Animal Breeding Considerations for Improved Animal Performance in Hot Environments

J. W. Fuquay

Department of Animal and Dairy Sciences, Mississippi State University, Mississippi, 39762, USA

خلاصة : تتضمن الخيارات المتاحة لتحسين أداء الحيوان بتغيير المكون الوراثي ، والتحسين الوراثي للسلالات المحلية بواسطة الانتخاب والتحسين وتضريب الإناث المحلية بسائل منوي من ذكور عالمية متفوقة وذلك لتحقيق هدف ممكن لتطوير سلالة جديدة أو ادخال سلالات جديدة عن طريق نقل الأجنة من سلالات خارجية متميزة إلى أمهات محلية أو استيراد سلالات خارجية مرغوبة. لكل من هذه الخيارات محاسن ومساوئ. يمكن الحصول على أسرع مكاسب باستيراد سلالات خارجية ولكن هذا الخيار مكلف وفي بعض الأحيان محدد باعتبارات صحية كما أنه يمكن أن تكون هناك صعوبة في عملية الأقلمة. تعتبر الأنظمة التي تستخدم المؤثرات الأمومية للإناث المحلية ذات حسنات وذلك لما فيه مصلحة الأقلمة والبقاء. ولمراعاة هذه التأثيرات الأمومية بالإضافة إلى معدل التحسين واحتمال التحسين الواسع فإن كلا من برامج التهجين التي تستخدم السائل المنوي لذكور أجنبية متفوقة وتلك التي تتضمن نقل أجنة متفوقة من سلالات متفوقة له حسنات متميزة. ونسبة للتأثير السلبي على قوة دورة الشبق وبقاء الأجنة وبقاء المواليد فإن الاجهاد الحراري يؤثر على نوعية أسلوب الإدارة لأي خيار يقع الاختيار عليه للتحسين الوراثي ولكن هذا له تأثير أقل في البرامج التي تستخدم أناثاً محلية.

ABSTRACT: A variety of options are available for improved performance including altering genotype with genetic improvement of indigenous breeds through selective breeding; upgrading through crossbreeding of indigenous females with semen from genetically superior exotic males with a possible goal of developing a new breed; and introduction of new breeds through transfer of embryos from genetically superior exotic breeds into indigenous females or importation of exotic animals of the desired breeding. Each option has its advantages and disadvantages. The most rapid gains might be possible through importation of exotic breeds, but this is expensive, sometimes limited by health regulations, and adaptation to the new environment can be a problem. In the interest of adaptation and survival, systems that utilize the maternal influences of indigenous females are advantageous. In consideration of these maternal influences along with rate of improvement and potential for extensive improvement, both crossbreeding programs that use semen from genetically superior exotic males and those that involve transfer of genetically superior embryos from exotic breeds have their unique merits. Heat stress, because of its negative impact on intensity of oestrus, embryo survival and neonatal survival will affect management of any option chosen for genetic improvement but should be of less concern in programs that utilize indigenous females.

Before deciding on strategies to use in altering genotype to improve productivity of cattle in hot environments, goals and guidelines of the breeding program must be established. Choices range from upgrading indigenous breeds to introducing genes from exotic breeds through crossbreeding programs using frozen semen or introduction of exotic breeds by way of importation of cattle or frozen embryos. Programs for genetic improvement of milk production through artificial insemination in the U. S. have been based on use of additive genetic variation of nuclear origin with the selection of genetically superior parents resulting from use of Mendelian principles and statistical methods to accurately predict their breeding value (Schutz et al., 1994). This has resulted in significant genetic progress. However, recently researchers have reported that 2 to 5% of the variation in milk yield can be accounted for by cytoplasmic inheritance presumably from mitochondrial DNA (Bell et al., 1985; Schutz et al., 1992). Since all of the cytoplasm and the mitochondrial DNA in the zygote is of maternal origin (the oocyte), the maternal influence on the milk production potential of offspring is somewhat greater than the paternal influence that comes only from nuclear chromosomes in the fertilizing sperm. Although not proven, of perhaps more importance is the suggestion that mitochondrial DNA may play a role in disease resistance (O'Neill and Van Vleck, 1988; Schutz et al., 1994). A link between mitochondrial DNA and specific diseases has been reported in mice (Little, 1933; Mayer et al., 1980) and humans (Merrill and Harrington, 1985). Indirect evidence of maternal influence on resistance to disease is provided by the high death loss that sometimes occurs when exotic cattle are imported, whereas offspring from crosses of indigenous cows with semen from exotic bulls survive quite well (personal communication, S. M. Imtiaz Hussain; M. E. Boyd). The passive immunity that these offspring obtain from absorption of colostral immunoglobulins contributes to their better survival, but other factors of cytoplasmic origin may be involved as well.

