of reproductive performance in seasonal calving beef cows and its association with performance traits. J. Anim. Sci. 92:1412–1422.

BIF, 2002. Guidelines for Uniform Beef Improvement Program, Beef Improvement Federation (BIF) Georgia.

Boldt, R. J. 2017. Genetic Parameters for Fertility and Production Traits in Red Angus Cattle. Master Diss. Colorado State University,Fort Collins, Colorado.

Borg, R. C. 2004. Developing breeding objectives for Targhee Sheep. Tesis Masters of Science. Virginia Polytechnic Institute and State University. 80 p.

Bourdon, R. & Golden, B. 2000. EPD's and economics: Determining the relative importance of traits. Available in: http://ansci.colostate.edu/ (10/10/2000).

Bourdon, R. M. 1998. Shortcomings of current genetic evaluation systems. Journal of Animal Science, v.76, p.2308-2323.

Brigham, B., S. Speidel and R. Enns. 2006. Alternative Definitions of Stayability. 2005–2006 Beef Improvement Federation Board of Directors: 75.

Brigham, B. 2011. Selection tools for optimal genetic and economic improvement. In: Proceedings Beef Improvement Federation, 43; 2011, Bonzeman. Proceedings… Bonzeman: BIF, p. 144-162.

Brumatti, R. C., Ferraz, J. B. S., Eler, J. P., and Formigonni, I. B. 2011. Desenvolvimento de índice de seleção em gado corte sob o enfoque de um modelo bioeconômico. Archivos de Zootecnia. vol.60 no.230.

Bullock, K. D., Bertrand, J. K., and Benysherk, L. L. 1993. Genetic and environmental parameters for mature weight and other growth measures in Polled Hereford cattle. Journal of Animal Science, v.71, n.7, p.1737-1741.

Cammack, K.M., M.G. Thomas, and R.M. Enns. 2009. Review: reproductive traits and their heritabilities in beef cattle. Prof. Anim. Sci. 25: 517-528.

Campos, G. S. 2013. Modelo bioeconômico e índices de seleção em bovinos da raça Aberdeen Angus. Master Diss. Faculdade de Agronomia, Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, Brasil (51 p.).

Caprio, A. O. 2000. PAINT - Programa de avaliação e identificação de novos touros. In: Simpósio Pecuária 2000 – Perspectivas Para o III Milênio. Pirassunpiunga. Anais do... Pirassununga: FZEA/USP.

Cardellino, R. A. 1995. Mejora genetica de bovinos de carne en condiciones extensivas. Archivos de Zootecnia. v.44, p.123-136.

Carthy, T. R., D. P. Ryan, A. M. Fitzgerald, R. D. Evans, and D. P. Berry. 2016. Genetic relationships between detailed reproductive traits and performance traits in Holstein-Friesian dairy cattle. J. Dairy Sci. 99: 1286-1297.

Cardoso, F. F., C. C. G. Gomes, B. P. Sollero, M. M. Oliveira, V. M. Roso, M. L. Piccoli, R. H. Higa, M. J. Yokoo, A. R. Caetano, and I. Aguilar. 2015. Genomic prediction for tick resistance in Braford and Hereford cattle. J. Anim. Sci. 93: 2693-2705.

Chen, P., T. J. Baas, J. W. Mabry, and K. J. Koehler. 2003. Genetic correlations between lean growth and litter traits in U.S. Yorkshire, Duroc, Hampshire, and Landrace pigs. J. Anim. Sci. 81:1700–1705.

Crews Jr, D. 2005. Multiple Trait Selection for maternal Productivity: The Hereford Maternal Productivity Index. Agriculture and Agri-Food Canada Research Centre. Lethbridge. Alberta. Canadá.

Coppieters, W., Mess, T. H. M., Druet, T. et al. 2009. Mapping QTL influencing gastrointestinal nematode burden in Dutch Holstein-Friesian dairy cattle. BMC Genomics, 10:96.

Cunningham, E. P., & McClintock, A. E. 1974. Selection in dual purpose cattle populations: defining the breeding objective. Anim. Prod. 18: 237-247.

Dekkers, J., J. Gibson, P. Bijma and J. Van Arendonk. 2004. Design and optimisation of animal breeding programmes. Lecture notes. Wageningen.

Dijkhuizen, A. A., Jalvingh, A. W., and Huirne, R. B. M. 1997. Critical steps in system simulation. In: Dijkhuizen, A. A.; Morris, R.S. (Eds.) Animal Health economics. Principles and applications. 1.ed. Sydney: University of Sydney, p.59-67.

Doyle, S. P., Golden, B. L., Green, R. D., and Brinks, J. S. 2000. Additive genetic parameter estimates for heifer pregnancy and subsequent reproduction in Angus females. J Anim Sci, v.78, p.2091-2098.

Enns, M. 2007. Selection Decision: Tools for Economic Improvement Beyond EPD. in Beef Sire Selection Manual. p.55-62. National beef cattle evaluation consortium.

Euclides Filho, K. 2001. O efeito do tamanho das reprodutrizes sobre a eficiência da produção de carne e de bezerros desmamados. In: Simpósio Nacional Sobre Produção e

Gerenciamento da Pecuária de Corte. Belo Horizonte. Anais do... Belo Horizonte: UFMG, p.197-208.

Evans, J. L., Golden, B. L., Bourdon, R. M., and Long, K. L. 1999. Additive genetic relationship between heifer pregnancy and scrotal circumference in Hereford cattle. J Anim Sci, v.77, p.2621-2628.

Exton, S., Archer, J., and Sundstrom, B. 2000. Feed eficiency EBVs. In: The Annual Feeder Steer SchooL, 5., Armidale. Proceedings...Armidale: Australian Angus; NSW Agriculture, p.88-89.

Falconer, D. S. 1981.Introduction to Quantitative Genetics, 2nd ed. Longman Group Ltd., London.

Ferraz, J. B. S., & Felício, P. E. 2010. Production systems – An example from Brazil. Meat Science, Champaign, v. 84, n. 2, p. 227-314.

Foote, R. H. 2003. Fertility estimation: a review of past experience and future prospects. Anim. Reprod. Sci. 75: 119-139.

Formigoni, I. B. 2002. Estimação de valores econômicos características componentes de Índices de seleção em bovinos de corte. Pirassununga. Dissertação (Mestrado) – Programa de Pós Graduação da Faculdade de Zootecnia e Engenharia de Alimentos da Universidade de São Paulo.

Garrick, D. 2005. Trends and developments in Genetic Evaluation of Beef Cattle in the United States. Pag 24 -31. in Proc. 9th World Angus Forum Tech. Meet., Angus in the Global Market. Am. Angus Assoc., Kansas City, MO.

Garrick, D. J., & Golden, B. L. 2009. Producing and using genetic evaluations in the United States beef industry of today. J. Anim. Sci. 87 (E.Suppl.): E11-E18.

Gibson, J. P., & Wilton J. M. 1998. Defining multiple-trait objectives for sustainable genetic improvement. J. Anim. Sci. 76: 2303-2307.

Golden, B. L.; Garrick, D. J.; Newman, S.; and Enns R. M. 2000. Economically relevant tratit a framework for the next generation of EPDs. Proceeding of the BIF 32nd Annual Research Symposium and Annual Meeting. 32: 2-13.Wichita, Kansas.

Gordon, H. M., & Whitlock, H. V. 1939. A new technique for counting nematode eggs in sheep faeces. Journal of Council of Science and Industry Research in Australia, v. 12, n. 1, p. 50-52.

Graser, H. V., & Tier, B. 1988. Genetic evaluation of beef cattle. Proc. Aust. Soc. Anim. Prod., v. 17, p. 97-99.

Gressler, S. L., Bergmann, J. A. G., Penna, V. M. et al. 1998. Estudo das associações genéticas entre perímetro escrotal e características reprodutivas de fêmeas da raça Nelore. In: Reunião Anual da Sociedade Brasileira de Zootecnia, 35, 1998, Botucatu. Anais... Botucatu: SBZ, p.368-370.

Grisi, L., Leite, C. R. Leite, Martins, S. R. J., Barros, M. T. A., and Andreotti, R. 2014. Reavaliação do potencial impacto econômico de parasitos de bovinos no Brasil. Braz. Journal Veterinary Parasitology, Jaboticabal, v. 23, n. 2, p. 150-156.

Groen, A. F. 1988. Derivation of Economic Values in Cattle Breeding: A Model at Farm Level. Agricultural Systems, 27, 195-213.

Hazel, L. & J. L. Lush. 1942. The efficiency of three methods of selection. Journal of Heredity 33(11): 393-399.

Hazel, L. N. 1943. The genetic basis for constructing selection indexes. Genetics 28(6): 476.

Henderson, C. R. 1963. Selection index and expected genetic advance. In: W. D. Hanson and H. F. Robinson (ed.) Statistical Genetics and Plant Breeding. NAS-NRC Publ. 982:141-162.

Jiang, X., A. Groen and E. Brascamp. 1999. Discounted expressions of traits in broiler breeding programs. Poultry science 78(3): 307-316.

Jones, H. E., Amer, P. R., Lewis, R. M., and Emmans, G. C. 2004. Economic values for changes in carcass lean and fat weights at fixed age for terminal sire breeds of sheep in the UK. Livestock Production Science 89, p. 1-17.

Jonsson, N. N. 2006. The productivity effects of cattle tick (Boophilus microplus) infestation on cattle, with particular reference to Bos indicus cattle and their crosses. Veterinary Parasitology 137, p. 1–10.

Jorge Junior, J., Cardoso, V. L., and Albuquerque, L. G. 2006. Modelo bioeconômico para cálculo de custos e receitas em sistemas de produção de gado de corte visando à obtenção de valores econômicos de características produtivas e reprodutivas. Revista Brasileira de Zootecnia, v.35, n.5, p.2187-2196.

Jorge Junior, J., Cardoso, V. L. and Albuquerque, L. G. 2007. Objetivos de seleção e valores econômicos em sistemas de produção de gado de corte no Brasil. Revista Brasileira de Zootecnia, v.36, n.5, p.1549-1558.

Kluyts, J., F. Neser and M. Bradfield. 2004. Development of breeding objectives for beef cattle breeding: derivation of economic values: review article. South African Journal of Animal Science 33(3): 142-158.

Koots, K. & J. Gibson. 1998. Economic values for beef production traits from a herd level bioeconomic model. Canadian Journal of Animal Science 78(1): 29-45.

Koots, K. R.; Gibson, J. P.; Smith, C.; and Wilton, J. W. 1994. Analyses of published genetic parameter estimates for beef production traits. 1. Heritability. Anim. Breed. Abstr. 62:309–338.

Lanna, D. P. 1997. Fatores condicionantes e predisponentes da puberdade e da idade ao abate. In: Simpósio Sobre Pecuária de Corte, 4., Piracicaba. Anais... Piracicaba: Fundação de Estudos Agrários Luiz de Queiroz, p.41-78.

Laske, C. H., B. B. M. Teixeira, N. J. L. Dionello, and F. F. Cardoso. 2012. Breeding objectives and economic values for traits of low input family-based beef cattle production system in the State of Rio Grande do Sul. R. Bras. Zootec. 41: 298-305.

Lin, C.V. 1978. Index selection for genetic improvement of quantitative characteres. Theor. AppI. Genet., 52:49-56.

Lôbo, R. B., Bezerra, L. A. F., Faria, C. U., Vozzi, P. A., Magnabosco, C. U., Bergmann, J. A. G., Oliveira, H. N., Castro, L. M., Espigolan, R., Pereira, A. S. C., Aguilar, I, and Baldi, F. 2018. Sumário de Touros das Raças Nelore, Guzerá, Brahman e Tabapuã: Edição Agosto de 2018. Ribeirão Preto, ANCP 112 pag.

Magnabosco, C.U., Sainz, R.D., Faria, C.U., Yokoo, M.J., Manicardi, F., Barbosa, V., Guedes, C., Leme, P.R., Pereira, A., Araújo, F.R.C., Sanches, A.C., and Lôbo, R.B., 2006. Avaliação genética e critérios de seleção para características de carcaça em Zebuínos: Relevância econômica para mercados globalizados. In: Simpósio de Produção de Gado de Corte, vol. 5, Viçosa, Brazil.

MacNeil, M., S. Newman, R. Enns and J. Stewart-Smith. 1994. Relative economic values for Canadian beef production using specialized sire and dam lines. Canadian Journal of Animal Science 74(3): 411-417.

MacNeil, M., R. Nugent and W. Snelling. 1997. Breeding for profit: an introduction to selection index concepts. Range Beef Cow Symposium.

McCosker, T. H., Turner, A. F., McCool, C. J. et al. 1990. Brahman bull fertility in North Australian rangeland herd. Anim. Breeding Abstr., 58(1):30.

Mezzadri, F. P. 2007. Cenário Atual da Pecuária de Corte - Aspectos do Brasil com Foco no Estado do Paraná - Curitiba: SEAB/DERAL/DCA.

Moser, D. W., J. K. Bertrand, I. Misztal, L. A. Kriese, and L. L. Benyshek. 1998. Genetic parameter estimates for carcass and yearling ultrasound measurements in Brangus cattle. J. Anim. Sci. 76:2542−2548.

Neves, J. P., P. B. D. Gonçalves, and J. F. C. Oliveira. 1999. Fatores que afetam a eficiência reprodutiva na vaca. Rev. Bras. Repr. Anim. 23: 105.

Newman, S., Harris, D. L., and Doollittle, D. P. 1987. Genetic analysis of components of a bioeconomic objective. II. Traits measured at weaning, postweaning growth and carcass composition. Journal Animal Breeding and Genetics; v. 104, n. 3, p., 193-205.

Ochsner, K. P. 2016. Development of Terminal and Maternal Economic Selection Indices in Beefmaster Cattle. Master Diss. University of Nebraska, Lincoln, Nebraska.

Ortiz Peña, C. D., Brito, F. V., Schenkel, F. S., Severo, J. L. P., Piccoli, M. L., Carvalheiro, R., Roso, V. M., and Cardoso, V. 2008. PAINT: Índice bioeconômico de fêmeas (RMat). In: Congresso Brasileiro das Raças Zebuínas. Anais do… Associação Brasileira dos Criadores de Zebu. Uberaba, MG. 7: 126-132.

Parkinson, T. J. 2004. Evaluation of fertility and infertility in natural service bulls. Vet. J. 168: 215-229.

Paz, C. C. P., & Luchiari Filho, A. 2000. Melhoramento genético e diferenças de raças com relação à qualidade da carne bovina. Pecuária de corte, n.101, p. 58-63.

Phocas, F., Bloch, C., Chapelle, P., Bécherel, F., Renand, G., and Ménissier, F. 1998. Developing a breeding objective for a French purebred beef cattle selection programme. Livestock Production Science. 57 49-65.

Ponzoni, R. W., & S. Newman. 1989. Developing breeding objectives for Australian beef cattle production. Anim. Prod. 49: 35-47.

Ponzoni, R. 1998. Accounting for both income and expense in the development of breeding objectives. Proceedings of the 9th Conference of the Australian Association of Animal Breeding and Genetics: 55-66.

Pravia, M. I. 2010. Desarrollo de objetivos e índices de selección en ganado para carne en Uruguay a través de un modelo bioeconómico. Master Diss. Universidad de la Republica, Montevideo.

Queiroz, S. A., Pelicioni, L. C., Silva, B. F., Sesana, J. C., Martins, M. I. E. G., Sanches. A., et al. 2005. Índices de seleção para um rebanho Caracu de duplo propósito. Revista Brasileira de Zootecnia, Viçosa, v. 34, p. 827-837.

Resende, M. D. V., Oliveira, E. B., and Higa, A. R. 1990. Utilização de índices de seleção no melhoramento de Eucalyptus. Boletim de Pesquisa Florestal, v.21, p.1-13.

Rosa, A. N., Martins, E. N., Menezes, G. R. O., and Silva, L. O. C. 2013. Melhoramento genético aplicado em gado de corte: Programa Geneplus- Embrapa. 1ª edição. Brasília, DF: Embrapa, 256 p.

Schneeberger, M., S. A. Barwick, G. H. Crow, and K. Hammond. 1992. Economic indices using breeding values predicted by BLUP. J. Anim. Breed. Genet. 109:180-187.

Smith, H. F. 1936. A discriminant function for plant selection. Ann Eugen, London, 7:240-250.

Snelling, W. M. 1994. Genetic analyses of binary stayability measures of beef females. PhD Diss. Colorado State Univ., Fort Collins.

Soares de Lima, J. M., Pravia, M. I., Ravagnolo, O., and Montossi, F. 2011. Índice de selección para la Cría: "Una nueva herramienta disponible em Uruguay para selecionar reproductores por su mérito econômico em la raza Hereford". Programa Nacional de Carne y Lana, INIA Uruguay. Anuário da Sociedad Criadores de Hereford del Uruguay.

Teixeira, B. B. M. 2013. Parameters and genetic tendency for performance traits and visual scores of Hereford and Braford. Master Diss. Universidade Federal de Pelotas, Pelotas.

Tess, M. & B. Kolstad. 2000. Simulation of cow-calf production systems in a range environment: I. Model development. Journal of animal science 78(5): 1159-1169.

Urioste, J. I., R. W. Ponzoni, M. Aguirrezabala, G. Rovere, and D. Saavedra. 1998. Breeding objectives for pasture-fed Uruguayan beef cattle. J. Anim. Breed. Genet. 115: 357-373.

Van Arendonk, J. 1985. A model to estimate the performance, revenues and costs of dairy cows under different production and price situations. Agricultural systems 16(3): 157-189.

Van Arendonk, J. A. M. 1991. Use of profit equations to determine relative economic value of dairy cattle herd life and production from field data. Journal of dairy science 74(3): 1101-1107.

Vercesi Filho, A. E. 1998. Objetivos econômicos da seleção de gado de leite. In: Simpósio Nacional de Melhoramento Animal, 2. Uberaba. Anais do...Viçosa: UFV, 1998. p.135-145.

Wolfova, M. et al. 2005. Breeding objectives for beef cattle used in different production system. 2. Model application to production system with the Charolais breed. Livestock Production Science, Amsterdan, v. 95, p. 217-230.

Zeng, X. 2013. Beef cattle maternal and terminal economic selection indices. M.S. Thesis Colorado State Univ., Fort Collins.

5 Chapter 1 Defining breeding objectives including tick count in Hereford and Braford of Southern Brazil

Abstract: The definition of the breeding goals (BG) should be the first step in the elaboration of a genetic improvement program, since this definition will guide the directions that the genetic evaluation program will take. The correct definition are determinant for effective genetic improvement, where the BG must be weighted according to their economic relevance given by their economic values (EV) and for the time and frequency that they will be expressed on the next generations. The aims of this study were to develop a bioeconomic model (BM) for a typical beef cattle full cycle production system (FCS) in Southern Brazil using Hereford (HH) or Braford (BO) breeds considering survival/adaptation, fertility/longevity, carcass and growth traits, and to define BG and estimating EV for PampaPlus breeding program. To estimate the BG and its respective EV a hybrid deterministic/stochastic BM was developed for HH and another for BO to characterize by simulation a FCS, with income based on harvest of fattened steers, surplus heifers and cull cows. For each animal category was calculated a profit equation. To calculate the EV for tick count (TICK) was developed a stochastic BM that considered chemical controls, weight loss and the probability of animal deaths caused by ticks or tick borne diseases. After defined de BG and their EV, each one was adjusted through the respective discounted genetic expressions (DEV) to account for population gene-flow. In the FCS of Southern Brazil the traits that affected the profit were weaning weight direct (WWd) and maternal (WWm), TICK, mature cow weight (MCW), subcutaneous backfat (FAT), ribeye muscle area (REA), post weaning gain (PWG), final gain (FG) and stayability (STAY). The BG with higher DEV was STAY followed by TICK, FAT, PWG, WWd, REA, FG, MCW and WWm. To select more profitable animals, the traits TICK, REA, FAT, STAY traits should be

included as BG in the PampaPlus breeding program, together with the traits conventionally identified as BG: WWd, WWm, PWG and FG.

