The use of real-time ultrasound to estimate variance components for growth and carcass traits in Nelore cattle

By

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Chapter 1: Background and Justification

Beef cattle production in Brazil

Brazil is a vast country with an area of 8,514,876 km^2 (IBGE, 2003), and diverse environmental conditions. The predominant ecosystems are tropical savannahs characterized by two distinct seasons, rainy and dry. During the rainy season (October – May) the weather is hot and humid with temperatures between 20º and 45ºC and relative humidity around 80 – 85 % (INMET, 2003). During the dry season the temperature is around 10º and 20ºC and the humidity around 40 – 50 % (INMET, 2003). The total human population is 169,872,856 (IBGE, 2003).

Table 1.1 – Land utilization in Brazil

Description	Area – millions of hectares	%
Amazon rain forest	350	41.2
Pasture	220	25.9
Cerrado (tropical savannahs)	151	17.9
Legal reserves	55	5.9
Crop	50	5.8
Urban centers, roads and lakes	20	2.5
Reforestation	5	0.8
TOTAL	851	100

Source: Pineda et al. (2002)

Brazil has the largest commercial cattle herd in the world with 175 million head (FAO, 2003). The most important genotype in Brazil is *Bos indicus* (Zebu) cattle represented by 8 breeds (Nelore, Guzerá, Tabapuã, Brahman, Gir, Indubrasil, Sindhi and Cangaian). They are characterized by adaptation to tropical conditions where hot temperatures and low pasture quality make the environment too harsh to raise *Bos taurus* cattle. The Nelore breed represents around 80% of *Bos indicus* cattle in Brazil.

Globally, livestock production accounts for more than 40 % of the gross value of agricultural production (FAO, 2003). Brazil has the largest commercial herd (Figure 1.1) in the world but productive indices and quality standards are relatively low.

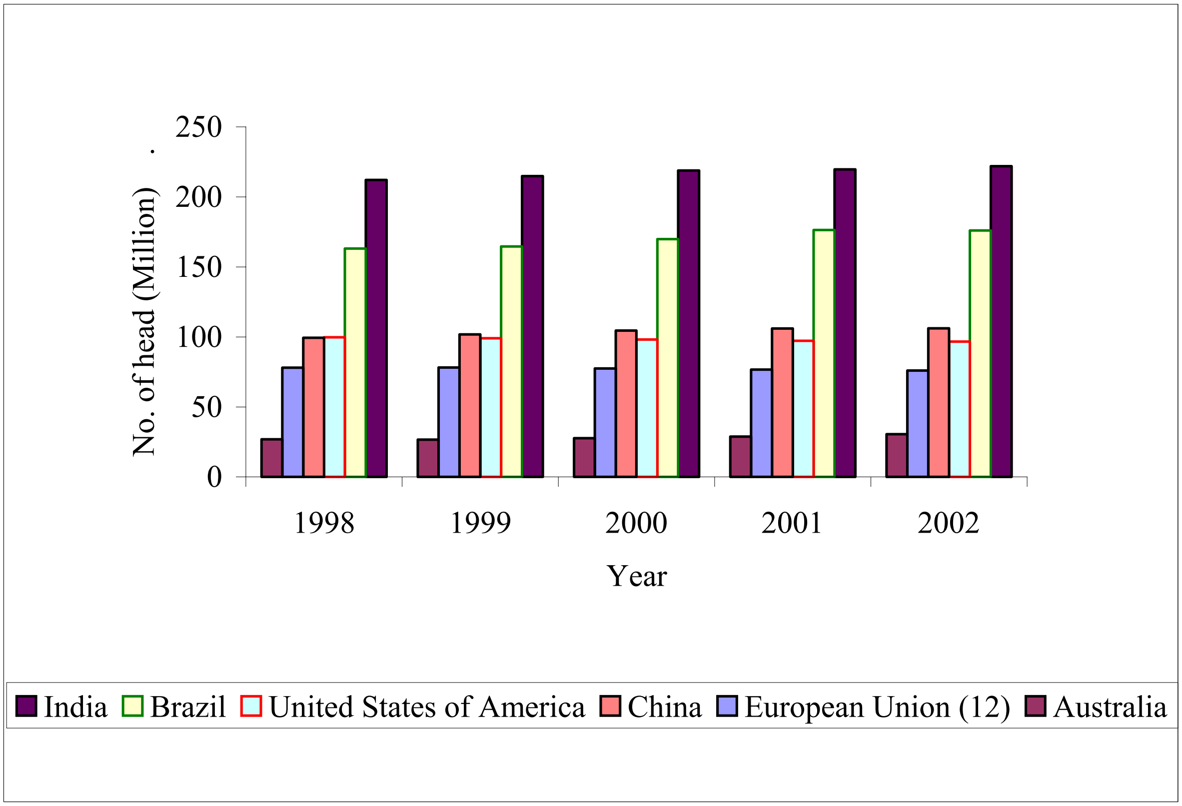


Figure 1.1 - World stocks of cattle

The Brazilian herd size increased at a rate of 1.84 % each year from 1993 to 2003 (Anualpec, 2003) but still needs to improve its harvest (turnoff) percentage (Figure 1.2). Some variables have been helpful in this process. The increased use of mineral supplementation, development of effective herd health programs, implementation of rotational grazing management and investments in soil fertility are some factors responsible for these results. Currently around 65 % of all Brazilian herds are receiving mineral supplementation and it is expected to be 80 % in 2012 (ANUALPEC, 2003).

Table 1.2 - Production efficiency of beef cattle in Brazil

Year	% of Harvest	Year	% of Harvest
1983	17.1	1994	21.0
1984	17.2	1995	23.9
1985	17.3	1996	24.0
1986	17.6	1997	22.3
1987	19.0	1998	22.2
1988	19.6	1999	22.1
1989	19.4	2000	21.9
1990	19.3	2001	22.1
1991	20.3	2002	22.6
1992	21.5	2003	24.2
1993	21.5		

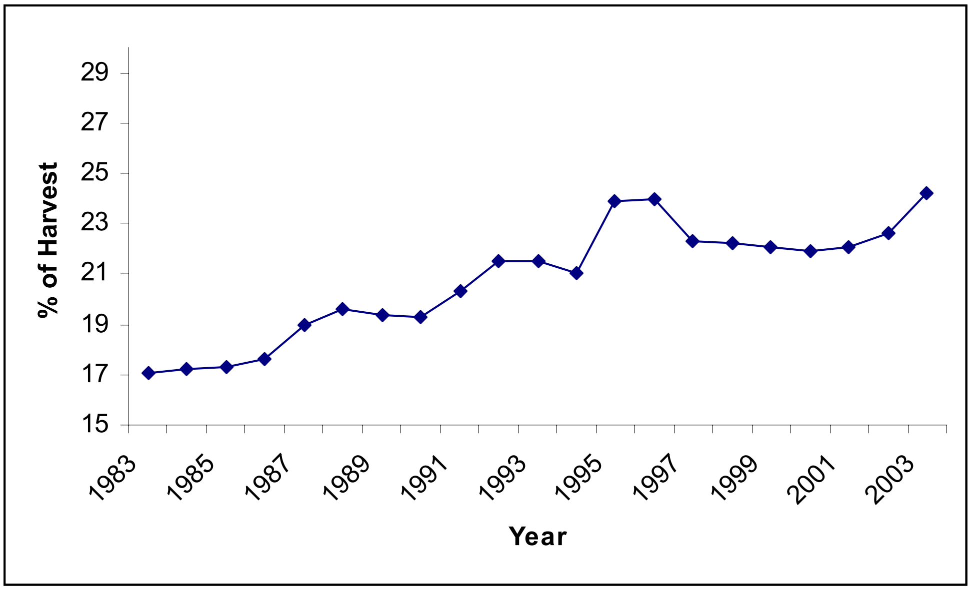


Figure 1.2 - Production efficiency of beef cattle in Brazil

Brazilian cattle breeders are faced with the challenges of producing beef to satisfy consumer demands for quantity and quality, using abundant, low-cost pasture systems, raising cattle that are productive and profitable under these environmental conditions. Also, the competition with other meats makes this project as one of the most important in the next generation. In particular, the poultry and swine industries are making rapid progress toward high quality standards at very competitive prices. Until now, the Brazilian breed associations have developed their genetic selection programs focusing on growth performance, milk production and fertility. None of the breeds has a program to improve carcass quality. However, in order to incorporate carcass traits in a genetic evaluation scheme and to design an appropriate breeding program all the breed-specific parameters must be established.

Consumer demand

It is well known that demand reflects the interest of consumer in buying a specific product. This demand depends upon a number of factors, including nutrition, food safety, culture, education, marketing, lifestyle, convenience, income, prices and other factors such as geography and logistics of distribution.

