THE ECONOMIC VALUE OF ASSISTED REPRODUCTIVE BIOTECHNOLOGY TO RUMINANT INDUSTRIES

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ABSTRACT

Assisted Reproductive Biotechnology (ARB) has a critical impact on ruminant industry, particularly for the meat and dairy cattle. The cattle breeding as industry has been expanded in the developed countries on the base of routine application of ARB such as estrous synchronization, ovulatory control, artificial insemination (AI), in vitro production (IVP) of embryos and embryo transfer (ET). The ruminant breeding in the developing countries is characterized by traditional conditions such as animal resources of low productivity and backwardness of farming reproductive techniques. Therefore, the economic value of ARB application is depending on the level and the way of its implementation. The adoption of techniques by individual farms will benefit them by the immediate actions such as AI with imported semen or transfer of embryos from selected donors. In order to achieve an industry with great and durable economic value the application of ARB should be carried out in combination with the organization of genetic selection based on Open Nuclear Breeding System (ONBS), genomic information and Best Linear Unbiased Prediction (BLUP), either at national or regional level. Scientific collaboration for technology transfer and reasonable exploitation of semen and embryo of selected donors from developed countries are the major advantages that made this approach a great economic value. The model of this ARB implementation and its economic value for dairy cattle industry under conditions of tropical developing country are described here.

Keywords: Ruminants, Cattle, ARB, economic value

INTRODUCTION

A ruminant industry characterized by the transformation of animal farming from traditional grazing systems to intensive industrial farming has begun in American and West European heartlands in the early 1930s and quickly widespread in developed countries as the results of intervention of scientific discoveries and technological advances in nutrition, veterinary and reproductive biology in the later years of the 20th century.

This transformation is considered as an indispensable trend for livestock production in the developing countries. According to the united nations environment programme (UNEP) investigations, the demand for livestock products would double in the next few decades to meet the over increased human population as more than nine billion in 2050 (Nellemann et al. 2009). A major demand for this increase will take place in the developing countries. By 2050, developing countries will consume 326 million metric tons (mmt) of meat and 585 mmt of milk, this consumption is considerably higher compared to 126 mmt of meat and 296 mmt of milk estimated for developed countries.

The rapid rise in ruminant production in most developing countries has been confronted in recent years by dwindling grazing resources, low productivity due to large distribution of small farms and backwardness of farming reproductive techniques. The application of Assisted Reproductive Biotechnology (ARB), including artificial insemination (AI), gamete and embryo freezing, multiple ovulation embryo transfer (MOET), and in vitro embryo production (IVP), is indispensable for developing intensive ruminant production in these circumstances. The reasonable combination of ARB and the genetic selection based on principle of open nuclear breeding system combined with best linear unbiased prediction (ONBS-BLUP) or Genomic BLUP (GBLUP) is the fundamental prerequisite for achieving sustainable ruminant industry.

The present review summarizes the recent approach of the above mentioned ARB in a ruminant industry and aspects of their economic impact at different levels of technical implementation with a specific focus on the developing countries.
ARB had different impacts on a ruminant industry, depending on the goal of the investment, the techniques involved and the levels of its implementation. Some strategies to use ARB for a ruminant industry have been proposed; (i) The usage in combination of AI, embryo transfer (ET), sexing, cloning and other related methods of genetic selection for long-term genetic improvement, (ii) The usage of one or more ARB technologies mainly to improve efficiency of the reproduction for the short term commercial objectives, and (iii) The usage in combination of ARB and genomics and DNA levels for genetic engineering and biomedical applications (Gengler and Druet 2001).

**AI and BLUP**

The commercial application of AI was initiated in the United States in the 1930’s and was developed on a global scale in bovine and porcine since the 1960’s (Foote 1981). Two astounding achievements were made: AI a potential technique for a ruminant industry were the development of semen extender in the 1940’s (Phillips and Lardy 1940) and the successful freezing of sperm for cryconservation in liquid nitrogen at -196°C in 1950’s (Polge et al. 1949). These discoveries allowed to produce 200,000 doses of semen for AI (10 ×10⁶ sperm per insemination) per sire per year. The application of AI with preserved (either chilled or frozen) semen for the transition of superior male genetics to more producers in the cattle industry has been growing exponentially on a global scale (Thibier and Wagner 2000). The number of produced semen doses is >250 million worldwide (FAO), fertility is above 80% for AI using fresh-liquid conserved semen, and above 60% for AI using frozen semen (Rodriguez-Martinez 2011).

