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REPRODUCTIVE TECHNOLOGY & GLOBAL PRODUCTION OF BEEF: WHY BEEF PRODUCERS IN THE U.S. NEED TO PAY ATTENTION[1]

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Introduction

Over the past 30 years, United States (U.S.) beef producers have witnessed the rapid development of reproductive technologies (e.g. fixed-time artificial insemination [FTAI], estrus synchronization [ES], and ultrasound) that can improve the genetic merit and reproductive management of a herd. Recent advances in FTAI in beef cattle and a market structure that recognizes and rewards producers for the quality of their cattle should increase the adoption of FTAI and related technologies. However, adoption of FTAI by cow calf producers has been slow in the U.S. To facilitate the adoption process several different approaches have been taken: field demonstrations, estrus synchronization courses, and internships. In comparison to U.S. beef producers, Brazilian beef producers have adopted reproductive technologies, including FTAI, more rapidly in relatively large herds, potentially providing a model for U.S. beef producers to follow.

Fifteen years ago the University of Missouri recognized the need for well trained/qualified individuals to assist in the implementation of estrus synchronization protocols/FTAI and developed a reproductive management internship in conjunction with Select Sires, Inc. (F.B. Miller Internship in Reproductive Management) to address this issue. The long term goal is for skills learned in the internship to be spread throughout the industry. The objectives of this internship include the following: 1) Provide undergraduate, graduate, and veterinary students (interested in reproductive management) with extensive practical training in the implementation of ES and AI programs in beef and dairy herds, and 2) Provide students with the ability to solve "real world" reproductive management problems, both individually and as a team. The internship has provided the opportunity for students to gain experience that a typical one to three day AI school could not provide. To date, the internship has provided opportunities for 156 students to work with over 200,000 heifers and cows in production settings in twelve states. Outcomes include the following: 1) Increased competency of students' reproductive management skills, 2) A deeper understanding of the U.S. beef and dairy industries, and 3) A network of allied industry contacts that expand career opportunities beyond the classroom.

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In 2011, with the increase in global use of reproductive technology and the need to understand how these technologies are being implemented in large herds, the internship was expanded to provide graduate students with "hands on" experience in the Brazilian beef industry. Objectives of this program include the following: 1) Gain extensive practical experience in implementing ES and AI protocols in large Brazilian herds, and 2) Provide students with knowledge of the Brazilian beef industry and global production of beef. One of the primary goals of the program is for students to learn strategies for implementing ES protocols and FTAI programs in large herds and applying that knowledge to beef herds in the U.S. Recently, two graduate students worked with over 20,000 beef heifers and cows located on more than fifteen farms and ranches in three states in Brazil. One of the primary benefits from their experience is an understanding of the rapid adoption of reproductive technology on Brazilian farms and the challenge that this presents to the U.S. in competing in the global beef sector. This article reviews global beef statistics, with a focus on U.S. and Brazilian beef herds, with emphasis on current reproductive technologies, implementation schemes, and an overview of conception to consumption in a Brazilian beef herd.

Global Statistics

(USDA/USDA Foreign Ag Service)

Cattle statistics. In 2007, the total number of cattle in the world was estimated at 1.02 billion. However, in 2010, that number was estimated to be about 997 million. Over 60% of the world's cattle are concentrated in three countries; India – 304 million, Brazil – 191 million, and China – 105 million. The U.S. inventory is currently about 92 million head, which only accounts for about 9% of the total global cattle inventory. A closer evaluation of these same statistics depicts an even more interesting trend. From 2007 to 2010, the global cattle inventory was reduced by almost 30 million head. The U.S. accounted for about 4 million of the reduction along with Argentina, Mexico, Russia, Venezuela, and others. Furthermore, India, Brazil, and China all increased their total number of cattle over the last 4 years.

Production statistics. Total production efficiency is the single most important statistic evaluated when looking at a production operation and the same holds true for global comparisons. First, looking at production expressed as calf crop in 2007, 298 million head of cattle were produced worldwide, but in 2011 that number is forecasted to be about 279 million head. Again, when looking at the ranking of countries in relation to production based on calf crop, India, Brazil and China rank 1, 2, and 3 respectively. However, in respect to calf crop, the U.S. makes up about 15% of the global inventory. Switching from calf crop with regard to production, and focusing on metric tons of beef produced, total global production is estimated at 57 million tons. The U.S. accounts for 21% of total beef production with about 12 million metric tons of beef produced per year, followed by Brazil with 18% (10 million metric tons), and Europe third at 14% (8 million metric tons). Although India, Brazil, and China may have the largest annual calf crops, the efficiency with which calves are converted into product is rather low.

Import statistics. The importation of beef is widespread among countries, but usually is high in countries that have low beef production and high domestic consumption. In 2010, the importation of beef commodities totaled about 7 million metric tons. Over 14% (1 million metric tons) was imported into the U.S., followed by Russia (950,000 metric tons), Japan

(700,000 metric tons), and Europe (500,000 metric tons). In the last ten years, with the exception of 2003-2005, the U.S. acquired over 50% of its import shares from Canada. However, the other countries listed obtained most of their imports from the South American beef producing countries, Australia, and the U.S. The U.S. is an exception since their import and export numbers are similar. This has been true for the U.S. beef industry for many years, due to the high demand for high quality U.S. beef and higher premiums.

Export statistics. With the increase in demand for high quality beef throughout the world, the pressure for delivering high quality product continues to grow. In 2010, about 8 million metric tons of beef was exported throughout the world. As covered in the section above, about 14% of exports end up in U.S. markets. Brazil, which ranks number two in total number of beef cows and third in the total amount of beef consumed, currently ranks number one in total tons of beef exported at 2 million metric tons. The U.S. and Australia rank second and third in the global export market, with 1.4 million metric tons and 1 million metric tons of beef exported, respectively. With the steady increase in demand for consuming high quality product the question becomes: Will export markets grow larger and if so which countries will dominate these markets?

Domestic consumption statistics. Increases in income, a growing middle class, and a taste for high quality beef are what have driven domestic consumption to an all time high. In the U.S. alone, there were over 12 million metric tons of beef consumed in 2010. This accounts for over 20% of the beef consumed worldwide, which is around 56 million metric tons. Not surprisingly, Europe and Brazil are a close second and third with about 8 million tons consumed, respectively. Also, it is important to note the rapid increases in beef consumption in both China and Japan in the last ten years mainly due to the dramatic growth of the middle class in both countries. Table 1 provides a summary of the global beef statistics discussed above. All information was obtained from the USDA/USDA Foreign Agriculture Service report in 2010.

Table 1. A list of the top ten beef producing countries in 2010 with total cattle/head/1,000; total calf crop/head/1,000; total beef produced/1,000 metric tons; total imports/1,000 metric tons; total exports/1,000 metric tons; and total domestic consumption/1,000 metric tons. All data is presented on a /1000 base.