Another factor that has bearing on the choice of methods to use in altering the genotype for improved performance in hot environments is the effect of heat stress on reproductive efficiency. In Bos taurus breeds, high ambient temperature has a negative effect on essentially all facets of reproduction including expression of oestrus, production of viable gametes, survival of embryos, and growth of the fetus. Although the most sensitive period is from oestrus to a few days thereafter, these negative effects are not limited to that period. Increased sensitivity to heat stress is concern when Bos taurus genes are introduced for the purpose of increasing genetic potential for high milk production.

This paper will evaluate alternatives for genetic improvement of cattle in hot climates and will describe how heat stress may affect the outcome of the methods chosen. It must be remembered that the effects of genetic improvement will not be realized unless management (nutritional, health, reproductive, environmental) is at a level that permits these animals to express their genetic potential.

Genetic Improvement of Indigenous Breeds

A plausible goal of the breeding program may be to upgrade the genetic potential of indigenous (native) breeds. A major advantage of this approach is that indigenous breeds should be well adapted to the environment with their productivity and well being affected only minimally by the environment. Disadvantages are that progress will be slow and, depending on the variation in the gene pool, may be limited.

For such a breeding program to be effective, it is essential that a production testing program be in place so that genetically superior parents (male and female) can be identified. Once identified, these animals could possibly be grouped into a breeder herd and utilized for semen and embryo production. Frozen semen and embryos from this source could then be used throughout the country to advance genetic progress. In addition to needing a good system for identifying genetically superior parentage, the success of such an animal improvement program is dependent upon, 1) adequate resources, to include buildings, equipment, and a readily available source of high quality water for media preparation, 2) a high level of technical expertise and, 3) good reproductive, nutritional, and health management of females to be used for insemination or as recipients in embryo transfer programs. The relevance and application of embryo transfer in developing countries has been discussed in recent papers (Boland and Gordon, 1989; McGuirk, 1989; Seidel and Seidel, 1989).

Use of multiple ovulation and embryo transfer is currently popular and has the advantage of both nuclear and cytoplasmic inheritance from genetically superior parents. However, because of numbers of offspring produced, its direct impact on the genetic improvement of a breed will be less than for artificial insemination. Through artificial insemination, a genetically superior bull can sire hundreds of thousands of offspring in a lifetime, while a cow of similar genetic merit that is superovulated to produce multiple embryos will, with present technology, likely produce fewer than 100 offspring. A template for an artificial insemination system using frozen semen from semen producing businesses is available in the United States. A recent estimate of annual gain for dairy herds in the U. S. that are using artificial insemination is 139 kg milk per cow per lactation (Powell, 1992). Whereas, superovulation of genetically superior females probably will not have a major direct impact on genetic progress in the entire population of animals, selected matings to produce bulls for use in artificial insemination can have a major effect.

Upgrading Through Crossbreeding

The breeding of indigenous females to production tested exotic males (e.g., Holsteins or Jerseys) of high genetic value via artificial insemination with imported semen appears to have considerable merit in harsh environments. This system would retain those maternal characteristics (cytoplasmic or other) that favour adaptation and survival of the offspring while introducing exotic genes that provide potential for higher productive efficiency. The ultimate goal of such a program might be to produce a synthetic breed that provides the optimum ratio of indigenous and exotic breeding to give the adaptability and productive efficiency that is desired. Achieving this goal would require a large number of animals managed in a well-planned breeding program and could take 10 or more years to achieve. Improvement would be more rapid than upgrading indigenous breeds.

