

Conference Paper

The Reproduction Performance in Domestic Animals Controlled by Genetic Mechanism: A Review

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ORCID<https://orcid.org/0000-0002-9165-8873>**Abstract.**

Reproduction in domestic animal is a very complex process. The process starts from gamete formation, release, gamete transport, fertilization, embryo and fetal development until delivery of the offspring by the dam. Reproduction holds the most important role in determining the success of livestock farming, profit or loss. The genetic selection of the reproductive traits became an important program to find out the merit candidate dam and bulls. At early time, the selection for reproduction traits was based on the visually phenotypic performance, and this is maintained for long time until present time. In the next phase, the values of heritability for reproduction traits was chosen as a basis of selection. The molecular aspect used for reproductive mechanism and expression was noted beginning in the 2000s using Polymerase Chain Reaction – Restricted Fragment Length Polymorphism (PCR-RFLP) and Single Nucleotide Polymorphism (SNP). The newest technique is to explore not only the role of DNA in the programming the reproductive mechanism, but the the expression of gen (nucleic DNA) at the Ribonucleic Acid (RNA) at the outside level of the cell nucleus.

Keywords: genetic factor, genetic material, SNP, reproduction process

1. Introduction

Reproduction in the most important factor determining the success of the breeding program, and even the livestock farming company or farmer. Reproduction ensures the maintain of existing of species, by generating the genetic material to the next generation, and future generation, called as offspring. Reproduction allows increasing the population size in the livestock breeding and farming. Reproduction success can improve the genetic variability, genetic value and perform a new breed or new strain by structured and controlled breeding program of livestock company. Reproduction in combination with breeding program could maintain the pure breed of species or line, or in the other hand, could be creating new breed and new strains. And, int the livestock farming company, reproduction plays beneficial role determining efficient of wasteful,

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profit or lost, sustainable or collapse. Easily could be said, that in the total livestock breeding and farming program and company the success of reproduction determines whether the breeding and farming program of the farm is profitable and sustainable or not [1,2].

Reproduction involves the complex mechanism in the body for both male and female animal, although the study in female is more huge number providing more available data than in male animal. This is because in the female involving more complex steps, cycle, and mechanism than in the male animal. The ovarian cycle, the estrous cycle and the reproductive cycle are the facts of the complexity in female than in male. However, principally the reproductive process both in the male and female is controlled by the same or at least similar mechanism involving the work and action of reproductive hormones.

The influence of hormones is then expressed in the reproductive or sexual behavior [3], and phenotypic reproductive performances such as the first calving or kidding [4], service per conception, days open, calving interval or kidding interval, fertility index and reproduction index [5,6,7]. In male, the influence of hormone is expressed for sexual behavior and semen production, scrotal circumference and semen production [8].

The reproductive hormone that regulates the reproduction process consists protein hormone, peptide hormone, amino acid hormone, and steroid hormone. Only protein or peptide hormone are regulated by the DNA codon in their action, but not for steroid hormone. However, reproduction in a complex series of all reproductive hormone, and therefore the all reproductive hormone should act and work together and simultaneously.

2. Hormonal Mechanism in Controlling Reproductive Activity

Reproduction activity in domestic animals is mainly controlled by the hormone works, although some others are by environment and management. The main axis of reproductive hormones hypothalamic-hypophyseal-gonadal is believed as the central dogma in the regulating and controlling the reproduction cycle in the male and female. Once the puberty is occurred, the continuous cycle in the ovary and testis is working along the reproductive life. The primary reproductive hormone involves the peptide hormones secreted by hypothalamus, anterior hypophysis, and other in ovary (like inhibin), and the other hormones are steroid hormones secreted in the gonad, estrogen-progesterone-androgen. The large molecule – peptide hormones are only regulated and controlled

their synthesis and secretion by DNA codon in the nucleus cell, while the other steroid hormones work as in a serial effect or cascade from the other influence hormones. The model of ovarian control, and follicle recruitment, selection and development has been proposed by several authors [9,10]. Although some models have been proposed, all authors considered and agreed that the ovarian activity is the central of all the reproduction mechanism in domestic animal [11]. The ovarian cycle is central to reproductive function. It is characterized by repeating patterns of cellular proliferation, differentiation and transformation that encompass follicular development and ovulation as well as the formation, function and regression of the CL. In the first part, the importance and regulation of final follicle growth and especially of angiogenesis and blood flow during folliculogenesis, dominant follicle development and CL formation. The reproduction expression is also influenced by some external factors like nutrition and environmental stress [12].