Country	Total cattle (No.)	Calf crop (No.)	Total tons	Imports/tons	Export/tons	Consumption (tons)
U.S.	92,550	35,000	12,000	1,250	1,000	12,000
Brazil	191,000	50,000	10,000	-	2,000	8,000
EU-27	87,500	30,000	8,000	490	160	8,100
China	105,000	49,000	5,000	-	-	5,500
India	304,000	62,000	3,000	-	725	2,000
Argentina	49,000	13,000	2,500	-	300	2,200
Australia	28,000	10,000	2,000	-	1,400	-
Mexico	21,000	7,000	1,500	330	100	2,000
Russia	17,000	7,000	1,250	950	-	2,300
Canada	13,000	5,000	1,275	250	525	990

As consumption of beef continues to climb, so does the demand for production of beef worldwide. In order for this demand to be met countries will need to increase production, by increasing herd numbers and (or) productivity. When considering Brazil with almost 200 million beef cows, and lower total pounds of beef produced than the U.S.; is it possible that improvements in their production systems will lead to their country eventually surpassing the U.S. in total beef production? Will Brazil become the leader in global beef production? These are relevant questions that face U.S. beef producers. In light of the preceding questions, the remainder of this review will focus on U.S. and Brazilian beef production systems, and specifically what Brazilian beef producers have been able to achieve with extensive adoption of reproductive technologies.

Comparison of Beef Herds in the U.S. and Brazil

Breed makeup. When comparing the average beef herd in the U.S. to that of an average Brazilian beef herd, one of the main factors to keep in mind is the climate in which animals are raised. First, consider the diverse climate across the U.S., ranging from subtropical climates in the southern states to a sub-arctic climate in the northern producing states. Brazil tends to have less variation in climate, with most of the beef producing states such as Mato Grosso do Sul, Mato Grosso, Acre, and Minas Gerais having a tropical environment. Heat stress in Brazil is an important factor in determining the most productive breed(s) to optimize beef or milk production. With these climate differences there tends to be large differences in breed makeup. There are over 250 breeds of cattle recognized worldwide, with over 60 breeds available to U.S. beef producers. Each breed is unique in its ability to produce and add value within the U.S. beef herd. As stated above, in the U.S. there are 92 million beef cattle, which are mostly made up of *Bos taurus* breeds (i.e. Angus, Hereford, Simmental), or crosses between breeds, except for southern producing states which have subtropical climates and utilize *Bos taurus*/*Bos indicus* crosses (i.e. Brangus, Braford). There is also a small proportion of straightbred *Bos indicus* cattle in the southern U.S. where extreme heat stress is a larger problem. According to a USDA report from 2007-2008, about 50% of beef cows are the result of two breed crosses, 25 % three breed crosses, and about 15-20% purebreds or straighbreds. In comparison, Brazil has nearly 200 million beef cattle that consist of 80% *Bos indicus* or *Bos indicus* crossed cattle (IBGE, 2008; Josahkian, 2000). The majority of *Bos indicus* cattle in Brazil are of the Nellore breed, which originated from India, and that first arrived in Brazil in 1868. Today, Brazil is the largest producer of Nellore cattle worldwide. Nellore is a *Bos indicus* species with a hump above its shoulders and loose skin. Cattle are usually white or gray in color with black skin, muzzle and tail. Nellore cattle tend to have long, deep bodies with clear underlines; cows have small udders and short teats. Nellore cows have a long and prolific reproductive life, distinct mothering ability, and cows tend to calve very easily due to their large frame and wide pelvic opening.

Bos indicus cattle tend to be extensively used within tropical climates due to their ability to adapt to heat stress and their resistance to parasites. However, there tends to be reduced production among *Bos indicus* cattle, due to lower levels of milk production and compromised carcass traits compared to *Bos taurus* breeds (Sartori et al., 2010). It has also been shown that *Bos indicus* cows, specifically Nellore, have a long postpartum anestrous interval in comparison to *Bos taurus* females which has contributed to lower reproductive efficiency over time (Filho and Vasconcelos, 2011). To address this issue, Brazilian beef producers have incorporated cross

breeding of *Bos indicus* and *Bos taurus* cattle in order to obtain the environmental adaptation of *Bos indicus* cattle and the higher production of *Bos taurus* cattle, along with the benefit of hybrid vigor (Sartori et. al, 2010). Most crosses are utilizing Angus genetics as the *Bos taurus* component, with the intention of improving quality of calves (i.e. age to puberty, meat quality, and reproductive performance).

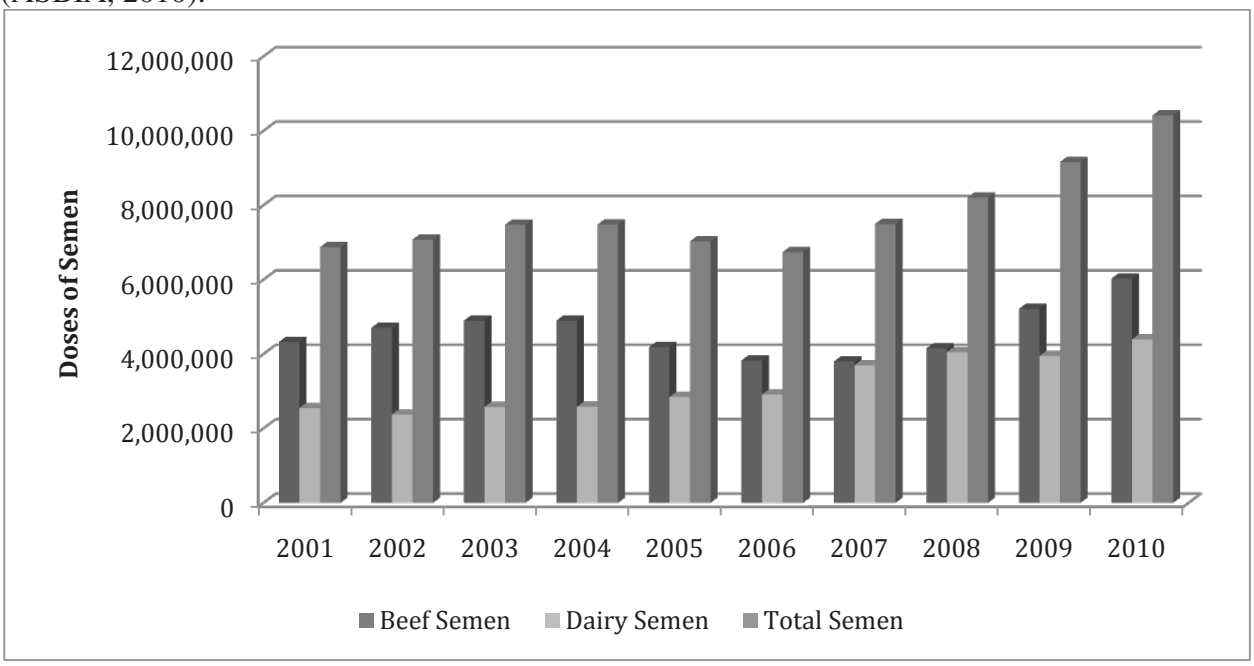
Average herd size. As previously reviewed, there are large differences in total numbers of beef cattle comparing the U.S. (92 million) and Brazil (200 million). Of those national totals, the U.S. has roughly 32 million beef cows compared to Brazil which is estimated to have 76 million. However, an even more striking statistic is the comparison of herd size between the two countries. In 2007-2008 the average herd size in the U.S. was reported to be in the range of 60 cows on 500,000 operations nationwide. In Brazil, the average herd size is estimated to range from 2,000-4,000 head depending on the state and region. Using 2,000 cows as the average herd size , it can be estimated that there are roughly 35,000 beef producers in Brazil. Also, within the U.S., a high proportion of cow herds are viewed as "hobby" herds, whereas the industry in Brazil does not follow this trend. It has been estimated in the U.S. that 69% of cow-calf operations are viewed as something other than the primary form of income in the household (NAHMS Beef Study 1997).

