EMERGING TRENDS IN ANIMAL REPRODUCTIVE TECHNOLOGY – A REVIEW

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Abstract

Technological advancement in animal reproduction is germane to improved animal productivity. The adoption of these advancements has heightened the supply of meat, milk and other animal products in developed countries. This review presents some improvements such as Artificial insemination, Computer assisted semen analysis, semen sexing and embryo transfer which has advanced animal productivity in the past years but are yet to be fully optimized in developing countries for various reasons. Factors ranging from lack of expertise to high cost of importing technology, unfriendly government policies and inadequate partnership between public and private entities among others were highlighted to hinder their adoption hence, the low output from livestock production in developing countries. Other technologies such as cloning, transgenesis and stem cells are yet to be restricted by ethics, high cost and low success rates and call for further research. It is thus highly essential for the specialist in Technical and Vocational Education and Training to research into domesticating some of these technologies for developing countries.

Keywords: Artificial insemination, Reproductive technology, Animal reproduction, Semen sexing, Embryo transfer

Introduction

The rate at which technological advancement is impacting all aspects of human endeavor which includes animal production is highly remarkable. The continuous increase in human population and awareness for sustainable healthy living has placed a huge demand on the supply of meat, milk, and other animal products. This has also resulted in scientist developing a more efficient and usage of improved techniques in animal production and reproduction.

Reproductive technology encompasses all current and anticipated uses of technology in human and animal reproduction, including Assisted Reproductive Technology (ARTs) among others (Mapletoft and Hasler, 2005). ARTs were developed during application to the target species, such as splitting embryos in cattle and intracytoplasmic sperm injection in humans. Clearly, managing reproduction is central to animal agriculture; for instance, ratios such as 10:3:1 for emphasis on reproduction: growth: carcass characteristics are frequently recommended to optimize profitability of beef cattle (Seidel, 2015). Research into physiology and embryology has provided a basis for the development of technologies that increase productivity of farm animals through enhanced control of reproductive function (Sejian *et al*., 2010).

Assisted reproductive technologies may also entail the relocation of the products of gamete fusion to a female, for example, if fertilisation has taken place *in vitro* or in another female. Other techniques encompassed by Assisted Reproduction Technologies include: intra cytoplasmic spermatozoa injection (where a single spermatozoon is caught and injected into an ovum); *in vitro* fertilization (where fertilization takes place outside the body); gamete intra fallopian transfer (where spermatozoa are injected into the oviduct to be close to the site of fertilization *in vivo*); embryo transfer (where embryos that have been derived either *in vivo* or *in vitro* are transferred to a recipient female to establish a pregnancy) and cryopreservation (where spermatozoa, ova or embryos are stored in liquid nitrogen) (Morrell, 2011).

Some of the various developments in the field of animal reproduction are discussed in this review

Artificial insemination

Artificial insemination (AI) is the manual placement of semen in the reproductive tract of the female by a method other than natural mating. It is one of a group of technologies commonly known as "assisted reproduction technologies" (ART), whereby offspring are generated by facilitating the meeting of gametes: spermatozoa and oocytes (Morrell, 2011).
Artificial insemination (AI) is by far the most important and dominant of the ARTs for cattle and some other species. For example, best estimates are that over 130,000,000 cattle are inseminated artificially each year worldwide (Vishwanath 2003). Furthermore, AI is used synergistically with other ARTs, such as embryo transfer and sexed semen.

Artificial insemination is considered the first reproductive biotechnology, created with the major intention of controlling the dissemination of venereal diseases. AI is still the main vehicle for rapid dispersal of desirable genes and has been the method of choice for the farmers around the world to improve the genetic potentiality of their livestock (Vishwanath, 2003). Artificial insemination has been in use with various familial species which include bees and human beings. It is the most frequently used among artificial reproductive technologies in farm animals, modernising the animal breeding industry during the 20th century contrary to medical use, where intra-uterine insemination is used only occasionally in human fertility treatment. Artificial insemination is undoubtedly the most frequent technique of domestic animals breeding as typified in reproduction of dairy cattle (about 80 % in North America and Europe), turkeys (approximately 100 % in intensive rearing) and swine production (over 90 % in North America and Europe). Artificial insemination is increasingly used in sheep, beef cattle, horses as well as poultry and has been adopted for other domestic species such as buffalo, deer, goats and dogs. It has also been used sporadically in breeding and preservation of endangered or rare species (Morrell, 2011).