Global meat prices declined in 2002 in response to the decrease in the meat consumption due to food safety problems that happened during this period. Foot and mouth disease and Bovine Spongiform Encephalopathy (BSE) outbreaks were the most important diseases that impacted meat prices during 2002. In order to meet international safety protocols Brazilian producers are adopting a national traceability program, SISBOV. It was established especially to attend European Union market demands but also it is helpful in many management programs. It is expected, in 2003, to have 1.17 million head in this program (Anualpec, 2003) collecting all information needed for strategic improvements in order to achieve higher quality standards for the beef market.

Table 1.3 - Global meat prices

	International Meat Price Index (FAO)	Meat International Indicative Prices			
		Chicken[1]	Swine[2]	Beef [3]	Lamb[4]
	(1990-92=100)		(US$/ton)		
1994	102	921	2,659	2,384	2,975
1995	99	922	2,470	1,947	2,621
1996	96	978	2,733	1,741	3,295
1997	96	843	2,724	1,880	3,393
1998	83	760	2,121	1,754	2,750
1999	84	602	2,073	1,894	2,610
2000	85	592	2,083	1,957	2,619
2001	84	645	2,077	2,138	2,912
2002	83	602[a]	1,883[a]	2257[b]	3,208[b]

Source: Beefpoint, 2003;FAO, 2002.
[1].Chicken units (American unit for exportation)
[2]. Frozen pork (American unit for exportation)
[3]. Manufactured Beef carcass
[4]. Hole Frozen Lamb carcass
[a]. January through August 2002.
[b]. January through July 2002.

However, the International Food Policy Research Institute of Washington, DC projected an increase of 55 % in world demand for animal products between 1997 and 2020 (Rosegrant et al., 2001). The world's appetite for meat is projected to jump enormously with China accounting for more than 40 % of this increase. The developing countries alone will increase 70 millions of tons of their meat demand form 2002 to 2020 (Anualpec, 2003). The world's population is expected to grow from 6 billion people in 2000 to 7.5 billion people in 2020 (Rosegrant et al., 2001). The population growth in

Asian countries, especially China, coupled with increases in their exchange rate relative to the US dollar will enhance meat consumption. In the last four years China's economy has grown 7 to 8 %/year and India, South Korea and other Asian countries have grown 5 to 6 %/year (Anualpec, 2003). Availability of land for farming is declining, and water for agriculture and other forces will challenge the capacity of the world's food production system.

In the last three years the international demand for beef has been growing around 300 and 400 thousand tons per year and the same growth rate is expected in the next 10 years (Anualpec, 2003). These authors also project an increase in Brazilian beef exportation around 170 % and 250 % in volume and price, respectively (Anualpec, 2003). Brazilian beef producers will need to improve their product quality in order to conform to international standards.

In order to understand consumer demand it is also important to study long-term forces such as income growth, population growth and educational changes. Therefore, strategic investments in research, new technologies, irrigation and logistics of distribution can contribute to achieve equilibrium between supply and demand. All of this will require more enlightened policies and substantial investments as cited above.

Beef carcass quality

Carcass quality represents one of the most important factors to define carcass value and its consistent and accurate determination is essential to the smooth functioning of the beef market. We can distinguish two major characteristics: retail product yield, and eating quality grade of the meat. Retail yield impacts directly upon income to producers and packers because it reflects the quantity of saleable meat in the whole carcass. Eating quality is more complex, being subject to a number of factors related to color, marbling, tenderness, juiciness and flavor, yet it has an important impact for all beef industry segments from producers to consumers.

Retail product yield is based on the total amount of muscle in comparison with fat and bone. The allometry of growth is characterized primarily by early bone development, then muscle growth and finally fat deposition. The allometry of growth can change based on genotype, sex, implant and nutrition programs, and all of these factors can affect the yield of meat.

Eating quality is affected by many characteristics as well. These factors are color, tenderness, juiciness and flavor. Tenderness is considered one of the most important factors in meat acceptability (Sainz et al. 2001). Tenderness is higher in young animals and tends to be lower in older animals because of the increase in connective tissue between the muscle fibers. Also, myofiber degradation tends to be lower in old animals during the *post-mortem* ageing process (Sainz et al., 2001). Juiciness also has an influence on meat palatability and it is related to fat deposition, specially marbling. All these characteristics are influenced by the same factors that affect the yield grade: genotype, age, sex, age, nutrition and use of hormones.

The importance of carcass traits to the beef industry is increasing, especially with the introduction of more detailed carcass specification systems and the payment of premiums for products satisfying the requirement and expectations of specific markets. Beef carcass quality premiums in the US have been based on yield and quality grades affected by the portion of muscle, fat and bone present (Herring et al., 1994; Tait et al. 2001). Brazilian cattle breeders are faced with the challenge to market their carcasses wheras government agents are responsible only for sanitary control. A packing plant employee grades the carcasses although some certified beef brands also have an agent present to check this process.

United States Carcass Grade System (USDA)

In 1916, the US Congress passed a law establishing the National Livestock Market News Service (Harris et al, 2001), originally created to facilitate accurate market reporting. Primarily it concerned only Quality Grade; Cutability Grades were added in 1969, and renamed as Yield Grades in 1973. The version for the USDA carcass grading system which is currently used was last revised in January 1997.

The Quality and Yield Grades contained in the US Department of Agriculture (USDA) system are used to segregate carcasses of different qualities into different classes. The Yield Grade represents the total of retail product and is expressed in grades from 1 to 5, higher to lower respectively. In order to determine this classification, a longitudinal cut is made to split the carcass in two halves, left and right sides. A transversal cut is then made between the 12^{th} and 13^{th} ribs, to separate the carcass halves into front and hind quarters. This exposes the *longissimus dorsi* (ribeye) muscle, allowing the grader to estimate the ribeye area and thickness of subcutaneous (back) fat (Figure 1). Finally, the kidney, pelvic and heart (KPH) fat is estimated as a percentage of carcass weight. These measurements plus hot carcass weight are included in the calculation of Yield Grade:

Yield Grade = 2.50

+ (2.5 × Adj. fat thickness, in.)

+ (0.2 × Kidney, pelvic, and heart fat, %)

+ (0.0038 × Hot carcass wt., lb.)

– (0.32 × Ribeye area, sq. in.)

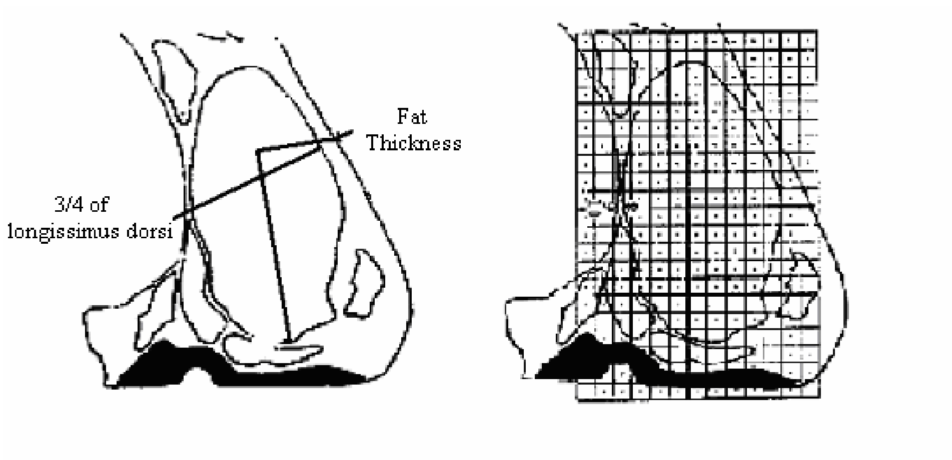


Figure 1.3 - Methods for measurements of fat thickness and ribeye area between 12^{th} and 13^{th} rib

The correlation between Yield Grade and four primal beef cuts (Chuck, Rib, Loin and Round) are presented in Table 1.4. Even though these cuts represent only 80 % of the total retail product, they represent 95 % of the carcass value therefore are used as an economic yield index.

Table 1.4 - Correlation between Yield Grade and percent of retail product for primal cuts[1]

Yield grade	% yield of primal cuts
1	52.6 - 54.6
2	50.3 - 52.3
3	48.0 - 50.0
4	45.7 - 47.7
5	43.3 - 45.4

[1]Primal cuts: rump, loin, rib and chuck.

Source: AMSA, 2001.

The Quality Grade classification is mainly dependent on skeletal maturity and degree of marbling. Moreover, carcasses from intact bulls are disqualified from the better grades. In the sex classification, males can be classified as steers, bullocks and bulls. Females are separated just into heifers and cows. The maturity classes are: A (9 to 30 months), B (30 to 42 moths), C (42 to 72 months), D (72 to 96 months) and E (over 96 months). This classification is done by the size, form and level of bone ossification and carcass cartilages; the teeth are not evaluated.