Adoption of AI. In the U.S., of the nearly 32 million beef cows, only about 55% of these cows are exposed for breeding during a defined breeding season and only 5-10% or 1.6-3.0 million cows are bred by AI (USDA report 2007-2008). However, it is estimated that approximately 15% of the 5.5 million replacement heifers are bred artificially, because of the emphasis placed on calving ease in heifers (Drovers Cattle Network). Each year it is estimated that 3.7 million units of beef semen are collected, however, only about 2.5 million units of semen are actually used (Drovers Cattle Network). For example, if there are 2.5 million units of semen used each year in the U.S. with an average conception rate of 60%, there will be 1.5 million calves born as a result of AI. In relation to the total calf crop of 35 million head (Table 1*)*, AI-sired calves would in theory account for 4 to 5% of the total calf crop.

Brazil, which is estimated to have 76 million beef cows, or 40% of the total estimated beef inventory (ANUALPEC, 2007), artificially inseminates roughly 7-12% of the cows nationwide. However, keep in mind that this 7-12% represents over two times the total number of cows inseminated in the U.S. This percentage accounts for 5-9 million beef cows. According to data from ASBIA (Brazilian Association of Artificial Insemination, 2010), there has been nearly a 40% increase in the volume of beef semen marketed in Brazil in the last ten years (Figure 1). Figure 1 also illustrates the overall growth of semen sales for both beef and dairy, which clearly points to the rapid adoption of AI in both industries. However, one interesting point is the comparison of semen sales in beef and dairy which tends to be the inverse of what is seen in the U.S. In 2010, ASBIA estimated that 6.1 million units of beef semen were used in AI programs in Brazil. Drovers Cattle Network estimates that Brazil imports about 5 million units of semen from the U.S. each year, with the vast majority being Angus. As mentioned previously, there has been a large emphasis placed on crossing *Bos indicus* and *Bos taurus* breeds to incorporate more of the quality-based traits from *Bos taurus* that *Bos indicus* cows lack; while at the same time conserving the heat tolerance and disease resistance characteristics of *Bos indicus* cattle. For example, considering a conception rate of 50%, it can be inferred that approximately 3 to 3.6

million beef cows in Brazil will have calves that result from AI in 2011, which represents 4-6% of the total calf crop. When compared to the U.S. calf crop, these percentages are similar; however, the total number of animals involved in AI programs is quite different. It is realistic to estimate that Brazil is breeding twice as many cows by AI each year compared to the U.S. Also, when considering the average herd size, the number of herds utilizing AI is much lower in Brazil compared to the U.S. For example, consider an average herd size of 2,000 cows in Brazil and 60 cows in the U.S.; if 3 herds in Brazil utilize AI, that's 6,000 head. To match these numbers in the U.S. it would take 100 herds to account for the three herds in Brazil. Because of these large herd sizes, attention has been focused on their adoption strategies compared to strategies in place within the U.S. beef system.

Figure 1. Evolution of AI in Brazil from 2001 to 2010. This graph depicts the evolution of AI in Brazil over the last ten years, by comparing total units of semen sold for beef and dairy (ASBIA, 2010).



Pregnancy diagnosis via ultrasonography. Beef producers should consider incorporating the use of proven technologies into their production system(s) to obtain profitable levels of performance while maintaining efficiency. One of those technologies involves the use of real-time ultrasonography for pregnancy diagnosis. There are many areas for application of ultrasound within the beef industry; however, this review will focus on reproductive management, specifically pregnancy diagnosis. According to the USDA beef report (2007-2008) pregnancy diagnosis via ultrasonography was utilized by 2.2% of all operations or 700,000 cows. As mentioned earlier, cattle in the U.S. involved in AI programs account for 5-10% of the total herd or 2 million cows. That means that over half of the cows involved in AI programs in the U.S. are not even confirmed pregnant via ultrasonography. When evaluating the percentage of cows that are diagnosed pregnant via rectal palpation the number is estimated to be 18%, or 6 million cows for all operations. Brazil on the other hand has been more aggressive in the use of ultrasound. It is estimated that ultrasound is used to determine pregnancy in 15-20% of the total

cow herd in Brazil. That percentage overlaps the total percent of cows on AI programs in Brazil, which is around 7-12%. So, it may be assumed that pregnancy status for almost all animals bred artificially in Brazil is determined via ultrasound. Factors that may be contributing to this high percentage include: Higher premiums for AI-sired calves, longer breeding seasons, or the increased use of re-synch protocols. It is very common in a Brazilian production system to utilize ultrasound heavily for diagnosing pregnancy in order to resynchronize cattle due to the long anestrus period in *Bos indicus* cows. This is most likely due to the fact that a large proportion of the cattle not bred are still not cycling therefore would benefit from another estrous synchronization program. Table 2 provides a summary of all the statistics discussed above.

There are noticeable differences in beef production systems between U.S. and Brazilian herds. In order to emphasize differences in reproductive management aspects of Brazilian beef systems, the remainder of this paper will focus on a more specific Brazilian beef enterprise.

Table 2. Comparison of U.S. and Brazilian beef herds. Data obtained from USDA Report 07-08, ASBIA 2010, and Brazilian researchers/ranchers.