Artificial insemination revolutionized animal breeding in the 20th century, particularly in combination with sperm cryopreservation. The AI industry has developed dramatically in most domestic species in the last few decades and its use is now widespread in intensive animal production. The development of other associated technologies, such as sperm selection and sex selection, are predicted to create powerful tools for the future, both for domestic livestock breeding and for the purposes of conservation (Morrell, 2011). The following are the associated benefits that has been associated to AI**:**

1. It helps prevents the spread of infectious or contagious diseases, that can be passed on when animals are in close contact or share the same environment.
2. The rate of genetic development and production gain can be increased, by using semen from males of high genetic merit for superior females.
3. It enables breeding between animals in different geographic locations, or at different times (even after the male´s death.
4. Breeding can occur in the event of physical, physiological or behavioural abnormalities.
5. AI is a powerful tool when linked to other reproductive biotechnologies such as sperm cryopreservation, sperm sexing.
6. AI can be used in conservation of rare breeds or endangered species.

Computer Assisted Sperm Analysis

In previous times, assessment of sperm quality has been based on subjective evaluation of parameters, such as mass and individual motility, and on objective parameters, such as semen concentration and morphology abnormalities (Verstegen, 2002). When subjective optical microscopic evaluation was used in humans and animals, variations of 30 to 60% have been reported in the estimation of the motility parameters of the same ejaculates (Coetzee *et al.*, 1999). To overcome this variability, different systems have been proposed such as turbidimetry (Donnelly *et al.*, 1998), laser-Doppler spectroscopy (Budworth *et al.*, 1987), and photometric methods (Burkman, 1991). However, these systems allow for a crude estimation of the whole population, combining total semen concentration and motility, without taking into account the evaluation of the individual spermatozoon. Other accurate techniques, such as flow cytometry (Aitken *et al.*, 1992), which allows the evaluation of concentration, and cellulose-acetate/nitrate filter (England and Allen, 1990) measure only a single semen parameter. However, an overall objective evaluation of the semen is still difficult to obtain, and semen analysis remains incomplete.

Computer-assisted sperm analysis (CASA) which was first proposed by Dott and Foster (1979) is often used interchangeably in the literature with "computer-aided sperm analysis". Computer-assisted sperm analysis refers to an automatic system, designed to provide the accurate, precise and meaningful information about sperm concentration, viability, dynamics or morphology, and to perform the statistical analysis of sperm population, based on the development of the continuous images of spermatozoa, digital processing and information analysis with the aids of video camera, video capture card and computer. The early and current CASA systems still require the intervention of operators, but the ideal CASA system only needs the operator to maintain the normal function of the system, place the semen sample on the apparatus and start the process of analysis, and analyse the output data (Amann & Katz, 2004).

Computer-assisted sperm analysis (CASA) systems have evolved over approximately 40 years, through advances in devices to capture the image from a microscope, huge increases in computational power concurrent with amazing reduction in size of computers, new computer languages, and updated/expanded software algorithms. Remarkably, basic concepts for identifying sperm and their motion patterns are little changed. Older and slower systems remain in use. Most major spermatology laboratories and semen processing facilities have a CASA system, but the extent of reliance thereon ranges widely (Amann & Waberski 2014). According to Amann & Waberski (2014), accuracy and sensitivity of each output measure is determined by the system's proprietary software, but each output value for sperm motion or concentration reflects the sperm-suspending medium, sample chamber depth, hardware, and instrument settings.

CASA systems:

1. project successive images of a sperm suspension onto a detector array.
2. detect objects based on intensity of pixels in a frame or light scatter.
3. use special software to extract desired information and produce the desired output.

CASA cannot accurately predict 'fertility' that will be obtained with a semen sample or subject. However, when carefully validated, current CASA systems provide information important for quality assurance of semen planned for marketing, and for the understanding of the diversity of sperm responses to changes in the microenvironment in research (Amann & Waberski 2014).

Sperm Sexing

The demand for sexed semen has been increased dramatically from the last decade. Of all the several attempts and approaches to spermatozoa sexing, the only method that has shown any promise is the method of sorting using DNA content by means of flow cytometry (Seijian *et al*., 2010). This technology is used for producing offspring of the desired sex, either male or female. Selecting the sex of the progeny using sex-sorted sperm has been an advantage for animal breeders (Johnson, 2000; Seidel, 2015). The principle of flow cytometric separates the fluorescent-labeled X-chromosome bearing spermatozoa from the sperms carrying fluorescent- labeled Y-chromosome. Sperm cells of interest are sorted with the speed of 15 million spermatozoa per hour (Garner, 2006) and accuracy of predicting the sex of calves is between 85% and 95% accurate (Garner, 2001). A minimum of 4 million spermatozoa represents the optimal compromise pregnancy in Mediterranean buffaloes, compared with conventional technologies of insemination together with oestrus synchronization (Gaviraghi *et al*., 2013). One of the special applications of sexed semen is for *in vitro* fertilization (IVF) by decreasing the cost and logistics of embryo transfer (ET) (Seidel, 2007).