The application of AI, followed by the introduction of progeny testing for dairy bulls in the 1950s and BLUP in the early 1970s, had a major impact on genetic improvement in dairy cattle programs (Smith 1984). BLUP method (Henderson 1973), which can compare the estimated breeding values of animals in different herds and simultaneously solve genetic and environmental effects, is the standard method for genetic evaluation in breeding programs. The difference between genetic gain in the pre- and post-BLUP periods was statistically significant as 5.5 ± 1.0 (P < 0.01) index units per year in the pre-BLUP period, and 16.5 ± 0.6 (P < 0.01) index units per year in the post-BLUP period (Avendaño et al. 2003). The combination of extensive use of AI with evaluations by BLUP has resulted in significant phenotypic and genetic gains in dairy production. A striking difference was reported for the genetic gain in the period of nearly no gain (2.55 kg milk, years 1960-1969) and the period of substantial gain (83.73 kg milk, years 1969-1979) (Van Vleck 1986). It is estimated that approximately 50% of the increase in milk production efficiency observed in developed countries during the second half of the 20th century can be attributed only to the genetic gain obtained by the widespread use of AI over conventional breeding (Bertolini and Bertolini 2009). Since the first introduction of BLUP for genetic evaluations in 1975, phenotypic progress for production in the Holstein breed in Canada has averaged 200 kg milk, 7.0 kg fat and 6.3 kg protein; the Lifetime Profit Index has received the intensity with 0.28 standard deviation units gain per year and protein yield at 0.26 standard deviations per year (Van Doormaal and Kistemaker, 2003).

**MOET and ONBS**

The histological study indicates that bovine ovary contains a large pool of primordial follicles at birth, but during the reproductive lifetime of a cow only less than 0.1% of them was recruited into a follicular wave and ovulated (Erickson et al. 1976). The progestagens (CIDR®, PRID® or CRESTAR®) in combination with gonadotropin hormones (PMSG, FSH, LH) for synchronization of estrus cycle and stimulation of the growth of advanced antral follicles have been used successfully for induction of multiple ovulatory (MOET) and for in vivo embryo production. An average of 4-6 (0-50) embryos can be collected per induction-cycle for a regime of 4-6 inductions per donor per year.

The first successful mammalian embryo transfer was performed in rabbits more than a century ago (Heap 1890). The discovery of the technique of non-surgical embryo collection and embryo transfer offered opportunities for developing MOET as a critical tool for cattle and ruminant industry. On a worldwide basis, more than 750,000 embryos are produced annually from super ovulated donors and more than 450,000 embryos are produced by in vitro fertilization, of which 54% were transferred after freezing and thawing (Mapletoft 2013). The introduction of MOET technology allowed to get more multiple progenies from genetically superior females with increased number of full-sibs families resulting in the high selection intensity and reduction of generation intervals leading to increase genetic gains (VanRaden et al. 1992). Animals produced by MOET techniques are often
used as top-reproducers for the establishment of nucleus herds, and "Juvenile MOET" in heifer offspring showed genetic gains of twice the numbers of those achieved with traditional progeny test schemes (Mapletoft 2013).

The ONBS (Cunningham 1979 and 1987) is a system of genetic selection and diffusion with two component Nucleus farm and peripheric population farm. A fundamental feature of nucleus breeding is the advantage of testing bulls under controlled nucleus conditions and a transfer of genetic material in the opposite direction between main population and nucleus. The ONBS in combination with MOET can offer the similar improvement of selection accuracy of sires and base females and increase the genetic gain by 20-45p.100 and 10-20p.100, respectively (Nicholais and Smith 1983).