	United States	Brazil
Total no. beef cows	32 million	76 million
Cowherd	Majority *Bos taurus*	Majority *Bos indicus*
Average herd size	60 head	2000-4000 head
% AI/total AI	5-10% / 1.6-3 million head	7-12% / 5-9 million head
Doses of semen used in 2010	~ 2.5 million	~ 6.1 million
Adoption of ES and AI	Slow	Fast
Pregnancy diagnosis via ultrasound	Low 2.2 %	High 15-20%

Reproductive Management

Estrus synchronization and FTAI. Estrus synchronization and AI are two of the most effective techniques to quickly and efficiently improve the genetics of a beef herd. As already mentioned, Brazilian beef herds, which are a majority *Bos indicus,* tend to lack many of the quality traits of *Bos taurus* breeds. However, since it is not practical to raise straightbred *Bos taurus* breeds in the tropical climates of Brazil, many Brazilian producers have begun to utilize a *Bos indicus/Bos taurus* cross. Furthermore, since raising *Bos taurus* bulls for natural service in production systems in Brazil is not an option due to heat stress and environment, one of the few ways to incorporate these genetics is through the use of ES and AI. Other considerations to take into account are the differences in reproductive physiology between the two types of cattle. Factors such as short duration of estrus (Pinheiro et al., 1998), low detection rate of estrus (Sartori et al., 2010), and longer periods of postpartum anestrus in *Bos indicus* cattle (Meneghetti and Vasconcelos, 2008) have plagued basic heat detection protocols for AI. Poor nutrition and the inability to restrict suckling on large herds leads to inhibition of GnRH/LH pulse frequency, resulting in delayed follicular development and reduced the maximum diameter of the dominant follicle (Williams et al, 1996; Bo et al, 2003), which also tends to have an effect on ES and AI programs. Because of short duration of estrus, low estrus detection rates and long postpartum anestrus intervals, FTAI, has become a tool for increasing the efficiency of AI (Meneghetti et al.,

2009). Fixed-time AI not only eliminates the need for estrus detection, but allows for appointment breeding of large groups of animals.

Because of differences in response to the various estrus synchronization protocols between *Bos indicus* and *Bos taurus* females, ES protocols in Brazil differ from those recommended in the United States. Many of the ES protocols recommended in Brazil involve the use of estradiol (i.e. estradiol cypionate [ECP], estradiol benzoate [EB], and estradiol 17-beta) to control follicular growth. A major concern facing beef producers in Brazil is whether estradiol will continue to be permitted for use in ES programs for beef cattle, similar to regulations prohibiting its' use in the U.S. **See Figure 2 for regulations governing use of estradiol in the United States.

Figure 2. **U.S. regulation of estradiol and related esters for use in cattle.

Estradiol products.

1) Numerous estradiol or estradiol ester products received NADA (New Animal Drug Application) approval from CVM (Center for Veterinary Medicine) for use as cattle growth promotants, and continue to be in use today. None of those products have NADA approval for use in cattle breeding management programs and their formulations are not amenable for such use.
2) SycroMate-B (6 mg Norgestomet implant for 9-days plus an injection of 3 mg Norgestomet and 5 mg estradiol valerate at time of implantation) was approved by CVM in 1982 for use as a beef cattle and dairy heifer breeding management product (estrus synchronization) but sale of this product ceased several years ago.
3) No estradiol containing products, other than SycroMate-B have been approved by CVM for use in breeding management programs.
4) To have a legal estrogen based product for use in cattle breeding management programs, a company needs to complete the CFR (Code of Federal Regulations) required research to address each of the NADA (New Animal Drug Application) Sections, achieve NADA approval, and market the product.

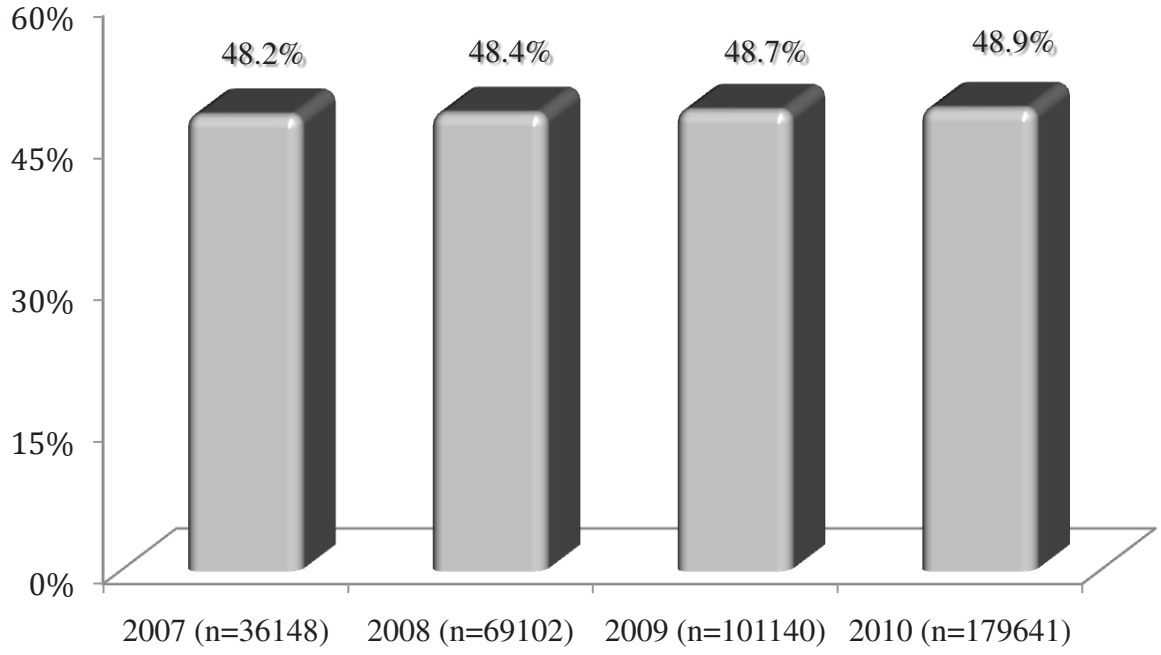
An example of a protocol within a Brazilian production system may include an injection of estradiol on the first day of the protocol, along with insertion of a CIDR for nine days. This promotes regression of antral follicles and emergence of a new follicular wave about four days after the start of the protocol (Bo et al, 2003). On day nine of the protocol CIDRs are removed and cows are administered a series of injections including prostaglandin $F_{2\alpha}$, estradiol, and equine chronic gonadotropin (eCG). This series of injections is critical for regressing any corpora lutea present, and ovulation of the dominant follicle for FTAI. The eCG injection is also administered on day nine to increase pregnancy rates resulting from FTAI protocols in *Bos indicus* cattle (Baruselli et al, 2004, Filho et al., 2009, Peres et al., 2009). With this particular protocol cattle will pass through a working facility three times which tends to minimize cost and labor. Currently there are two progestin based products used extensively in ES protocols within Brazil, CIDR (1.9 g progesterone) and Sincrogest, which is a comparable product to the CIDR. Also, in regard to these progestin-based protocols, reuse of these devices may occur up to four times. For example, producers may utilize first-use devices in mature cows, second- and third-