Key Words: beef cattle, bioeconomic models, breeding goals, economic values, tick resistance.

5.1 Introduction

Currently, several breeding programs have developed selection indexes with weights based on the economic values of each breeding goal (BG), prioritizing, or giving greater focus on traits that maximize the economic return of the activity (Formigoni, 2002).

In this way, the definition of the breeding goals and their respective economic values should be the base point for the establishment of an genetic improvement program, since will guide the selection for economic relevant traits (Urioste et al., 2000; Garrick & Golden, 2009).

Several biologic traits can affect the profitability of beef cattle herds, that varies according to the production system particularities. These traits are defined as BG and the correct definition are determinant for effective genetic improvement, where the BG must be weighted according to their economic relevance (Amer et al., 2001; Pravia et al., 2014).

As many factors and traits influence the economy of beef cattle production, for the estimation of economic values for BG, it is necessary to develop an specific bio-economic model for each breed and production system, considering all the elements that affect the performance of farms, as the genetics, nutrition and economic management (Jones et al., 2004).

A general option to maximizing the profitability across the Southern Brazilian beef chain would use a full cycle economic index because this production system includes all production phases (calf cropping, stocking, and finishing) and, therefore had the greatest correlation between economic indexes with other specialized systems (Costa et al., 2017).

In this production system, many traits need to be considered, such as survival/adaptation, fertility/longevity, carcass and growth traits, and these traits must be economically evaluated through its economic values adjusted by the discounted genetic expressions take into account the frequency and the time that a trait will be expressed. This considers an animal life cycle, as selecting traits that result in more rapid changes in the profit could give more economic benefit compared to traits that take longer to be expressed (McClintock & Cunningham, 1974; Borg, 2004).

The aims of this study were to develop a bio-economic model for a typical full cycle beef cattle production system in Southern Brazil using Hereford (HH) or Braford (BO) breeds considering survival/adaptation, fertility/longevity, carcass and growth traits, that allows defining BG and estimating economic values adjusted by the discounted genetic expressions for PampaPlus breeding program.

5.2 Materials and methods

To determine the BG and its respective economic values, was used the Ponzoni & Newman (1989) procedure, based in four steps: (i) specification of typical production systems; (ii) identification of income and expenses sources in the commercial herds; (iii) determination of biological traits that influence the income and expenses; and (iv) estimation of economic values for each trait included in the selection goals.

i. Specification of typical production systems

There are three main beef cattle production system in Southern Brazil, which are Calf-crop, Full cycle and Rearing and finishing production systems, which were detailed by Costa et al. (2017), who developed three economic indexes, one for each production system, where the positioning of the animals was tested against each selection index, by ranking correlation among the three indexes developed, being verified a high correlation between these indexes, indicating that only one economic index could be used to promote genetic improvement for the three production systems.

On this way, only the Full cycle production system, that considers the production system as whole, was considered, to avoid multiplicity of selection indexes, which may reduce understanding and acceptance by breeders.

The Full cycle production system is characterized by extensive production on grass-based feed, resulting in the sale of 24 months old fat steers, 30 months old fat heifers and fattened cull cows.

ii. Identification of income and expenses sources in the commercial herds

To identify the incomes and expenses was developed a hybrid bio-economic model that was deterministic regarding herd structure, feed demand, veterinary and labour costs, and performance, and stochastic for carcass value and tick burden. Models were specific for HH and BO breeds and in both cases based on 10,000 females.

The first step was to define the herd structure, which was done using a Leslie matrix model (Leslie, 1945; 1948). The parameters used in the Leslie matrix were the distribution of pregnancy and survival rates (**SR**) of each dam age and were calculated based on the PampaPlus database, considering dams until 10 years old once the proportion of dams older than this was very low in this population. These parameters are shown in Table 5.1 as well the number of animals generated in each category.

Table 5.1 – Survival rates, pregnancy rates and number of animals according to animal age and category used to specify Leslie matrix parameters.

Animal category	Age of animals	Survival rate (%)	Pregnancy rate (%)	Number of animals
		Females		
fcalf	0-7 months	-	-	1,930
yrhf	7 months - 1 year	97.50	-	1,293
yrhh	7 months - 1 year	97.50	-	588
y2hh	1 - 2 years	97.50	-	574
y3hh	24 - 30 months	99.00	-	551
y2hf	2 years	99.00	-	1,280
dam3	3 years	99.00	82	1,266
dam4	4 years	78.00	64	987
dam5	5 years	79.00	72	780
dam6	6 years	93.00	72	725
dam7	7 years	87.00	72	630
dam8	8 years	80.00	68	504
dam9	9 years	75.00	64	378
dam10	10 years	60.00	60	226
		Males		
mcalf	0 - 7 months	-	-	1,930
yrst	7 months - 1 year	97.50	-	1,881
y2st	1 - 2 years	97.50	-	1,834
bulls	-	-	-	138

fcalf = female calf; yrhf = yearling replacement heifer; yrhh = yearling heifer to harvest; y2hf = two years old replacement heifer; y2hh = two years old heifer to harvest; y3hh = 30 month-old heifer to harvest; dam3-10 = three years old dam to ten years old dam; mcalf = male calf; yrst = yearling steer; y2st = two years old steer.

The definition of herd structure is necessary to correctly determine income and expenses of the production system according the animal category.

Definition of the Expenses

The costs of this production system were divided into four main cost centers: feed, labor (permanent and temporary labor), veterinary (vaccines, control of endo and ectoparasites, drugs and costs with veterinarians), and finally, cost with mineral supplementation for the animals.

Feed costs. To calculate the feed costs, the first step was estimate the feed requirements per animal category, that was based on the average live weight and physiological stage of the animals, such as growing, growing and pregnancy, maintenance and pregnancy or fattening.

The average live weight of the dams was calculated based on the mature cow weight (**MCW**), measured at weaning of their progenies, and the maturing rate of dams, that were calculated in R Software (Anon, 2016) through Brody's growth curve (Brody, 1964) using 20,574 and 33,708 weight records from PampaPlus for HH and BO dams, respectively.

Thus, to estimate the live weight of dams was used the following equation:

$$\mathrm{LWage} = \mathrm{MCW} - (\mathrm{MCW} - \mathrm{BTW})^{(-\,\mathrm{MR} \times \mathrm{age})}$$

where: LW is the average live weight of dams, age is the age in days of the dams, MCW is the mature cow weight, BTW is the birth weight (34.685 kg and 34.86 kg, for HH and BO, respectively in PampaPlus database), and MR is the maturing rate.

The energy requirements in mega calories per day was calculated based on the follow equations, that as based on NRC (2000):

for calves, yearling and two years heifers and steers the total energy requirements (NEt) per day, in mega calories required per animal was calculated by:

$$NEt = NEm + RE;$$

for first calving dams by:

$$NEt = (DMg \times NEgd) + NEm + NEc + NEl,$$

and, finally, for dams by:

$$NEt = NEm + NEc + NEl + NEd.$$

In the equations above RE is the retained energy, DMg is dry matter for gain, NEgd is net gain energy per kilogram of dry matter, NEm is net maintenance energy per kilogram of dry matter, NEfg is net energy for fetal growth in megacalories per day during the last trimester, NEl is net energy for milk production, and NEd is the delta value, which varies according to the animal's body condition score (Buskirk et al. 1992). These values were calculates as follows.

Metabolic energy (Mega calorie per kilogram of dry matter):

$$ME = \frac{(TDN \times 3.608)}{100}$$

TDN is the total digestible nutrients, equal to 55%.

Net maintenance energy per kilogram of dry matter:

$$NEmd = (1.37 \times ME) - \left(0.138 \times (ME^2)\right) + \left(0.0105 \times (ME^3)\right) - 1.12$$

Net gain energy per kilogram of dry matter:

$$NEgd = (1.42 \times ME) - \left(0.174 \times (ME^2)\right) + \left(0.0122 \times (ME^3)\right) - 1.6$$

Previous body score effect for compensatory growth correction:

$$PBSE = 0.8 + \left((BS - 1) \times 0.05\right),$$

where: BS is the body score, which was considered equal to 5 for dams and growing animals and equal to 7 for finishing animals.

Fasting body weight:

$$BWf = BW \times 0.96,$$

where: BW is the body weight.

Maintenance net energy in mega calorie per kilogram of metabolic weight:

$$NEm = PCJe^{0.75} \times (0.077 \times GGE \times PBSE)$$

where: GGE is genetic group effect, were is equal to 1 for taurines and 0.95 for crossbreed animals.

Dry matter for maintenance:

$$DMm = \frac{NEm}{NEmd}$$

Dry matter intake:

$$DMI = BW^{0.75} \times (0.0194 + 0.0545 \times NEmd) + (0.2 \times MP) \times \left(\frac{\left(\frac{94-13500}{1500}\right)}{100}\right),$$

where: MP is the milk production, which was considered and average of 4.00 and 4.44 kilograms per day for HH and BO dams, respectively, which first calving cows and second calving cows produce 19 and 5% less of this value (Rodrigues et al., 2014).

Dry matter for gain:

$$DMg = DMI - DMm$$

Net energy for fetal growth in mega calorie per day during the last trimester:

$$NEc = \frac{(2.15 \times 90)}{280}$$

Net energy for milk production:

$$NEl = MP^{0.75},$$

and finally, retained energy:

$$RE = 0.0635 \times ((0.96 \times BW)^{0.75}) \times ((0.956 \times ADG)^{1.097})$$

The energy requirements, in mega calorie per day, for all animal categories was showed in Table 5.2.

Table 5.2 – Parameters of herd according to breed.

Category	Age	Feed	Nº days	ALW		ER		US$ per A*LW*
				HH	BO	HH	BO	
mcalf	33-205	NG	173	74.98	74.77	3.04	2.89	1.67
yrst	206-266	NG	60	194.84	194.60	4.72	4.53	1.58
yrst	267-387	CP	120	253.04	242.60	7.33	6.87	1.58
y2st	388-612	NG	225	339.29	339.05	7.17	6.87	1.61
y2st	733	CP	120	425.54	387.05	10.83	9.76	1.61
bulls	-	NG	365	700.0	-	-	-	4.06
fcalf	33-205	NG	173	68.73	69.29	2.75	2.74	1.48
yrhf	206-365	NG	160	209.57	210.13	5.36	5.07	1.45
y2hf	730	NG	365	307.11	298.07	6.61	6.05	1.48
y3hh	730-900	NG	170	385.49	365.57	7.89	6.56	1.48
dams	-	NG	365	524.2	456.7	12.26	11.51	1.21
cull6	1460-1580	CP	120	483.30	452.06	12.98	12.59	1.21
cull8	1825-1945	CP	120	521.86	478.76	13.45	12.92	1.21

Age = age of animal, in days; Feed = type of feed; NG = native grassland; CP = cultivated pasture; ALW = average body weight, in kg; ER = energy requirements in megacalories per day; US$ per *ALW* = average price per kilogram of live weight; fcalf = female calf; yrhf = yearling heifer; y2hf = two years old heifer; y3hh = 30 month old heifer to harvest; dam = dams; mcalf = male calf; yrst = yearling steer; y2st = two years old steer; bulls = bulls, cull6 = six permanent teeth cull cows; cull8 = eight or more permanent teeth cull cows.

To calculate the feed cost for each animal category first was calculated a base cost in dollars per mega calorie (CMcal), using yearling steer requirements and the following equation:

$$\mathrm{CMcal} = \frac{[\mathrm{Rental\ cost}]}{(\mathrm{StR} \times \mathrm{NEt})},$$

where: StR is the stocking rate in natural grassland or cultivated pasture (360 kg or 810 kg of live weight per hectare, respectively); Rental cost was expressed in US$ per hectare per day, estimated in US$ 0.24 for natural grassland and U$S 1.47 for cultivated pasture; NEt is the energy requirements, in mega calories per day, based in a yearling steer parameters.

The total feed cost the herd was calculated by summing the energy requirements of each the animal categories (Table 5.2) multiplied by the cost per mega calorie, considering natural grassland based feed or cultivated pasture based feed.

Labor costs. According to the Anualpec (2015), for FCS farms, an employee is able to take care of 329 animal units (AU) per year, which corresponds to 148,050 kilograms of live weight.

Based on this value, the weight of all the animals was added and then divided by 450 kilograms, generating the total AU value on the property, which was later divided by the number of animal units that each employee is able to take care of per year, generate the necessary amount of employees for this production system. Animal categories that do not stay the whole year on the farm (calves, harvest heifers and cull cows) had their costs accounted according the period that they stay on the farm.

In order to calculate the value of the salary of each employee, a survey was carried out with the union of rural workers in Southern Brazil, which totaled US$ 6,545.45 per year (salary plus charges). In this way, the total value of the salary cost of the employees was added, dividing by the total kilograms of live weight in the farm, to then generate the cost of labor per kilogram of live weight. This information allowed to account in the bioeconomic model for the increase in labor cost due to the increase in animal weight.

Veterinary costs. The veterinary costs were estimated according to the sanitary plan performed annually to take care of the herd health, which varied according to the animal category (Table 5.3).

Table 5.3 - Herd sanitary schedule.

	Endo	Ecto	FMD	BOVR	BLD	CLOS	BRU	IBR + BVD	LEP
mcalf	1	1	1	2	1	1	-	-	-
yrst	2	3	1	1	1	1	-	-	-
y2st	3	6	1	1	1	1	-	-	-
fcalf	1	1	1	2	1	1	1	-	-
yrhf	2	1	1	1	1	1	1	-	-
y2hf	3	6	1	1	1	1	-	2	2
dams	3	6	1	1	1	1	-	1	1
yrhh	2	1	1	1	1	1	1	-	-
y2hh	3	6	1	1	1	1	-	-	2
y3hh	1	2	1	1	1	1	-	-	-
Cull cows	1	1	1	1	1	1	-	-	-

Endo = endoparasites; Ecto= ectoparasites; FMD = foot-and-mouth disease; BOVR =Bovine rabie; BLD = Black leg disease; CLOS = Clostridiosis; BRU = Brucellosis; IBR + BVD ; LEPT = Leptospirosis; fcalf = female calf; yrhf = yearling replacement heifer; y2hf = two years old replacement heifer; yrhh = yearling harvest heifer; y2hh = two years old harvest heifer; y3hh = 30 months old heifer to harvest; dam = dams; mcalf = male calf; yrst = yearling steer; y2st = two years old steer.

The cost of each treatment was estimated through market research to determine the value per dose, when the drug is applied in a single dose, or per kilogram of live weight for drugs applied as a function of the live weight of the animal.

Vaccines against foot-and-mouth disease, rabies, blackleg, clostridiosis, brucellosis, IBR / BVD and leptospirosis had an average cost per dose of US $ 0.454, 0.182, 0.364, 0.364, 0.606, 2.121 and 0.242, respectively.

The controls of endo and ectoparasites are performed through the use of products related to live weight of the animals (Table 5.2), where the cost of chemical control per kilogram of live weight was US$ 0.0021 and 0.0024, respectively.

Mineral costs. The average mineral salt intake per animal considered was 0.07% of the live weight (Moreira et al., 2001), where the average value of one kilogram of mineral salt practiced in the region was US$ 0.32. Thus, the mineral supplementation cost per animal category depended on their average live weight.

Total costs. The total cost is the sum of feed, veterinary, labor and mineral supplementation costs of all animal categories.

Definition of the Incomes

In this production system, the revenues are given by 24-month-old finish steers, 30-month-old fats harvest heifers, and fattened cull cows.

To perform the simulation of the carcass values of the animals in the bio-economic model, a base price survey was performed for each kilogram of hot carcass in the region, which was identified as US$ 3.12 per kilogram of hot carcass for steers and US$ 2.79 for females.

After this survey, the value of carcass kilogram for each animal was calculated considering the main bonus grid of carcasses of the HH and BO breeds in Brazil practiced in the year 2018, which classifies the carcasses of animals that have phenotype of HH and BO according to the age of the animal, measured through of animal dentition, hot carcass weight and fat score (Table 5.4).

Table 5.4 – Brazilian Hereford and Braford Association bonus price table in 2018 according to sex, age and hot carcass weight.

Category	FAT_SC	TEETH	CWT (kg)	BONUS
1	1	-	-	-20%
2	2	-	-	0%
3	3	-	<180	0%
4	3	0 or 2	180-199	3%
5	3	0	200-219	7%
6	3	0	220-240	8%
7	3	0	>240	10%
8	3	2	201-239	7%
9	3	2	240-259	8%
10	3	2	>260	10%
11	3	4-6	180-239	3%
12	3	4-6	241-259	7%
13	3	4-6	260-279	8%
14	3	4-6	>280	10%
15	3	>6	-	0%

FAT_SC = subcutaneous fat score; TEETH = number of permanent teeth according animal age CWT = carcass weight; Bonus = increment in the carcass base price.

To calculate the average final weight (**FW**) of the animals that generate income, was considered the type of feed and the average daily gain according to the type of feed and the period, in days, in which each animal receives a certain diet.

Depending on the feed (natural grassland or cultivated pasture), the average daily gain (**ADG**) and the stocking rate (**StR***)* were different. The ADG of natural grassland (**ADGng**) was 0.340 kg with a 360 kg/ha of StR. which represents the post-weaning ADG of the female PampaPlus population and the ADG on cultivated pasture (**ADGcp**) composed of ryegrass (*Lolium multiflorum*) and/or black oat (*Avena strigosa*) was 0.800 kg with a corresponding StR of 810 kg/ha (Beretta et al., 2002).

For males, the life cycle on the farm was as follows: after the weaning, when calves are 205 days old, the male calves were backgrounded in natural grassland for 60 days, then they went to winter cultivated pasture for more 120 days, after this, returned to natural grassland for more 225 days during summer and fall, and finally they went to cultivated pasture again for more 120 days to be finished, weighing an average FW of 473.30 kg.

For females, at weaning, 64.27% of the female calves were selected to replace the herd. These females were matting at 24-month-old and fed only with natural grassland. Other female calves that was not selected to replace the herd (harvest heifers) also are feed only with natural grassland, but remains in the farms until 30 months old, when are slaughtered with an average weight of 474.75 kg and 476.03 kg for HH and BO, respectively.