**In Vitro Fertilization (IVF), Ovum pick-up (OPU) and Sexing.**

In vitro production of embryo by IVF and OPU, embryo sexing and micromanipulation were considered to be the third generation of ARB (Bertolini and Bertolini 2009). OPU is a nonsurgical technique developed in late 1980’s on the base of the using laparoscopy for collection of human in vivo oocyte. OPU allows to aspirate antral follicles in ovaries with the frequencies of 5-10 twice a week and the numbers of oocytes per week varied from 15 to 20. Potentially, via OPU-IVP, a donor cow may yield 15-20 oocytes each week (collection or 15-20 oocytes once a week, respectively). Considering the usual rates of development and losses obtained after IVP and ET, a cow may potentially produce 50 to 100 calves each year. OPU can greatly reduce a generation interval as it provides a method to use very young animals in selection schemes (Gengler and Druet 2001) to increase the annual rate of genetic progress by 10-30% when compared to using MOET alone (Bertolini and Bertolini 2009). A rapid expansion in the commercial application of OPU procedures coupled with the IVP technologies and ONBS in a dairy nucleus suggests benefits at the top end of those now expected for MOET programs, i.e. around 20-25% faster than the rate of genetic improvement with a national progeny-testing scheme (Leitch et al. 1995; Lohuis 1995). Breeding programs combining GS with MOET or MOET + JIVET have increased genetic gain of 39% and 83%, respectively, while the inbreeding was limited to a 10% increase over 20 years (Granleese et al. 2014).

**Cloning-somatic cell nuclear transfer (SCNT)**

Cloning by nuclear transfer consists of two different methods: embryonic cell nuclear transfer and somatic cell nuclear transfer. While the potential for cloning animals has been realized for at least over the last 25 years, it is only recently that sufficient advances have been made to allow the technology to advance to a stage where it is possible to have widespread commercial applications. From a practical point of view, embryonic cell nuclear transfer could be used to multiple the embryos obtained from MOET or IVF-OPU; Embryonic nuclear transfer has been attempted and succeeded in small and large ruminants using blastomeres from 8-16 cell stage embryos (cattle), 32 cell stage embryos (goats) or sheep ICM-cell. The first mammal to have been successfully cloned from a somatic cell was Dolly the sheep born in 1997. SCNT has been proven to be successful in up to 23 species, including large and small ruminant such as cattle, buffalo, horse, and goat (Vajta and Gjerris 2006).

Cloning can be used to increase the number of cows and bulls with superior genetics for increased milk yield, and increased availability of stock with desirable genetic traits (Rodriguez-Martinez 2011). A cost-effective approach that combines genomic analyses with reproductive technologies can reduce generation interval by rapidly producing high genetic merit calves (Poothappillai et al. 2014); individual fibroblast cell lines were established from flushed early stage embryos for cell culture. DNA isolated from fibroblast cell lines was submitted for genomic enhanced genotyping for the generation of high genomic merit calves. The selected cells were used as donor cells in SCNT. The in vitro embryo development rate on day 7 (day is defined as the day of SCMT) was 23.7% and high quality embryos were selected and transferred individually to synchronized recipient cows. Pregnancy initiation at 40 days of gestation was 69% (11/16) and more 30% of pregnancies continued through gestation to produce calves. This approach is scalable and can lead to considerable savings for acceleration of genetic gain in cattle by reduction of generation interval, the producing animals with the desired genetics is obtainable within a timeframe of approximately one year.

**ARB and Genomic approach**

The application of new technology called genomic selection is considered to revolutionize the dairy cattle breeding. Genomic selection refers to selection decisions based on the idea that a specific gene called hereafter QTL/ETL (quantitative or economical trait loci) is responsible for part of the phenotype (Georges et al. 1995). Main advantages of QTL/ETL in breeding programs are: 1) an increase in accuracy in selection through additional information directly related to the genotype; 2) a possibility to reduce generation interval by adding a new selection
stage at earlier age (Gengler and Druet 2001).