use in heifers, and fourth use for re-synchronizing mature cows. It should be pointed out, that the concentration of progesterone in the Brazilian CIDR (1.9 g), exceeds that of the U.S. CIDR (1.38 g). As already indicated, most Brazilian protocols are set up for FTAI, where all cattle are inseminated at a predetermined fixed-time. These protocols have achieved pregnancy rates that consistently approach 50%, which has been acceptable for Brazilian producers. Figure 3 summarizes pregnancy rates in a subset of cooperating Brazilian beef herds from 2007 to 2010. Based on Figure 3 it is clear that pregnancy rates have not changed much in the last four years, but the benefit of being able to incorporate *Bos taurus* genetics into *Bos indicus* herds through FTAI has gained widespread acceptance. However, note the number of females inseminated increased from 36,148 in 2007 to 179,641 in 2010. (It is important to note that these protocols and their accompanying recommendations are not approved in the U.S. and mention of them in this manuscript in no way implies promotion of their use.)

Pregnancy determination. As previously mentioned, ultrasound is used extensively in Brazil to diagnose pregnancy and determine fetal age. Since premiums are commonly paid for the *Bos indicus/Bos taurus* crossbred calves it is beneficial to know whether cows are pregnant as a result of FTAI or natural service. Another explanation is that since most large production systems in Brazil tend to have fairly long breeding seasons (i.e. 4 months), early pregnancy diagnosis allows producers the opportunity to re-synchronize cows for an additional FTAI. Nevertheless, Brazilian beef producers have aggressively adopted ultrasound technology into their herds and are utilizing it in a way that benefits their individual production systems.

Embryo production. Another reproductive technology being used extensively in Brazil involves the transfer of in vivo and in vitro produced embryos. In 1995 there were ~50,000 beef embryos produced in Brazil. In ten years that number grew to ~250,000 embryos, with half being produced in vitro and half in vivo. Furthermore, in 2009 the number of embryos produced grew to ~300,000 with over 75% being produced in vitro. Brazil accounts for 9.3% of the total global supply of in vivo produced embryos and 66% of the total in vitro embryo production; collectively this accounts for ~30% of total embryo production worldwide. The reason for these high numbers of in vitro produced embryos may partially be explained by the high success rates of in vitro embryo production in *Bos indicus* cattle. Viana and Camargo (2007) suggested that due to the greater antral follicle population in *Bos indicus* cattle in relation to *Bos taurus* cattle, in vitro embryo production has been much more successful in *Bos indicus* breeds. In a recent study, *Bos indicus* cows were compared to *Bos taurus* cows in which cows in both breeds were synchronized to induce the emergence of a new follicular wave. Follicles were aspirated and oocytes were fertilized to produce in vitro embryos. *Bos indicus* cows had 41 visible follicles, 37 total oocytes recovered, and a 28% blastocyst rate. This was compared to *Bos taurus* cows which had 22 visible follicles, 15 total oocytes recovered and a 14% blastocyst rate (Gimenes et al., 2010). This experiment highlights differences between the two breeds and what may be accomplished in adopting these technologies. The high success rate of in vitro produced embryos has had a large impact on producing Nellore bulls and replacement Nellore females for Brazilian beef producers.

Figure 3. Summary of pregnancy rates resulting from fixed-timed AI in Brazil. Provided by JLM Vasconcelos.



Conception to Consumption

Brazil has become a major player in the global beef industry with over 191 million head of cattle, 2 million metric tons of beef exported, and an increase in domestic consumption to 8 million tons. These advances are credited in large part to companies including, Lageado and Marfrig as well as producers themselves. The following section will highlight areas within Brazil's beef industry that follow the conception to consumption theory, and provide insight into the beef production cycle. This section will include a vision for Brazilian beef production, including heifer development, numbers of cows in production, and slaughter cattle (grass fed and/or feedlot). This section also highlights company objectives for Lageado Agricultural Consulting, LTD and the Marfrig Group.

Vision for Brazilian beef production. The vision for Brazilian beef production is hard to define because of the large numbers of beef cattle in Brazil and diversity among their producers. However, Brazilian researchers and producers speculate that with the increase in premiums for beef and increased demand for beef products there will be an associated increase in the adoption of technology to support this need. Specifically, with regard to reproductive management, increases in the adoption of ES and FTAI are anticipated, along with increases in the use of ultrasound and embryo transfer. There is speculation that within ten years the Brazilian beef industry will be largely transformed because of improvements in productivity and efficiency. However, one major challenge that faces Brazilian beef producers is the reduced value of the U.S. dollar, which in turn decreases the value of the REAL (R$, Brazil's currency).

Heifer development, cows in production, and slaughter cattle. The production cycle for beef in Brazil is slower in comparison to the U.S., but is improving as producers place greater selection pressure on animals to reach puberty at earlier ages, increase muscling, and improve meat quality. This is being accomplished in large measure by crossbreeding (*Bos taurus*); combining predominantly Angus genetics into *Bos indicus* based herds. Heifers are usually obtained by retaining replacements from the herd; however, producers purchase replacement heifers from local sale barns. It is not uncommon for producers to distinguish herds in which cows are bred to produce straightbred animals for replacements and a separate herd for producing crossbreds. Typically heifers are bred via AI at 24 months of age, but with selection pressure for earlier age at puberty some producers are able to begin breeding heifers as early as 16 to 18 months of age. These producers are beginning to see higher pregnancy rates among the crossbred Angus-Nellore females. The question still remains however, as to how these crossbred females will perform compared to Nellore females. Nellore cows will reach a mature size of 924 to 990 lbs (420 to 450 kg) at approximately 36 mo of age. These cows will be maintained in the herd as long as they continue to be productive, similar to U.S. standards. Additionally, Nellore cattle are typically finished in pasture-based or grass-fed systems. Pastures usually consist of *Brachiaria*, which includes a number of tropical grasses used extensively throughout Brazil. In grazing systems, animals will reach slaughter weight in 2.5 to 3 years depending on available forage, sex, and production system. Since this system is based on forage production, and Brazil is located in a tropical climate, the production of forage is abundant; however droughts during the dry season dictate the production cycle and the numbers of cattle that can be produced. Another method for producing slaughter animals is in feedlots, however all animals raised in feedlots are normally left intact. The main reason for leaving bull calves intact in Brazil is that most beef exported from Brazil enters European markets and the European Union prohibits use of growth promoting hormones. Leaving males intact allows for the secretion of naturally occurring hormones, which results in these animals being more efficient in the feedyard.