Marbling (intramuscular fat) is the major characteristic in the quality grade classification. Marbling is evaluated visually, accounting for quantity and distribution of fat in the *longissimus dorsi* between the 12^{th} and 13^{th} ribs. If necessary, standard USDA cards are used as a reference for marbling classification to guarantee better accuracy by USDA graders. Figure 1.4 shows the main marbling classes.

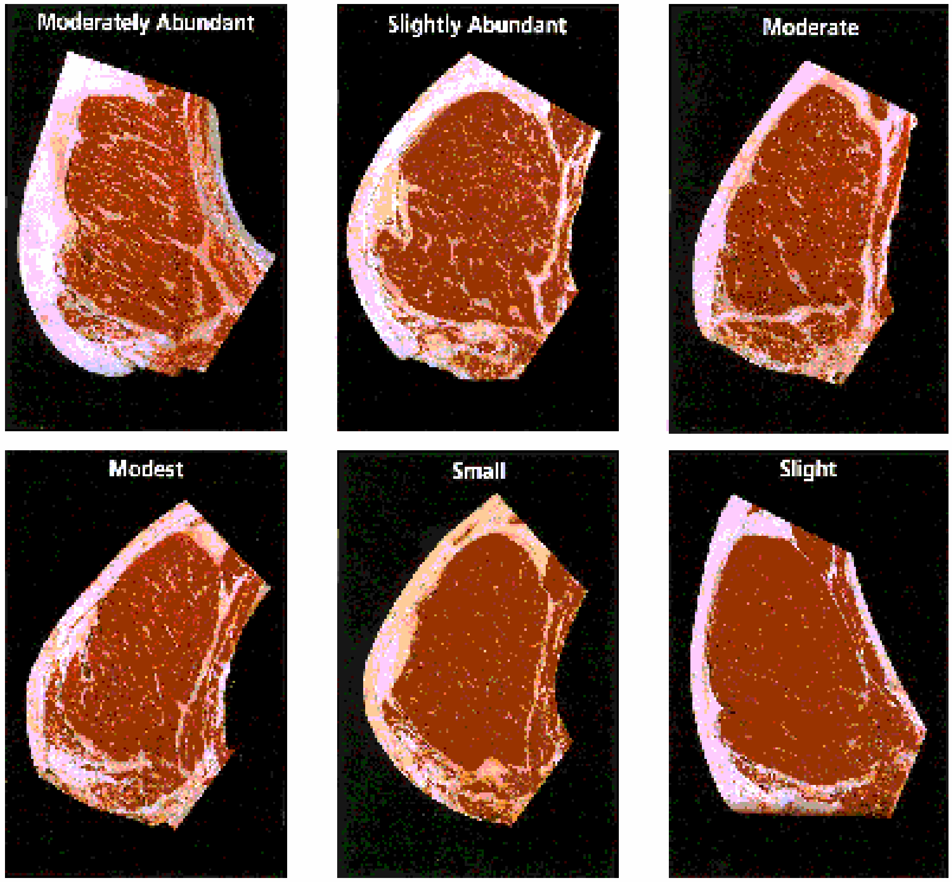


Figure 1.4 - USDA marbling classes for beef

Source:AMSA, 2001.

For animals up to 30 months of age (A maturity) without defects (e.g., coarse texture, discoloration), marbling is the major factor that determines Quality Grade (Figure 1.5). Carcasses from animals between 30 and 42 months (B maturity) must have more marbling to be classified as Prime, Choice or Select. Carcasses with C, D or E maturity are disqualified from these classes and do not receive premiums.

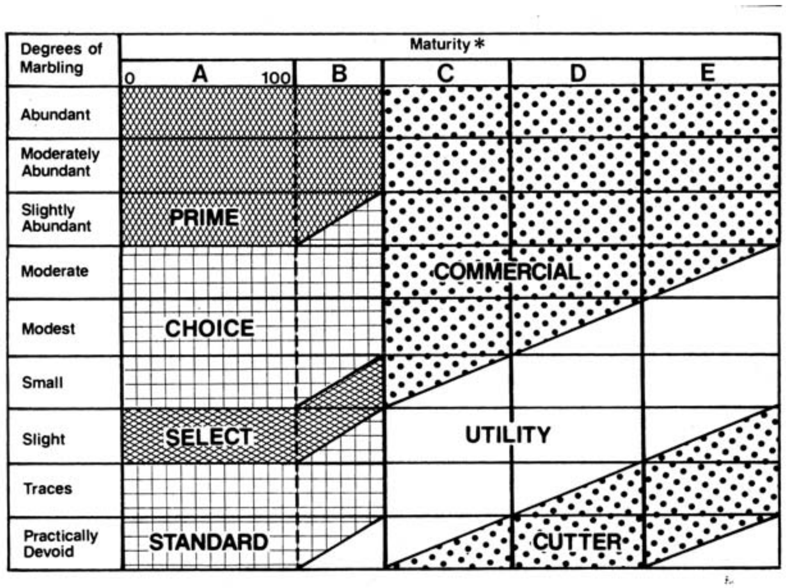


Figure 1.5 - USDA Quality Grade system for different degrees of marbling and maturities

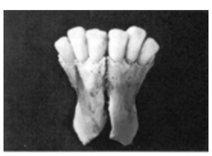
Source: Boggs e Merkel, 1990.

In the United States, where most of the cattle are fed and harvested before 30 months of age, 80 to 90% of carcasses are classified as Choice or Select. An average difference price of $0.12/lb between these grades encourages US producers to finish their animals so as to maximize marbling and Quality Grade. At the same time, price grids impose severe penalties on carcasses with Yield Grades of 4 and 5, so that producers must avoid getting cattle over-fat. Biologically, maximizing intramuscular fat and avoiding excess subcutaneous and internal fat is not an easy task.

Brazilian Carcass Grading System (BRASIL)

The Brazilian carcass grading system is called “BRASIL” and was established in the early 1970’s when a commission was established in order to create the national grading system (Felício, 1999). The grading is done by subjective measurements of maturity, conformation, fat cover and also sex and hot carcass weight. Maturity is estimated by evaluation of the permanent teeth as presented in Table 1.5.

Table 1.5 - Age of eruption of permanent teeth in beef cattle (months)

Appearance[1]	Permanent teeth	Approximately age of eruption of permanent teeth	
		Bos indicus[2]	*Bos taurus*[3]
	0	-	-
	2	20 - 24	18 - 28
	4	30 - 36	24 - 31
	6	42 - 48	32 - 43
	8	52 - 60	36 - 56

Sources: [1]Lawrence et al., 2001; [2]Corrêa (1996); [3]Kirton (1989).

Carcass conformation is subjectively evaluated in five categories: C=convex; Sc = sub-convex; Re = flat; Sr = sub-flat; Co = concave. In this system the fat cover is also subjectively evaluated, the quantity of fat, with different scores from 1 to 5: 1 = total absence of fat; 2 = 1 a 3 mm; 3 = 3 a 6 mm; 4 = 6 a 10 mm; 5 = over 10 mm of fat cover.

Hot carcass weight is used in the grading system and in the marketing process as well. The grading system has some rules regarding minimum weight but no category has a limit for maximum weight. Together these evaluations comprise the grades using the letters "BRASIL", presented in Table 1.6. Some private companies have their own grading systems and the payment of premiums for carcass quality are still in the initial stages.

Table 1.6 - Brazilian beef carcass grading system

Class	Sex[1]	Maturity (Permanent teeth)	Fat Cover[2]	Carcass confromation[3]	Minimum carcass weight (kg)
B[4]	C, F	0 – 4	2, 3, 4	C, Sc, Re	C=210, F=180
	M	0	2,3, 4	C, Sc, Re	M=210
R	C, F	0 – 6	2, 3, 4	C, Sc, Re	C=220, F=180
A	C, F	0 – 6	1 and 5	C, Sc, Re, Sr	C=210, F=180
	M	0	1 and 5	C, Sc, Re, Sr	C=210, F=180
S	C, F	0 – 8	1 – 5	C, Sc, Re, Sr	C=225, F=180
I	M, C, F	0 – 8	1 – 5	C, Sc, Re, Sr	no restrictions
L	M, C, F	0 – 8	1 – 5	Co	no restrictions

[1]Sex: C = castrated male; F = female; M = intact male.
[2]Fat Cover: 1 = total absence of fat; 2 = 1 to 3 mm; 3 = 3 to 6 mm; 4 = 6 to 10 mm; 5 = over 10 mm of fat cover.
[3]Carcass conformation: C, convex; Sc, sub-convex; Re, flat; Sr, sub-flat; Co, concave.
[4]The HILTON standard is a B class excluding intact males (M) and fat cover 4.
Source: Felício, 1999.