Recent development in sperm sexing include the use of two or more nozzles in the configuration of sperm sorter instead of one, which will speed up the sperm sexing process and decrease cost of production. Insemination in lactating Jersey cows near ovulation yielded higher pregnancy rates (Bombardelli *et al*., 2016). An increase in the pregnancy rate was observed through AI by using sexed semen in heifers of buffalo when compared with conventional semen (Campanile *et al*., 2011). Conception rate can be further increased if the sexed semen is deposited near the junction of uterus and oviduct by using a special catheter (Mohammed, 2018). The pregnancy rate was non-significant in heifers and in buffalo that has parturated at least once and cows after using sexed semen (Lu *et al*., 2015). Half dose of sexed semen gave 94% more results compared with non-sexed semen in lactating dairy cattle (Xu, 2014).

Semen sexing can be used for enhancing progeny testing program, increase breeding male production, reduce the incidence of sex-linked diseases and conservation of superior and rare animals. One of the main limitations of this technique is the low number of sexed sperm produced per unit of time, and sexed sperm display a variety of damages, such as destabilization of sperm membrane and capacitation-like changes thereby reducing lifespan of sorted spermatozoa in the female genital tract (Gosálvez *et al.*, 2011). However, new generation flow cytometer with high sorting rates have opened avenues for increasing sorted sperm output with minimal or no damage to sperm (Choudhary *et al.*, 2016).

Embryo Transfer

Embryo Transfer (ET**)** is an important tool to improve livestock at faster rate as well as provides an opportunity to utilize the genetic contribution of both male and female (Mapletoft, 2013; Hasler, 2014). ET involves superovulation, an important step for increasing the number of oocyte from superior donors (Mapletoft, 1985). The transfer of mammalian embryos was first achieved by Walter Heape in 1890. Subsequently, progress in embryo transfer has been reported in various domestic species (Drost, 2007). The birth of the first calf through embryo transfer was achieved by Betteridge (2006). Although superovulation in buffalo started three decades ago (Drost *et al.,* 1976), the first live calves from bubaline embryos were born in 1983 in the USA and later in India (Purohit *et al.,* 2003). Several protocols for superovulation of cattle and buffaloes, i.e. the concept of multiple ovulation and embryo transfer (MOET) were established in 1987 (Smith, 2001). MOET is now well developed and commercially used across the world. According to the 2016 statistics for embryo collection and transfer in domestic animals by the International Embryo Transfer Society, the contribution of North America, Europe and Asia to the global embryo production was 52, 20 and 17%, respectively, while the percentages of global embryos transferred in North America, Europe and Asia were 52, 22 and 14%, respectively. The average number of ET calves produced from donors has increased from 1 to more than 10 per year (Bousquet and Blondin, 2004).

According to Mapletoft (2013), More than 750 000 embryos, on average, are being produced from superovulated animals. It was evident that MOET programs could result in increased selection intensity and reduced generation intervals, resulting in increased genetic gain. For ET, synchronization of donor and recipient is a prerequisite for proper embryo recovery, ET and recognition of embryo in recipient cattle (Rodriguez-Martinez, 2012). Superovulation is carried out in donors using hormonal preparations (Mapletoft, 2013), mainly follicle stimulating hormones purified from porcine pituitaries (FSH-P) or pregnant mare's serum gonadotrophin (PMSG). The response of PMSG was more but had adverse effect on the embryo recovery hence FSH preparations were preferred. On superovulation, there is increased in follicles and release of numerous ova from multiple follicles and hence double insemination with semen from superior bull is to be carried out. This is followed by flushing of embryos on day 6/7 in cattle and on day 5/6 in buffalo. Two methods have been followed, i.e., surgical and non-surgical. Surgical flushing results in increased number of embryos as compared to non-surgical but the former is more time and labor consuming and usually done in small ruminants (Drost *et al.,* 1976).

For non-surgical flushing, Foley's or Rusch catheter is used and suitable flushing medium is flushed in and out of the uterus to harvest the embryos at appropriate time post-estrus. Once the embryos are recovered, they are evaluated for features such as compactness, degree of degeneration, and suitability for transfer to the recipients programed along with the donors or else can be cryopreserved for future transfer. The conception rate following embryo transfer in cattle and buffaloes is around 35-45%, and the main limiting factor for the ETT is that this technique involves costly hormones, labor intensive protocols and expertise in addition to the poor super ovulatory response and pregnancy outcomes, especially in buffaloes.