The cows that do not get pregnant were destined to slaughter and were classified as 3-4 years old (**Cull6**) or 5 or more years old (**Cull8**) cull cows. This classification was made because if cows up to six teeth could get bonus price, according to the Table 5.4. These cull cows were finished during a period of 120 days in cultivated winter pasture composed of ryegrass and black oat and their average slaughter weight for six teeth cull cows 531.31 and 500.06 kg and for eight teeth or more cull cows was 580.78 and 533.47 kg for HH and BO breeds, respectively.

A stochastic model was used to obtaining simulated carcass values. The values of age of animals at slaughter (**AGE**), final live weight, and ultrasound measurements of longissimus muscle area (**ULMA**) and backfat thickness (**UFAT)** were simulated through the *mvrnorm* function of the MASS package of R software (Venables & Ripley, 2002), which simulates a random values as a function of the mean of a variable and its phenotypic covariance with the other simulated variables.

For the simulation of the animals ages (in days) the following equation was used:

$$AGE = muAGE + (rnorm \times \sigma_{fAGE})$$

where: AGE = age of animals, in days, *muAGE* = average age of animals, in days according to the determinist model specifications; *rnorm* is a random value for standard normal distribution; σ_{fAGE} = phenotypic standard deviation age of animals.

After generating an age for each animal, the probabilities of each animal present 0, 2 and 4 teeth according to their age, in days, was estimated through the following equations (M. D. MacNeil, personal communication, 2017):

$$P4 = -0.01112 + (0.00003348 \times AGE),$$

$$P2 = -0.48822 + (0.001364 \times AGE), \text{ and}$$

$$P0 = 1 - P2 - P4,$$

where: P0 = probability of dentition equal to zero teeth, P2 = probability of dentition equal to 2 teeth; P4 = probability of dentition equal to 4 teeth; AGE = age of the animal, in days.

For each animal, a probability value between 0 and 1 was generated through the *runif* function of R software (R Core Team, 2018). After generating this value, for animals that presented a probability value less than or equal to P0, the dentition corresponded to zero teeth. For animals that presented a probability value higher than P0 and smaller than the sum of P0 and P2, the dentition corresponded to two teeth. For animals that presented a probability value higher than or equal to the sum of P0 and P2, the dentition corresponds to four teeth.

To generate the hot carcass weight, was used the follow equation:

$$cwt = \frac{FW \times cy}{100}$$

where: cwt = hot carcass weight; FW = average final live weight; cy = carcass yield.

To estimate the carcass yield, was used the follow equation (Cardoso, 2013):

$$cy = 49.89 - (0.018438 \times FW) + (0.573246 \times FAT) + (0.12112 \times REA) + (rnorm \times \sigma_{fcy})$$

The estimation of subcutaneous fat of the carcasses was performed through the following equation (Cardoso, 2013):

$$FATc = -0.105 + (1.0349 \times FAT) + (rnorm \times \sigma_{fFAT})$$

where: FATc = subcutaneous fat of the carcasses, in millimeters, FAT = subcutaneous fat of the carcass measured by ultrasonography, in millimeters; *rnorm* = random value; σ_{fcy} = phenotypic standard deviation of carcass yield in percentage; σ_{fFAT} = phenotypic standard deviation of subcutaneous fat of the carcass measured by ultrasonography.

After generated the quantitative values of subcutaneous fat in each carcass, they were classified into five different fat scores, where the score 1 corresponds to values lower than 1 millimeter (mm) of subcutaneous fat in the carcass, score 2 corresponds to values higher than 1 and lower than 3 mm, score 3 corresponds to values higher than 3 and lower than 6 mm, score 4 corresponds to values higher than 6 and lower than 10 mm, and finally score 5, that corresponds to values higher than 10 mm of subcutaneous fat in the carcass.

For carcasses that had a fat score of less than one, the price for each kilogram was 80% of the base price, assuming a penalty due to the poor subcutaneous fat of the carcass, and for the carcasses that obtained a fat score equal to two, the price for each kilogram was equal to the base price, assuming that these carcasses did not get a sufficient subcutaneous fat to obtain a bonus price.

The revenues from this production system were calculated using the following equation:

$$Revenue = N\ animals\ \times\ (1 + bp)\ \times Base\ price\ \times cwt$$

where: *N amimals* = number of steers, harvest heifers or cull cows; *bp* = percentage of bonus price or discount; Base price = base price for each animal category; cwt = hot carcass weight.

Profit equation (Profit)

$$\begin{aligned}\text{Profit} = {} & (\text{strevenue} + \text{hhrevenue} + \text{Cull6revenue} + \text{Cull8revenue}) \\ & - (\text{mccost} + \text{yrstcost} + \text{y2stcost}) \\ & - (\text{fccost} + \text{yrrhcost} + \text{y2rhcost} + \text{yrhhcost} + \text{y2hhcost} + \text{y3hhcost} \\ & + \text{damscost} + \text{cullcost})\end{aligned}$$

where: strevenue = fat steers revenue; hhrevenue = harvest heifers revenue; Cull6revenue = 6 teeth cull cows revenue; Cull8revenue = 8 teeth cull cows revenue; mccost = male calves costs; yrstcost = yearling steers costs; y2stcost = 24-month-old steers costs; fccost = female calves costs; yrrhcost = yearling replacement heifer costs; y2rhcost = 24-month-old replacement heifer costs; yrhhcost = yearling harvest heifer costs; y2hhcost = 24-month-old harvest heifer costs; y3hhcost = 30-month-old harvest heifer costs; damcost = dams costs; cullcost = cull cows costs.

Determination of biological traits that influence the income and expenses

The biological traits that influence the income and expenses identified in the bio-economic model were the direct weaning weight (WWd), in kg, maternal weaning weight (WWm), in kg, tick count (TICK), units of tick, mature cow weight (MCW), in kg, which considers the average weight of dams, subcutaneous backfat at 18 months old (FAT), in mm, which considers the backfat thickness, ribeye area at 18 months old (REA), in cm², measure of *longissimus* muscle between 12-13th rib, post weaning gain, measured at 18 months old (PWG), in kg, that is the average daily gain when animals are growing, final gain, measured at 18 to 24 months old (FG), in kg, that is the average daily gain on fattening phase, and stayability (STAY), in percentage, which accounts the percentage of dams older than six years old in the herd and having given birth to at least three calves.

Determination of economic value for tick resistance (TICK)

To estimate the economic results regarding the TICK and its economic value (EV) (losses due the tick infection) was adapted a bioeconomic model originally developed by Simões (2017) in R software (Anon, 2016), based on the parameters described in Table 5.2 and Table 5.5, by means of stochastic simulation.

The effect of tick infestation was calculated considering the costs with chemical treatments, labor, weight losses due to the level of tick infestation and losses due to the occurrence of animal deaths due to diseases transmitted by a tick, like tick fever caused by infections of *Babesia sp*. and *Anaplasma sp.* (Jonsson, 2006).

The weight losses of the animals due the tick infestation were calculated before the chemical control and after the effective period of the acaricide. In this period was considered a loss of 1.18 grams per tick per day in the animals (Jonsson, 2006). The total number of days that each animal lost weight due to tick infestation was 105 days considering one outbreak between November and December, and two outbreaks between March and August. Weight loss was calculated only for commercial animals between 12 and 24 months of age.

In addition to the previously described parameters, the probability of death due the tick incidence used was the same verified by Simões (2017), that simulate a tick infestation curve following an exponential distribution with E (x) = 1/λ, where λ is equal to 0.0158504.

Deaths due tick infestations were computed according to deaths diagnosed in the experimental herd, which was 2.56% per year. The simulation of each death was calculated using the threshold model, based on a uniform distribution (between 0 and 1), according to the number of ticks in the animal's body and the death probabilities showed in Table 5.5.

Table 5.5 – Death probabilities due to tick infestation per outbreak.

	Outbreak
nTicks < = 19	0.30%
19 < nTicks < = 61	0.70%
61 < nTicks < = 117	1.20%
117 < nTicks < = 157	1.80%
157 < nTicks < = 172	2.40%
172 < nTicks < = 190	3.20%
190 < nTicks < = 512	6.00%
512 < nTicks < = 714	11.90%
nTicks > 714	41.30%

nTicks = number of ticks; Outbreak 1 = outbreak of tick in November; Outbreak 2 = outbreak of tick in February; Outbreak 3 = outbreak of tick in May.

The losses with weight losses were calculated by the multiplication of the number of grams lost due to tick infestation, times the price per kilogram of each animal category. The injury to an animal's death was calculated by the amount needed to buy an animal of the same category to reset this unit lost.

It was also calculated the losses due to the need for chemical control and veterinary preventive treatments against tick fever according to each animal category.

For bulls it was considered one preventive treatment against tick fever and two chemical controls against tick infestation. For the other animal categories were considered two preventive treatment against tick fever and six chemical treatments against tick infestation. The cost per kilogram of live weight of tick fever preventive treatment and chemical control was US$ 0.02 and US$ 0.004, respectively.

These losses (Lchetrea) were calculated using the following equation:

$$\text{Lchetrea} = (\text{LW} \times \text{nanimals}) \times [(\text{US\$ kg\_tickp} \times \text{Nºchem controls}) + (\text{US\$ kg\_tickc} \times \text{Nºprevtreatment})]$$

where: LW is the average live weight of animals in each category; nanimals is the number of animals in each animal category; US$ kg_tickp is the cost of preventive treatment against tick fever per kg of live weight; US$ kg_tickc is the cost of chemical control against tick infestation per kg of live weight.

After the identification of the sources of expenses and losses (weight loss deaths and costs with chemical control and preventive treatments), a total cost/loss was obtained by adding up all the losses for each category of animals. This stochastic simulation was replicated 18,000 times to obtain the averaged parameters over replications.

Determination of economic value (EV)

To estimates the EV first a bio-economic model was developed and a base profit or loss in the case of TICK was calculated. After this, each BG was increased in one unit without changing the other traits in separate simulations. The differences between profits observed in these latter simulations and profit from the baseline simulation divided by the number of dams were the EV of the respective trait (MacNeil et al., 1994).

Discounted genetic expressions

The discounted genetic expressions (DGEs) for weaning, annual, slaughter, and end-of-cow-life traits were calculated in maternal purpose HH and BO cattle. The traits are determined by the frequency and time necessary for a trait to be expressed.

The parameters used in these equations to calculate the DGEs were estimated from 10,000 female simulated herd, obtained by Leslie matrix using actual data from PampaPlus breeding program database.

The calculations of DGEs for the BG used in this work were based on the approaches outlined by Amer (1999) and Amer et al. (2001) for sire breeding replacement females, and the expressions coefficient for each BG utilized are shown in Table 5.6.

Table 5.6 – Expressions coefficient used for each breeding goal.

Breeding goal	Abbreviation	Expressions coefficient
Weaning weight direct	WWd	$(1-K) \times (X_{RW} + X_{TB})$
Weaning weight maternal	WWm	$(1-K) \times (2 \times X_{RW})$
Tick count	TICK	$(1-K) \times X_{RA}$
Mature cow weight	MCW	$(1-K) \times X_{RA}$
Subcutaneous fat	FAT	$K \times X_{TS}$
Ribeye area	REA	$K \times X_{TS}$
Post weaning gain	PWG	$(1-K) \times (2 \times X_{RW})$
Final gain	FW	$K \times X_{TS}$
Stayability	STAY	$(1-K) \times X_{RC}$

X_{TB} and X_{TS} are numbers of discounted expressions of a sires genes at birth and slaughter, respectively, per calf born.

X_{RA} , X_{RW} , X_{RH} and X_{RC} are numbers of discounted expressions of a sires genes in his daughters at annual calvings, weaning of their calves, replacement heifer age and at culling, respectively, per female calf born which is destined to become a replacement.

K is the average proportion of a bulls progeny not destined to be replacements and is calculated as: $1 - \left(\frac{1}{2 \times P}\right)$, where P is the proportion of a sires daughters which become replacement heifers.

Given that the purchasing power of money can vary over the years depending on the annual interest rate and inflation, and that the BG may take different times to express themselves in the next generations, it is important to consider an annual rate discount to calculate economic values. Thus, the annual discount rate used in this study was the same used by Amer et al. (2001) of 7%.

A sensibility analysis of the DGEs was made changing the discount rates in 0, 3, 5, 7, 10, 14 and 21%.

The complete methodology of DGE is shown in Appendix 1.

5.3 Results and discussion

Even though, the Brazilian Hereford and Braford Association considers HH and BO as a single breed in the PampaPlus genetic evaluation program, in terms of BG and variance components, a bio-economic model was developed for each breed, considering their specific parameters and, consequently, was estimated EVs for BG for HH and BO separately.

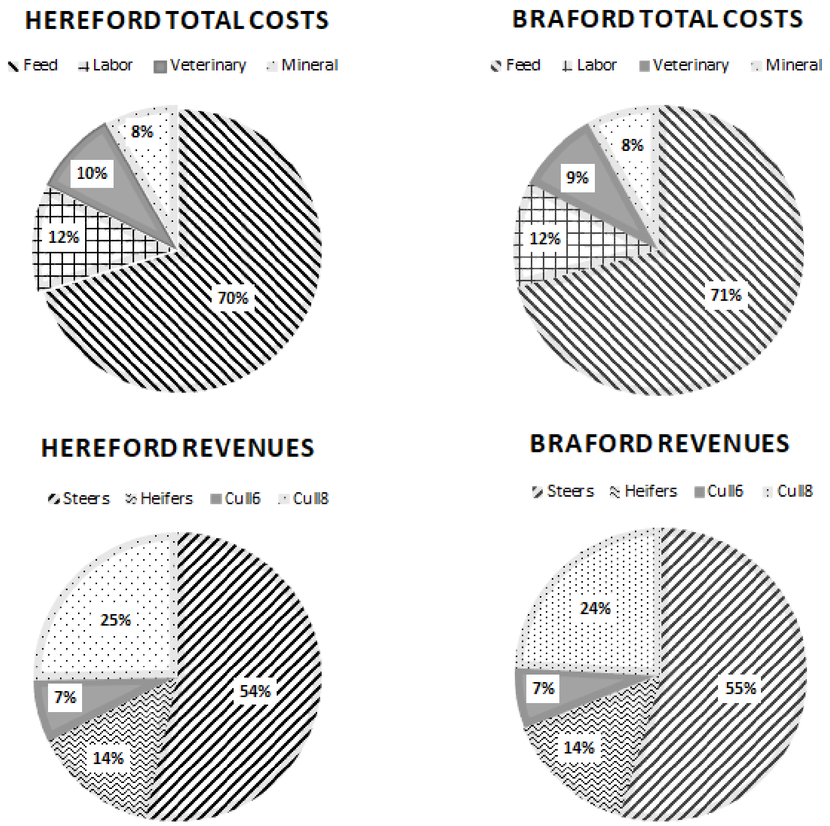
Through the Brody's curve the mature cow weight estimated ware 524.2 kg and 456.7 kg and the maturing rate was 0.001558 kg and 0.001885 kg for HH and BO dams, respectively. These values served as the basis to calculate all female weights used in the bio-economic models for both breeds and, consequently, the feed requirements and all costs based on the average live weight (Table 5.2).

The total feed cost of the herd was calculated by summing the energy requirements of each the animal categories multiplied by the cost per mega calorie, considering natural grassland based feed (US$ 0.025 per mega calorie) or cultivated pasture based feed (US$ 0.094 per mega calorie).

Individual bioeconomic models were developed by breed, but both models presented similar results for costs and revenues composition, where was verified that feed the herd accounted the most of the cost of production, followed by mineral supplementation, labor, and finally, veterinary costs (Figure 5.1).

This result is similar to found by Pravia et al. (2014), who observed through a bioeconomic model based on a Uruguayan beef cattle herd that 61% of total production costs were related to feeding, and 48% of the total revenue was related to the sale of fattened steers.

Figure 5.1 – Proportion of total costs and revenues for Hereford and Braford breed.



Steers = 24 month old steers; Heifers = 30 month old heifers; Cull6 = six permanent teeth cull cows; Cull8 = eight or more permanent teeth cull cows.

For incomes, in both bio-economic models the main source was the sale of fattened steers followed by the sale of cull cows, and finally, harvest heifers (Figure 5.1).

The final value of the carcasses of the HH and BO steers was very close since the parameters used in the simulation were practically the same (Tables 5.7 and 5.8).

Table 5.7 - Results of the carcass simulation of the Hereford breed.

	Steer_value	Price	AGE	FW	REA	FAT	CY	CWT	FATC	FAT_SC	TEETH
Min.	422.73	2.50	411.8	295.1	34.46	0.002	44.50	150.1	0.008	1.000	0.00
1stQu.	752.12	3.12	641.6	446.4	60.01	3.271	50.32	229.8	3.170	3.000	0.00
Median	807.88	3.12	687.2	473.4	64.82	4.380	51.51	243.7	4.432	3.000	0.00
Mean	808.48	3.11	687.2	473.4	64.83	4.399	51.52	243.8	4.456	2.955	0.94
3rdQu.	868.48	3.12	732.7	500.5	69.65	5.510	52.73	257.5	5.704	3.000	2.00
Max.	1,165.76	3.12	980.3	643.9	92.27	10.738	58.77	339.5	11.747	5.000	4.00
	y3hh_value	Price	AGE	FW	REA	FAT	CY	CWT	FATC	FAT_SC	TEETH
Min.	359.70	2.23	633.6	313.1	29.12	0.0007	41.80	148.9	0.004	1.000	0. 00
1stQu.	641.21	2.79	853.9	447.8	56.78	3.2644	48.01	220.2	3.175	3.000	2.00
Median	687.27	2.79	900.0	475.0	61.67	4.3701	49.22	233.6	4.422	3.000	2.00
Mean	687.27	2.77	899.6	474.9	61.65	4.3877	49.22	233.6	4.447	2.954	1.56
3rdQu.	739.70	2.79	945.5	502.1	66.52	5.4930	50.44	246.9	5.679	3.000	2.00
Max.	977.88	2.79	1,159.3	625.2	91.09	10.8673	57.08	318.9	11.949	5.000	4.00
	Cull6_value	Price	AGE	FW	REA	FAT	CY	CWT	FATC	FAT_SC	TEETH
Min.	392.73	2.23	831.2	346.0	32.71	0.0054	38.16	158.4	0.001	1.000	6.00
1stQu.	667.58	2.79	1,049.0	504.3	60.13	3.4810	45.48	235.0	3.391	3.000	-
Median	730.91	2.79	1,095.3	531.4	64.89	4.5844	46.70	247.8	4.631	3.000	-
Mean	724.24	2.78	1,095.0	531.4	64.89	4.5985	46.70	248.0	4.657	3.025	6.00
3rdQu.	773.64	2.79	1,141.1	558.7	69.65	5.7045	47.92	261.0	5.904	3.000	-
Max.	1,039.09	2.79	1,347.7	688.8	95.88	11.5806	54.23	338.9	12.422	5.000	6.00
	Cull8_value	Price	AGE	FW	REA	FAT	CY	CWT	FATC	FAT_SC	TEETH
Min.	449.09	2.23	1,553	390.3	35.28	0.0046	38.23	185.6	0.003	1.000	8.00
1stQu.	702.12	2.79	1,780	553.3	60.15	3.4755	44.56	252.6	3.384	3.000	-
Median	739.39	2.79	1,825	581.1	64.85	4.5783	45.78	265.5	4.635	3.000	-
Mean	737.58	2.78	1,825	580.8	64.89	4.5900	45.78	265.7	4.653	3.027	8.00
3rdQu.	776.06	2.79	1,871	608.1	69.59	5.6885	47.00	278.5	5.894	3.000	-
Max.	976.67	2.79	2,111	748.4	93.49	11.3223	52.86	350.4	12.377	5.000	8.00

Steer_value = whole carcass price of steer; y3hh_value = whole carcass price of harvest heifer; Cull6_value = whole carcass price of six teeth cull cows; Cull8_value = whole carcass price of eight teeth cull cows; Price = price per kilogram of hot carcass; AGE = age of animals, in days; FW = final weight; REA = ribeye area, in mm; FAT = ultrasound subcutaneous backfat, in mm; CY = carcass yield; CWT = hot carcass weight; FATC = subcutaneous fat in the carcass, in mm; FAT_SC = subcutaneous fat score; TEETH = number of permanent teeth according animal age.