Meat quality characteristics

Tenderness

The tenderness of meat is one of the most important factors influencing palatability. The structural differences among muscles that help determine their tenderness include their myofibrillar component and the amount of connective tissue. The most common procedure to objectively evaluate tenderness is the Warner-Braztler shear force, an objective procedure where the peak force required to shear a cylindrical cooked core of meat is measured. It is commonly reported in pounds or kilograms. On the other hand, subjective tenderness can be measured using a trained taste panel or household consumers that are asked to rate the meat using a hedonic scale. When we compare values of Warner-Braztler shear force and consumer panels, correlations around 88 % indicate that both are accurate to determine tenderness (Mc Kenna, 2003).

Factors affecting beef tenderness include the connective tissue component, the myofibrillar component, and possible cold-shortening. The connective tissue component affecting tenderness is the amount and solubility of collagen within the muscle. In addition, specific myofibrillar proteins are degraded during post-mortem ageing of muscle under chiller conditions and there is evidence that the cysteine proteases, in particular the calpains, are responsible for this degradation (Hopkins & Thompson, 2000; Koohmaraie, 1996). In addition, rapid chilling (before *rigor mortis*), can result in shortening of the myofibrils, toughening the meat. This is why a minimal amount of fat cover is essential for maintaining meat quality, as it acts as thermal isolation. The use of electric stimulation has also been shown to accelerate *rigor mortis*, preventing cold-shortening and stimulating proteolytic enzyme activity (Riley et al., 2003). Benefits of electrical stimulation appear to be greater for Brahman or crossbred Brahman beef than for *Bos taurus* beef (Riley et al., 2003).

Research done by Shackelford et al. (1995) compared tenderness of ten major muscles from *Bos indicus* and *Bos taurus* cattle showing significant differences in five muscles when cooked as steaks and four when roasted. Shear force of the *longissimus dorsi* muscle was not highly related to shear force of other muscles. Thus, systems that accurately predict the tenderness of *longissimus dorsi* of a carcass will likely do little to predict the tenderness of other muscles.

Reverter et al. (2003), studying tropical breeds in Australia found genetic correlations of marbling (intramuscular fat) with sensory (consumer) panel tenderness score) and Warner-Braztler shear force of 0.31 and -0.31 respectively. The cooking process also has an important influence on the tenderness. Wheeler et al. (1999) presented results showing small differences in tenderness between Low Select carcasses and Top Choice carcasses when the consumers cooked the beef well done.

Flavor

Flavor is an important component to define acceptability of any food product. Especially in meat, it is a very subjective and complex factor. The meat composition changes by diet, sex, age, and breed and these can have important influences on meat flavor. The volatile components of lipids within meat are the major contributors to meat flavor and these can also change during the storage process having a significant influence on meat flavor. The carbohydrate content of meat can be reduced in the pre-slaughter process; for example stress may increase the intensity of off-flavors in beef, lamb and pork (Paganini, 2001).

Juiciness

Juiciness is related to the amount of moisture released from the meat during mastication and to the degree of salivation induced by fat (Paganini, 2001). The water-holding capacity of meat has a direct effect on shrinkage of meat during storage and improper storage can make an enormous difference in juiciness. Also during improper thawing some water crystals can rupture the cellular membrane losing juiciness. Cooking and processing also has a large influence on the capacity of meat to be juicy. For example, beef cooked well-done will rarely if ever be juicy. Juiciness is also directly related with marbling where cuts with more marbling will be juicier.

Lean tissue color

The color of meat is associated with chemical changes in muscle pigments, primarily myoglobin. The pigment called myoglobin can be found in different forms (redox states) giving the meat different colors. The heme portion of the pigment is of special interest because the color of meat is partially dependent on the oxidation state of the iron within the heme ring. Some factors can cause changes in color such low oxygen tension, heat, salt, ultraviolet light, low pH and surface dehydration. The animal's age can also affect the meat color, due to increasing the myoglobin concentration (Aberle et al., 2001).

Fat thickness at 12th/13th rib

The subcutaneous fat cover is an important trait and has been measured since the use of A-Mode ultrasound in 1950's (Stouffer, 1991). The fat thickness is measured perpendicular to the animal and the measured point is located ¾ of the distance from the chine (medial) end to the lateral end of the *longissimus dorsi* muscle. Genetic selection for this trait can be for increased or decreased fat depth. Increasing fat depth leads to a decrease in retail yield (Tait el al., 2001). However, most market specifications require a minimum fat depth. All certified Brazilian beef brands require a minimum of subcutaneous fat (usually 3 mm) and most of time only around 50 – 60 % of animals finished on natural pastures can reach this goal and receive their premium benefits. In other markets such as the US, the selection is for reduced fat thickness and increased meat yield. Caution should be placed on the selection for extremely low fat EPDs for replacement heifers as this may indicate females that are more difficult to get in calf.

Fat Color

Some differences in fat color may be observed in animals finished under different conditions. Reverter el al. (2003) observed that animals finished on grain had significantly whiter fat than animals finished on pasture. The difference in fat color is explained by the accumulation of β-carotene in the subcutaneous and intramuscular fat observed in animals raised and finished on pasture. The fat color is also associated with genotype, sex and age of animals.

Percentage of intramuscular fat

The percentage of intramuscular fat is also called "marbling" and is characterized by the fat deposition between the muscle bundles. Marbling has been studied in many research projects because it is associated with quality, flavor, and juiciness, and because the market places a premium on carcass that grade Choice or above. Consequently producers in the US are encouraged with premiums to select for highly marbled animals. Marbling is a moderately heritable trait and it can be selected for without increasing the Yield Grade.

Percentage retail product

Retail product yield has been a trait of significant importance in beef cattle for generations. It has economic impact on producers, retailers, packers and also consumers. It is important to realize that both carcass and ultrasound data can be used to evaluate cattle for percentage retail product. Tait (2002) presented the impact some traits have on percentage retail product. He presented some rules of thumb for looking at the changes related to these measurements, when run through the genetic evaluation percent retail product equation:

For each 0.1 inch decrease in fat, % retail product increases ~ 1%

For each 1.0 square inch increase in ribeye area, % retail product increases ~ 1.2%

For each 100 lbs decrease in carcass weight, % retail product increases ~ 1.3%

The retail product yield is directly dependent on other factors as gender, use of hormones and genetics. This trait is moderately heritable ($h^2 \approx 0.39$; AAA, 2003), and can be very important in the genetic selection process.

Genetic influences on carcass quality

Heritabilities and genetic correlations among carcass traits for several *Bos taurus* breeds have been published previously (Moser el al, 1998, Wilson et al. 2001; Reverter, 2003). Carcass traits heritabilities have been determined as high - moderate in several studies and these vary from 0.29 to 0.64 depending on trait, breed and sex (Wilson et al. 2001; Reverter, 2003). Smith et al. (1992) used ultrasound to estimate the fat thickness to within 2.54 mm (1/10 inch) in 62 % of the steers. The correlation of carcass and ultrasound fat thickness measurement is dependent of technician skills and also with changes during the carcass processing (Smith et al., 1992). Several studies have shown the favorable and moderate strong genetic correlations between carcass measurements and ultrasound measurements (Wilson, et al. 1998; Moser et al., 1998). No studies have examined the use of ultrasound for genetic selection for carcass merit in *Bos indicus* breeds.

Application of Real-Time Ultrasound to genetic improvement programs

Several studies have demonstrated that real-time ultrasound (RTU) can be used to measure carcass composition (Stouffer, 1991; Wilson, 1998; Herring, 1998). Carcass composition is defined as the relative proportions of lean, fat, and bone in the carcass (Wilson, 1992). Other electronic evaluation methods include mechanical and optical probes, electromagnetic scanning, electrical impedance, X-ray measurements, computerized tomography, and nuclear magnetic resonance. These methods can also be used to obtain animal measurements but RTU is more cost-effective when used on a large scale and also more practical to use in the field. Real-time ultrasound has been used to measure rib-eye area, external fat thickness and intramuscular fat. This technology has been used in both live beef cattle (Stouffer, 1991.; Doyle et al, 1998) and in hot beef carcass (Stouffer, 1991;Yujun L. et al., 1995; Amin et al, 1995; Perkins T. et al., 2003). The use of RTU has been used also as an important technology in improving uniformity of feeder and developing advanced computer modeling (Sainz, R.D., Oltjen J. W., 1994).

Ultrasound carcass evaluation can benefit all segments of the beef industry - breeder, producer, feeder, packer, retailer and consumer - because of its accuracy in determining carcass merit. This accuracy was reached in the 1980s when RTU was introduced with a linear array transducer with a larger number of crystals (64-100). Its utility in genetic selection programs was demonstrated in the 1990s. Beef cattle seedstock breeders in Australia have had estimated breeding values (EBV) for scanned carcass traits including eye muscle area and subcutaneous fat depths between the 12th and 13th ribs and at the P8 (rump) site since 1990 (Reverter, 2000). RTU has the potential of allowing the beef cattle industry to obtain expected progeny differences (EPD) for carcass traits for a much larger share of the seedstock population, and at a much lower cost and significantly faster rate than is possible with progeny testing (BIF, 1996).