Other recent technologies such as Cloning (process of creating identical copies of organism by asexual means), transgenesis (process of introducing an exogenous gene of interest into the genome of living organism) and stem cells (The undifferentiated cells having capability to produce unlimited cells of similar nature by differentiation leading to the birth of multicellular organisms) are advanced technologies. These techniques are greatly limited for several reasons such as ethics, high cost and low success rates and demand further research (Binyameen *et al.*, 2019).

Conclusion

Adoption of modern techniques in reproductive technology for improved animal production is inevitable. Most of the reproductive techniques discussed above and many more could be described as becoming stale in many developed countries. However, for various reasons, they are yet to be averagely optimized for livestock improvement by developing countries. Various factors ranging from lack of expertise to high cost of importing technology, unfriendly government policies and inadequate partnership between public and private entities among others reasons which vary in different locations are underlining factors which have grossly limited their adoption hence, the low output from livestock production in developing countries. It is thus highly essential if the specialist in Technical and Vocational Education and Training can research into domesticating some of these technologies to solve a global problem being certain of available market to adopt new innovations to allow livestock production meet up with the demand pressure fostered by increasing human population.

References

Aitken R. J, Buckingham D, West K, Wu F. C, Zikopoulos K, Richardson D. W. (1992). On the contribution of leucocytes and spermatozoa to the high levels of reactive oxygen species recorded in the ejaculated of oligozoospermic patient *Journal of Reproductive Fertility* 94:45 l-462.

Amann R. P, Katz D. F (2004) Reflections on CASA after 25 years. *Journal of Andrology* 25:317–325

Amann, R. P., & Waberski, D. (2014). Computer-assisted sperm analysis (CASA): Capabilities and potential developments. *Theriogenology, 81(1), 5–17.e3.* doi:10.1016/j.theriogenology.2013.09.004

Betteridge, K.J. (2006) Farm animal embryo technologies: Achievements and perspectives. *Theriogenology*, 65: 905-913.

Binyameen M., M. Saleem and A. Riaz (2019). Recent trends in bovine reproductive biotechnologies. Retrieved 20 September 2020 from: http://www.cabi.org/cabreviews. doi: 10.1079/PAVSNNR201914052

Bombardelli G. D, Soares H. F, Chebel R. C. (2016). Time of insemination relative to reaching activity threshold is associated with pregnancy risk when using sex-sorted semen for lactating Jersey cows. *Theriogenology* 85(3):533–9.

Bousquet D, Blondin P. (2004). Potential uses of cloning in breeding schemes: dairy cattle. *Cloning & Stem Cells* 6(2):190–7.

Budworth P. R, Ammann R. P, Hamerstedt R. H. (1987). A miucrocomputer-photographic method for evaluation of motility and velocity in bull sperm. *Journal of Dairy Science* 70:1927-1936.

Burkman L. J. (1991). Discrimination between non hyperactivated and classical hyperactivity motility patterns in human spermatozoa using computarezed image analysis. *Fertility Sterile* 55:363-371.

Campanile G, Gasparrini B, Vecchio D, Neglia G, Senatore E, Bella A, (2011). Pregnancy rates following AI with sexed semen in Mediterranean Italian buffalo heifers (Bubalus bubalis). *Theriogenology* 76(3):500–6.

Choudhary K. K, Kavya K. M, Jerome A, Sharma R. K (2016). Advances in reproductive biotechnologies, *Veterinary World, 9*(4): 388-395.

Coetzee K, Kruger T. F, Lombard C. J. (1999). Repeatability and variance analysis on multiple computer-assisted (IVOS) sperm morphology readings. *Andrologia* 3(1): 163- 168.

Donnelly E. T, Lewis S. E, McNally J. A, Thompson W. (1998). *In vitro* fertilization and pregnancy rates: The influence of sperm motility and morphology on IVF outcome. *Fertily Sterile* 70:305-314.

Dott H. M, Foster G. C (1979). The estimation of sperm motility in semen, on a membrane slide, by measuring the area change frequency with an image analyzing computer. *Journal of Reproductive Fertility* 55:161-166.

Drost, M. (2007) Advanced reproductive technology in the water buffalo. *Theriogenology*, 68: 450-453.

Drost, M., Brand, A. and Aarts, M.H. (1976) A device for nonsurgical recovery of bovine embryos. *Theriogenology*, 6(5): 503-508.