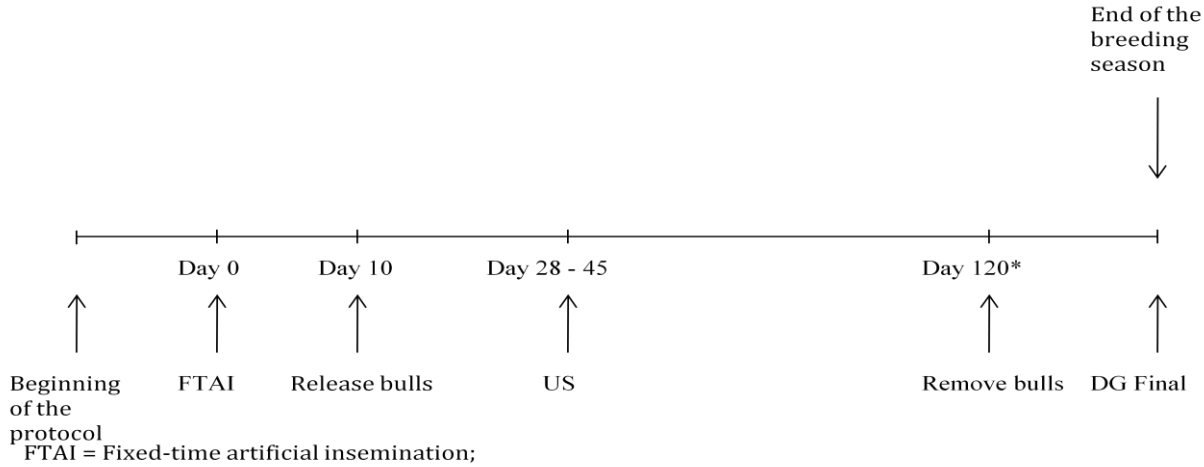
Lageado Agricultural Consulting, LTD. Lageado Agricultural Consulting, LTD is located in Mineiros, GO and has been in business since 2001. Lageado provides expertise in consulting, technical assistance, and product services for beef and dairy cattle. Recognized by the technical quality of its professionals, the team currently consists of 18 employees including veterinarians, animal scientists, inseminators and administrative personnel. Lageado provides services to more than 120 farms and ranches in eight states; Goias, Mato Grosso, Mato Grosso do Sul, Para, Rio de Janeiro, and Sao Paulo. Lageado provides services in the area of reproduction, nutrition, and sanitary control. Lageado focuses in large part on reproductive management: ultrasound, FTAI and conventional (AI). During the 2009 to 2010 breeding season, Lageado coordinated insemination of more than 70,000 cows, and completed more than 160,000 inseminations over the last three breeding seasons. During the 2010 to 2011 breeding season Lageado expected to inseminate more than 100,000 cows. With these numbers Lageado became the largest company in Brazil involved with FTAI of beef cattle. In the area of nutrition, Lageado offers technical support services that encompass the entire production system. Each nutrition plan is developed in accordance with the characteristics of each property. The plans involve nutrient management, formulation of diets and supplements, creep feeding, semi-confinement and confinement in order to reduce cost of gain and liters of milk produced.

Since the company's inception, Lageado has maintained a partnership with Pfizer Animal Health, and Dr. Jose Vasconcelos, UNESP-Botucato. In 2003 to 2004, these partners developed an ES protocol for beef cows similar to the one mentioned previously. This protocol has been used extensively in Brazil in recent years with approximately 1 million cows synchronized per year. In 2006, Lageado initiated a partnership with Alta Genetics, as the regional distributor of semen in the states of Goiás, Mato Grosso and Mato Grosso do Sul. Alta Genetics is the leading semen provider in Brazil, and was the first company to market 2 million units of semen in 2008. Also in 2008, Lageado partnered with the Marfrig Group and the Marfrig Angus Development Program. This program encourages crossbreeding using Angus genetics and will be explained in further detail in the next section of this review. This program provides producers with above market premiums for these animals along with offering an option to receive advanced payment for artificial insemination services. Lageado along with its partners seek to be a link to strengthen the meat production chain. Collectively, their ultimate goal is to create opportunities to increase profitability of its customers and contribute to the production of safe, high quality foods that meet increasing consumer demands.

Lageado developed four producer friendly schedules that allow producers to choose the package that best matches the farm's goals. Figures 4 and 5 are examples of how each package is scheduled. The responsibilities that Lageado assumes during the program include, assessment of semen quality, (meets standards recommended by the Ministry of Agriculture Livestock and Supply), a breeding soundness exam of bulls to be used as clean-up bulls with the ratio of one bull to every 75 cows inseminated at FTAI, establish and implement the protocols, and train farm staff. Lageado also assumes responsibility for the loss of CIDR's, semen and material required for FTAI.

Producers must agree to provide food and overnight accommodations during the period of work on the property, management of cattle on program and application of drugs when requested, proper storage of drugs, and ensure proper body condition of cattle prior to FTAI. In packages that require heat detection, the producer assumes responsibility for detection of estrus unless they choose to use an inseminator from Lageado for a set price per day. The producer also must have a minimum of 100 head to receive services from Lageado.

Figure 4. Diagram of scheduled activities for producers from Lageado in Brazil. The schedule includes FTAI, pregnancy diagnosis via ultrasound, and schedules for when to release and remove bulls.



FTAI = Fixed-time artificial insemination;

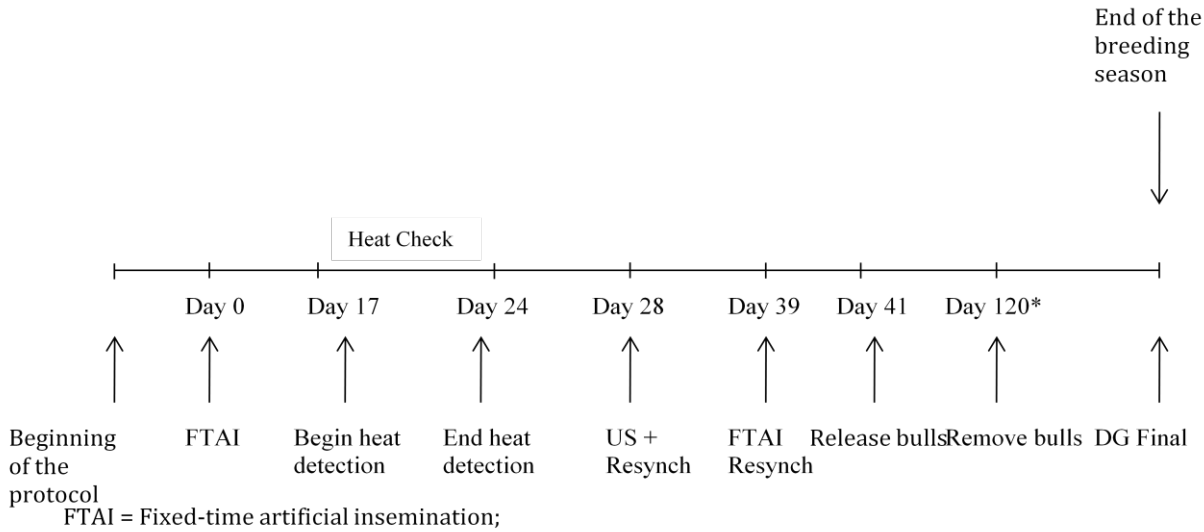
Obs. Heat = Heat detection;

U.S. = Early pregnancy diagnosis by ultrasonography

DG = Final diagnosis of pregnancy after the end of the breeding season

* = The period of the breeding season and in each particular property

Figure 5. Diagram of scheduled activities by producer and Lageado in Brazil, involving FTAI, pregnancy diagnosis by ultrasound, re-synchronization, and schedule of when to release and remove bulls.