Table 5.8 - Results of the carcass simulation of the Braford breed.

	Steer_value	Price	AGE	FW	REA	FAT	CY	CWT	FATC	FAT_SC	TEETH
Min.	422.73	2.50	411.8	294.9	34.46	0.002	44.51	150.0	0.008	1.000	0.00
1stQu.	751.82	3.12	641.6	446.2	60.01	3.272	50.32	229.7	3.170	3.000	0.00
Median	807.27	3.12	687.2	473.1	64.82	4.380	51.51	243.6	4.432	3.000	0.00
Mean	808.18	3.11	687.2	473.2	64.83	4.399	51.53	243.7	4.456	2.955	0.94
3rdQu.	868.18	3.12	732.7	500.3	69.65	5.510	52.73	257.4	5.704	3.000	2.00
Max.	1,165.45	3.12	980.3	643.7	92.27	10.738	58.78	339.4	11.747	5.000	4.00
	y3hh_value	Price	AGE	FW	REA	FAT	CY	CWT	FATC	FAT_SC	TEETH
Min.	362.12	2.23	633.6	316.0	29.12	0.0007	41.75	150.1	0.004	1.000	0.00
1stQu.	644.55	2.79	853.9	450.7	56.78	3.2644	47.96	221.4	3.175	3.000	2.00
Median	690.91	2.79	900.0	477.9	61.67	4.3701	49.16	234.7	4.422	3.000	2.00
Mean	691.21	2.77	899.6	477.8	61.65	4.3877	49.17	234.8	4.447	2.954	1.56
3rdQu.	743.03	2.79	945.5	505.0	66.52	5.4929	50.38	248.1	5.679	3.000	2.00
Max.	981.52	2.79	1,159.3	628.1	91.09	10.8673	57.02	320.0	11.949	5.000	4.00
	Cull6_value	Price	AGE	FW	REA	FAT	CY	CWT	FATC	FAT_SC	TEETH
Min.	364.85	2.23	831.2	314.7	32.71	0.005	38.73	145.9	0.001	1.000	6.00
1stQu.	634.24	2.79	1,049.0	473.1	60.13	3.481	46.06	223.3	3.391	3.000	-
Median	673.94	2.79	1,095.3	500.2	64.89	4.584	47.27	236.1	4.631	3.000	-
Mean	683.64	2.78	1,095.0	500.2	64.89	4.598	47.28	236.3	4.657	3.025	6.00
3rdQu.	738.79	2.79	1,141.1	527.4	69.65	5.705	48.50	249.3	5.904	3.000	-
Max.	1,003.03	2.79	1,347.7	657.5	95.88	11.581	54.80	327.0	12.422	5.000	6.00
	Cull8_value	Price	AGE	FW	REA	FAT	CY	CWT	FATC	FAT_SC	TEETH
Min.	406.97	2.23	1,553	343.0	35.28	0.005	39.11	166.4	0.003	1.000	8.00
1stQu.	654.55	2.79	1,780	506.0	60.15	3.475	45.44	235.6	3.384	3.000	-
Median	691.82	2.79	1,825	533.8	64.85	4.578	46.65	248.5	4.635	3.000	-
Mean	690.61	2.78	1,825	533.5	64.89	4.590	46.65	248.7	4.653	3.027	8.00
3rdQu.	728.79	2.79	1,871	560.8	69.59	5.689	47.87	261.6	5.894	3.000	-
Max.	926.36	2.79	2,111	701.0	93.49	11.322	53.74	332.3	12.377	5.000	8.00

Steer_value = whole carcass price of steer; y3hh_value = whole carcass price of harvest heifer; Cull6_value = whole carcass price of six teeth cull cows; Cull8_value = whole carcass price of eight teeth cull cows; Price = price per kilogram of hot carcass; AGE = age of animals, in days; FW = final weight; REA = ribeye area, in mm; FAT = ultrasound subcutaneous backfat, in mm; CY = carcass yield; CWT = hot carcass weight; FATC = subcutaneous fat in the carcass, in mm; FAT_SC = subcutaneous fat score; TEETH = number of permanent teeth according animal age.

PampaPlus have some traits that are not a mandatory measurement traits, like carcass traits, being free choice of producer to carry out these measures on animals, thus, currently, this breeding program does not regularly perform ultrasound measurements for the ribeye muscle area, subcutaneous backfat and intramuscular fat that allow the generation of individualized phenotypic data by breed, being a limitation to be overcome for the adoption of selection indexes based on the proposed bioeconomic model.

There may additional variation between these two breeds, and it would be necessary to increase the number of animals evaluated for carcass traits for each breed separately to allow the estimation of more distinctive EV for these BG on HH and BO cattle.

The difference in the final value of the carcass of the HH and BO cull cows was hight, as the parameters used in the bio-economic models were individualized by breed, where through the PampaPlus database it was possible to verify that the mature weight of HH cows was substantially higher than BO cows, resulting in heavier carcasses (Tables 5.7 and 5.8).

Around 2.5% of the animals reached a fat score equal to 1, which corresponds to insufficient fat cover in the carcasses, 20% presented a fat score 2, receiving only the base price, and the other animals presented a fat score equal to 3 or more, receiving different bonuses depending on age and carcass weight (Table 5.9).

Table 5.9 – Percentage of animals in each bonus grid according to Brazilian Hereford and Braford Association bonus price table in 2018.

Category	HHst	HHhh	HHCull6	HHCull8	BOst	BOhh	BOCull6	BOCull8
1	2.64	2.69	2.19	2.15	2.64	2.69	2.19	2.03
2	19.54	19.41	16.80	-	19.54	19.41	16.80	-
3	0.05	0.15	0.00	-	0.06	0.06	0.10	-
4	0.93	2.37	-	-	0.94	0.93	-	-
5	4.56	3.86	-	-	4.60	2.27	-	-
6	13.01	7.47	-	-	13.03	6.12	-	-
7	21.19	6.79	-	-	24.12	10.21	-	-
8	12.20	30.32	-	-	12.27	21.18	-	-
9	12.92	18.31	-	-	12.90	21.17	-	-
10	9.07	7.26	-	-	9.02	14.58	-	-
11	0.33	0.81	25.28	-	0.33	0.55	44.35	-
12	0.32	0.39	32.36	-	0.32	0.47	26.66	-
13	0.17	0.16	18.94	-	0.17	0.29	8.75	-
14	0.06	0.02	4.43	-	0.06	0.07	1.14	-
15	-	-	-	97.85	-		-	97.97
Total	100	100	100	100	100	100	100	100

HHst = Hereford steers; HHhh = Hereford harvest heifers; HHCull6 = six permanent teeth Hereford cull cows; HHCull8 = eight or more permanent teeth Hereford cull cows; BOst = Braford steers; BOhh = Braford harvest heifers; BOCull6 = six permanent teeth Braford cull cows; BOCull8 = eight or more permanent teeth Hereford cull cows. 1 – 15 is the cathegory of bonus according to Table 5.4.

Economic values

In the full cycle production system of Southern Brazil the main traits that affected revenues and expenses were WWd, WWm, TICK, MCW, FAT, REA, PWG, FG and STAY. These BG and their EV are shown in Table 5.10.

Table 5.10 - Economic values (EV), in US$ and Discounted economic values (DEV) for Hereford and Braford breeding goals.

		Hereford		Braford	
	DGE	*EV*	*DEV*	*EV*	*DEV*
WWd	0.55	0.53	0.29	0.52	0.28
WWm	0.77	-0.25	-0.19	-0.26	-0.20
TICK	0.55	-21.46	-11.80	-18.97	-10.49
MCW	0.55	-0.16	-0.09	-0.16	-0.09
FAT	0.26	11.84	3.08	11.48	3.03
REA	0.26	1.03	0.27	0.99	0.26
PWG	0.55	0.64	0.35	0.64	0.35
FG	0.26	0.56	0.15	0.54	0.14
STAY	0.11	499.00	54.89	550.00	60.50

WWd = direct weaning weight (kg); WWm = maternal weaning weight (kg); TICK = tick count (Log_{10} (count)); MCW = mature cow weight (kg); FAT = subcutaneous backfat (mm); REA = ribeye muscle area (cm^2); PWG = post weaning gain (kg); FG = final gain (kg); STAY = stayability; DGE = discounted genetic expressions; DEV are economic weights discounted by genetic expressions

The reproductive trait STAY was the one with the highest economic value, differing to the sequence of economic importance presented by Bourdon & Golden (2000), which lists survival/adaptation traits as most important in relation to reproductive traits. This order founded may possibly change in herds with higher reproductive rates than those found in southern Brazil.

The high EV for STAY signs that the reproductive traits are directly linked with the number animals born per year, and consequently, the number of animals available for sale. Similarly, Soares de Lima et al. (2011), Laske et al. (2012), Pravia et al. (2014) and Costa et al. (2017) estimating EV for breeding goals in similar production systems found higher economic value for birth rate in relation to other growth traits.

The trait with high influence the system profitability, and with second higher economic value was TICK (the negative signal sign less tick per count). This trait has high EV because tick can affect directly the chemical costs, average daily gain, mainly in younger animal categories, could cause slow growth, weight losses and eventually animal deaths (Jonsson, 2006). This result make sense because when an animal die, is one unity that generate expenses and will not generate revenues. Similarly when an animal get sick and the farmer need to spent money to take care, the profit get with such animal is lessened, either by the increase in costs or by the delay in growth and fattening.

The carcass traits FAT and REA presents the 3th and 4th high EV, respectively, probably due the direct impact in the carcass bonus grid and to increase the hot carcass weight, that is the final product. However, carcass traits are directly linked with quantity of product (beef) available to sale and price obtained by this product.

The MCW and WWm had negative economic value in this production system. These traits have EV much dependent to the feed cost of the production systems.

Generally, the economic value of bigger cows were favored when feed costs were lower (Laske et al. 2012), but for production systems that need to feed animals with hay and/or concentrated feed, the feed costs with maintenance are high, and consequently the EV for MCW and WWm are very low or negative, since the benefit of selling heavier cows is limited by higher costs for herd maintenance (Groen, 1989; MacNeil et al.,1994; Kluyts et al., 2003).

MCW needs to be selected carefully because increasing the herd size and the milk production results in increased feed requirements, and it is not recommended for non-intensive production systems or production systems that do not have a high quality feed. Thus, the selection to increase MCW and WWm is just recommended for breeders that have cows with small frame size or low milk cows and/or abundant and inexpensive feed supply.

When the traits had their EVs adjusted through the discounted genetic expressions (DEV), the order practically does not change, continuing the sequence STAY, TICK and FAT as the ones of higher EVs, although FAT and STAY have their EV very reduced when compared to the value of EV without the DGE because these traits need a long time to express themselves.

Several authors report the need to adjust the EV according to the frequency and time that a characteristic spend to be expressed in the herd through genetic improvement, as the selection for characteristics that express themselves more quickly in the herd results in more rapid changes in the profit being able to give more economic benefit compared to traits that take longer to be expressed (McClintock & Cunningham, 1974; Borg, 2004).

The discount rate used in this study was the same used by Amer et al. (2001) of 7%, although Bird & Mitchell (1980) say that the reasonable estimate of discount rate would be 3% per annum.

In similar studies, Pravia (2010) estimate DGEs using a discount rate of 5%, Zeng (2013) uses 3% and Amer (1999) 7%.

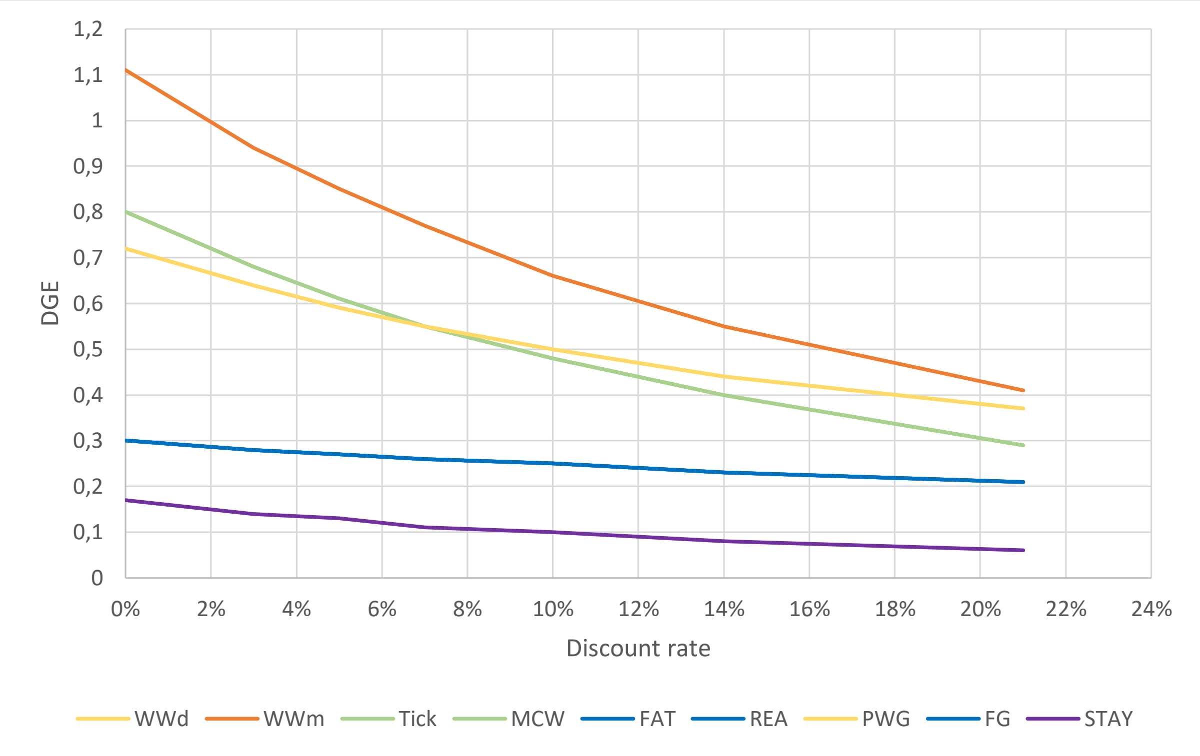
The Figure 5.2 shows the changing trend of the DGEs based on varying discount rates. This indicates that increasing discount was associated with decreasing of DGEs.

All trait categories had a negative trend with increasing of discount rate. However, because of the influence of varying discount rate, the impact degrees were not the same for different kind of traits. The discount rate has low influence on the DGEs of traits that need long time to be expressed as STAY, FAT, REA and FG, and large impact on the DGEs of maternal animals whose gene is expressed early, as WWm, WWd, TICK, MCW and PWG.

The sensitivity test showed that the DGEs for most of the traits categories are robust to changes in discount rate, considering a reasonable range of 3 to 10%.

In this way, the sooner the trait is expressed, the greater the influence of the discount rate.

Figure 5.2 - Sensitivity of Cumulative Discounted Gene Expressions (DGEs) on changing discount rate.



5.4 Conclusions

The traits weaning weight direct and maternal, tick count, mature cow weight, subcutaneous backfat, ribeye muscle area, post-weaning gain, final gain, and stayability are identified as breeding goals due to their ability to change the profitability of full cycle production systems in Southern Brazil, where the trait with high economic value was the stayability, followed by tick count and subcutaneous backfat, even when the economic values are adjusted by the discounted genetic expressions.

To select more profitable animals, the traits tick count, ribeye muscle area, subcutaneous backfat and stayability should be included as breeding goals in the PampaPlus breeding program, together with the characteristics conventionally already identified as breeding goals weaning weight direct and maternal, mature post-weaning gain and final gain.

5.5 Literature cited

Abiec. 2017. Associação Brasileira dos Exportadores de Carne. Disponível em: http://abiec.com.br/ExportacoesPorAno.aspx - Acessado em 01/08/2018.

Amer, P. 1999. Economic accounting of numbers of expressions and delays in sheep genetic improvement. New Zealand Journal of Agricultural Research 42(3): 325-336.

Amer, P. R., G. Simm, M. G. Keane, M. G. Diskin, and B. W. Wickham. 2001. Breeding objectives for beef cattle in Ireland. Livest. Production Sci. 67 223–239.

Anualpec. 2015: Anuário da Pecuária Brasileira. São Paulo: FNP, 400p.

Anon., 2016, R: A language and environment for statistical computing. R. Foundation for Statistical Computing, Available at: http://www.R-project.org/. Vienna, Austria.

Beretta, V., J. F. P. Lobato, and C. G. M. Netto. 2002. Produtividade e Eficiência Biológica de Sistemas de Produção de Gado de Corte de Ciclo Completo no Rio Grande de Sul. R. Bras. Zootec. 31: 991-1001.

Berry, D. P., & R. D. Evans. 2014. Genetics of reproductive performance in seasonal calving beef cows and its association with performance traits. J. Anim. Sci. 92:1412–1422.

Bird, P. & G. Mitchell. 1980. The choice of discount rate in animal breeding investment appraisal. Animal Breeding Abstracts.

Borg, R. C. 2004. Developing breeding objectives for Targhee Sheep. Tesis Masters of Science. Virginia Polytechnic Institute and State University. 80 p.

Bourdon, R. & B. Golden. 2000. EPD's and economics: Determining the relative importance of traits. Available in: http://ansci.colostate.edu/ (10/10/2000).

Brody, S. 1964. Bioenergetics and Growth. Hafner Publishing Company Inc., New York. NY.

Buskirk, D. D., R. P. Lemenager, and L. A. Horstman. 1992. Estimation of net energy requirements (NEm and NED) of lacting beef cows. Journal of Animal Science, v.70, p.3867-3876.

Cardoso, L. L. 2013. Estimativas do rendimento comercial de novilhos com a utilização de ultrassom. Tese (Doutorado) – Universidade Federal do Rio Grande do Sul, Faculdade de Agronomia, Programa de Pós- Graduação em Zootecnia, Porto Alegre, BR-RS.

Cardoso, F. F., C. C. G. Gomes, B. P. Sollero, M. M. Oliveira, V. M. Roso, M. L. Piccoli, R. H. Higa, M. J. Yokoo, A. R. Caetano, and I. Aguilar. 2015. Genomic prediction for tick resistance in Braford and Hereford cattle. J. Anim. Sci. 93: 2693-2705.