England G. C. W, Allen W. E. (1990). Evaluation of cellulose acetate/nitrate filters for measuring the motility of dog spermatozoa. *Journal of Reproductive Fertility* 88:369-374.

Garner D. L. (2006). Flow cytometric sexing of mammalian sperm. *Theriogenology* 65(5):943–57.

Garner, D. L. (2001) Sex-sorting mammalian sperm: Concept to application in animals. *Journal of Andrology*., 22(4): 519-526.

Gaviraghi A, Puglisi R, Balduzzi D, Severgnini A, Bornaghi V, Bongioni G, (2013). Minimum number of spermatozoa per dose in Mediterranean Italian buffalo (Bubalus bubalis) using sexed frozen semen and conventional artificial insemination. *Theriogenology* 79(8):1171–6.

Gosálvez, J., López-Fernández, C., Fernández, J. L., Gouraud, A. and Holt, W. V. (2011) Relationships between the dynamics of iatrogenic DNA damage and genomic design in mammalian spermatozoa from eleven species. *Molecular Reproductive Development*, 78: 951-961.

Hasler, J.F. (2014) Forty years of embryo transfer in cattle: A review focusing on the journal. Theriogenology, the growth of the industry in North America, and personal reminisces. *Theriogenology*, 81: 152-169.

Johnson, L. A. (2000) Sexing mammalian sperm for production of offspring: The state-of-the-art. *Animal Reproduction Science*, 60-61: 93-107.

Lu Y, Liao Y, Zhang M, Yang B, Liang X, Yang X, (2015). A field study on artificial insemination of swamp and crossbred buffaloes with sexed semen from river buffaloes. *Theriogenology* 84(6):862–7.

Lu, J. C., Huang, Y. F., & Lü, N. Q. (2013). Computer-aided sperm analysis: past, present and future. *Andrologia, 46(4), 329–338.* doi:10.1111/and.12093

Mapletoft R. (2013). History and perspectives on bovine embryo transfer. *Animal Reproduction* 10(3):168–73.

Mapletoft, R.J. (1985) Embryo transfer in the cow: General procedures. *Rev. Sci. Tech. Off. Int. Epiz.*, 4(4): 843-858.

Mapletoft, R.J. (2013) History and perspectives on bovine embryo transfer. *Animal Reproduction*, 10(3): 168-173.

Mohammed K. M. (2018). Application of advanced reproductive biotechnologies for buffalo improvement with focusing on Egyptian buffaloes. *Asian Pacific Journal of Reproduction* 7(5):193.

Morrell, M. J. (2011). Artificial Insemination: Current and Future Trends. Artificial Insemination in Farm Animals. doi:10.5772/17943

Purohit, G. N., Duggal, G.P., Dadarwal, D., Kumar, D., Yadav, R.C. and Vyas, S. (2003) reproductive biotechnologies for improvement of buffalo: The current status. *Asian Australian Journal of Animal Science*, 16(7): 1071-1086.

Rodriguez-Martinez H. (2012). Assisted reproductive techniques for cattle breeding in developing countries: a critical appraisal of their value and limitations. *Reproduction in Domestic Animals* 47:21–6.

Seidel Jr G. (2007). Overview of sexing sperm. *Theriogenology* 68(3):443–6.

Seidel, G. E. (2015). Lessons from Reproductive Technology Research. *Annual Review of Animal Biosciences, 3(1), 467–487.* doi:10.1146/annurev-animal-031412-103709

Seidel, G. E. Jr. (2014) Update on sexed semen technology in cattle. *Animal*, 8(1): 160-164.

Seijian V. Meenambigai T. V. Chandirasegaran M. and Naqvi S. M. K. (2010). Reproductive Technology in Farm Animals: New Facet and Findings: A review. *Journal of Biological Sciences* 10(7): 686-700

Smith, A.K. (2001) Retrospective study of the effect of superovulation on subsequent fertility in embryo-transfer donors. *Vet. Rec.*, 148(4): 114-116.

Verstegen, J., Iguer-Ouada, M. and Onclin, K. (2002). Computer assisted semen analyzers in andrology research and veterinary practice. *Theriogenology, 57(1), 149–179.* doi:10.1016/s0093-691X(01)00664-1

Vishwanath, R. (2003). Artificial insemination: the state of the art. *Theriogenology*. 59, 571-584

Xu Z. (2014). Application of liquid semen technology improves conception rate of sex-sorted semen in lactating dairy cows. *Journal of Dairy Science* 97(11):7298–304.