# TECHNOLOGY INNOVATIONS TO ENHANCE LIVESTOCK AGRIBUSINESS

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## ABSTRACT

*In vitro* embryo production (IVP) offers a way to build a sustainable and productive dairy cattle industry in tropicai areas. For about 100 years breeding efforts have centered on synthetic breed formation without success, but this 100 year effort reaffirms the superiority of the first cross of *Bos taurus* and *B. indicus* and generally, the inferiority of all crosses subsequent to the first. IVP permits the limiting life history characteristics of low reproductive rate and 1 : 1 sex ratio to be circumvented. There are no remaining technological barriers to implementation. Since *B. javanicus* has higher tropical adaptation than *B. indicus*, it is suggested that first crosses of this species with *B. taurus* be evaluated.

**Key word:** *In vitro* embryo production, *B. javanicus*, *B. indicus*, *B. taurus*, agribusiness

## ABSTRAK

### INOVASI TEKNOLOGI UNTUK MENINGKATKAN AGRIBISNIS HEWAN TERNAK

Produksi embrio secara *in vitro* menawarkan sebuah cara untuk membangun industri sapi perah yang produktif dan berkelanjutan pada daerah-daerah tropis. Selama hampir 100 tahun program pemuliaan ternak dipusatkan pada pembentukan bangsa "ternak komposit" dengan hasil yang tidak berarti, tetapi usaha 100 tahun ini meneguhkan superioritas dari silangan pertama *Bos taurus* dan *B. indicus*, serta secara umum membeberkan inferioritas semua silangan yang mengikuti silangan pertama. Produksi embrio secara *in vitro* (in vitro embryo production = IVP) telah dapat mengatasi permasalahan rendahnya laju reproduksi dan nisbah kelamin. Masa kini, tidak terdapat hambatan teknologi untuk bisa diterapkan. Karena *B. javanicus* memiliki adaptasi tropis yang lebih tinggi daripada *B. indicus*, disarankan bahwa hasil persilangan pertama dari spesies ini dengan *B. taurus* agar dievaluasi.

**Kata kunci:** Produksi embrio secara in vitro, *B. javanicus*, *B. indicus*, *B. taurus*, Agribisnis

## INTRODUCTION

Cattle are used by man as a foodstuff, a provider of draught power, a reserve of wealth as well as a number of minor uses such as fuel, pharmaceuticals, sport, maintenance of ecosystems, etc. There are about 1.5 billion cattle in the world, and cattle are usually reared in grass-based ecosystems. Substantial problems occur when cattle rearing is attempted in grass-poor regions, particularly the tropics. If meat or milk is the primary product of an agricultural enterprise then it is the females that are the primary production units, and production by these units centers on reproduction. Female productivity can vary by an order of magnitude depending upon genetics and environmental circumstances. Herein I will review life history characteristics of cattle and environmental circumstances that limit productivity and attempt to show how technological intervention can ameliorate effects of heredity and/or environment.

## GENETIC RESOURCES

Outside the tropics, the word "cattle" means member of the species *Bos taurus*; within the tropics the definition is expanded to include *B. indicus* and its crosses with *B. taurus*. (Most taxonomists ,e.g., GROVES (1981) do not grant separate species status to *B. indicus*, but it is a useful convenience that will be exploited here). Here in Southeast Asia, the center of origin of the genus Bos, "cattle" also refers to members of the species *B. javanicus*, but it is little known outside the region, and even within the region its particular adaptation is underutilized in my view. In the mountains of Central Asia, *B. mutus*, the yak, and its crosses with, mainly, *B. taurus* are "cattle". There are a few thousand domesticated *B. gaurus* occurring in hills and mountains surrounding the Brahmaputra river in Tibet, India and Bangladesh, and similarly there are bison (*B. bison*) kept for meat production in North America. *B, sauveli*, the kouprey, is probably extinct as there have been no reliable sightings reported for over 30 years. First crosses are possible with more or less ease between all member of the genus, but further crosses are either impossible (i.e., $F_1$ males are often infertile) or suffer from recombination load (RUTLEDGE, 2001). Thus our genetic resources are the various breeds in taurus and indicus, the domestic forms of yak, banteng and gaur, and whatever crosses biology permits.

These taxonomic groups differ widely in production ability and adaptation to environments. In the interest of time and space, I will consider only possibilities afforded by *Bos taurus, B. indicus* and B. *javanicus*, their crosses (within species) or hybrids (between species). Further, I will consider only production systems wherein milk production for human food is of primary importance. In temperate regions the optimal genetic choice is taurus either as purebred (chiefly Holstein) or increasingly crosses of Holstein with other Northern European dairy breeds. However, as we move towards the tropics, lack of adaptation forces crossing with indicus as classical genotype by environmental interactions exist making the purebred taurus unfit and populations of taurus unsustainable without continued recruitment of breeders from temperate regions. Exceptions occur where effects of tropical latitude can be overcome either by artificial cooling (Israel, Saudi Arabia or Arizona) or elevation (Kenya, Northern Vietnam or Columbia).

All cattle more or less share three life history characteristics that limit their usefulness in dairy production systems. First, the secondary sex ratio is 1:1. Second the litter size is small, normally one. And three, production commences at advanced age relative to many other farm animals with few production cycles. A joint consideration of these three reveals there is little reproductive excess in cattle populations. This lack of reproductive excess severely limits possible breeding structures in crosses or hybrids. It is our contention that technology can be employed to alter these life history characteristics leading to production efficiencies both at the level of the individual cow or at the level of the population. Many scenarios are possible and only a sampler of possibilities can be discussed.