Costa, R. F., B. B. M. Teixeira, M. J. Yokoo, and F. F. Cardoso. 2017. Economic selection indexes for Hereford and Braford cattle raised in southern Brazil. J. Anim. Sci. 95:1–13.

Formigoni, I. B. 2002. Estimação de valores econômicos características componentes de Índices de seleção em bovinos de corte. Pirassununga. Master Diss.– Programa de Pós Graduação da Faculdade de Zootecnia e Engenharia de Alimentos da Universidade de São Paulo.

Garrick, D. J., & B. L. Golden. 2009. Producing and using genetic evaluations in the United States beef industry of today. J. Anim. Sci. 87 (E.Suppl.): E11-E18.

Gibson, J. P., & J. M. Wilton. 1998. Defining multiple-trait objectives for sustainable genetic improvement. J. Anim. Sci. 76: 2303-2307.

Groen, A. F. 1989. Economic Values in Cattle Breeding. I. Influences of Production Circumstances in Situations without Output Limitations. Livest. Prod. Sci. 22: 1-16.

Jones, H. E., P. R. Amer, R. M. Lewis, and G. C. Emmans. 2004. Economic values for changes in carcass lean and fat weights at fixed age for terminal sire breeds of sheep in the UK. Livestock Production Science 89, p. 1-17.

Jonsson, N. N. 2006. The productivity effects of cattle tick (*Boophilus microplus*) infestation on cattle with particular reference to Bosindicus cattle and their crosses. Vet. Parasitol. 137: 1–10.

Kluyts, J. F., F. W. C. Neser, M. J. Bradfield. 2003. Development of breeding objectives for beef cattle breeding: Derivation of economic values. South African Journal of Animal Science, v.33, p.142-158.

Laske, C. H., B. B. M. Teixeira, N. J. L. Dionello, and F. F. Cardoso. 2012. Breeding objectives and economic values for traits of low input family-based beef cattle production system in the State of Rio Grande do Sul. R. Bras. Zootec. 41: 298-305.

Leslie, P. H. 1945. The use of matrices in certain population mathematics. Biometrika. 33:183-212.

Leslie, P. H. 1948. Some further notes on the use of matrices in population mathematics. Biometrika. 35: 213-245.

MacNeil, M. D., S. Newman, R. M. Enns, and J. Stewart-Smith. 1994. Relative economic values for Canadian beef production using specialized sire and dam lines. Can. J. Anim. Sci. 74: 411-417.

McClintock, A. E., & E. P. Cunningham, E. P. 1974. Selection in dual purpose cattle populations: defining the breeding objective. Anim. Prod. 18: 237-247.

Moreira, F. B., I. N. Prado, U. Cecato, F. Y. Wada, W. G. Nascimento, N. E. Souza. 2001. Níveis de suplementação de sal proteinado para bovinos nelore terminados a pasto no período do inverno. In: Reunião Anual da Sociedade Brasileira de Zootecnia, 38., 2001, Piracicaba. Anais... Piracicaba: Sociedade Brasileira de Zootecnia, 2001. p.923-924.

National Research Council (NRC). 2000. Nutrient requirements of beef cattle. 7.ed. (Up Date) Washington, DC: National Academy Press, 2000. 242p.

Ponzoni, R. W., & S. Newman. 1989. Developing breeding objectives for Australian beef cattle production. Anim. Prod. 49: 35-47.

Pravia, M. I. 2010. Desarrollo de objetivos e índice de selección en ganado para carne en Uruguay a través de un modelo bioeconómico. Master Diss. Universidad de la Republica, Montevideo.

Pravia, M. I., O. Ravagnolo, J. I. Urioste, D. J. Garrick. 2014. Identification of breeding objectives using a bioeconomic model for a beef cattle production system in Uruguay. Livestock Science, v.160, p.21-28.

Rodrigues, P. F., L. M. Menezes, R. C. C. Azambuja, R. W. Suñé, I. D. Barbosa Silveira, and F. F. Cardoso. 2014. Milk yield and composition from Angus and Angus-cross beef cows raised in southern Brazil1. J. Anim. Sci. 2014.92:2668–2676.

Soares de Lima, J. M., M. I. Pravia, O. Ravagnolo, F. Montossi. 2011. Índice de selección para la Cría: "Una nueva herramienta disponible em Uruguay para selecionar reproductores por su mérito econômico em la raza Hereford". Programa Nacional de Carne y Lana, INIA Uruguay. Anuário da Sociedad Criadores de Hereford del Uruguay.

Urioste, J. I., R. W. Ponzoni, M. Aguirrezabala, G. Rovere, and D. Saavedra. 1998. Breeding objectives for pasture-fed Uruguayan beef cattle. J. Anim. Breed. Genet. 115: 357-373.

Venables, W. N., & B. D. Ripley. 2002. Tree-Based Methods. In: Modern Applied Statistics with S. Statistics and Computing. Springer, New York, NY.

5.6 Appendix 1 - Discounted Genetic Expressions for PampaPlus Breeding Goals

When a breeding program targets the selection for a group of traits, using a selection index, it is expected that some traits will express less than others because some traits will only manifest itself at the end of the animal's life cycle, as carcass weight, for example, and others will manifest in the beginning of life cycle, as birth weight or weaning weight, so the time is relevant for the decision of how much weight should be given in the selection process (Gibson & Wilton, 1998).

On this way, the discounted expressions models could adjust the economic values through coefficients calculated that take into account the frequency and the time that a trait will be expressed, considering animal life cycle. Thus, selecting traits that result in more rapid changes in the profit could give more economic benefit compared to traits that take longer to be expressed (McClintock & Cunningham, 1974; Borg, 2004).

Hill (1974) describes economic values as a return on investment, where the investment is the selection decision. If all traits were expressed immediately due genetic selection, the true profit would be described by the economic values and rate of genetic change. In reality, changes in performance from selection are not realized quickly and economic traits are expressed at different rates over many years. So, the discounting genetic expressions adjusts economic values to express the value of future profit from genetic improvement at the time of selection.

Thus, this appendix details how the cumulative discounted gene expressions (DGEs) of traits expressed differently in time were calculated for a full cycle system and checked for sensibility to discount rates changes.

Discounted genetic expressions. The DGEs for birth, slaughter, annual and end-of-cow-life traits were calculated for Hereford and Braford cattle. The traits were determined by the frequency and time point they are expressed. The calculations of discounted genetic expressions for the breeding goals used in this work was based on the approaches outlined by Amer (1999) and Amer et al. (2001) for sire breeding replacement females, and the expressions coefficient for each breeding goal utilized are shown in Table 5.6.1.

The parameters used in these equations to calculate the DGEs were estimated from 10,000 female simulated herd, obtained by Leslie matrix using actual data from PampaPlus breeding program database.

The discounted expressions for the following traits were calculated as: X_{RA} for annual traits expressed by adult cows every year (pregnancy, maternal ability, mature weight, parasites counting), X_{RW} for traits expressed in cows offspring at weaning (direct weaning weight), X_{RS} for terminal traits expressed in steers (final gain, carcass traits) and X_{RC} for traits expressed in cows in the end of life (stayability).

Table 5.6.1 – Expressions coefficient used for each breeding goal.

Breeding goal	Abbreviation	Expression coefficients
Weaning weight direct	WWd	$(1-K) \times (X_{RW} + X_{TB})$
Weaning weight maternal	WWm	$(1-K) \times (2 \times X_{RW})$
Tick count	TICK	$(1-K) \times X_{RA}$
Mature cow weight	MCW	$(1-K) \times X_{RA}$
Subcutaneous fat	FAT	$K \times X_{TS}$
Ribeye area	REA	$K \times X_{TS}$
Post weaning gain	PWG	$K \times X_{TB}$
Final gain	FW	$K \times X_{TS}$
Stayability	STAY	$(1-K) \times X_{RA}$

X_{TB} and X_{TS} are numbers of discounted expressions of sires genes at birth and slaughter, respectively, per calf born.

X_{RA} , X_{RW} , X_{RH} and X_{RC} are numbers of discounted expressions of sires genes in his daughters at annual calvings, weaning of their calves, replacement heifer age and at culling, respectively, per female calf born which is destined to become a replacement.

K is the average proportion of a bulls progeny not destined to be replacements and is calculated as: $1-\left(\frac{1}{2 \times P}\right)$, where P is the proportion of a sires daughters which become replacement heifers.

For this, first it is necessary to calculate the genetic expressions for a trait expressed annually by a cow (X_{RA}), by heifers (X_{RH}), and at the end of the life of a cow (X_{RC}). It also requires the calculation of the number of expressions expressed at birth (X_{RL}) and slaughter (X_{RS}) of calves of replacement cows.

The discounted expressions X_{RA}, X_{RC}, X_{RH}, and X_{RW} are calculated as:

$$\boldsymbol{X_{RA}} = \mathbf{q}'\mathbf{D}\mathbf{g}_{\mathbf{sum}} \cdot \frac{1}{2}$$

$$\boldsymbol{X_{RC}} = \mathbf{q}'\mathbf{G}\mathbf{g}_{\mathbf{sum}} \cdot \frac{1}{2}$$

$$\boldsymbol{X_{RH}} = \mathbf{q}'\mathbf{H}\mathbf{g}_{\mathbf{sum}} \cdot \frac{1}{2}$$

and,

$$\boldsymbol{X_{RW}} = \mathbf{q}'\mathbf{D}\mathbf{g}_{\mathbf{sum}} \cdot \frac{1}{2}\mathbf{D}'\mathbf{q}. \frac{v}{S_2}$$

To calculate these expressions, it is first necessary to define the vectors **s** and **p**, where the vector **S** is a vector *n* x 1 of probabilities that a cow survives and passes the age range *i* -1 for the age group *i*, considering *i* = 1 until *i* = *n*, being *n* the highest age considered, that in the present study was nine years (*n* = 9).

Based on the data from the PampaPlus herd, it was defined that the vector **s** and **p** is as follows:

$$\mathbf{s}' = [0.00, 0.00, 0.99, 0.78, 0.79, 0.93, 0.87, 0.80, 0.75, 0.60, 0.00]$$

p is also an *n* × 1 vector corresponding to the number of calves reaching a reproductive age or slaughter age per cow in each age group *i*. The first birth is assumed at three years of age, so the elements of $\mathbf{p}_1$, $\mathbf{p}_2$, $\mathbf{s}_1$, and $\mathbf{s}_2$ carry values equal to zero.

$$\mathbf{p}' = [\,0.00, 0.00, 0.78, 0.61, 0.68, 0.68, 0.68, 0.65, 061, 0.57]$$

Now let c be a cull for age threshold ($c \leq n$), in other words, all cows above the age of c, are culled, irrespective of their potential future survival. A vector (**a**) of probabilities of a cow surviving to age i, given that it was alive at age 1, can now be calculated where:

$$a_i = \begin{cases} \prod_{j=2}^{i} S_2 & i = 2\ to\ c \\ 0, & otherwise \end{cases}$$

For the database PampaPlus example,

$$\mathbf{a}' = [0.00, 0.00, 0.99, 0.77, 0.61, 0.57, 0.49, 0.39, 0.30, 0.18]$$

The probability of a cow dying or being culled at i years of age, $\mathbf{d}_i$, can be calculated as:

$$\boldsymbol{d}_i = \begin{cases} 1 - \boldsymbol{a}_1 & for\ i = 2 \\ \boldsymbol{a}_{i-1} - \boldsymbol{a}_1 & for\ i = 3\ to\ c + 1 \\ 0, & otherwise \end{cases}$$

$$\mathbf{d}' = [0.00, 0.00, 0.01, 0.218, 0.162, 0.043, 0.074, 0.099, 0.099, 0.000]$$

Let **D** be an h by h transition matrix with columns of survival probabilities lagged by one row for each new birth year where h is the planning horizon in years from birth of the self replacing female. The(i,j)th element of **D** is specified as:

$$\boldsymbol{D}_{i,j} = \begin{cases} \boldsymbol{a}_{i-j} & for\ j < i - 1\ and\ i - j \leq c \\ 0, & otherwise \end{cases}$$

Similar matrices of survival probabilities for cull cow, **G**, and replacement heifer, **H**, expressions, respectively, are calculated as:

$$\boldsymbol{G}_{i,j} = \begin{cases} \boldsymbol{d}_{i-j} & for\ j < i-1\ and\ i-j \leq c \\ 0, & otherwise \end{cases}$$

and

$$\boldsymbol{H}_{i,j} = \begin{cases} 1 & for\ i+1 = j \\ 0, & otherwise \end{cases}$$

For the database PampaPlus example,

$$D = \begin{bmatrix} 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 \\ 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 \\ 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 \\ 0.99 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 \\ 0.77 & 0.99 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 \\ 0.61 & 0.77 & 0.99 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 \\ 0.57 & 0.61 & 0.77 & 0.99 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 \\ 0.49 & 0.57 & 0.61 & 077 & 0.99 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 \\ 0.39 & 0.49 & 0.57 & 0.61 & 0.77 & 0.99 & 0.00 & 0.00 & 0.00 & 0.00 \\ 0.30 & 0.39 & 0.49 & 0.57 & 0.61 & 0.77 & 0.99 & 0.00 & 0.00 & 0.00 \end{bmatrix}$$

$$G = \begin{bmatrix} 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 \\ 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 \\ 0.01 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 \\ 0.22 & 0.01 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 \\ 0.16 & 0.22 & 0.01 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 \\ 0.04 & 0.16 & 0.22 & 0.01 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 \\ 0.07 & 0.04 & 0.16 & 0.22 & 0.01 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 \\ 0.10 & 0.07 & 0.04 & 0.16 & 0.22 & 0.01 & 0.00 & 0.00 & 0.00 & 0.00 \\ 0.10 & 0.10 & 0.07 & 0.04 & 0.16 & 0.22 & 0.01 & 0.00 & 0.00 & 0.00 \\ 0.17 & 0.10 & 0.10 & 0.07 & 0.04 & 0.16 & 0.21 & 0.01 & 0.00 & 0.00 \end{bmatrix}$$

and,

$$H = \begin{bmatrix} 1.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 \\ 0.00 & 1.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 \\ 0.00 & 0.00 & 1.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 \\ 0.00 & 0.00 & 0.00 & 1.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 \\ 0.00 & 0.00 & 0.00 & 0.00 & 1.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 \\ 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 1.00 & 0.00 & 0.00 & 0.00 & 0.00 \\ 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 1.00 & 0.00 & 0.00 & 0.00 \\ 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 1.00 & 0.00 & 0.00 \\ 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 1.00 & 0.00 \\ 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 1.00 \end{bmatrix}$$

Vectors containing increments of gene flows ($\mathbf{g}_k$) can be calculated for each generation k as:

$$\mathbf{g}_k = \frac{1}{2} f\mathbf{D}\mathbf{g}_{k-1}$$

For k=1 to m generations (*m* = 5 in this study) and starting with $\mathbf{g}_1' = [1, 0 \ldots 0]$, and the factor of ½ to account for the cows genetic contribution to her progeny and where *f* is the number of heifers required as replacements (at first reproductive age) per cow calving per year. Under the assumption of a constant herd age structure, *f* can be calculated as the proportion of 2 years old cows relative to all cows calving:

$$f = \frac{1}{\sum_{i=1}^{c} \mathbf{a}_i} = 0.2425$$

Rows of each $\mathbf{g}_k$ vector correspond to the year of expression of the genes so that each $\mathbf{g}_k$ is of dimension *h*. Aggregate yearly genetic expressions accumulated over generations are therefore calculed as:

$$\mathbf{g}_{sum} = \sum_{k=1}^{m} \mathbf{g}_k$$

For the example, and considering gene-flows through five generations,

$$\mathbf{g}_1 = \begin{bmatrix} 1.00 \\ 0.00 \\ 0.00 \\ 0.00 \\ 0.00 \\ 0.00 \\ 0.00 \\ 0.00 \\ 0.00 \\ 0.00 \end{bmatrix}, \mathbf{g}_2 = \begin{bmatrix} 0.00 \\ 0.00 \\ 0.00 \\ 0.12 \\ 0.09 \\ 0.07 \\ 0.07 \\ 0.06 \\ 0.05 \\ 0.03 \end{bmatrix}, \mathbf{g}_3 = \begin{bmatrix} 0.00 \\ 0.00 \\ 0.00 \\ 0.00 \\ 0.00 \\ 0.00 \\ 0.01 \\ 0.02 \\ 0.02 \\ 0.03 \end{bmatrix}, \mathbf{g}_4 = \begin{bmatrix} 0.000 \\ 0.000 \\ 0.000 \\ 0.000 \\ 0.000 \\ 0.000 \\ 0.000 \\ 0.000 \\ 0.000 \\ 0.002 \end{bmatrix}, \mathbf{g}_5 = \begin{bmatrix} 0.00 \\ 0.00 \\ 0.00 \\ 0.00 \\ 0.00 \\ 0.00 \\ 0.00 \\ 0.00 \\ 0.00 \\ 0.00 \end{bmatrix}, \text{ and } \mathbf{g}_{sum} = \begin{bmatrix} 1.00 \\ 0.00 \\ 0.00 \\ 0.12 \\ 0.09 \\ 0.07 \\ 0.08 \\ 0.08 \\ 0.07 \\ 0.06 \end{bmatrix}$$

Thus, an average cow first express her genes in her own generation at a year set equal to 1. Three years later, 0.12 of her genes are expected to be first expressed in a daughter from her first calving, while four years later, 0.09 of her genes are expected to be first expressed in a daughter from her second calving. Note that the expected first expression from the second calving is lower because of the probability of the cow dying between first and second calvings.

After calculate the matrices **D**, **G** and **H** can now be used to multiply first expressions to the multiple expression of genes for each cow over its expected life span. Also, let **q** be a vector (dimension *h*) of discount coefficients with elements defined as:

$$\mathbf{q}_i = \left(\frac{1}{1+r}\right)^{i-1}$$

$$\mathbf{q} = [1.00, 0.93, 0.87, 0.82, 0.76, 0.71, 0.66, 0.62, 0.58, 0.54]$$

So that the discount coefficient is 1 at birth of the heifer replacement and *r* (0.07) is the discount rate. The number of genetic expressions for a trait expressed annually by a self-replacing cow is therefore calculated as:

$$\boldsymbol{X}_{\boldsymbol{RA}} = \mathbf{q}'\mathbf{D}\mathbf{g}_{\mathbf{sum}} \cdot \frac{1}{2}$$

The discounted numbers of end of cow life expressions (X_{RC}), heifer replacement expressions (X_{RH}) and calf at weaning expressions (X_{RW}) for a self-replacing female are calculated as:

$$X_{RC} = \mathbf{q}'\mathbf{G}\mathbf{g}_{\mathbf{sum}} \cdot \frac{1}{2}$$

$$\boldsymbol{X_{RH}} = \mathbf{q}'\mathbf{H}\mathbf{g}_{\mathbf{sum}} \cdot \frac{1}{2}$$

and,

$$\boldsymbol{X_{RW}} = \mathbf{q}'\mathbf{D}\mathbf{g}_{\mathbf{sum}} \cdot \frac{1}{2}\mathbf{D}'\mathbf{q} \cdot \frac{v}{S_2}$$

where v is the number of calves reaching slaughter age or sold per cow calving and S_2 (0.98) is calf survival from weaning to slaughter or replacement age.