The crossing of Bos indicus and Bos taurus cattle to produce new breeds with a desired combination of traits has met some success in the beef cattle industry with the Santa Gertrudis and Brangus breeds serving as two examples. However, a long-term study starting in the late 1940's in the southern United States that compared Red Sindhis or Brahmans crossed with Holsteins or Jerseys was abandoned after about 20 years. The conclusion was that dairy breeders in the southern U. S. would profit more from selection within the European breeds than from introducing Zebu genes for improved adaptation (Branton et al., 1966). They suggested that Zebu-European dairy breed crosses would likely be better justified in the more adverse tropical regions of the world.

Recent research by Cunningham (1989) would appear to support this conclusion. Using 46 data sets that were available from crossbreeding of local Bos indicus (from India and other countries) with improved Bos taurus dairy breeds (primarily Holstein or Jersey), Cunningham (1989) observed an almost linear improvement in age at first calving, first lactation milk production, and calving interval of cows with up to 50% Bos taurus with little change seen beyond 50% Bos taurus. Significant heterosis was seen in the F_1 crosses as they performed better than expected based on parental data. Heterosis was not seen in the F_2 generation. Cunningham concluded that there was a great deal to be gained from crossing Bos indicus and Bos taurus dairy breeds in tropical countries.

Less technical expertise is needed to establish an artificial insemination program using high quality frozen semen purchased from another country than is needed in the genetic improvement programs discussed in the previous section. Trained artificial insemination technicians are necessary and for high fertility, it is essential that good reproductive, nutritional, health and environmental management be practised.

Introduction of New Breeds

Introduction of exotic breeds of high genetic merit is a method that can potentially increase the milk producing capabilities of a country rapidly. Importation of cattle for this purpose has the advantages of knowing the sex of the animal and realization of almost immediate productivity after entry into the country. However, importation of cattle is not without its challenges. Initially, the purchase and transport of these animals will be an expensive venture and frequently limited by health regulations. If this obstacle is surmounted, the second challenge is survival in their new environment (Mahon and Rawle, 1987). The combination of transportation stress and a novel environment that includes new diseases, new and perhaps limited feeds, and harsh climatic stressors can result in significant death losses (personal communication, S. M. Imtiaz Hussain; M. E. Boyd). Even if survival rates are good, performance may be disappointing because of these stressors and a lack of understanding of the management that will be needed for them to produce near their genetic potential. In spite of these challenges, there are success stories and, under the right conditions, importation of cattle can be a viable option for increasing the genetic potential for milk production.

Importation of frozen embryos circumvents many of the problems associated with importation of live animals. Transportation cost is much lower. When one considers the genetics that can be purchased as frozen embryos, the total price is much more reasonable than purchase of live animals. Frozen embryos can be purchased from the top 10 to 15% of the population (Mahon and Rawle, 1987) while the donor cows that produced those embryos would likely not be available for purchase and, if available, would be expensive. Embryos that survive transfer into recipient cows that are adapted to the environment of the country will be affected less severely by that environment after birth than will imported animals. Although their cytoplasm will be that of the donor cow, at birth they will receive passive immunity from their recipient mothers through absorption of colostral immunoglobulins. This provides time for their own immune systems to develop in the proper environment. Another advantage of importation of frozen embryos is their safety with regard to transmission of diseases. Thibier and Nibart (1987) reported that after more than 1000 transfers, there was no transmission of disease even though the majority of embryos were from donors that likely were seropositive to bovine leukaemia virus and infectious bovine rhinotracheitis virus/infectious pustular vulvovaginitis virus.