In dairy cattle, selection decisions on candidates are made now widely based on Genomically Enhanced Breeding Values (GEBV) instead of Estimated Breeding Values (EBV) obtained after progeny testing. A method to include genomic information in national BLUP evaluation was proposed by Ducrocq and Liu (2009). In France, genomic evaluations became official in 2009, the bulls that were pre-selected according to genomic information have been used and the first records of their daughters will be included in the national BLUP evaluation in 2013. This issue is also relevant at the international level, since the trade of bull semen is based on EBV from Multiple Across Country Evaluations (MACE) that is computed assuming an unbiased national EBV. This strategy should have at least double the rate of genetic gain in the dairy industry. In subsequent generations, only marker information is required to calculate GEBV. The increase in reliability is so sufficiently high that at least 2 dairy breeding companies are already marketing bull teams for commercial use, based on their GEBV only, at an age of 2 years (Hayes et al, 2009).

**ECONOMIC EVALUATION OF ARB IMPACT ON RUMINAL INDUSTRY**

**Methodology**

As mentioned above, the main impact of ARB on the animal industry is based on the increase of genetic gain and this effect of ARB is varied, depending on the level of technical implementation. A study reported by Lohuis (1995) showed that the annual genetic gain in dairy cattle increased correspondently with the level of the technique implementation from AI to MOET, MOET plus OPU-IVP (Fig 1).

Therefore, the evaluation of ARB investment is not only based on the genetic output but also on economic efficiency of the investment. To obtain an accurate calculation of economic revenues of the breeding programs the absolute economic values are needed (Groen et al. 1997). To ensure a successful investment, the preparation for animal breeding should involve three major steps; (i) the definition of a breeding goal: setting up the aggregate genotype and deciding what traits to be included, (ii) b) determination of the methodology in deriving economic values, the estimation of the breeding value in the information index, i.e. the estimated breeding value for each trait and for each potential breeding animal, and (iii) The final and third step is the optimization of a breeding program, optimizing the organization to routinely gather information on potential breeding animals and/or their relatives, and to select and mate breeding animals to breed the next generation (Groen et al. 1997).

The term functional trait is used to summarize those characters of an animal which increase efficiency not only by higher output of products but also by reduced costs of input. Major groups of breeding goal traits belonging to this category are health, fertility, calving ease, efficiency of feed utilization, and milking ability.

The derivation of economic values requires a good theoretical basis, proper methodology in terms of models including physiological modeling of animal production, farm economics, social aspects, and appropriate assumptions on future production circumstances (Groen et al. 1997). The choice of an aggregate genotype is the starting point in setting up breeding programs. The aggregate genotype is used to represent the genetic merit of an animal. The sum of its genotypes for several traits is the economic value of a trait and expresses to what extent the economic efficiency of the production has been improved at the moment of expression of one unit of genetic superiority to that of a trait (assuming a distinct genotype for each economic trait), each genotype being weighted by their predicted contribution to the increase in the overall objective (Hazel 1943). This contribution is determined by the so-called cumulative discounted expressions and economic values (Groen 1989). Multiplying the economic value by the cumulative discounted expression gives the discounted economic value.

Over the years, multi-disciplinary efforts were made to objectively assign economic values. After Selection index theory (Hazel 1943) the net genetic improvement which can be brought about by selecting among a group of animals is the sum of the genetic gains made for the several traits which have economic importance. It is logical to weight the gain made for each trait (Gi) by the relative economic value of that trait (ai). Thus, the average genetic superiority of a selected group over the group from which it was chosen is as follows;

$$H = a_1G_1 + a_2G_2 + \cdots + a_nG_n.$$

And the relative economic value for each trait depends upon the amount of profit that may be expected in order to increase each unit of improvement in that trait. After Groen et al. (1997), economic values are defined by the
population level rather than by the level of an individual animal. The micro-economic approach of an individual farm is chosen.

\[ \text{Revenues farm} = Y_p = nyp \ (\text{Dfl yr}^{-1}), \]
\[ \text{Costs farm} = X_v p_v + C_{fa} + C_{ff} \]
\[ = n(x, p_v + c_a) + C_{fa} \ (\text{Dfl yr}^{-1}). \]

where \( n \) is the number of animals at the farm, \( y \) the level of product output (kg animal \(^{-1}\) yr \(^{-1}\); \( Y = ny \); \( p \) the price per unit product (Dfl kg \(^{-1}\)), \( x \) the level of input of production factor \( v \), variable per animal (kg animal \(^{-1}\) yr \(^{-1}\); \( X_v = nX_v \)); \( p_v \) the price per unit production factor \( v \) (Dfl kg \(^{-1}\)), \( C_{fa} \) the costs of input of production factor \( fa \), fixed per animal (Dfl animal \(^{-1}\) yr \(^{-1}\); \( C_{fa} = nC_{fa} \)), and \( C_{ff} \) the costs of input of production factor \( ff \), fixed per farm (Dfl yr \(^{-1}\)).