Note that $v = \mathbf{a}'\mathbf{p}.(\mathbf{1}'\mathbf{a})^{-1}$ where vectors **a**, **p** and **1** are all of dimension n and all elements of **1** are ones.

$$\mathbf{1} = [1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00]$$

and,

$$v = 0.679$$

K is the average proportion of a bulls progeny not destined to be replacements and is calculated as:

$$K = 1 - \left(\frac{1}{2 \times P}\right) = 0.67$$

where P is the proportion of a sires daughters which become replacement heifers (P = 0.659 in PampaPlus exemple).

For the PampaPlus exemple, the result of the discounted expressions calculations is: X_{RA} = 1.6774, X_{RC} = 0.3456, X_{RH} = 0.6332, X_{RW} = 1.1626, X_{RS} = 0.3937, X_{TB} = 0.5 and, K = 0.67.

The discounted genetic expressions for the PampaPlus breeding goals of weaning weight direct, weaning weight maternal, tick count, mature cow weight, subcutaneous fat, ribeye area, post weaning gain, final gain and stayability are showed in Table 5.6.2.

Table 5.6.2 – Discounted genetic expressions (DGE) for each PampaPlus breeding goal.

Breeding goal	Equation	DGE
Weaning weight direct	$(1-K) \times (X_{RW} + X_{TB})$	0.55
Weaning weight maternal	$(1-K) \times (2 \times X_{RW})$	0.77
Tick count	$(1-K) \times X_{RA}$	0.55
Mature cow weight	$(1-K) \times X_{RA}$	0.55
Subcutaneous fat	$K \times X_{RS}$	0.26
Ribeye area	$K \times X_{RS}$	0.26
Post weaning gain	$(1-K) \times (X_{RW} + X_{TB})$	0.55
Final gain	$K \times X_{RS}$	0.26
Stayability	$(1-K) \times X_{RC}$	0.11

X_{TB} and X_{RS} are numbers of discounted expressions of a sires genes at birth and slaughter, respectively, per calf born.
X_{RA} , X_{RW} , X_{RH} and X_{RC} are numbers of discounted expressions of a sires genes in his daughters at annual calvings, weaning of their calves, replacement heifer age and at culling, respectively, per female calf born which is destined to become a replacement.

5.6.3 Literature cited

Amer, P. 1999. Economic accounting of numbers of expressions and delays in sheep genetic improvement. New Zealand Journal of Agricultural Research 42(3): 325-336.

Amer, P. R., G. Simm, M. G. Keane, M. G. Diskin, B. W. Wickham. 2001. Breeding objectives for beef cattle in Ireland. Livest. Production Sci. 67 223–239.

Borg, R. C. 2004. Developing breeding objectives for Targhee Sheep. Tesis Masters of Science. Virginia Polytechnic Institute and State University. 80 p.

Gibson, J. P., & J. M. Wilton. 1998. Defining multiple-trait objectives for sustainable genetic improvement. J. Anim. Sci. 76: 2303-2307.

Hill, W. G. 1974. Prediction and evaluation of response to selection with overlapping generations. Animal Production 18(02): 117-139.

McClintock, A. E., & E. P. Cunningham. 1974. Selection in dual purpose cattle populations: defining the breeding objective. Anim. Prod. 18: 237-247.

6. Chapter 2 - Economic indexes including tick resistance for Hereford and Braford breeds raised in Southern Brazil.

Abstract: Several biologic traits can affect the profitability of beef cattle herds, that varies according to the production system particularities. These traits are defined as breeding goals (BG) and the correct definition are determinant for effective genetic improvement, where the BG must be weighted according to their economic relevance. A general option to maximizing the profitability across the Southern Brazilian beef chain would use a full cycle economic index because this production system includes all production phases (calf cropping, stocking, and finishing) and, therefore had the greatest correlation between economic indexes with other specialized systems. The aims of this study were to develop an economic selection index that maximize the profit and combines survival/adaptation (tick resistance), reproduction (stayability) carcass (ribeye muscle area and subcutaneous fat) and growth traits (direct and maternal weaning weight, mature cow weight, post weaning gain and final gain) in a typical full cycle beef cattle production systems in Southern Brazil using Hereford or Braford breeds. The calculated relative importance and selection response of the BG were 9.31 and 8.90 for weaning weight direct and, were 5.17 and 5.24 for maternal, 5.26 and 4.53 for tick count, 6.53 and 6.37 for mature cow size, 10.34 and 9.68 for ribeye muscle area, 8.80 and 8.32 for subcutaneous backfat, 10.90 and 10.62 for post weaning gain, 4.59 and 4.32 for final gain, and 39.11 and 42.02 for stayability, for Hereford and Braford breeds. Using the developed economic indexes, it is possible to increase the fertility of the animals and the adaptation of the herd to the parasitism by the tick, increasing the profitability of the productive systems of southern Brazil, that historically have serious problems related to the low reproductive rates and with tick parasitism. The relative importance and selection response of the BG for Hereford and Braford were similar, indicating that an economic index with same weights can be used for both breeds in PampaPlus breeding program.

Key Words: beef cattle, breeding goals, economic values, parasite resistance, selection indexes.

6.1 Introduction

Several biologic traits can affect the profitability of beef cattle herds, that varies according to the production system particularities. These traits are defined as breeding goals (BG) and the correct definition are determinant for effective genetic improvement, where the BG must be weighted according to their economic relevance (Amer et al. 2001; Pravia et al. 2014).

To improve the profit in this production system several traits need to be considered, such as survival/adaptation, fertility/longevity, feed intake and growth traits, and these traits must be economically evaluated through its economic values and selected together using preferably economic indices, even if this selection method results in a lower genetic gain per trait because depending on the correlation between them, the direct selection for one trait can affect negatively another important trait (Hazel, 1943; Enns, 2007).

A general option to maximizing the profitability across the Southern Brazilian beef chain would use a full cycle economic index because this production system includes all production phases (calf cropping, stocking, and finishing) and, therefore had the greatest correlation between economic indexes with other specialized systems (Costa et al., 2017).

The selection for stayability, carcass traits, growth traits, and tick resistance impacts directly in to the production systems, as by the increases in the number of animals and the quality and quantity of meat available to the market, the herd energy requirements and the costs associated with it, and by in the reduction of losses by tick infections (Laske et al., 2012; Cardoso et al., 2015; Costa et al., 2017).

The aims of this study were to develop an economic selection index that maximize the profit and combines survival/adaptation (tick resistance), reproduction (stayability), carcass (ribeye muscle area and subcutaneous fat) and growth traits (direct and maternal weaning weight, mature cow weight, post weaning gain and final gain) in a typical full cycle beef cattle production systems in Southern Brazil using Hereford (HH) or Braford (BO) breeds.

6.2 Materials and methods

Economic Selection indexes

Two economic indexes were determined, one for Hereford and another for Braford, using their respective parameters and economic values. The vector of the weighting coefficients in the indexes (**b**) was computed by the following equation (Schneeberger et al., 1992):

$$\mathbf{b} = \mathbf{G}_{11}^{-1} \times \mathbf{G}_{12} \times \mathbf{v}$$

where: $\mathbf{G}_{11}^{-1}$ is the inverse of genetic (co)variance matrix between the selection criteria in the indexes, $\mathbf{G}_{12}$ is the genetic covariance matrix between the selection criteria and BG, and **v** is the vector of economic values for the BG.

The economic values of vector **v** were those obtained in Chapter 1. The selection criteria used in the economic index used to compose the $\mathbf{G}_{11}$ were the same BG identified in the bio-economic model and used to compose the $\mathbf{G}_{12}$ matrix were weaning weight direct (WWd) and maternal (WWm), tick count (TICK), mature cow weight (MCW), subcutaneous backfat, measured by ultrasonography at 550 days old (FAT), ribeye muscle area, measured by ultrasonography at 550 days old (REA), post weaning gain (PWG) and stayability (STAY). As the final gain (FG) is not measured in the PampaPlus Breeding program, it was used just as BG.

The genetic parameters used in $\mathbf{G_{11}}$ and $\mathbf{G_{12}}$ (Table 6.1) were derived from PampaPlus data for WWd, WWm, MCW, PWG, FG and STAY traits (Teixeira et al. 2013; Teixeira, 2018), TICK from Cardoso et. al. (2015), and FAT and REA from Meyer et al. (2004).

Table 6.1 - Heritability (diagonal), phenotypic correlations (below diagonal), genetic correlations (above diagonal) and phenotypic variances (last line).

	WW-d	WW-m	TICK	MCW	FAT	REA	PWG	FG	STAY
WW-d	0.130	-0.571	-0.120	0.358	-0.050	0.540	0.395	0.395	0.000
WW-m	0.000	0.090	0.000	0.049	0.000	0.000	-0.018	-0.018	0.000
TICK	0.000	0.000	0.190	0.000	0.000	0.000	0.000	0.000	0.000
MCW	0.114	0.000	0.000	0.180	-0.130	0.100	-0.134	-0.134	0.000
FAT	0.060	0.000	0.000	-0.050	0.322	-0.050	0.000	0.000	0.000
REA	0.240	0.000	0.000	0.000	0.090	0.266	0.000	0.000	0.000
PWG	-0.160	0.000	0.000	-0.031	0.000	0.000	0.100	1.000	0.000
FG	-0.160	0.000	0.000	-0.031	0.000	0.000	1.000	0.100	0.000
STAY	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.190
σ^2_p	789.996	806.791	0.101	3024.868	2.760	45.270	963.480	963.480	0.248

σ^2p = phenotypic variance; WWd = direct weaning weight (kg); WWm = maternal weaning weight (kg); TICK = tick count (Log_{10} (count));MCW = Mature cow weight at weaning (kg); FAT = subcutaneous backfat (mm); REA = ribeye muscle area (cm^2); PWG = post- weaning gain (kg); FG = final gain (kg); STAY = stayability (%).

The economic values used to compose the vector $\boldsymbol{v}$ in the selection indices were estimated in Chapter 2, where the discounted economic values (DGE) of each trait were used (Table 5.10).

As the genetic parameters of the tick count characteristic were estimated in Log, in vector $\boldsymbol{v}$ the estimated tick count DGE was used in this unit (Log_{10}(tick count)). After calculated the selection response for tick count, it was converted to the tick count unit, and then multiplied by the DGE of the tick count, in units, to obtain the economic genetic gain per generation of this trait.

The BG' genetic gains (ΔGo) were calculated using the following equation:

$$\Delta G_o = \left(\frac{i}{\sigma_I}\right) G'_{12} G_{11}^{-1} Var_{(\hat{u})} b$$

where: i is the selection intensity, taking a value of 1.49 in this study, $\sigma_I = \sqrt{b'\,Var(\hat{u})\,b}$, that is the selection index standard deviation; $Var_{(\hat{u})} = B'P\,B$, where: B = $P^{-1} \times G_{11}$, P is the phenotypic (co)variance matrix among the selection criteria, $\mathbf{G_{11}}$ is the genetic (co)variance matrix among the selection criteria and, $\mathbf{G_{12}}$ is the genetic covariance matrix between the selection criteria and BG, and **v** is the vector of economic values for the BG.

The accuracy of economic selection index (R_{IH}) was calculated as $R_{IH} = \sigma_I / \sigma_H$, where: σ_H is equal to $\sqrt{w'\,C\,w}$, where **C** is the genetic (co)variance matrix among the BG, and ***w*** is the vector of economic values of the BG.

The economic genetic gain for the i^th BG ($\Delta G\$_{(i)}$) was calculated using the equation $\sum \Delta G\$_{(i)} = \Delta Go_{(i)} \times \mathbf{v}_{(i)}$ (Pravia, 2010).

To compare the economically weighted indexes with the current empirical index used by PampaPlus (IQG) was used the empirical weighting described in Costa et al. 2017 for the IQG selection criteria, maintaining the breeding goals identified in this work.

6.3 Results and discussion

The economic selection index proposed for full cycle system based in Hereford and Braford breeds in Southern Brazilian was calculated considering the economic values for each BG.

The relative importance and selection response of the BG for Hereford and Braford were similar, as can be seen below.

Relative importance of BG (RI)

The trait with higher relative importance (RI) in this production system was the STAY, followed by the carcass traits and TICK (Table 6.2). This result was expected because usually reproductive traits have a direct impact on the number of animals born per year and, consequently, increase the number of animals available for sale, as also are reported by Laske et al. (2012).

When the economic values were multiplied by the discounted genetic expressions, the relative importance of STAY had a significant reduction, since this is a trait that takes many years to express itself in the next generations. However, it remained the trait with the most relative importance, proving the economic priority of selection driven to reproductive traits.

Although TICK has the second higher economic value, evidencing that its change in a unit present a high economic impact in full cycle beef cattle production system in Southern Brazil, when its economic value was multiplied by the σg of TICK, results in a small value and, consequently, small relative importance. This occurs because the heritability and genetic variability of TICK are low and, consequently this trait presents a lower response to the selection being more difficult change one unity of this trait than others with larger genetic variance.

Table 6.2 - Economic values (EV) and discounted economic values (DGE), in US$, and relative importance (RI) for Hereford and Braford breeding goals.

			Hereford				Braford			
	σ_g	DGE	*EV*	*RI%*	*DEV*	*RI%*	*EV*	*RI%*	*DEV*	*RI%*
WWd	10.13	0.55	0.53	3.41	0.29	9.31	0.52	3.15	0.28	8.90
WWm	8.52	0.77	-0.25	1.35	-0.19	5.17	-0.26	1.33	-0.20	5.24
TICK	0.14	0.55	-21.46	1.91	-11.86	5.26	-18.97	1.59	-10.49	4.53
MCW	23.33	0.55	-0.16	2.37	-0.09	6.53	-0.16	2.23	-0.09	6.37
FAT	0.89	0.26	11.84	6.69	3.13	8.80	11.48	6.11	3.03	8.32
REA	12.01	0.26	1.03	7.86	0.27	10.34	0.99	7.11	0.26	9.68
PWG	9.82	0.55	0.64	3.99	0.35	10.90	0.64	3.76	0.35	10.62
FG	9.82	0.26	0.56	3.49	0.15	4.59	0.54	3.17	0.14	4.32
STAY	0.22	0.11	499.00	68.92	56.84	39.11	550.00	71.54	62.65	42.02

WWd = direct weaning weight (kg); WWm = maternal weaning weight (kg); TICK = tick count (Log_{10} (count)); MCW = mature cow weight (kg); FAT = subcutaneous backfat (mm); REA = ribeye muscle area (cm²); PWG = post weaning gain (kg); FG = final gain (kg); STAY = stayability (%); σ_g = genetic standard deviation; DGE = discounted genetic expressions;

Economic Selection Indexes

The economic selection indexes developed for HH and BO breed (EIHH and EIBO), allowed to weight the BG in order to bring the greatest economic return resulting in higher overall genetic economic gain (Table 6.3).

Table 6.3 - Economic weights (*b*), in US$, and Response per generation (R_g), Economic response (*R$*) and participation on the overall genetic gain for each breeding goal (%) for Hereford and Braford breeding goals.

	EIHH				*EIBO*			
	b	*Rg*	*R$*	$\frac{R_g\$_i}{\sum R_g\$_{ij}}$	*b*	*Rg*	*R$*	$\frac{R_g\$_i}{\sum R_g\$_{ij}}$
WWd	0.29	3.84	1.12	11.30 %	0.29	3.56	1.01	9.65 %
WWm	-0.19	-1.66	0.32	3.22 %	-0.20	-1.55	0.31	2.94 %
TICK	-11.86	-0.01	0.13	1.30 %	-10.49	-0.01	0.09	0.90 %
MCW	-0.09	-1.28	0.11	1.15 %	-0.09	-1.31	0.12	1.10 %
FAT	3.13	0.13	0.42	4.25 %	3.03	0.12	0.37	3.49 %
REA	0.27	0.80	0.22	2.21 %	0.26	0.74	0.19	1.85 %
PWG	0.35	2.09	0.73	7.42 %	0.35	1.95	0.69	6.52 %
FG	0.15	1.71	0.25	2.56 %	0.14	1.59	0.23	2.15 %
STAY	56.84	0.12	6.57	66.60 %	62.65	0.12	7.50	71.39 %
OG$			9.87				10.45	
R_{IH}			0.455				0.452	

EIHH = economic index for Hereford breed; EIBO = economic index for Braford breed; $OG\$$ = overall genetic economic response ($OG\$ = EV \times DGE \times Rg$); R_{IH} = index accuracy; WWd = direct weaning weight (kg); WWm = maternal weaning weight (kg); TICK = tick count, (Log_{10} (count)); MCW = mature cow weight (kg); FAT = subcutaneous backfat (mm); REA = ribeye muscle area (cm²); PWG = post weaning gain (kg); FG = final gain (kg); STAY = stayability (%).

The overall genetic gain, in dollars per year, was US$ 9.87 and US$ 10.45 for HH, BO, respectively, where survival/adaptation and reproductive traits contributed with around 70% of this value in both breeds.

This result is similar to that described by Bourdon & Golden (2000), who described that survival/adaptation and reproductive traits are the ones that can have the greatest impact on the profitability of productive systems.

Our results shows the importance to include this reproductive and adaptation traits on the index, as the selection just for growth and productive traits for many years could reflect negatively on reproduction and survival traits, as reported in pigs (Chen et al. 2003; Arango et al. 2005) and dairy cattle (Berry et al., 2014; Carthy et al. 2016)

The use of EIHH and EIBO indexes will result in a reduction of MCW and WWm. This is due to the negative economic value for these traits.

The reduction or maintenance of the WWm is interesting to avoid increase milk production and consequently energetic requirements of the cows, but the selection for this characteristic should be mainly associated with the WWd and PWG to ensure that the reduction of cow contribution in the development of the calves do not will affect the weaning weight and does not compromise the weight gain after this period, since WWd and PWG have considerable economic value and can positively impact the profitability.

The MCW is a trait that must constantly be reevaluated, because although it is directly associated with the size of the dams and consequently with the energy demand of the herd, it also has a high correlation with the final weight and hot carcass weight of the animals (Meyer et al., 2004), being directly associated with the costs and revenues of this production system.

Despite the carcass trait FAT has moderate to high economic value, its unity and genetic parameters are low, resulting in a small response per generation.

Currently empirical index and alternative economic indexes

Using the current empirical index weighting of the IQG of PampaPlus for the breeding goals identified in this study, it was possible to verify that both the economic genetic gain obtained through the empirically weighted indices (Table 6.4) were significantly lower than the economic genetic gains obtained by the EIHH and EIBO indices (Table 6.3), evidencing the need to change the current PampaPlus index to obtain greater economic returns.

In addition, it can be verified that the accuracy of IQGHH and IQGBO indexes was very close to zero, possibly due to the fact that the breeding goals are low correlated with the selection criteria currently used in the PampaPlus IQG.

Table 6.4 - Response per generation (R_g), Economic response (*R$*) for Hereford and Braford breeding goals using PampaPlus empirical weights.