FTAI = Fixed-time artificial insemination;

Obs. Heat = Heat detection;

U.S. =Early pregnancy diagnosis by ultrasonography

DG = Final diagnosis of pregnancy after the end of the breeding season

* = The period of the breeding season and in each particular property

Lageado also provides expected results (Table 3) to the producers outlining each package. The table shows a range of results including FTAI pregnancy rate, pregnancy rate after heat detection, pregnancy rate after resynchronization, total AI pregnancies, natural service pregnancies, and pregnancy rate at the end of the breeding season. The cost per animal (Table 4) is broken down into four groups up to 250 head, 250 to 500 head, 500 to 1,000 head, and > 1,000 head. The price shown is an average in Brazilian Reais and U.S. dollars per group.

Table 3: Results expected from the implementation of FTAI.

	Package 1: FTAI	Package 2: FTAI + heat detection	Package 3: FTAI + heat detection + resynchronization	Package 4: FTAI + resynchronization
FTAI pregnancy rate	40-55%	40-55%	40-55%	40-55%
Pregnancy rate after heat detection	-	6-12%	6-12%	-
Pregnancy rate after resynchronization	-	-	15-20%	15-25%
Total AI pregnancies	40-55%	46-67%	61-87%	55-80%
Natural service pregnancies	30-40%	25-30%	10-20%	10-20%
Pregnancy rate at the end of the breeding season	70-95%	71-95%	71-95%	70-95%

*The variation in outcomes is based on body condition of cattle during implementation of the protocol.
**Expected results for multiparous Nellore cows > than 35 days postpartum.

Table 4. Cost per animal according to package and herd size in Brazilian Reais (R$) and U.S. dollars ($).

Total	Package 1 (R$/cow)	Package 3 (R$/cow)	Package 4 (R$/cow)
Up to 250	R$38.00 - $24.00	R$48.00 - $30.00	R$49.00 – $31.00
250-500	R$35.00 - $22.00	R$45.00 - $28.00	R$45.00 - $28.00
500-1000	R$33.00 - $21.00	R$45.00 - $28.00	R$45.00 - $28.00
above 1000			

Marfrig Group. The Marfrig Group is the third largest Brazilian food processing company, after JBS and Brasil Foods. Marfrig has an operational base in 22 countries exporting to over 100 countries, and is the fourth largest beef producer in the world. Marfrig has 90,000 employees and operates the following processing plants: 33 cattle plants (Brazil-24, Argentina-5, Uruguay-4); 21 chicken plants (Brazil-14, Europe-4, United States-3); 48 plants for industrial and processed goods (Brazil-16, Europe-11, United States-8, Argentina-5, Uruguay-3, China-1, Thailand-1, Malaysia-1, South Korea-1, Australia-1); 4 pork processing plants (Brazil); 2 turkey processing plants (Brazil-1, Europe-1); 5 lamb processing facilities (Uruguay-3, Chile-1, Brazil-

1); and 27 feed processing facilities for chickens, turkeys, and pigs (Brazil-21, United States-3, Europe-3). Marfrig's daily processing capacity includes 31,200 cattle; 10,400 pigs; 10,400 lambs; 35,000 turkeys; and 3.7 million chickens.

Marfrig Angus Development Program. The Marfrig Angus Development Program was launched in 2007 and is a technical program that creates a relationship for producers to better connect farms with the industry by developing standards and certification for high quality beef. The Marfrig Group encourages the use of DNA-tested sires for meat quality (tenderness and marbling). They also encourage the use of artificial insemination or fixed-time artificial insemination. The entire process including artificial insemination, pregnancy diagnosis, and calving is assisted by a technician trained and certified by the Marfrig Angus Development Program. The company also provides advanced payment to meet the cost of artificial insemination. Angus or Angus crossbred animals are eligible to participate in the program as long as they meet specific requirements, including: percentage Angus, age, minimum weight, sex and back fat (Table 5). All animals must be enrolled in the national animal identification system (SISBOV). The slaughter process is certified by the Angus Brazilian Association (ABA), and the meat is marketed to SEARA ANGUS and may be found in supermarkets, restaurants and steakhouses in Brazil.

Table 5. Requirements for Marfrig Angus Development Program.

Standard animal	
Breed	Angus or Angus crosses
Percentage Angus	50% Angus or above
Age	Baby tooth – intact animals, castrated and female – up to 2 teeth
Minimum weight	225 kg carcass for males; 195 kg carcass for females
Sex	Males and females
Finishing degree	3-6 mm - minimum
Traceability	Animals must be entered in Sisbov

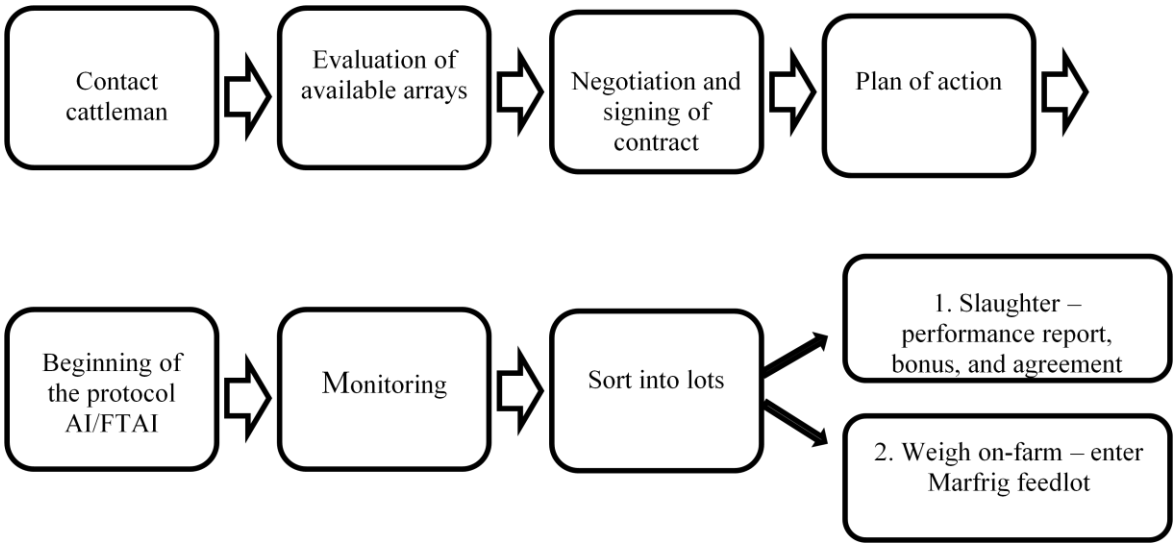
Objectives. The Marfrig Angus Development Program encourages the production of animals with percentage Angus genetics (blood level of 50% minimum) in order to better coordinate the supply of high quality beef and promote the use of new technologies in the field that generate greater profit for producers.