The economic value within the cost price and interest is given by Eq: the cost price before genetic improvement minus the cost price after genetic improvement, multiplied by the original level of output \( y \) per animal.

\[ EV`\text{'cost price'} = y \left( \frac{(\text{costs farm})}{Y} - \frac{(\text{costs farm}}{Y + \delta Y} \right) \]

The method for incorporating the competitive market position in economic values was presented by De Vries (1989) and Ollivier et al. (1990). Up today, three common ways to calculate MEVs of breeding goal traits were proposed: (i) from a single profit equation, as its partial derivative with respect to each trait (e.g. Knap 1990; Hermesch et al. 2003), (ii) from a bio-economic multi-equation model, evaluated for differential values of each trait (e.g. Faust et al., 1992), and (iii) trait by trait (Habier et al. 2010). Methods for derivation of economic values were summarized recently by Knap (2014).

The effect of biotechnologies on genetic improvement was formalized by Falconer (1989) in equations that describe relation of genetic gain \( 'G \) and ARB via the selection intensity

\[ \Delta G = r_{GG} \sigma G \]

Where \( r_{GG} \) is the correlation between the actual and additive genetic value predicted, also called accuracy of evaluation, \( i \) is the selection intensity (expressed as the standard normal selection differential) and \( VG \) is the genetic standard deviation. Biotechnologies will act mainly by allowing an increase in selection intensity (by enhancing reproductive efficiency of animals) and by increasing the accuracy of evaluation (by additional information or increase in number of progenies). However, intensive use of some biotechnologies could also affect genetic variance (Gengler and Druet 2001).

Using computer simulation programs to estimate the economic value has been reported by some authors. SelAction is a noncommercial system programmed in Borland Delphi 5.0 and runs under Microsoft Windows 95/98/NT (www.zod.wau.nl/abg/) (Misztal et al. 1998). Recently, the software ZPLAN (Willam et al. 2008) was developed for evaluation of both the genetic and the economic consequences of the different breeding strategies for a given investment horizon using 2 criteria to compare the value of the different breeding strategies: (1) Annual monetary genetic gain (AMGG) was used as the genetic evaluation criterion, and was defined as the average increase per year in monetary superiority of the progeny of the selected animals after one round of selection; and (2) Discounted profit (DP) for the economic evaluation, defined as the discounted monetary profit based on the genetic superiority and expressed as the improved profit per animal in the total population over the given investment period. All results for AMGG and DP were expressed as relative values referring to the values of the reference scenario of the hybrid scheme, which were set to 100 (Thomasen et al. 2014).

