Pocket K No. 40

Biotechnology for the Livestock Industry

Meat and milk from farmed animals including livestock (cattle, goat and buffalo) and poultry are sources of high quality protein and essential amino acids, minerals, fats and fatty acids, readily available vitamins, small quantities of carbohydrates and other bioactive components.[1] The Food and Agriculture Organization (FAO) 2008 estimate shows that meat consumption has grown with increase in population. The average global per capita meat consumption is 42.1 kg/year with 82.9 kg/year in developed and 31.1 kg/year in developing countries in a recommended daily animal-sourced protein per capita of 50 kg per year[2]. Milk on the other hand is consumed in various forms: liquid, cheese, powder, and cream at a global per capita consumption of 108 kg per person per year which is way below the FAO recommended daily consumption of 200 kg.

Some poor countries may not be able to sustain these levels of meat and milk requirement, leading to malnutrition. Demand for meat and milk production is also expected to double in 2050 in developing countries, where population is expected to double. Thus, increasing production and the safe processing and marketing of meat and milk, and their products are big challenges for livestock producers.

Biotechnology is being harnessed in various aspects of the livestock industry to hasten breed development for improved animal health and welfare, enhanced reproduction, and improved nutritional quality and safety of animal-derived foods.

Reproductive Animal Biotechnology

Various biotechnology methods are used in improving the breeding stock of animals. These include artificial insemination (AI), embryo transfer (ET), in-vitro fertilization (IVF), somatic cell nuclear transfer, and the emerging technology on somatic cell nuclear transfer.

Artificial Insemination. One of the earliest perfected technology is artificial insemination (AI) where new breeds of animals are produced through the introduction of the male sperm from one superior male to the female reproductive tract without mating. AI reduces transmission of venereal disease, lessens the need of farms to maintain breeding males, facilitates more accurate recording of pedigrees, and minimizes the cost of introducing improved genetics.[3] Various technologies have evolved that led to the efficient use of AI in developing desired livestock, including the methods of freezing semen or cryopreservation and sperm sexing.

In-vitro Fertilization. In case other artificial reproductive techniques fail due to difficulties such as blocked reproductive systems, non-responsive ovaries in the females, marginal semen quality and quantity in the male, and presence of disease, in vitro fertilization (IVF) is used. The fertilization of the sperm and the egg is conducted in vitro (outside the animal’s body) at specific environmental and biochemical conditions. To date, successful IVFs have been conducted in various animal species due to advances in embryo production and cryopreservation of reproductive cells. Since the birth of the first rabbit conceived through IVF in 1959,[4] IVF offsprings have been born in mice, rats, hamsters, cats, guinea pig, squirrels, pigs, cows, monkeys, and humans.[5]

Embryo Transfer. Embryo transfer (ET) from one mother to a surrogate mother makes it possible to produce several livestock progenies from a superior female. Selected females are induced to superovulate hormonally and inseminated at an appropriate time relative to ovulation depending on the species and breed. Week-old embryos are flushed out of the donor's uterus, isolated, examined microscopically for number and quality, and inserted into the lining of the uterus of surrogate mothers.

ET increases reproductive rate of selected females, reduces disease transfer, and facilitates the development of rare and economically important genetic stocks as well as the production of several closely related and genetically similar individuals that are important in livestock breeding research. The International Embryo Transfer Society (IETS) estimated that a total of approximately 550,000 in vivo derived bovine embryos, 68,000 sheep embryos, 1,000 goat embryos were transferred worldwide in 2004.[6]

Somatic Cell Nuclear Transfer. Somatic cell nuclear transfer (NF) is a technique in which the nucleus (DNA) of a somatic cell is transferred into a female egg cell or oocyte in which the nucleus has been removed to generate a new individual, genetically identical to the somatic cell donor.[7] This technique was used to generate Dolly from a differentiated adult mammary epithelial cell which demonstrated that genes that are already inactivated in differentiated tissues can be completely reactivated.[3] NF technology creates possibility of generating clones from superior genotype and can be used to efficiently evaluate effects of genotype x environment interactions and testing or dissemination of transgenics. Problems on high rate of pregnancy loss, survival of newborn and increased incidence of abnormal development due to incorrect reprogramming of nuclear DNA (epigenetic inference) and unusual conditions during in-vitro processes make this a pre-commercial technology.

Genomics and Marker-Assisted Selection (MAS) Applications

The discovery and identification of DNA sequences or molecular markers associated with important animal traits has various applications that include trait improvement, heritability determination, and product traceability.

Molecular marker-assisted introgression (MAI). Markers are used to guide livestock breeders in selecting individuals expressing the introgressed gene. A series of backcrossing to the recipient parent is usually done in conventional breeding. With the use of molecular markers, the time and number of backcrossing cycles incurred in selection and identification of the desired individual are reduced. Today, molecular markers are being used in various livestock trait improvement activities such as growth, meat quality, wool quality, milk production and quality, and disease resistance.[8]

Parentage, product traceability and genotype verification. Molecular markers are reliable tools used by regulatory bodies to ensure product quality and food safety. Livestock parentage and its products can be identified and traced using molecular markers from farm to the abattoir, and from the cut up carcass to consumer's plate. A similar DNA-based technology has also been developed to detect the presence of around 211 bp fragments to facilitate testing of very small meat samples from the supermarket.[9]

Screening for undesirable genes. Genetic diseases and physical defects can be traced and documented in livestock animals using molecular markers.[9] The cause and origin of these problems can be easily traced to the genetic changes and DNA mutations as they manifest in the protein structure and function.[10] With DNA testing, animals carrying these defective genes are easily identified and are culled from the livestock breeding program.

The Future of DNA-based Technology in Livestock Improvement

Currently, complete genomic sequencies of important farm animals such as that of chicken[11] and bovine[12] have been released, and genomic sequences of pig, goat, and sheep are now in progress. With advances in sequencing farm animal genome, the continuing progress in molecular marker technology, and the use of reproductive biotechnology, windows of research opportunities will be opened to improve and revolutionize the livestock industry. In the future, it will be possible to obtain information on the genetic constitution of the animals that will allow a prediction of the production potential of an animal at birth, or perhaps even as a fetus, as well as the selection of animals best suited to a specific production environment.

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