Overall goal

Improvement of carcass and meat quality traits is vital to Brazil's beef industry because the domestic and especially the international markets are placing increased emphasis on product quality. Until now, all genetic improvement programs for *Bos indicus* breeds have focused on selection for performance, fertility, milk producing capacity and stayability. Other criteria, such as temperament, have also been used by some producers. This study was designed to define parameters that are necessary to develop a carcass merit program. This experiment aimed to evaluate the growth patterns and optimal age points for carcass evaluation in Nelore cattle raised under pasture and feedlot conditions. These variables include variance components (i.e., heritabilities, genetic and phenotypic correlations), that are necessary to establish models and protocols for a carcass merit selection program. Evaluations of this type will improve the understanding of the genetics of growth and carcass composition in the Nelore breed, and possibly provide some economic benefit to the producers. The importance of selection for carcass quality becomes more important as the value-based marketing programs pay additional premiums for increased carcass quality.

Chapter 2: The use of ultrasound to evaluate growth and carcass quality in Nelore cattle

Introduction

Real-Time Ultrasound (RTU) scanning gives an accurate and repeatable measure of external fat and longissimus muscle area in beef cattle (BIF, 1996; Wilson et al., 1998; Hassen et al., 1999; Crews et al, 2002). For several years, studies has shown the accuracy of using RTU for carcass evaluation. These studies have also shown the importance of using highly skilled technicians for image collection in the field and also for the laboratory interpretation of the images (Wilson et al., 1998). Several studies have shown the favorable and moderately strong genetic correlations between carcass measurements and ultrasound measurements (Wilson, et al. 1998; Moser et al., 1998). The traditional carcass progeny test may be limited by only providing accurate evaluations on a biased sample of a few popular sires and little information on females (Crews et al. 2002). In addition, the cost and time needed for these evaluations limits their large-scale application in genetic selection programs.

Most studies with RTU in beef cattle have been conducted to develop breed-specific genetic parameters and providing the breed associations the information required to develop their carcass evaluation programs. Several associations are now publishing carcass Expected Progeny Differences (EPD), predicted from ultrasound data. No Zebu breed has developed genetic parameters to predict EPD for carcass traits. Heritabilities and genetic correlations among carcass traits were published for several *Bos taurus* breeds (Moser el al, 1998, Wilson et al. 2001; Reverter, 2003). Heritabilities have been estimated to be moderate for most carcass traits (Wilson et al. 2001; Reverter, 2003).

Before ultrasound measurements of seedstock can be used for genetic prediction of carcass merit, breed-specific parameters, such as growth curves and optimal age points for data collection need to be established. Important differences exist between *Bos indicus* and *Bos taurus* animals in growth parameters, such as physiological maturity at measurement. Differences in management systems, such as pasture vs. concentrate feeding, may also be important. Beef carcass premiums in the US are based on Yield and Quality Grades, which are affected by the proportions of muscle, fat and bone in the carcass (Herring et al., 1994; Tait et al. 2001). Real-time ultrasound technology provides the opportunity to measure these traits and select animals with high breeding values. This study was carried out to support the development of carcass evaluation in genetic selection programs for Zebu cattle raised under grazing systems. The adoption of these programs becomes more important as value-based marketing programs in Brazil begin to pay additional premiums for improved carcass quality.

Materials and methods

Live animal data

Data from 1,721 bulls and heifers were collected for these analyses. Animals were measured at approximately 15, 18, 21 and 24 months of age, but due to the sale of animals it was not always possible to have records for all different ages for each animal. The cattle were raised in central Brazil, which is characterized as humid tropics with predominantly African grasses (e.g., *Brachiaria*, *Panicum* spp.) and rainfall around 1800 mm. All animals had free-choice access to water and mineral-salt supplement during the experimental period. All animals were weighed and scanned on the same day by an APTC-accredited technician. The same technician was also responsible for image analysis. The ultrasound machine used for scanning was an Aloka 500V (Corometrics Medical System, Wallingford, CT) using a 3.5-MHz, 17.2cm linear array transducer. The animals were scanned for ribeye (*longissimus dorsi*) area (ULMA); fat thickness over the *longissimus dorsi* at a point ¾ the length ventrally of the ribeye and between the 12^{th} and 13^{th} ribs (UFAT); and fat thickness over the rump (URFAT), at the junction of the *biceps femoris* and *gluteus medium* between the ischium and illium, and parallel to the vertebrae as was described by Greiner (2003). Vegetable oil was used as a coupling agent to obtain adequate acoustic contact. In addition other live-animal measures including body weight and hip height were taken and recorded for each animal. The images were digitized and stored using an image capture system (Blackbox, Biotronics, Ames, IA, USA). Images were analyzed using the Image-J software package (National Institutes of Health, USA). The perimeter of the longissimus muscle was traced from the digitized images and the software computed muscle area. Similarly, the subcutaneous fat thickness measurements were made by marking the top and bottom interfaces of the fat layers, and the linear measurement made by the program. Contemporary group was defined as animals of the same sex and herd, raised in the same environment, in the same management group, scanned and weighed on the same day. The maximum range of ages within ultrasound contemporary groups was 90 days. Data were edited to remove animals that lacked or had inconsistent pedigree information. However, animals were not required to have measurements for all three ultrasound traits, or at all ages.

Data analyses

Models were built using the MIXED procedures of SAS (SAS Institute, Cary, NC) and three different analyses were performed.

Analysis 1. This model was used to determine significant (P < 0.05) fixed effects for each trait (weight, ULMA UFAT, URFAT):

```
PROC MIXED;
CLASS ID CG AGEc MG MONTHSCAN;
MODEL REA =CG*MG MONTHSCAN AGEc AGEc*MONTHSCAN;
RANDOM ID(CG*MG);
Lsmeans MONTHSCAN / PDIFF=all;
Lsmeans AGEc / PDIFF=all;
Lsmeans AGEc*MONTHSCAN / PDIFF=all;
```

Contemporary group (CG) included herd of origin, gender, region and scanning and weight at the same date. There were 23 contemporary groups for all characteristics analyzed: weight, ULMA, UFAT and URFAT. The animals were grouped in five age classes (AGEc): A, 15-16 months; B, 17-18 months; C, 19-20 months; D, 21-22 months and E, 23-24 months. Animals from different management systems were classified in three different groups; 1, pasture; 2, pasture with supplementation; and 3, fed with high energy diets. In order to fit the model the month of scan was separated into five groups: Mar-02, Jun-02, Oct-02, Jan-03 and Mar-03. The *F*-test statistic was used for each trait to determine whether the variable in the model was significant.

Analysis 2. Least square means were calculated from a fixed effect model to determine how the seasonality and age might influence body weight and carcass measurements. The following model was used to perform these analyses:

```
PROC MIXED;
CLASS ID CG AGEc MG MONTHSCAN;
MODEL REA =CG*MG MONTHSCAN AGEc AGEc*MONTHSCAN;
RANDOM ID(CG*MG);
Lsmeans MONTHSCAN / PDIFF=all;
Lsmeans AGEc / PDIFF=all;
Lsmeans AGEc*MONTHSCAN / PDIFF=all;
```

Analysis 3. In order to test the model for a carcass merit evaluation program and find out which effects need to be under control, the MIXED procedure of SAS was performed for each trait (weight, ULMA, UFAT, URFAT). Fixed effects were age in months (AGEm), month of scanning (MONTHSCAN), contemporary group (including management group; CG*MG). The interaction between AGEm and MONTHSCAN was used to test the slopes for homogeneity, and the individual animal within contemporary and management group was included to account for repeated measures on the same animal. The following model was performed for these analyses:

```
PROC MIXED;

CLASS ID CG AGEc MG MONTHSCAN;

MODEL REA=CG*MG MONTHSCAN AGEm AGEm*MONTHSCAN / SOLUTION;

RANDOM ID(CG*MG);

Lsmeans MONTHSCAN / PDIFF=all;
```

Results and Discussion

Ultrasound genetic parameters

As shown in Table 2.1, all animals were evaluated in a 9 month age range, from 15 to 24 months of age. Although some animals were extremely heavy, most of the animals were on pasture (MG = 1), evaluated around 318 kg at 19 months of age. The animals in MG 2 and 3 were significantly heavier than animals in MG 1 ($P < 0.001$). The range in subcutaneous fat (UFAT and URFAT), shows the potential in the Nelore breed for finishing. Usually, these animals are not able to express their genetic potential because of the low nutritional level present under tropical pasture conditions.