**ARB as an effective tool to improve economic value for a ruminant industry**

A review on economic values of different functional traits for dairy cattle during period up to 1996 was given by Groen et al. (1997). The recent results reported by different research groups show that Economic values are sensitive to production circumstances and they may differ between nations (e.g. legislation on environmental issues, animal welfare or milk quota, or pricing levels), or regions and farms (e.g. Intensity of farming system).
A study of Abay et al. (2012) on Norwegian beef cattle showed that the marginal economic values (EUR per unit of the trait per suckler cow and per year) for Limousin and Simmental, Charolais (intensive – Continental group) and Hereford and A. Angus (extensive – British group) were 5.57 and 5.05 for carcass weight, 0.18 and 0.20 for growth rate, -31.75 and -28.26 for calving difficulty, -1.47 and -0.97 for calving interval, respectively. For three breeds Simmental, Brown Swiss and Holstein-Friesian breeding under different farming circumstances within Slovenia, absolute economic values were slightly negative for milk yield for all breeds (-0.02 to -0.046 per kg milk), positive for milk components (0.55 to 1.45€ per kg fat, and 2.89 to 3.38€ per kg protein); high absolute economic values were calculated for survival (7.37 to 9.55€ per %) and absolute economic values for calving interval were approximately -1€ per day for all breeds, while the economic value for beef daily gain was 0.14€ per kg for Brown Swiss and 0.32€ per kg for Simmental (Haas et al. 2013). For the Holstein cattle used in the commercial dairy population in Brazil, the average economic values (RS) for MY, PY and FY were 0.51, 6.41 and 1.94, respectively (Cardoso et al. 2014). Economic values of production traits (carrier, fat, protein, and dressing percentage) and functional traits (conception rate, survival rate, body weight, and rumen capacity) were calculated for Holstein cattle of Costa Rica using two different systems fixed herd-size and fixed milk-output. Economic values for fixed herd-size were 0.04 for carrier, 5.25 for fat, 3.95 for protein, 0.92 for dressing percentage, 1.30 for conception rate, 2.42 for survival rate, 0.81 for body weight and 84.53 for rumen capacity. With a milk-output the respective values were 20.04, 3.53, 2.91, 0.88, 0.85, 3.18, 0.51 and 45.59 (Vargas et al. 2002).

ARB has an impact on a ruminant industry, firstly by the improvements in reproductive performance. The application of AI and estrus synchronization allows farms to control the interval to first insemination and fertility, the voluntary waiting period. In general, pregnancies obtained by artificial insemination are cheaper than those originated by natural service. The major reason is that AI programs result in similar or better reproductive performance and are cheaper to implement than natural service programs because of the high costs of acquiring and feeding bulls (Ribeiro et al., 2012). According to Lima et al. (2009), exposing cows to natural service was $32.7 more expensive/cow/yr compared with timed AI. The study of Giordano et al. (2011) showed that the application of the double Ovsynch program for first AI followed by resynchronization of non-pregnant cows with Ovsynch starting on day 32 after the previous AI (DO-Res) and the double Ovsynch program for first and subsequent AI (DO-DO) for the timed AI programs in lactating dairy cows and it resulted in $45 and $69 more income per cow/yr, respectively, although they were $17 (DO-Res) and $21 (DO-DO) more expensive/cow/yr than the AI based on detection of estrus.

Recent investigation shows that with the average result in more 40-45% pregnancies, ET has become a more attractive tool to improve reproductive efficiency in dairy industry. Ribeiro et al. (2012) compared the costs of five breeding programs for lactating dairy cows including ET from super ovulated (SOV) cows; in vitro produced embryos from oocytes collected by ovum pick up (IVP-OPU) or from oocytes of dairy cows obtained at slaughterhouses (IVP-S); timed AI; and timed AI combined with insemination after detection of estrus (timed AI + DE). The results indicated that when the five programs were evaluated for first breeding only, the costs per pregnancy were the lowest for timed AI + DE with conventional semen (72 US$ and 90 US$ for TAI and sexed AI), the highest for ET with sexed semen (235.6 US$ for conventional ET and 267.4 US$ for sexed ET) at all fertility levels evaluated, so when a pregnancy per AI is 35%, ET using SOV, IVP-OPU and IVP-S would have to achieve more than 65% fertility to generate a pregnancy of a similar value.

**ARB and ruminant industry for developing countries**

The early model of ONBS with AI and MOET for developing countries was proposed by Hodges in 1990 in a program organized by FAO. This system with 200 cows at nucleus herd and 500 ETs was calculated to get genetic change from 1.8 to 2 % per year (Fig.2).

The advantages of this system for the developing countries are their possibility to make them realize, with reasonable investment, that integration of smallholder farms is the most important component of livestock production in the region.