Mahon and Rawle (1987) have described the criteria needed for successful transfer of frozen/thawed embryos in a developing country. Of primary concern is selection and management of recipients. Recipients should be healthy, reproductively sound females of high fertility that are on a good plane of nutrition. Failure to provide recipients that meet these criteria is a frequent shortcoming for countries not having an established embryo transfer program. These recipients should be at the proper stage of their cycle (day 6, 7 or 8) and have a well formed corpus luteum. It is equally important that the embryo be of high quality (grade 1 or 2). While skilled technicians are needed for transfer of embryos, with current technology the procedures are not much more involved than those for artificial insemination. Voelkel and Hu (1992) described a procedure using ethylene glycol as a cryoprotectant, with direct rehydration of the embryo in the holding media within the straw after thawing, that resulted in about 50% pregnancy rate after direct transfer of embryos to recipients. Although pregnancy rates from frozen/thawed embryos in developing countries sometimes approach the success rates from developed countries, Bos indicus recipients seem to have lower fertility than Bos taurus or Bos taurus-Bos indicus crosses (Mahon and Rawle, 1987). As with other systems, genetic improvement through importation of embryos must be accompanied by improved management to realize the potential gain that it provides.

The Impact of Heat Stress on Methods Chosen for Genetic Improvement

Heat stress has a negative impact on most factors important to reproductive success and genetic improvement in Bos taurus breeds. These include expression of oestrus, conception rate (which includes fertilization and embryonic survival), fetal growth and postnatal survival. The most dramatic effects are an expression of oestrus and embryonic survival.

INTENSITY OF OESTRUS: Reduced intensity and shorter periods of oestrus have been reported during heat stress (Gangwar et al., 1965; Her et al., 1988). In a study conducted at a research station in the Punjab Province of Pakistan, we synchronized a group of 36 dairy cows (half Jersey and half Holstein with half of each breed lactating) and observed them for oestrus at 6 h intervals from June 1 through October 31 (Imtiaz Hussain et al., 1992). All of these cows remained cyclic during that period as confirmed by blood progesterone patterns. During this 5-mo period, oestrus was detected in 35 to 40% of all cycles and was not affected by breed or lactation status. The greater heat tolerance of Jerseys compared to Holsteins as reported in the literature (Stott, 1961; Fuquay et al., 1980) and confirmed in this study by lower rectal temperatures (38.3 vs 38.5°C; $P<.01$) was not expressed in oestrual behaviour. Since accurate detection of oestrus is critical to successful use of either artificial insemination in breeding females or embryo transfer in recipient females, it has a marked limiting effect on use of these methods of genetic improvement when using Bos taurus cows during hot seasons. Cooling of lactating Bos taurus dairy cows during the summer has improved expression of oestrus (Her et al., 1988; Younas et al., 1993) and should be recommended when these programs for genetic improvement are conducted during hot seasons using these breeds. Bos indicus breeds likely would be affected less than Bos taurus breeds, which favours their use as the maternal line in genetic improvement programs.

CONCEPTION RATE: A number of research reports confirm the negative impact of heat stress on conception rate in Bos taurus dairy cows (Stott, 1961; Thatcher et al., 1974; Gwazdauskas et al., 1975). In most of these, the criteria used to measure conception rate did not permit relative comparison of its effects on fertilization as compared to embryo survival. Boland and Gordon (1989) reported some reduction in fertilization rate in superovulated Holstein cows in hot season as compared to cool season. However, most critical research suggests that heat stress has a greater effect on embryo quality (Boland and Gordon, 1989; Putney et al., 1989) and embryo survival (Alliston et al., 1965). Ulberg's laboratory has reported evidence that elevated core temperature from about the time of oestrus to a few days thereafter has a direct negative effect on embryonic survival (Ulberg and Burfening, 1967). Other factors are likely involved, as Ingraham (1976) observed a negative relationship between fertility and high temperature-humidity index starting 11 d before breeding in Holsteins.