Table 2.1 - Summary statistics for live-scan ultrasound data

Variable	n	Mean	Median	Minimum	Maximum	Standard deviation
Age, mo	2723	19	19	15	24	2.64
Weight, kg	2719	321	318	156	852	57.52
ULMA, cm^2	2600	47.80	47.35	14.73	98.24	8.85
UFAT, mm	2597	1.5	1.3	0.4	11.7	0.62
URFAT, mm	2571	2.0	1.8	0.4	12.1	0.97
Hip height, m	1221	1.38	1.37	1.22	1.62	0.06

Significance of model fixed effects

The major objective of this analysis was to study the fixed effects of contemporary and management group (CG*MG), age class (AGEc), month scanned (MONTHSCAN), and age class × month of scanning (AGEc*MONTHSCAN) on body weight and the RTU measurements. The MIXED procedure was performed for each trait. Table 2.2 presents the fixed effects for body weight. All fixed effects were significant (P < 0.001) including the AGEc*MONTHSCAN term, indicating a significant interaction between age and season on body weight.

Table 2.2 - Type 3 tests of fixed effects for body weight

Effect	Numerator df	Denominator df	F Value	Pr > F
Contemporary groups	33	2631	53.98	< 0.0001
Month scanned	4	28	14.1	< 0.0001
Age class	4	28	52.59	< 0.0001
Age class * Month scanned	16	28	3.63	0.0014

The F-test shows significant effects (P < 0.0001) of contemporary and management group, month scanned and age class on ULMA (Table 2.3). The AGEc*MONTHSCAN term was also significant, indicating an interaction between age and season on ULMA. Longissimus muscle area is closely related to body weight, so this result is consistent with that shown in Table 2.2 above.

Table 2.3 - Type 3 tests of fixed effects for longissimus muscle area

Effect	Numerator df	Denominator df	F Value	Pr > F
Contemporary groups	33	2512	20.57	< 0.0001
Month scanned	4	27	10.31	< 0.0001
Age class	4	27	18.03	< 0.0001
Age class * Month scanned	16	27	1.16	0.3537

It should be noted that back fat had significant influences from all fixed effects ($P < 0.01$, Table 2.4). The contemporary and management group accounted for the greatest variation in back fat. The age class effect on back fat deposition could be fundamental because of the need for this measurement in young animals to reflect the variability at older ages or in the carcass. The association between RTU and carcass measures of fat thickness increases as the time between measures decreases (Crews et al., 2002).

Table 2.4 - Type 3 tests of fixed effects for back fat

Effect	Numerator df	Denominator df	F Value	Pr > F
Contemporary groups	33	2509	37.71	< 0.0001
Month scanned	4	27	8.70	0.0001
Age class	4	27	8.53	0.0001
Age class * Month scanned	16	27	3.16	0.0041

By contrast to back fat, rump fat thickness was only significantly affected by contemporary and management group ($P < 0.0001$, Table 2.5). Neither month of scanning nor age class had any effect on the URFAT ($P > 0.05$).

Table 2.5 - Type 3 tests of fixed effects for rump fat

Effect	Numerator df	Denominator df	F Value	Pr > F
Contemporary groups	33	2489	34.88	< 0.0001
Month scanned	4	22	1.49	0.2388
Age class	4	22	2.31	0.0900
Age class * Month scanned	16	22	2.08	0.0556

Seasonality effects on body weight and carcass traits

Least square means for body weight and RTU traits were calculated to present the phenotypic variation of weight, ULMA, UFAT, URFAT in different ages classes and more important in different scanning periods (Tables 2.6, 2.7, 2.8, 2.9). These results illustrate the variation in body weight and RTU that was a concern in evaluation for a genetic selection program. During the dry season (May – October), animals presented lower measurements and this could be a concern if the contemporary groups are not accounted for as we discuss later. Table 2.6 shows the body weight within different age classes and in different seasons. A linear increase of body weight was observed when we compare the average within each class. The same was not observed in different scanning periods where cattle lose weight, especially during June and October.

Table 2.6 - Least square means for body weight (kg)

Age class (months)	Month scanned					Average
	Mar-02	Jun-02	Oct-02	Jan-03	Mar-03	
15-16	330	296	313	352	357	330
17-18	358	313	337	382	371	352
19-20	380	342	376	390	404	378
21-22	411	361	414	423	429	408
23-24	425	373	415	464	430	421
Average	381	337	371	402	398	X

In Table 2.7, the ULMA measurements in different age classes and scanning periods are presented. ULMA is a very good indicator of carcass muscling, which is a large component of the total carcass weight. Therefore, muscle growth also reflects overall body weight gain. A small decrease in muscle area for all age classes was observed, similarly to results presented for body weight, especially in June. The highest average ULMA was observed in January, during the rainy season when the pastures are at the best nutritional stage. ULMA growth was linear among the age classes. Mean longissimus muscle area growth rate was approximately 1.34 cm^2/month for all age classes and seasons.

Table 2.7 - Least square means for longissimus muscle area (cm^2)

Age Class (months)	Month scanned					Average
	Mar-02	Jun-02	Oct-02	Jan-03	Mar-03	
15-16	48.41	45.24	55.97	55.30	56.32	52.25
17-18	51.46	48.06	51.76	58.12	57.91	52.46
19-20	54.32	50.32	57.31	59.10	61.19	56.45
21-22	57.50	55.08	62.05	63.87	60.50	59.80
23-24	62.62	54.99	60.59	66.91	64.81	61.98
Average	54.86	50.74	57.53	60.66	60.14	X

The back fat thickness for different age classes and scanning periods is presented in Table 2.8. Small differences were observed in back fat deposition among age classes and scanning periods. It appears from these results that nutritional level was limiting fat deposition in animals raised under pasture conditions. Low variability of fat thickness in Nelore cattle due to management and level of nutrition may be a problem in predicting genetic differences in fat deposition potential (Wilson, 1992).

Table 2.8 - Least square means for back fat (mm)

Age Class (months)	Month scanned Mar-02	Jun-02	Oct-02	Jan-03	Mar-03	Average
15-16	2.16	1.85	3.61	1.72	1.95	2.26
17-18	2.14	1.92	1.62	1.77	1.92	1.88
19-20	2.22	1.95	1.82	1.82	1.91	1.94
21-22	2.52	1.95	1.86	1.78	2.14	2.05
23-24	2.14	1.89	1.84	1.78	2.14	1.96
Average	2.24	1.91	2.15	1.77	2.01	X

Rump fat is deposited earlier and is generally greater than back fat. This can be important in the data analyses in order to minimize errors of interpretation and identification of animals with fat deposition potential. Rump fat is **34 %** greater than back fat for animals on this plane of nutrition, raised on tropical grass with an average of 1.3 mm for back fat. Similar growth curve patterns are observed for both UFAT and RUFAT, with small decreases in June and January (Table 2.9).

Table 2.9 - Least square mean for rump fat (mm)

Age Class (months)	Month scanned Mar-02	Jun-02	Oct-02	Jan-03	Mar-03	Average
15-16	2.79	2.71	4.26	2.33	2.43	2.90
17-18	2.89	2.74	2.25	2.62	2.50	2.60
19-20	3.05	2.90	2.29	2.67	2.59	2.70
21-22	2.70	2.95	2.44	2.46	2.53	2.61
23-24	2.52	2.91	2.40	2.43	2.86	2.62
Average	2.79	2.85	2.73	2.51	2.58	X

Accounting for contemporary and management group effects

The contemporary and management group and age accounted for a relatively large portion of observed variance in response variables ($P < 0.001$). As shown in Table

2.10, the month of scanning (i.e., season) had no effect on body weight (P > 0.05) when the contemporary and management groups are properly accounted for.

Table 2.10- Type 3 tests for fixed effects and differences in slopes of body weight vs. age

Effect	Numerator df	Denominator df	F Value	Pr > F
Contemporary groups	33	2647	61.44	< 0.0001
Month scanned	4	27	1.61	0.2009
Age	1	27	861.77	< 0.0001
Age * Month scanned	4	27	6.76	0.0007

The fixed effects on ULMA are presented in Table 2.11. Again, there were no significant effects of month of scanning, indicating that there were no significant seasonality effects (P > 0.05) in the longissimus muscle area measurements. On the other hand, highly significant effects of contemporary and management group and age were observed (P < 0.0001). In order to generate Expected Progeny Differences (EPD) it will be fundamental to have the contemporary and management group under control, and to standardize the age at scanning.

Table 2.11 - Type 3 tests for fixed effects and differences in slopes of longissimus muscle area vs. age

Effect	Numerator df	Denominator df	F Value	Pr > F
Contemporary groups	33	2530	24.70	< 0.0001
Month scanned	4	24	1.93	0.1378
Age	1	24	273.01	< 0.0001
Age * Month scanned	4	24	0.81	0.5292

Ultrasound back fat measurements were also significantly affected of the contemporary and management group (P < 0.0001, Table 2.12). Back fat deposition was not significantly influenced by month of scan or by age (P > 0.05), nor was there any significant Age × Month of scan interaction, indicating that the previously observed seasonal effects were removed by including the contemporary and management group, and accounting for the repeated measures. Variability is an issue in any carcass merit genetic selection program. Animals must be in a good nutritional state in order to express their genetic potential.