	IQGHH		*IQGBO*	
	Rg	*R$*	*Rg*	*R$*
WWd	3.804	1.10	3.803	1.08
WWm	-0.150	0.03	-0.153	0.03
TICK	-0.003	0.04	-0.003	0.03
MCW	1.563	-0.14	1.563	-0.14
FAT	-0.010	-0.03	-0.010	-0.03
REA	0.483	0.13	0.483	0.13
PWG	3.656	1.28	3.656	1.28
FG	1.212	0.18	1.212	0.17
STAY	0.011	0.66	0.011	0.73
OG$	-	3.26	-	3.29
R_{IH}	0.005	-	0.004	-

IQGHH = index for Hereford breed weighted by PampaPlus empirical weights; IQGBO = index for Braford breed weighted by PampaPlus empirical weights; $OG\$$ = overall genetic economic response ($OG\$ = EV \times DGE \times Rg$); R_{IH} = index accuracy; WWd = direct weaning weight (kg); WWm = maternal weaning weight (kg); TICK = tick count, (Log_{10} (count)); MCW = mature cow weight (kg); FAT = subcutaneous backfat (mm); REA = ribeye muscle area (cm^2); PWG = post weaning gain (kg); FG = final gain (kg); STAY = stayability (%).

As the relative importance and selection response of the BG for HH and BO were similar, was calculated the selection response using an index with the weights based on the average between the economic values for HH and BO.

The correlation between the EIHH and EIBO with this average index was 0.99974 and 0.99976, respectively, indicating that the same index could be an option to maximize the profit in both breeds.

6.4 Conclusions

Using the developed economic indexes, it is possible to increase the fertility of the animals and the adaptation of the herd to the parasitism by the tick, increasing the profitability of the productive systems of southern Brazil, that historically have serious problems related to the low reproductive rates and with tick parasitism.

The relative importance and selection response of the breeding goals for Hereford and Braford were similar, indicating that the same economic index with similar weights can be used for both breeds in PampaPlus breeding program.

6.5 Literature cited

Amer, P. R., G. Simm, M. G. Keane, M. G. Diskin, B. W. Wickham. 2001. Breeding objectives for beef cattle in Ireland. Livest. Production Sci. 67 223–239

Arango, J., I. Misztal, S. Tsuruta, M. Culbertson, and W. Herring. 2005. Threshold-linear estimation of genetic parameters for farrowing mortality, litter size, and test performance of Large White sows. J. Anim. Sci. 83:499–506.

Berry, D. P., & R. D. Evans. 2014. Genetics of reproductive performance in seasonal calving beef cows and its association with performance traits. J. Anim. Sci. 92:1412–1422.

Bourdon, R. & B. Golden. 2000. EPD's and economics: Determining the relative importance of traits. Available in: http://ansci.colostate.edu/ (10/10/2000).

Cardoso, F. F., C. C. G. Gomes, B. P. Sollero, M. M. Oliveira, V. M. Roso, M. L. Piccoli, R. H. Higa, M. J. Yokoo, A. R. Caetano, and I. Aguilar. 2015. Genomic prediction for tick resistance in Braford and Hereford cattle. J. Anim. Sci. 93: 2693-2705.

Carthy, T. R., D. P. Ryan, A. M. Fitzgerald, R. D. Evans, and D. P. Berry. 2016. Genetic relationships between detailed reproductive traits and performance traits in Holstein-Friesian dairy cattle. J. Dairy Sci. 99: 1286-1297.

Chen, P., T. J. Baas, J. W. Mabry, and K. J. Koehler. 2003. Genetic correlations between lean growth and litter traits in U.S. Yorkshire, Duroc, Hampshire, and Landrace pigs. J. Anim. Sci. 81:1700–1705.

Costa, R. F., B. B. M. Teixeira, M. J. Yokoo, and F. F. Cardoso. 2017. Economic selection indexes for Hereford and Braford cattle raised in southern Brazil. J. Anim. Sci. 95:1–13.

Enns, M. 2007. Selection Decision: Tools for Economic Improvement Beyond EPD. in_ Beef Sire Selection Manual. p.55-62. National beef cattle evaluation consortium.

Hazel, L. N. 1943. The genetic basis for constructing selection indexes. Genetics 28(6): 476.

Laske, C. H., B. B. M. Teixeira, N. J. L. Dionello, and F. F. Cardoso. 2012. Breeding objectives and economic values for traits of low input family-based beef cattle production system in the State of Rio Grande do Sul. R. Bras. Zootec. 41: 298-305.

Meyer, K., D. J. Johnston, and H. U. Graser. 2004. Estimates of the complete genetic covariance matrix for traits in multi-trait genetic evaluation of Australian Hereford cattle. Aust. J. Agric. Res. 55: 195-210.

Pravia, M. I. 2010. Desarrollo de objetivos e índices de selección en ganado para carne en Uruguay a través de un modelo bioeconómico. Master Diss. Universidad de la Republica, Montevideo.

Pravia, M. I., O. Ravagnolo, J. I. Urioste, D. J. Garrick. 2014. Identification of breeding objectives using a bioeconomic model for a beef cattle production system in Uruguay. Livestock Science, v.160, p.21-28.

Reis, Â. P., A. A. Boligon, M. J. Yokoo, and F. F. Cardoso. 2017. Design of selection schemes to include tick resistance in the breeding goal for Hereford and Braford cattle. J. Anim. Sci. 95:572–583.

Schneeberger, M., S. A. Barwick, G. H. Crow, and K. Hammon. 1992. Economic indices using breeding values predicted by BLUP.J. Anim. Breed. Genet. 109: 180-187.

Teixeira, B. B. M. 2013. Parameters and genetic tendency for performance traits and visual scores of Hereford and Braford. Master Diss. Universidade Federal de Pelotas, Pelotas.

Teixeira, B. B. M. 2018. Breeding selection criteria of the Hereford and Braford breeds. Thesis (Doctor) – Programa de Pós-Graduação em Zootecnia. Universidade Federal de Pelotas, Pelotas.

7. Chapter 3 - Economic carcass index for Aberdeen Angus breed participating of the Promebo Genetic Evaluation Program.

Abstract: The opportunities for expansion of the beef market are closely associated with meat quality. Aiming to supply this growing market several breeders' associations from many countries have implemented genetic evaluation programs that include the genetic improvement of carcass traits. In order to maintain and improve the carcass quality of the Aberdeen Angus herds participating in the Promebo Genetic Evaluation Program, the objective of this work was to identify the breeding goals through a bio-economic model (BM) related to carcass traits, and to develop a carcass index weighted economically, considering the economic values (EV) of the breeding goals and relative importance of each selection criteria used in this index. For the identification of the breeding goals, and subsequent definition of their respective EV, a deterministic bio-economic model was developed simulating a herd of 50,000 animals to generating profit equations. The values of live weight at slaughter (FW), ribeye muscle area (REA), subcutaneous backfat thickness (FAT) and intramuscular fat (IMF) used in the BM were simulated to calculate the carcass values of the animals, considering the three main Aberdeen Angus breed bonus tables in Brazil, which qualify the carcasses according to the age of the animals, and the weight and degree of fat of the carcasses. The breeding goals identified was the FW, FAT, IMF and REA.The economic value of FAT (US$ 17.62) and IMF (US$ 5.02) was much higher than FW (US$ 1.45) and REA (US$ 2.02), that is, the change in one unit of these traits has a superior economic result. This is because the scales related to subcutaneous and intramuscular fat are smaller. The FW and REA account for 74.18% of the relative importance of the breeding goals, followed by FAT and IMF, evidencing that the traits related to the quantity of meat are superior to the qualitative ones. The developed BM was able to identify which biological traits related to the carcasses of the animals presented greater

profitability, being they the FW of the animals, REA, FAT and IMF. The economic index of carcasses should be adopted by the Promebo Genetic Evaluation Program because presents the weighting of the selection criteria that results in a higher economic return to the production systems that use the Aberdeen Angus breed when compared to the empirical indexes currently used in this genetic evaluation program.

Key Words: beef cattle, bio-economic models, breeding goals, economic values, carcass traits.

7.1 Introduction

The opportunities for expansion of the beef market are closely associated with meat quality, and among the characteristics related to beef quality, tenderness is considered to be the organoleptic characteristic with the greatest influence on the acceptance of meat by consumers (Paz & Luchiari Filho, 2000; Magnabosco et al., 2006).

However, most of beef meat produced in Brazil is characterized by a low degree of tenderness, since almost 80% of this meat is derived from Zebu herds located in the tropical region (Ferraz & Felicio, 2010), where it is estimated that part of the variation in meat tenderness may be related to genetic factors of the animals, and the other part related to other factors, such as type of feed, stress, slaughter conditions, carcass cooling, maturation, cooking method and cooking point (Schroeder & Kovanda, 2003).

The emerging demand for organoleptic quality and food safety of beef has modified the meat market, where beef cuts presented in trademarks that have proven origin and come from animals of breed recognized for having superior quality, has received added value, causing slaughterhouses to establish compliance specification standards in the purchase of the animals, attributing bonuses to the producers (Ferraz & Felício, 2010; Barcellos & Oaigen, 2014).

Aiming to occupy this growing market niche, several breeders' associations from many countries have implemented genetic evaluation programs that include the genetic improvement of carcass traits (BIF, 2002), searching for earlier and heavier animals with higher yields of carcass, greater marbling, and with sufficient subcutaneous fat finishing to preserve meat during the postmortem period (Watanabe et al., 1993; Magnabosco et al. 2006).

As the quality of the bovine carcass can be affected by more than one trait, the selection through indexes that contemplate economically weighted breeding objectives is considered the most efficient methodology for the improvement of multiple traits simultaneously, where the superiority of index selection grows with the number of characteristics involved (Hazel & Lush, 1942; Newman et al.,1994; Bourdon,1998).

In order to maintain and improve the carcass quality of the Aberdeen Angus herds participating in the Promebo Genetic Evaluation Program, the objective of this work is to identify the breeding goals through a bio-economic model related to carcass traits, and to develop a carcass index weighted economically, considering the economic values of the breeding goals and relative importance of each selection criteria used in this index.

7.2 Materials and methods

For the identification of the breeding goals, i.e., the traits of economic importance, and subsequent definition of their respective economic values, a stochastic bio-economic model was developed simulating a population of 50,000 animals.

Due to the difficulty of obtaining actual carcass measurements by the cost and difficulty of collecting the data, the values of live weight at slaughter (FW), ribeye muscle area (REA), subcutaneous backfat thickness (FAT) and intramuscular fat (IMF) were simulated, through the *mvrnorm* function of the R software MASS package (Venables & Ripley, 2002), which simulates a random value as a function of the mean of a variable and its phenotypic covariance with the other simulated variables.

The sample size of 50,000 carcasses was chosen to increase the accuracy of the simulated data. The averages of each simulated variable and its respective genetic parameters (Cardoso, 2013) are presented in Table 7.1.

Table 7.1 - Means and standard deviation (diagonal), genetic correlation (above diagonal), phenotypic covariance (below diagonal) and phenotypic variances (bottom line).

	AGE	FW	FAT	REA	IMF
AGE	687.27 (67.79)	0.52	-0.10	0.13	0
FW	1420.96	457.54 (40.31)	0.05	0.36	0
FAT	-11.18	3.33	4.36 (1.65)	-0.23	0
REA	62.75	103.32	-2.70	64.98 (40.31)	0
IMF	0.00	0.00	0.00	0.00	3.75 (1.10)
σ_P^2	4595.48	1624.90	2.72	50.69	1.21

AGE = age of animals (days); FW = final live weight (kg); FAT = subcutaneous fat (millimeters); REA = ribeye muscle area (cm²); IMF = intramuscular fat (%); σ^2p = phenotypic variance.

To generate the hot carcass weight, the following equation was used:

$$cwt = \frac{FW \times cy}{100}$$

where: cwt = hot carcass weight; FW = final live weight; cy = carcass yield.

To estimate the carcass yield was utilized the following equation (Cardoso, 2013):

$$cy = 49.89 - (0.018438 \times FW) + (0.573246 \times FAT) + (0.12112 \times REA) + (rnorm \times \sigma_{fcy})$$

The estimation of subcutaneous fat of the carcasses was performed through the following equation (Cardoso, 2013):

$$FATc = -0.105 + (1.0349 \times FAT) + (rnorm \times \sigma_{fFAT})$$

where: FATc is the subcutaneous fat, in mm, FAT is the subcutaneous fat of the carcass measured by ultrasonography, in mm; *rnorm* is a random value for standard normal distribution; σf is the phenotypic standard deviation of subcutaneous fat measured by ultrasonography.

After the quantitative values of subcutaneous fat were generated in each carcass, they were classified into five different fat scores, where the score 1 corresponds to values lower than 1 mm of subcutaneous fat in the carcass, score 2 corresponds to values higher than 1 and less than 3 mm, score 3 corresponds to values higher than 3 and less than 6 mm, score 4 corresponds to values higher than 6 and less than 10 mm, and finally score 5, which corresponds to values higher than 10 mm of subcutaneous fat on the carcass.

The simulated ages, in days, from the multivariate normal distribution above were used to specify the probabilities of each animal presenting 0, 2 and 4 teeth at slaughter, through the following equations (Michael Macneil, personal communication 2017):

$$P4 = -0.01112 + (0.00003348 \times AGE)$$

$$P2 = -0.48822 + (0.001364 \times AGE)$$

$$P0 = 1 - P2 - P4$$

where: P0 = probability of dentition equal to zero teeth, P2 = probability of dentition equal to 2 teeth; P4 = probability of dentition equal to 4 teeth; AGE = age of the animal, in days.

For each animal, a probability value between 0 and 1 was generated through the R software function *runif* (R Core Team, 2018). After generating this value, for animals that presented a probability value less than or equal to P0, the dentition corresponded to zero teeth. For animals that presented a probability value higher than P0 and smaller than the sum of P0 and P2, the dentition corresponded to two teeth. For animals that presented a probability value higher or equal to the sum of P0 and P2, the dentition corresponds to four teeth.

In order to simulate the carcass values of the animals, was considered the three main Aberdeen Angus breed bonus tables in Brazil, which classify the animals according to age, measured by animal dentition, hot carcass weight, subcutaneous fat and through the percentage of intramuscular fat (Table 7.2).

Table 7.2 – Price increase of carcases, in percentage, according to slaughterhouse, hot carcass weight, age and fat score.

Teeth \ CWT					
Slaughterhouse 1					
Teeth \ CWT	< 165	165 - 199	200 - 219	220 - 239	> 240
0	0%	3%	7%	8%	10%
	< 165	165 - 199	200 - 239	240 - 259	> 260
2	0%	3%	7%	8%	10%
	< 165	165 - 239	240 - 259	260 - 279	> 280
4	0%	3%	7%	8%	10%
Slaughterhouse 2					
Teeth \ CWT	< 180	180 - 199	200 - 219	219 - 239	> 240
0	0%	3%	5%	7%	10%
	< 180	180 - 199	200 - 239	240 - 259	> 260
2	0%	3%	5%	7%	10%
	< 180	180 - 239	240 - 259	260 - 279	> 280
4	0%	3%	5%	7%	10%
Slaughterhouse 3					
FAT_SC \ CWT	< 196	196 - 209	210 - 224	225 - 269	270 - 299
3	0%	1%	2%	4%	3%
	< 196	196 - 209	210 - 224	225 - 269	270 - 299
4	0%	2%	3%	5%	4%

CWT = hot carcass weight, Teeth = number of permanent teeth; FAT_SC = fat score.

The three main bonus tables are elaborated according to the local market of the region of each slaughterhouse, where the most important factors for slaughterhouses 1 and 2 are the age of the animal (permanent dentition equal to 0, 2 and 4 teeth) and the hot carcass weight given that the animal has subcutaneous fat classified with a score of 3 or more.

However, the slaughterhouse 3 only bonuses carcasses of animals with an age equal or less than two teeth, but it classifies the animals according to the hot carcass weight and subcutaneous fat finishing, considering animals with a fat score equal to three or equal or greater than four.

The market price (Base price) for the kilogram of hot carcass was US$ 3.03, being this value assumed as the base price in the bio-economic model.

For carcasses that had a fat score of less than one, the assumed price for each kilogram was 80% of the base price, assuming a penalty due to the poor subcutaneous fat finishing of the carcass.

For the carcasses that obtained a fat score of two, the assumed price for each kilogram was equal to the Base price, assuming that these carcasses did not reach a sufficient subcutaneous fat finishing to obtain a bonus.

A bonus of 5% on the Base price was considered for carcasses of animals which had an intramuscular fat percentage of 5.8% or higher.

The revenue of the system was calculated by the following equation:

$$Revenue = Nanimals \times (1 + pp) \times Base\ price \times cwt$$

where: *Namimals* = number of animals; *pp* = percentage of bonus and / or discount; *Base price* = market base price per kilogram of hot carcass weight; cwt = hot carcass weight.

As three bonus tables were simulated, the average of the total profit was calculated between them, in order to calculate the economic value of each breeding goal.

Economic values (EV) of the breeding goals

For the calculation of the economic value of each trait, the following equation was used:

$$EV = \frac{R' - R}{Number\ of\ animals}$$

where: R and R’ are the revenues before and after increasing by one unit in each trait, keeping all other characteristics in their mean values, divided by the number of animals (MacNeil et al., 1994).

Economic carcass index

To determine the vector of economic weights (b) used in the economic carcass index, the following equation was computed (Schneeberger et al., 1992):

$$\mathbf{b} = \mathbf{G}_{11}^{-1} \times \mathbf{G}_{12} \times \mathbf{v}$$

where: $\mathbf{G}_{11}^{-1}$ is the inverse of the genetic (co)variance matrix among the selection criteria used in the index; $\mathbf{G}_{12}$ is the genetic (co)variance among the selection criteria and the breeding goals used in the index; $\mathbf{v}$ is the vector of estimated economic values for the breeding goals.

The selection criteria used were preweaning weight gain (PRG), postweaning weight gain (PWG), ribeye muscle area (REA), subcutaneous backfat (BFAT) and intramuscular fat (IMF).

The breeding goals identified through the bioeconomic model were the FW, REA, FAT and IMF.

The genetic parameters utilized in the $\mathbf{G}_{11}$ and $\mathbf{G}_{12}$ matrix are presented in Table 7.1.

Relative Importance (RI)

The relative importance of each selection criteria of the economic carcass index, expressed in percentage, was estimated through the following equation, which considers the economic weight and the genetic information of each selection criteria, through their genetic standard deviations:

$$RI_i = \frac{|b_i| \times \sigma_{g(i)}}{\sum_{i=1}^{t}\left(|b_i| \times \sigma_{g(i)}\right)} \times 100$$

where: b_i is the economic weight of the i^{th} selection criteria used in the economic carcass index; $\sigma_{g(i)}$ is theenetic standard deviation of the i^{th} selection criteria used in the economic carcass index.

7.3 Results and discussion

Through the use of the developed bio-economic model, it was possible to simulate quantitative values for the carcasses of the animals, which were later classified in the different bonus classes or penalization according to the hot carcass weight, age, and fat score.

Table 7.3 shows the descriptive statistics of the data generated, and the values paid according to the three bonus tables currently used for animals of the Aberdeen Angus breeds and their crosses.

Table 7.3 – Descriptive analysis of data generated through simulation.