## GENETIC CONCEPTS

There are three genetic phenomena that need consideration: Additive genetic merit which for our purposes is largely the breed average; heterosis which is the deviation of the crossbred from parental average, and complimentarity which is a property of crossing systems and favorable complementarity occurs when one parent furnishes either directly (or more often by transmission) superiority lacking in the other parent. The first two are nearly always measurable whereas the latter is not and is therefore neglected by quantitative geneticists. In the absence of epistasis or between locus interaction, Cunningham's Greek Temple Model graphically summarizes all relevant information on breed average and heterosis (CUNNINGHAM, 1987). There is in the animal breeding literature little indication that this model is inappropriate for crosses within species, however there is a vast amount of information on crosses between taurus and indicus indicating that the model is inappropriate for between species hybridization (REGE, 1998; RUTLEDGE, 2001).

It is convenient to imagine two traits dairy suitability and tropical adaptation recognizing that each has component traits. Generally taurus dairy breeds are superior in dairy suitability and inferior in tropical adaptation, the reverse is true for indicus. Since performance of the $F_1$ (cross or hybrid) is defined solely by parental breed average plus a little heterosis (usually favorable and always maximal in the $F_1$ ), opportunity for complementarity is apparent. Superiority of the $F_1$ has long been known (CUNNINGHAM and SYRSTAD, 1987)-as has the inferiority of further crosses (SYRSTAD, 1989). Meta analysis of data assembled by REGE (1998) by RUTLEDGE (2001) indicates that the inferiority stems from recombination load caused by breakup of coadapted gene complexes at meiosis.

## OPTIMAL BREEDING SCHEMES

The ideal situation would be a synthetic breed having many parental breeds in its founding so as to maximize retained heterosis. The parental breeds should be superior in dairy suitability or tropical adaptation so that the composite had superiority in both. But a the bulk of evidence is that this ideal in unattainable because of recombination load. Not that attempts haven't been made; that great student of tropical cattle J.P. Maule lists Grati (Indonesia), Jamaica Hope (Jamaica), Karan Swiss and Karan Fries (India), Pitanguerias (Brazil), Siboney (Cuba), Sunandini (India), Australian Milking Zebu and Australian Friesian Sahiwal (both Australia) as dairy breeds based on taurus X indicus crosses, but none has made much impact on tropical diary production.

Since a single breed is not possible it would seem that the next best alternative is to utilize $F_1$ crosses for dairying. Such animals experience no recombination load; they have half the superiority of the better parent in dairy suitability and tropical adaptation, both augmented by maximally obtainable heterosis. This system is practiced to a limited extent in South America, but at great expense because of the low reproductive excess of cattle and the (inescapable?) fact that half the calves born are male. I have elsewhere shown the calculations that a sustainable system relying on indicus cows and A.I. to taurus bulls would require some at least 1,500 indicus cows to provide 100 $F_1$ heifers annually (RUTLEDGE, 1998).

Crossbreeding has an advantage over breeding that is usually overlooked and is that it requires none of the infrastructure (MOET, progeny testing, sire evaluation, recording, large population size, etc.) required for breeding. In the scheme outlined no purebreds, except for a few bulls, need to be kept, rather female gametes are harvested as a byproduct of populations elsewhere.

## RELEVANT TECHNOLOGIES

Over 330 years ago (DE GRAFF, 1672) described the antral follicle. About 150 years later von Baer discovered that those follicles contained the mammalian ova (VON BAER, 1828). About 110 years later *in vitro* maturation of a mammalian oocytes was obtained (Pincus and Enzmann, 1935). Fifteen years later (WILLET *et al.*, 1951) successfully transferred a calf to a surrogate mother. And then just 37 years later a calf was born from an *in vitro* matured ovum, fertilized *in vitro* and cultured *in vitro* (SIRARD *et al.*, 1988). In just six more years Ian Gordon's *Laboratory Production of Cattle Embryos* (GORDON, 1994) appeared and it is now in its second edition. It has been a long process, but the crucial technology–*in vitro* embryo production-needed to break the dependence on *in vivo* embryo production is widely available and indeed often part of the curriculum of undergraduates in Animal Science. This core technology enables entirely new breeding systems that circumvent the problems of low reproductive excess and 50:50 sex ratio. The ideal $F_1$ embryo can be produced cheaply and in bulk. There are no technological barriers to continuous $F_1$ systems wherein each cow in the entire production system is an $F_1$ and each pregnancy is initiated by transfer of an $F_1$ female embryo. The technology has been available for over 15 years and it is ripe for exploitation.

## IMPLEMENTATION

The science and technology for a dairy industry in South East Asia based on taurus X indicus crosses exists in most countries. What is needed is someone to act as a leader in technology implementation. High quality taurus oocytes are available at abattoirs in New Zealand and Australia, and of course frozen semen is available anywhere. Sexing of embryos is not difficult.

## FUTURE RESEARCH

Indonesia has a unique bovine resource in the Bali cow. It is fully adapted to the tropics–more so than the zebu which evolved in temperate regions. Its reproductive rate is much greater than any other bovine, and recall that for meat and milk production, reproductive rate is very important. Banteng semen can be used to fertilize taurus eggs and blastocyst production is no different from usual protocol. It would be of great interest scientifically to evaluate the suitability of Bali cow X Holstein hybrids as milk producers here in Indonesia.

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