Table 2.12 - Type 3 tests for fixed effects and differences in slopes of back fat vs. age

Effect	Numerator df	Denominator df	F Value	Pr > F
Contemporary groups	33	2525	57.19	< 0.0001
Month scanned	4	26	0.77	0.5573
Age	1	26	0.00	0.9629
Age * Month scanned	4	26	1.25	0.3166

The rump fat analysis presented similar behavior as shown for the back fat measurements. RUFAT was significantly affected by the contemporary and management group (P < 0.0001), and by age (P < 0.01).

Table 2.13 -Type 3 tests for fixed effects and differences in slopes of rump fat vs. age

Effect	Numerator df	Denominator df	F Value	Pr > F
Contemporary groups	32	2506	47.57	< 0.0001
Month scanned	4	20	1.24	0.3251
Age	1	20	9.36	0.0062
Age * Month scanned	4	20	2.22	0.1040

On-farm age adjustments

Models for adjustment of longissimus muscle area and rump fat from ultrasound scan on live animals were developed using the MIXED procedure from SAS. The linear models estimate the longissimus muscle area and rump fat at 550 days of age based on the actual age and ULMA or RUFAT measurements.

Age regression models would be best fitted using individual within-animal regressions. In some cases, however, it might be useful to predict the animal's growth rate and adjust the nutritional management in early growth stages. Adjustment factors for REA (cm^2) and rump fat (mm) are:

$ULMA_{550}$ = ULMA + 0.0473 (± 0.00715) x (550 – Age in days)

$RUFAT_{550}$ = RUFAT + 0.00193 (± 0.00804) x (550 – Age in days)

Repeatability

Another question was to verify whether RTU measurements were made with sufficient repeatability. In the literature most results for repeatability include both the image collection (scanning) and the image interpretation (analysis) operations. These values cover a large range from 0.5 to 0.9 (Renand et al. 1997). The repeatability of back fat thickness (Table 2.14) was considered very low and it might be explained by the slow fat deposition in Zebu cattle raised on tropical pasture, i.e., a low energy diet. The thickness of the subcutaneous fat layer in these bulls compared to the highly variable fat steers and cows generally used in other experiments was certainly the main reason for the low repeatability observed for UFAT.

Table 2.14 - Repeatability coefficients for body weight and ultrasound carcass measurements in Nelore cattle

Trait	Repeatability
Live scan weight (wt)	0.37
Longissimus muscle area (ULMA)	0.44
12-13th back fat thickness (UFAT)	0.035
Rump fat thickness (URFT)	0.62

On the other hand, repeatability values for URFAT and ULMA achieved moderate repeatabilities, 0.62 and 0.44, respectively. It should be noted that these repeatability values were obtained by serial scans with intervals of three months, not hours or days as in other studies. Repeatability estimates could be higher if the scanning interval was shorter.

Conclusions and application

The present study confirmed the obvious, that Nelore cattle raised on tropical pastures exhibit growth patterns and carcass compositions that are very different from those observed in *Bos taurus* cattle raised on high-concentrate diets. It seems logical that breed-specific research must be done in order to develop a genetic improvement program for carcass merit. In this study, grazing Nelore bulls had minimal fat deposition, far below that needed to reach acceptable carcass grades. On the other hand, Nelore bulls and heifers fed high-energy diets showed that the Nelore breed has the potential to improve carcass quality and meet international market standards.

The analyses showed that the contemporary and management group is the most important fixed effect in controlling the body weight and carcass traits. Animals raised on tropical pastures are directly affected as the seasons (rainy and dry) change. One of the most important issues for this work was to test how the season might influence the ultrasound scanning protocol for a carcass merit evaluation program. It is normal that animals evaluated in the dry season have phenotypic differences compared to animals scanned during the rainy season. Seasonality had no effect on carcass traits and body weight once the contemporary group was accounted for. With these results, cattle breeders have a powerful tool to select animals to meet specific market demands. Some markets will demand lean meat while others will prefer fatter meat but both will be supplied with high quality carcasses.

Chapter 3: Variance components for carcass traits in Nelore cattle

Introduction

Brazilian beef producers are faced with the challenges of meeting increasingly stringent market demands under vastly different production environments and at an extremely low cost. To do this successfully, producers require knowledge of genetic factors that affect the production system and can increase their income. Among these, carcass quality traits may be considered along with the more traditional performance characteristics. Heritabilities and genetic correlations among carcass traits for several *Bos taurus* breeds have been published (Moser el al, 1998, Wilson et al. 2001; Reverter, 2003). Several studies have shown that carcass traits in *Bos taurus* cattle are moderately heritable (Wilson et al. 2001; Reverter, 2003). Ultrasound technology provides an opportunity to cost-effectively estimate carcass attributes on the live animal (Berthoud, 2000). Genetic evaluations for carcass traits based on ultrasound measurements of *Bos indicus* cattle have the potential to increase the rate of genetic progress and reduce the expense involved in a traditional progeny test.

One of the primary objectives of this research project was to apply real-time ultrasound (RTU) technology for collection of data on carcass traits in Nelore cattle in Brazil, and to develop Expected Progeny Differences (EPDs) for these traits. Important variables, such as differences in anatomy between *Bos taurus* and *Bos indicus* cattle, in physiological maturity at measurement, and in management systems (pasture vs. high energy diets) were considered in this study.

The ultimate goal of this study was to estimate genetic parameters and calculate EPDs for external 12-13th rib fat (UFAT), rump fat thickness (P8) and ribeye area (REA). Before RTU measurements of seedstock can be used for genetic prediction of carcass merit, breed-specific parameters such as heritabilities, genetic and phenotypic correlations must be determined. This paper summarizes results of evaluations of carcass traits in Nelore cattle using ultrasound.

Materials and methods

Live animal data

Data from 1,721 bulls and heifers were collected for these analyses. Animals were measured at approximately 15, 18, 21 and 24 months of age, but due to the sale of animals it was not always possible to have records for all different ages for each animal. The cattle were raised in central Brazil, which is characterized as humid tropics with predominantly African grasses (e.g., *Brachiaria*, *Panicum* spp.) and rainfall around 1800 mm. All animals had free-choice access to water and mineral-salt supplement during the experimental period. All animals were weighed and scanned on the same day by an APTC-accredited technician. The same technician was also responsible for image analysis. The ultrasound machine used for scanning was an Aloka 500V (Corometrics Medical System, Wallingford, CT) using a 3.5-MHz, 17.2cm linear array transducer. The animals were scanned for ribeye (*longissimus dorsi*) area (ULMA); fat thickness over the *longissimus dorsi* at a point ¾ the length ventrally of the ribeye and between the 12th and 13th ribs (UFAT); and fat thickness over the rump (URFAT), at the junction of the *biceps femoris* and *gluteus medium* between the ischium and illium, and parallel to the vertebrae as was described by Greiner (2003). Vegetable oil was used as an coupling agent to obtain adequate acoustic contact. In addition other live-animal measures including body weight and hip height were taken and recorded for each animal. The images were digitized and stored using an image capture system (Blackbox, Biotronics, Ames, IA, USA). Images were analyzed using the Image-J software package (National Institutes of Health, USA). The perimeter of the longissimus muscle was traced from the digitized images and the software computed muscle area. Similarly, the subcutaneous fat thickness measurements were made by marking the top and bottom interfaces of the fat layers, and the linear measurement made by the program. Contemporary group was defined as animals of the same sex and herd, raised in the same environment, in the same management group, scanned and weighed on the same day. The maximum range of ages within ultrasound contemporary groups was 90 days. Data were edited to remove animals that lacked or had inconsistent pedigree information. However, animals were not required to have measurements for all three ultrasound traits, or at all ages.

Pedigree

The 1,721 animals in the final data set were produced by 85 different sires and 23 contemporary groups were formed. The full relationship matrix was constructed by incorporation of all available pedigree data of the University of São Paulo – Ribeirão Preto and ANCP (National Breeders and Researchers Association). The pedigree file used for calculation of the inverse numerator relationship matrix contained 25,941 animals, including those augmented so that each animal with data had two ancestral generations.

Genetic evaluations

Heritabilities (h^2) were estimated with single-trait analyses. A bi-variate Restricted Maximum Likelihood (REML) analysis was used to estimate the genetic (r_g) and phenotypic (r_p) correlations between pairs of traits. A minimum of three different start values for genetic and environmental variances was used for single-trait analyses. Multiple Trait Derivative Free Restricted Maximum Likelihood (MTDFREML) was used in order to establish the variance components and genetic parameters. The fixed effects in the model included age of dam and contemporary group. Accuracies of EPDs were calculated by the software as described by the Beef Improvement Federation (BIF, 1996).