In addition to elevated core temperature during heat stress, other factors identified by our laboratory that may negatively affect fertility are loss of body condition (Fuquay et al., 1993) and reduced luteal progesterone secretion (Howell et al., 1994). Recently, we have demonstrated that injection of GnRH (Factrel®, Ft. Dodge Lab., Inc., Fort Dodge, IA) at oestrus in lactating Holsteins followed by insemination 10 to 12 h later resulted in some improvement in first service conception rate (28.6 vs 17.7%) when compared to saline controls in a summer experiment (Ullah, 1994). The difference between these groups appeared to be higher embryonic survival in the GnRH injected cows. Of those cows that appeared pregnant on d 20 postbreeding as indicated by high serum progesterone, more ($P<.05$) of the saline controls were not confirmed pregnant by rectal palpation on d 50 than the GnRH treated cows. Injection of GnRH resulted in higher luteal progesterone secretion with no effect on rectal temperature. Therefore, the heat stress-induced suppression of luteal progesterone that we have observed may be sufficient to affect fertility. Fan cooling, in addition to lowering rectal temperatures and improving oestrual responses, can increase luteal progesterone secretion (Younas et al., 1993) and improve body condition (Fuquay et al., 1993), which provides potential for higher fertility. In our Pakistani study, Jerseys had lower rectal temperatures and higher luteal progesterone secretion than Holsteins during the summer (Imtiaz Hussain et al., 1992). This complements the research of Stott (1961) and Badinga et al. (1985) who reported higher fertility in Jerseys than Holsteins during the summer. Lactation is another factor to consider because of the high metabolic heat production associated with high feed intake and synthesis of milk (Fuquay et al., 1981). This could account for higher fertility in heifers than lactating cows in hot environments (Badinga et al., 1985).

From these data, we can suggest that if a decision is made to use an exotic rather than an indigenous breed as the maternal line for genetic improvement programs in hot environments, Jerseys would be a good choice. If there is a choice, nonlactating heifers would be favoured over lactating cows. Further, it seems evident that a cooling system for these cows would be essential. The most practical approach in the interest of reproductive efficiency would be to concentrate the breeding and embryo transfer programs into the cooler months of the year.

FETAL GROWTH AND POSTNATAL SURVIVAL: Heat stress after midgestation has resulted in retarded fetal growth in cattle (Collier et al., 1982) and sheep (Brown et al., 1977). In sheep, the problem can be severe, particularly for twin pregnancies (Dreiling et al., 1991). In cattle, the problem does not appear to affect neonatal survival and probably is not severe enough to require extraordinary management, although postpartum milk yield may be affected negatively by late gestation heat stress (Moore et al., 1992).

The effect of heat stress at time of parturition on neonatal survival is of concern. Stott et al. (1976) reported that Holstein calves subjected to severe heat stress immediately after birth in Arizona had higher mortality than similar calves placed in a cooled shelter. This higher death loss appeared to be due to reduced absorption of immunoglobulins from colostrum. In the interest of genetic improvement in hot environments, this is a concern. If one concentrates the insemination or the embryo transfer program into the cooler seasons of the year, there is good likelihood that some of the calvings will take place under heat stress conditions. This may not be a big problem when indigenous females are mated to exotic males. I am not aware of published data that addresses this question. However, if new breeds are being introduced through transfer of embryos from exotic breeds into indigenous cows, it is more concern because of the dependence of the resulting exotic calf, containing no indigenous cytoplasm, on passive immunity from maternal immunoglobulins found in colostrum. A primary factor affecting genetic improvement is generation interval. To that end, survival both in-utero and postnatally is essential.

Implications

Due to of problems associated with adaptation and survival when exotic breeds are introduced into a harsh novel environment, programs for genetic improvement that utilize the maternal influences of indigenous females are advantageous. In the interest of rate of improvement and potential for extensive improvement, both crossbreeding programs using semen from genetically superior exotic males on indigenous females and transfer of genetically superior embryos from exotic breeds into indigenous females have their unique merits. Heat stress, because of its negative effects on intensity of oestrus, embryo survival and neonatal survival, will affect the management of either crossbreeding or embryo transfer programs, but should be of less concern when these programs are used on indigenous as compared to exotic females. Finally, it must be remembered that improved genotypes only provide potential for higher performance. Management of the animals determines the expression of the improved genotype.

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