Contract. The program also creates a relationship between producers and the industry through a contract that specifies the rights and obligations of each party. Marfrig's policy is to recruit farms/cattle within a radius of 500 km from the nearest slaughtering facility or feedlot, however, there are case by case exceptions.

How the Marfrig program works. The two parties meet, negotiate, and sign a contract; this includes the planning of activities, and the responsibilities (technical and financial) of the producer. After the first insemination, monitoring visits are scheduled between the technical and farm staff to prepare for shipments to the nearest feedlot or processing plant. After the animals have been harvested, the producer receives a performance report and the bonus for their animals.

For unfinished animals (calves or steers), the animals are weighed on-farm for a 50% weight yield. All steps within the Marfrig program are illustrated in Figure 3.

Figure 6. Diagram of steps involved in the Marfrig Angus Development Program.



Summary

Increased global demand for beef stemming from an expanding middle class with a preference for beef and the means to afford it raises the question as to where supplies will originate. Based on statistics cited in this manuscript, it is clear that the U.S. beef industry faces growing challenges from major global competitors. The Brazilian beef industry has invested heavily in the adoption of reproductive and genetic technologies to increase productivity. The challenge the U. S. beef industry now faces is whether educators, veterinarians, and beef producers in this country will optimize the transfer and adoption of technology that ensures our county's position as the global leader in the production of high quality beef, or whether that role be relinquished to more technically astute and competitively advantaged international players.

References

ANUALPEC 2007. Anuário da Pecuária Brasileira, 2007, Instituto FNP, São Paulo.

ASBIA. 2010. ASSOCIAÇÃO BRASILEIRA DE INSEMINAÇÃO ARTIFICIAL. 2010. Disponível em: http://www.asbia.org.br/novo/upload/mercado/relatorio2010.pdf> Acesso em 10/06/2011.

Bo, G.A., P.S. Baruselli, and M.F. Martinez. 2003. "Pattern and manipulation of follicular developmentin *Bos indicus* cattle." Animal Reproduction Science 78 307-326.

Baruselli, P. S., E. L. Reis, et al. 2004. "The use of hormonal treatments to improve reproductive performance of anestrous beef cattle in tropical climates." Animal Reproduction Science 82-83: 479-486.

Drovers Cattle Network "AI trends - here and abroad." Maday, J. 2011.

Gimenes, L.U., M.L. Ferraz, A.B. Araújo, N.P. Fantinato, M.R. Chiaratti, L.G. Mesquita, J.S.P. Arango, M. Raposo, D.C. Souza, G.D. Calomeni, R. Gardinal, C.L.V. Rodriguez, L.A. Trinca, F.V. Meirelles FV and P.S. Baruselli. 2010. "OPU at different times of a synchronized follicular wave did not affect IVP in *Bos indicus, Bos taurus* and *Bubalus bubalis*." Reproduction, Fertility and Development 22 293.

IBGE 2008. Instituto Brasileiro de Geografia e Estatística. 2008.

Josahkian, L. A. "Genetic improvement program for Zebu breeds." Proc. 3rd Natl. Anim. Improv.Symp. p. 76-93, 2000.

Meneghetti, M. and J.L.M. Vasconcelos. 2008. "Calving date, body condition score, and response to a timed artifical insemination protocol in first-calving beef cows." Braz J Vet Anim Sci 60: 786-93.

Meneghetti, M., O. G. S. F., R.F.G. Peres, G.C. Lamb, J.L.M. Vasconcelos. 2009. "Fixed-time artificial insemination with estradiol and progesterone for *Bos indicus* cows I: Basis for development of protocols." Theriogenolgy 72: 179-189.

National Animal Health Monitoring System Report. 2007.

Peres, R.F.G, I.C. Junior, O.G. Sa´ Filho, G.P. Nogueira and J.L.M. Vasconcelos. 2009. "Strategies to improve fertility in Bos *indicus* postpubertal heifers and nonlactating cows submitted to FTAI." Theriogenolgy 72 681-689.

Pinheiro, O.L., C.M. Barros, R.A. Figueredo, E.R. Valle, R.O. Encarnacao and C.R. Padovani (1998). "Estrous behaviour and estrus-to-ovulation interval in Nelore cattle with natural estrus or estrus induced with prostaglandin F2α or norgestomet and estradiol valerate." Theriogenology 49: 667-681.

Sa´ Filho, O.G., J. L. M. Vasconcelos. 2011. "Treatments to Optimize the Use of Artificial Insemination and Reproductive Efficiency in Beef Cattle under Tropical Environments." Veterinary Medicine International.

Sa´ Filho, O.G., M. M. Meneghetti, R.F.G. Peres , G.C. Lamb , J.L.M. Vasconcelos. 2009. "Fixed-time artificial insemination with estradiol and progesterone for *Bos indicus* cows II: Strategies and factors affecting fertility." Theriogenolgy 72: 210-218.

Sartori, R., M. B., PS Baruselli, L.U. Gimenes, R.L. Ereno, and C.M. Barros (2010)."Physiological differences and implications to reproductive management of *Bos taurus* and *Bos indicus* cattle in a tropical envoronment. Reproduction in Domestic Ruminants VII. Nottingham, United Kingdom, Nottingham University Press.

Williams GL, Gazal OS, Guzman Vega GA and Stanko RL 1996 "Mechanisms regulating suckling-mediated anovulation in the cow". Animal Reproduction Science 42 289-297.

USDA and USDA Foreign Ag Service Report 2010.

USDA 2007-2008 Report – Part II: Reference of Beef Cow-calf Management Practices in the United States.

Viana JHM and Camargo LSA (2007). "Bovine Embryo production in Brazil: A new scenario." Acta scientiae Veterinariae 35 920-924.