Results and discussion

The number of observations and simple statistics for the traits evaluated in this study are presented in Table 3.1. Note that the number of records is over 2,500 for all traits, due to repeated measurements on each of the 1,720 animals.

Table 3.1 - Summary statistics for live-scan ultrasound data

Variable	**Number of records**	**Mean**	**Standard deviation**	**Coefficient of variation, %**
Longissimus muscle area at the $12^{th-}13^{th}$ rib, cm^2	2597	52.75	9.71	18.4
$12\text{-}13^{th}$ rib fat thickness (UFAT), mm	2594	1.8	1.2	65.9
Rump fat (URFAT), mm	2568	2.5	1.7	69.3
Age at measurement, days	2597	576	119	20.7

Heritabilities (h^2), genetic (r_g) and phenotypic (r_p) correlations between pairs of traits are presented in Table 3.2. Heritability estimates for longissimus muscle area, backfat and rumpfat were 0.29, 0.44, and 0.62, respectively. The estimate for heritability for ultrasound longissimus muscle area of 0.29 agrees well with literature estimates. Moser (1998) estimated the same heritability working with 3,583 records from Brangus bulls and heifers. However, the estimate for rump fat thickness (0.62) seems to be in the upper range of previous studies. In general these estimates for ultrasound carcass traits were in agreement with other analyses.

Table 3.2 - Heritabilities (*h^2*), genetic and phenotypic correlations[1] for carcass traits in Nelore cattle

Trait	ULMA	UFAT	URFAT
Longissimus muscle area (ULMA)	**O.29**	-0.22	-.23
12-13th back fat thickness (UFAT)	0.0504	**0.44**	0.89
Rump fat thickness (URFT)	0.0529	0.0042	**0.62**

[1]Heritability estimates on the diagonal, genetic correlations above and phenotypic correlations below the diagonals

The genetic correlations among carcass traits were estimated in order to evaluate the potential impacts of a selection program for carcass value. Using a bi-variate model including *longissimus muscle* area with 12-13th backfat thickness and rumpfat, genetic correlations of -0.22 and -0.23, respectively, were obtained. Reverter et al. (2000) also found a low negative correlation between ULMA and UFAT, -0.04 and -0.29 for Angus and Hereford bulls respectively. The same authors also found a low negative correlation between ULMA and URFAT, -0.07 and -0.13 for Angus and Hereford respectively. Although it is a low negative correlation, selecting animals for increased muscling would be expected to have the correlated effect in decreasing subcutaneous fat deposition. In fact, genetically faster growing, more muscular steers have less total body fat (Devitt, et al. 2001). This moderate antagonistic genetic relationship needs to be carefully analyzed. Selection to improve retail yield percentage reduces fat deposition at all sites through the body. This may have implications for female fertility because body condition is an important factor in female reproductive performance and a minimum fat cover may be necessary for puberty and conception.

Using the bi-variate model, the estimated genetic correlation between 12-13th rib backfat thickness and rump fat was 0.89. A high genetic correlation of 0.74 was also reported for 12-13th backfat thickness and rump fat in *Bos taurus* cattle (Wilson, 2001). This indicates that animals that are more predisposed to deposit subcutaneous fat do so at both sites.

The MTDFREML procedure provided a Best Linear Unbiased Prediction (BLUP) of the EPDs. These EPDs provide estimates of the genetic merit of each animal, by condensing a broad range of information on each animal and their relativse into a single number for a given trait. Table 3.3 presents the mean, standard deviation, and range for each EPD. It is notable that the genetic variation observed in this small group of animals already demonstrates the potential to make significant genetic progress by selection, especially for ULMA where the genetic variation is greater. Accuracy is an important tool for managing risk and needs to be carefully evaluated. In order to make genetic progress for fat deposition the animals should be under good nutritional management, to have the opportunity to express their genetic potentials. The EPD for back fat and rump fat is also present in Table 3.3 with a moderate to high accuracy. The rump fat EPD tends to be more variable than back fat EPD, and may therefore respond more rapidly to genetic selection. Caution should be taken in selecting extremely fat or extremely lean animals because either can negatively influence the animal's physiology and decrease overall productivity.

Level of accuracy is primarily associated with the trait's heritability, number of progeny that have been evaluated for a particular sire, and how the progeny are distributed among different contemporary groups.

Table 3.3 - Mean, standard deviation and minimum and maximum Expected Progeny Difference (EPD) and accuracy (ACC) for carcass traits in Nelore cattle[1]

Variable[a]		Mean	Standard deviation	Minimum	Maximum
ULMA, cm^2	EPD	-0.3660	0.89	-3.2110	3.1665
	ACC	0.60			
UFAT, mm	EPD	-0.031	0.12	-0.775	0.970
	ACC	0.68			
URFAT, mm	EPD	-0.100	0.26	-1.070	1.315
	ACC	0.76			

[a] ULMA= Longissimus muscle area, UFAT= back fat and URFAT= rump fat

Conclusions and application

Ultrasound technology offers a way to cost-effectively measure carcass traits in live animals with an accuracy level required to develop estimated breeding values (EPD). Breed-specific parameters should be determined to account for differences in anatomy and physiology, in order to ultimately to develop a carcass merit program. Heritabilities for carcass traits in Nelore cattle are moderate to high, varying from 0.29 to 0.62. Ultrasound and carcass data are now being combined to estimate breeding values (EPDs). The EPDs for all traits presented a range that gives the possibility to significantly improve carcass quality in Nelore cattle.

This study presents the genetic parameters for carcass traits in Nelore cattle, for which carcass quality has been an important issue in order to reach an international standard and expand their market. Ultrasound scanning produced consistent and heritable results for Nelore cattle. These measurements taken using standardized procedures, may be used in genetic evaluation scheme to improve growth and carcass traits.

Chapter 4 – Conclusions and implications

This research project studied the use of Real-Time Ultrasound to estimate variance components for growth and carcass traits in Nelore cattle. The Nelore bulls and heifers exhibited growth patterns and carcass composition very different from *Bos taurus* breeds. It was noticeable that Nelore cattle had insufficient fat deposition in order to reach acceptable carcass grades. In order to evaluate Nelore cattle, especially raised under pasture conditions, animals should reach at least 16 months in order to express their genetic potential and have enough fat deposition (over 1.2 mm) for accurate measurements (Crews, 2001).

The heritability for ultrasound longissimus muscle area was moderate (0.29). The high correlation between ULMA and percentage of lean meat yield provides an opportunity to select animals that produce more meat. Heritabilities for subcutaneous fat depth were 0.44 and 0.62 for UFAT and URFAT, respectively. These are therefore highly heritable traits and should respond rapidly in any genetic selection program. The genetic correlation between UFAT and RUFAT was 0.89, indicating that animals that are more predisposed to deposit subcutaneous fat do so at both sites. Selection for <u>increased</u> fat deposition should produce animals with the potential to finish at an earlier age. In selecting animals for <u>decreased</u> fat deposition, caution should be taken because of potential detrimental effects on female fertility.

Physiologically, it is expected that animals with rapid muscle growth tend to mature and deposit fat at a later age. The genetic correlation between longissimus muscle area and subcutaneous fat was lowly negative (-0.22), but some animals presented positive EPDs for both characteristics, showing the opportunity to improve both traits simultaneously.

Contemporary and management group was the most important fixed effect for all weight and carcass characteristics. Once these were accounted for, seasonality had no effect on body weight and carcass traits, indicating that these evaluations may be conducted during any season, as long as this is done within properly constituted contemporary groups. Since Expected Progeny Differences (EPDs) are estimated within contemporary groups, this is not unexpected. No interaction between months of scanning and age in months was observed ($P > 0.05$) for any carcass trait, further confirming the lack of a seasonal effect.

Nelore cattle showed a broad range of EPDs for all RTU traits, especially for ULMA. The ULMA EPD ranged from -3.21 to +3.16 cm^2, showing that a good genetic selection program could have an important economic impact contributing to the whole beef industry from breeders to consumers. The URFAT EPD had a range of -1.07 to +1.32 mm of fat depth. With this genetic variation, in addition to a heritability of 0.62, the minimum of 3 mm of back fat required by most Brazilian branded beef programs could be reached in a short period. Accuracy for all traits was moderate to high, around 70, minimizing the producers' risk in the selection process. The phenotypic correlations were low for all carcass traits, probably because they were all raised under similar conditions, thus minimizing environmental variation.

This research project presented the genetic parameters required for a carcass trait genetic improvement program for Nelore cattle. This breed now has the basic tools to make significant improvements in their selection process and consequently enhance the quality of the product, a necessary step to gaining new markets and being widely recognized around the world as the premier tropical beef cattle breed.

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