	SLG1 (US$)	SLG 2 (US$)	SLG 3 (US$)	Base price (US$)	AGE (dias)	FW (kg)	REA (cm²)	FAT (mm)	IMF (%)	CY (%)	CWT (Kg)	FATC (mm)	FATsc (escore)	TEETH (dentes)
Min.	371.52	371.52	371.52	2.42	420.5	296.9	36.63	0.002	0.01534	44.33	153.3	0.0005	1.000	0.0000
1st Qu.	706.36	697.27	683.64	3.03	641.8	430.2	60.21	3.274	3.00837	50.64	222.8	3.1695	3.000	0.0000
Median	761.21	752.42	741.52	3.03	686.7	457.6	64.97	4.362	3.74929	51.84	236.9	4.4176	3.000	0.0000
Mean	761.82	756.67	735.45	3.01	687.3	457.5	64.99	4.381	3.74869	51.84	237.0	4.4398	2.952	0.9529
3rd Qu.	822.12	818.48	788.48	3.03	733.0	484.6	69.82	5.481	4.48581	53.04	250.9	5.6694	3.000	2.000
Max.	1,067.27	1,067.27	991.82	3.03	1007.8	632.3	93.42	11.072	8.54079	59.99	315.8	12.5561	5.000	4.000

SLG1 = value of the carcass, in dollars, paid by Slaughterhouse 1; SLG2 = value of the carcass, in dollars, paid by Slaughterhouse 2; SLG3 = value of the carcass, in dollars, paid by Slaughterhouse 3; Base_price = value of one kilogram of hot carcass weight; AGE = age in days of animals; FW = average final weight; REA = ribeye muscle area; FAT = subcutaneous fat, measured by ultrasonography; IMF = intramuscular fat, , measured by ultrasonography; CY = carcass yield; CWT = hot carcass weight; FATC = subcutaneous fat in the carcass; FAT_{SC} = subcutaneous fat score; TEETH = number of permanent teeth in the animals.

It can be seen that the economic values of the carcass traits are dependent on the preference of the customer and accordingly to market.

The bonus table offered by the Slaughterhouse 1 is the most profitable for producers, with the average value per carcass being 0.68 and 3.46% higher than that paid by the Slaughterhouse 2 and the Slaughterhouse 3, respectively.

Despite this difference, it should be considered that the bonus table offered is based on the market that each slaughterhouse operates, considering local aspects of demand. However, the variation of the average price paid by the carcasses among the three tables was not important.

In addition, the correlation between the value per kilogram of hot carcass between the Slaughterhouse 1 and Slaughterhouses 2 and 3 were 0.998 and 0.986, respectively, and between Slaughterhouses 2 and 3 was 0.987 (Table 7.4), showing that the selection for the same carcass qualitative and quantitative traits possibly will result in the increase of the value paid by the carcasses in the three slaughterhouses.

The correlation between the values paid by the slaughterhouses and the selection objectives ranged from 0.896 to 0.924 for CWT, 0.790 and 0.826 for FW, 0.408 to 0.478 for FATsc, 0.342 to 0.370 for age of animals, 0.319 to 0.350 for REA, and finally, 0.030 to 0.033 for IMF (Table 7.4).

Table 7.4 – Correlation between the indices and the expected difference in the progeny (DEP) of each selection criteria of the Empirical Carcass Index (INDC), Final Index (INDF), and Economic Carcass index (INDCe).

	deps$INDC	deps$INDCe	deps$INDF	dep_GNDd	dep_GPDd	dep_REAs	dep_EP8Ss	dep_GIMFs	dep_Cs	dep_SC	dep_Ms
deps$INDC	1.000	0.957	0.834	0.815	0.901	0.722	0.583	0.258	0.547	0.560	0.463
deps$INDCe	0.957	1.000	0.895	0.840	0.799	0.751	0.593	0.321	0.674	0.696	0.618
deps$INDF	0.834	0.895	1.000	0.885	0.807	0.520	0.330	0.180	0.820	0.808	0.784
dep_GNDd	0.815	0.840	0.885	1.000	0.731	0.500	0.382	0.238	0.596	0.560	0.508
dep_GPDd	0.901	0.799	0.807	0.731	1.000	0.469	0.301	0.188	0.534	0.508	0.435
dep_AOLSd	0.722	0.751	0.520	0.500	0.469	1.000	0.357	0.119	0.368	0.407	0.351
dep_EP8Sd	0.583	0.593	0.330	0.382	0.301	0.357	1.000	0.195	0.173	0.259	0.143
dep_GIMSd	0.258	0.321	0.180	0.238	0.188	0.119	0.195	1.000	0.065	0.108	0.030
dep_CSd	0.547	0.674	0.820	0.596	0.534	0.368	0.173	0.065	1.000	0.719	0.800
dep_SCs	0.560	0.696	0.808	0.560	0.508	0.407	0.259	0.108	0.719	1.000	0.789
dep_MSd	0.463	0.618	0.784	0.508	0.435	0.351	0.143	0.030	0.800	0.789	1.000

deps$GNDd= expected difference in the progeny of postbirth weigh gain; deps$GPDd= expected difference in the progeny of postweaning weigh gain; deps$REA= expected difference in the progeny of ribeye muscle are, measured at 550 days of age; deps$EP8s= expected difference in the progeny of subcutaneous backfat, measured at 550 days of age; deps$IMFs= expected difference in the progeny of intramuscular fat, measured at 550 days of age; deps$Cs= expected difference in the progeny of conformation scor e, measured at 550 days of age; deps$SC= expected difference in the progeny of scrotal circumference; deps$Ms= expected difference in the progeny of musculature score, m easured at 550 days of age;

As was descibed three bonus table, to calculate the economic values for the breeding goals FW, REA, FAT and IMF was made the average value between Slaughterhouse 1, 2 and 3 for each carcass.

The economic value of FAT and IMF was much higher than FW and REA, that is, the change in one unit of these characteristics has a superior economic result. This is because the scales related to FAT and IMF are smaller, so the change in a unit of FAT or IMF is more difficult than the change of a unit of FW or REA.

The CWT and the FW, which are directly related, be the traits that have the greatest impact on the economic result.

This result is directly reflected in the superiority of the relative importance of FW in relation to the other traits (Table 7.5). Therefore, it is the characteristic that has the higher potential to impact the profitability of production systems. In addition, FW and REA account for 74.18% of the relative importance of the breeding goals, followed by FAT, REA and IMF, evidencing that the traits related to the quantity of meat are superior to the qualitative ones.

This result is similar to the findings by Ochsner (2016) where the relative importance for hot carcass weight and ribeye muscle area was of 65%.

Thus, this implies that the use of a selection index based on these values of relative importance will result in greater weighting for FW and REA, causing a higher genetic gain on them.

Table 7.5 – Economic values, relative importance and economic weights of the breeding goals and selection criteria.

Breeding goals	Economic value	Relative importance (%)	
FW	US$ 1.45	57.72	
REA	US$ 2.02	16.46	
FAT	US$ 17.62	20.30	
IMF	US$ 5.02	5.52	
Selection criteria			*b*
PRG		8.46	1.22
PWG3		41.48	6.42
REAS		22.99	8.35
EP8S		22.06	56.63
IMFS		5.00	12.85

b = economic weight; FW = average final weight; REA = ribeye muscle area; FAT = subcutaneous fat; IMF = intramuscular fat; PRG = pre-weaning weight gain; PWG = postweaning weight gain; REAS = ribeye muscle area; measured by ultrasonography; EP8S = subcutaneous backfat, measured by ultrasonograph; IMFS = intramuscular fat, measured by ultrasonography.

Although not being widely used in Brazil yet, bonus tables based on the carcass quality have been used in several countries as a way of encouraging the production of high quality meat.

In the United States of America (USA), since the carcass quality-based price tables were introduced in the early 1990s, the adoption of the bonus tables caused a rapid change in the payment method of animal carcasses, where the percentage of animals sold under bonus tables was 16% in 1996, to 45% in 2001 and then to 62% in 2006 (McKenna et al.,2002; Schroeder et al., 2003).

As a consequence, meat quality programs, such as the Aberdeen Angus certified beef program, have increased their market share by certifying high-quality cuts of meat, also increasing the reward of producers of this type of animal, culminating in a significant increase in the percentage of Aberdeen Angus animals in the USA (Janzen et al. 2016).

Selection Indices

Currently, PROMEBO has two main selection indices, which are empirical, the Empirical Carcass Index (INDC) and the Final Index (INDF).

The first one has a weight of 10% for post birth weight gain until weaning (PBG), 10% for post weaning weight gain (PWG), 5% for conformation score at 550 days old (Cs), 5% for precocity score at 550 days old (Ps), 5% for musculature score at 550 days old (Ms), 20% for ribeye muscle area measured by ultrasonography (REAS), 10% for the subcutaneous fat, measured by ultrasonography on the *Longissimus dorsi* muscle between the 12th and 13th rib (FATS), 15% for the subcutaneous backfat, measured by ultrasonography (EP8S), and 15% for the intramuscular fat measured by ultrasonography on the *Longissimus dorsi* muscle between the 12th and 13th rib (IMFS).

$$\begin{aligned}\mathrm{INDC} = {} & \left(\frac{0.10}{\sigma_{\mathrm{PBG}}} \times \mathrm{DEP\_PBG}\right) + \left(\frac{0.15}{\sigma_{\mathrm{PWG}}} \times \mathrm{DEP\_PWG}\right) + \left(\frac{0.05}{\sigma_{\mathrm{Cs}}} \times \mathrm{DEP\_Cs}\right) \\ & + \left(\frac{0.05}{\sigma_{\mathrm{Ps}}} \times \mathrm{DEP\_Ps}\right) + \left(\frac{0.05}{\sigma_{\mathrm{Ms}}} \times \mathrm{DEP\_Ms}\right) + \left(\frac{0.20}{\sigma_{\mathrm{REA}}} \times \mathrm{DEP\_REAS}\right) \\ & + \left(\frac{0.10}{\sigma_{\mathrm{FATS}}} \times \mathrm{DEP\_FATS}\right) + \left(\frac{0.15}{\sigma_{\mathrm{EP8S}}} \times \mathrm{DEP\_EP8S}\right) + \left(\frac{0.15}{\sigma_{\mathrm{IMFS}}} \times \mathrm{DEP\_IMFS}\right)\end{aligned}$$

where: σ_{Trait} is the genetic standard deviation of each trait; DEP_Trait is the expected difference in the progeny of each trait.

The second index, which is the most used to rank the sires, weighs 25% for weight gain from birth to weaning (PBG), 5% for conformation score at weaning (Cw), 8% for direct weaning precocity (WP), 8% for musculature score at weaning (Mw), 25% for post-weaning weight gain (PWG), 5% for conformation score at 550 days old (Cs), 8% for weight at 550 days old (Ws), 8% for musculature score at 550 days old (Ms), 8% for scrotal circumference (SC), and is calculated as follows:

$$\text{INDF} = \left(\frac{0.25}{\sigma_{\text{PBG}}} \times \text{DEP\_PBG}\right) + \left(\frac{0.05}{\sigma_{\text{Cw}}} \times \text{DEP\_Cw}\right) + \left(\frac{0.08}{\sigma_{\text{WWd}}} \times \text{DEP\_WP}\right)$$
$$+ \left(\frac{0.08}{\sigma_{\text{Mw}}} \times \text{DEP\_Mw}\right) + \left(\frac{0.25}{\sigma_{\text{PWG}}} \times \text{DEP\_PWG}\right) + \left(\frac{0.05}{\sigma_{\text{Cs}}} \times \text{DEP\_Cs}\right)$$
$$+ \left(\frac{0.08}{\sigma_{\text{Ws}}} \times \text{DEP\_Ws}\right) + \left(\frac{0.08}{\sigma_{\text{Ms}}} \times \text{DEP\_Ms}\right) + \left(\frac{0.08}{\sigma_{\text{SC}}} \times \text{DEP\_SC}\right)$$

where: σ_{Trait} is the genetic standard deviation of each trait; DEP_Trait is the expected difference in the progeny of each trait.

In the bioeconomic carcass index developed (INDCe), the subjective visual scores are no longer considered, since the ultrasound measurements are already considered.

In this index, the relative importance of the selection criteria is higher for PWG, REAS, EP8S, PBG, and IMFS, respectively (Table 7.5). However, differently of the empirical indices, the economic weights (b) of each selection criterion are used to multiply by their respective values of expected difference in progeny (DEP), being these values of b the result of multiplication of the matrices $\mathbf{G}_{\mathbf{11}}^{-\mathbf{1}}$ e $\mathbf{G}_{\mathbf{12}}$and the vector of economic values **v**.

In this way, the INDC is calculated as follows:

$$\text{INDCe} = (1.22 \times \text{DEP\_PBG}) + (6.42 \times \text{DEP\_PWG}) + (8.35 \times \text{DEP\_REAS})$$
$$+ (56.63 \times \text{DEP\_EP8S}) + (12.85 \times \text{DEP\_IMFS})$$

where: PBG and PWG are described before, REAS is the ribeye muscle area measured by ultrasonography, EP8S is the subcutaneous backfat, measured by ultrasonography, IMFS is the intramuscular fat measured by ultrasonography on the *Longissimus dorsi* muscle between the

12^{th} and 13^{th} rib, and DEP_Trait = expected difference in the progeny of each trait, that correspond to a half of the estimated breeding value.

In Table 7.4 is shown the correlation between the indexes, that was considered high for the three indexes studied.

The correlation between INDC and INDCe are high compared to the correlation of both with INDF because have more selection criteria in common used in these indexes.

This result shows that INDC and INDF indexes already used in the PROMEBO breeding program have the weights for the selection criteria very close to the economic optimum, however, the values resulting from the use of the economic carcass index provide an economic estimate for the breeder's decisions on the selection, and it is possible to represent in the currency the value aggregated in the carcasses of the sons of one sire to an average bull of the breed.

In this way, in practical terms, with the results obtained it is already possible to select bulls that breed animals with the potential to produce more profitable carcases, where each bull can be chosen according to its economic contribution, being another option of choice at the moment to select the animals that will produce the next generation on farms.

7.4 Conclusions

The developed bio-economic model was able to identify which biological characteristics related to the carcasses of the animals added greater value to the system, being them the final weight of the animals, the ribeye muscle area, the subcutaneous fat and the percentage of intramuscular fat. These traits should be considered as a breeding goal to increase the revenue of production systems that use the Aberdeen Angus breed.

The economic index of carcasses should be adopted by the Promebo Genetic Evaluation Program because presents the weighting of the selection criteria that results in a economic assessment of carcass added value to the prospected offspring of selection candidates. This would aid producers to identify superior seedstock for the production systems that use the Aberdeen Angus breed and target to delivered certified beef.

7.5 Literature cited

Barcellos, J. O. J., & R. P. Oaigen. 2014.Cadeia produtiva da carne bovina e os sistemas de produção na bovinocultura de corte. In: OAIGEN, R. P. (Coord.). Gestão na bovinocultura de corte. Guaíba: Agrolivros. P. 21-43.

BIF. 2002. Guidelines for Uniform Beef Improvement Programs, 8th Edition.

Cardoso, L. L. 2013. Estimativas do rendimento comercial de novilhos com a utilização de ultrassom. Tese (Doutorado) – Universidade Federal do Rio Grande do Sul, Faculdade de Agronomia, Programa de Pós- Graduação em Zootecnia, Porto Alegre, BR-RS.

Ferraz, J. B. S., & P. E. Felício. 2010. Production systems – An example from Brazil. Meat Science, Champaign, v. 84, n. 2, p. 227-314.

Janzen, M. G., J. M. Riley, and K. T. Coatney. 2016. Recent Changes in Profitability Determinants for Cattle Feeder. Paper presented at the Southern Agricultural Economics Association 2016 Annual Meeting, San Antonio, Texas.

MacNeil, M. D., S. Newman, R. M. Enns, and J. Stewart-Smith. 1994. Relative economic values for Canadian beef production using specialized sire and dam lines. Can. J. Anim. Sci. 74: 411-417.

Magnabosco, C. U., R. D. Sainz, C. U. Faria, M. J. Yokoo, F. Manicardi, V. Barbosa, C. Guedes, P. R. Leme, A. Pereira, F. R. C. Araújo, A. C. Sanches, and R. B. Lôbo. 2006.

Avaliação genética e critérios de seleção para características de carcaça em Zebuínos: Relevância econômica para mercados globalizados. In: Simpósio de Produção de Gado de Corte, vol. 5, Viçosa, Brazil.

McKenna, D. R., D. L. Roberts, P. K. Bates, T. B. Schmidt, D. S. Hale, D. B. Griffin, J. W. Savell, J. C. Brooks, J. B. Morgan, T. H. Montgomery, K. E. Belk, and G. C. Smith. 2002. "National BeefQualityAudit-2000:Survey of Targeted Cattle and Carcass Characteristics Related to Quality, Quantity, and Value of Fed Steers and Heifers." Journal of Animal Science 80:1212–22.

Paz, C. C. P., & A. Luchiari Filho. 2000. Melhoramento genético e diferenças de raças com relação à qualidade da carne bovina. Pecuária de corte, n.101, p. 58-63.

R Core Team. (2018). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-projec.org/.

Schneeberger, M., S. A. Barwick, G. H. Crow, and K. Hammon. 1992. Economic indices using breeding values predicted by BLUP.J. Anim. Breed. Genet. 109: 180-187.

Schroeder, T. C., & J. Kovanda. 2003. Beef alliances: motivations, extent, and future prospects. Veterinary Clinics of North America: Food Animal Practice, Maryland Heights, v. 19, n. 2, p. 397-417.

Venables, W. N. & B. D. Ripley. 2002. Modern Applied Statistics with S. Fourth Edition. Springer, New York. ISBN 0-387-95457-0.

8 General conclusion

Through the developed bioeconomic models, it was possible to identify the biological traits that have an impact on the profitability of the full-cycle production systems that use the Hereford and Braford breeds in the Southern of Brazil were weaning weight direct and maternal, tick count, mature cow weight, subcutaneous backfat, ribeye muscle area, post-weaning gain, final gain, and stayability

Considering that the breeding goals are not expressed in the same way and at the same time in the life of the animals, the use of the discounted genetic expressions to adjust the economic values of each breeding goals was necessary to standardize the economic values as a function of time required for the manifestation of each trait in the next generations.

As the productive systems of southern Brazil historically have serious problems related to the low reproductive rates and with tick parasitism, to select more profitable animals, the traits tick count, ribeye muscle area subcutaneous backfat and stayability should be included as breeding goals in the PampaPlus breeding program, and is recommended the use of the developed economic indexes.

The developed carcass bio-economic model for Aberdeen Angus breed was able to identify which biological characteristics related to the carcasses of the animals added greater value to the system, being them final weight of the animals, ribeye muscle area, subcutaneous fat and percentage of intramuscular fat. These traits should be considered as a breeding goal to increase the revenue of production systems that use the Aberdeen Angus breed.

The economic index of carcasses should be adopted by the Promebo Genetic Evaluation Program because presents the weighting of the selection criteria that results in an economic assessment of carcass added value to the prospected offspring of selection candidates. This would aid producers to identify superior seedstock for the production systems that use the Aberdeen Angus breed and target to delivered certified beef.