The system of genetic improvement for the Holstein Friesian cattle population in Uganda is an example of implementing adaptation of ONBS to realize under the condition of livestock consisting of mainly smallholder farms. The nucleus was organized on the base existed farms and consisted of two units: the central unit and the dispersed unit which consist of farmers with least twenty cows keeping in the fenced dairying production system for AI and
conducting contemporary testing of daughters of different bulls. ZPLAN computer simulator programme was used to model the breeding and evaluating annual monetary genetic gain (AMGG). System consists of a population of 100,000 animals of which 700 are in the nucleus, 10 YB or test bulls from which 4 proven bulls (PB) are selected for a restricted selection index to get AMGG of 1.00 Ugcp, R of 1.34 Ugcp and P of 1.26 Ugcp. Although all the genetic gain was achieved in the nucleus, genetic gain disseminated to the base population via PB and 95% of farmers in the base population with one or two cows, who do not invest in the programme, is being the major beneficiaries of improved genetics. (Nakimbugwe 2005)

The development of ONBS-MOET and IVP in Brazil is an example of ARB contribution as a critical success factor in the exploitation of the natural advantages for livestock and ruminant industry. With the livestock population sizes consisting 209.5 million of beef and dairy cattle, 9.09 million of goat and 14.18 million of sheep, Brazil has the largest commercial Zebu herd in the world; Brazilian semen market in 2013 was estimated in 13 million straws. In 1994, a joint program of progeny testing and a MOET nucleus scheme involving meat and milk traits as breeding goals was commenced. The development of this program is based on highly capacitated Artificial Insemination and Embryo Transfer Centrals and in vitro fertilization laboratories, which points to the need of around 15,000 genetic superior bulls/yr and 450,000 young replacement bulls/yr (Madalena et al. 2012).

One of breeding approaches which have widely practiced in tropical developing countries is the crossbreeding to exploit breed complementarily. Local indigenous breeds with adaptive attributes have been crossed with exotic breeds to increase rapid production of meat or milk. Example of successful hybrids are Girolando (Holstein/Gir) crossbreds in Brazil, Carora (Brown Swiss: zebu) in Venezuela, Siboney (Holstein: Brahman) in Cuba, Hope (Jersey: Sahiwal) in Jamaica (Madalena 2005). Ha-An, the dairy cattle breed in Vietnam (Figure 3) is an example of crossbreeding between local Yellow X Sindhi X Holstein resulted in high tropical adaptation and considerable upgrading in milk production (average of 4500 kg per year, individual 7000 kg per year).

Crossbreeding for dairying is a major tool in intensification of cattle production in developing countries. However, many crossbreeding operations have carried out spontaneously, without either long-term genetic-economic strategies or the implementation of necessary techniques for genetic evaluation. In order to remedy this situation the ONBS adapted for crossbreeding program was proposed (Philipsson et al. 2011). A nucleus herd (Figure 4) of selected animals of the pure indigenous breed is kept for continuous selection within the breed and for mating with an exotic breed to produce F1 males for distribution to village herds. Crossbred females in the village herds are bred to new F1 males from the nucleus herd to produce the next generation of females at farm level. Determining clearly the crossbreeding strategy, species or breeds selected and direction of genetic upgrading, method to maintain genetic variation, the rational rate of inbreeding and genetic gain are recommended as indispensable inputs for genetic and economic evaluations.

**CONCLUSION**

ARB with the capacity to control totally the reproductive performance has become the indispensable technical platform for ruminant industry. The reasonable combination of ARB and the genetic selection based on principle of ONBS-Blup or Genomic BLUP (GBLUP) is the fundamental prerequisite for achieving sustainable ruminant industry. Therefore, the successful implementation of ARB is not only calculated on the genetic output but also on economic efficiency of the investment. The level of ARB implementation should be based on the definition of important traits and results of accurate calculation of their economic values. There is a great demand for rapid establishment of ruminant industry in developing countries in the coming decades. Developing collaboration for training and formation in ARB and genetic management, exchange of animal genetic resources should be carried out to meet this challenge.

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Fig. 1. Annualized genetic gain and potential benefit of embryo techniques to genetic improvement programs. Data from Lohuis, 1995.

Fig. 2. Example of Open Nucleus Breeding System for dairy cattle. From Hodges, 1990.
Fig. 3. Ha-An cow and calf born after embryo transfer.

Fig. 4. Open nucleus herd breeding scheme—basis for conserving an indigenous breed and upgrading local population.