Ovarian hormones play a central role in successful reproduction in the female animal and they principally act by their feedback effects in the hypothalamo-hypophyseal-ovarian axis to coordinate various events in reproduction. The ovary produces both steroid and nonsteroid hormones and other substances. The steroid hormones have important role in expression of estrus, feedback control of gonadotrophin secretion, follicular development and ovulation. Estrogen mainly has positive feedback during follicular phase and in causing preovulatory gonadotrophin surge and progesterone mainly a negative feedback on LH secretion during the luteal phase. The peptide hormones, especially the inhibins, along with estrogens play a significant role in control of follicular development through regulation of FSH secretion. An understanding of their role and mechanism of action, types and expression of their receptors in various target organs has facilitated use of these hormones, their analogues, antagonists in control and manipulation of events during oestrous cycle-the estrus, follicular development, gonadotrophin secretion and ovulation [13].

The reproduction process in male takes the similar mechanism as in the female. The process of testicular development that leads to initiation of spermatogenesis in bulls involves complex maturation mechanisms of the hypothalamus-pituitary-testes axis. Sexual development can be divided into three periods according to changes in gonadotropins and testosterone concentrations, namely the infantile, prepubertal, and pubertal periods. The infantile period is characterized by low gonadotropin and testosterone secretion and relatively few changes in testicular cellular composition. The prepubertal period is characterized by a temporary increase in gonadotropin secretion, the so called early gonadotropin rise. The pubertal period is characterized by reduced

gonadotropin secretion, increased testosterone secretion, initiation of spermatogenesis, and the eventual appearance of sperm in the ejaculate. The rapid testicular growth observed after 6 months of age in bulls occurs when circulating gonadotropin concentrations are decreasing, which points to the existence of important gonadotropin releasing hormone (GnRH) independent mechanisms regulating testicular development [14].

Formation of spermatozoa starts near the basement membrane when a spermatogonium divides to form other spermatogonia and ultimately primary spermatocytes. The primary spermatocytes are moved from the basal compartment, through the junctional complexes between adjacent Sertoli cells, into the adluminal compartment, where they eventually divide to form secondary spermatocytes (not shown) and spherical spermatids. The spermatogonia, primary spermatocytes, secondary spermatocytes, and spherical spermatids all develop in the space between two or more Sertoli cells and are in contact with them. During elongation of the spermatid nucleus, the spermatids are repositioned by the Sertoli cells to become embedded within long pockets in the cytoplasm of an individual Sertoli cell. When released as a spermatozoon, a major portion of the cytoplasm of each spermatid remains as a residual body within a pocket of the Sertoli cell cytoplasm [15].

There are inter-relationships among hormone production in the Leydig cells and seminiferous tubules and the feedback control of gonadal hormones on the hypothalamus and anterior lobe of the pituitary gland. An increased level of testosterone (T) in peripheral blood, either as a result of increased production by the testes or following injection of exogenous hormone, provides negative feedback on the hypothalamus to suppress pulsatile discharge of GnRH and thus suppress discharge of luteinizing hormone (LH) from the anterior pituitary. Consequently, the Leydig cells receive less LH stimulation which results in less T being produced. Estrogens (E) are produced by the Leydig cells and to some extent by the Sertoli cells. The ratio of T to E reaching the anterior pituitary may affect the relative amounts of LH and FSH secreted by the gonadotrophs. Based on studies with rams, inhibin (I) suppresses discharge of FSH from the anterior pituitary gland. The physiological roles of E and prolactin (PRL) in adult domestic males remain conjunctural. Sertoli cells produce an androgen-binding protein (ABP) which serves as a carrier for testosterone and may aid in maintaining a high androgen concentration within the seminiferous tubules or in providing testosterone to the epithelium lining the proximal portion of the epididymis [12].

3. Reproduction Traits

The simple classic method for evaluating the reproductive performances is by visually observation, by making records on the reproduction activities or by calculating the reproductive parameters. In the cows, the common variables are the age of first mating and calving, first mating after calving, service per conception, days open and calving interval are in the concerned [16]. In the dairy company, the one of important reproduction traits for young cow candidate are the age of heifer at mating and calving, since this parameter is closely related to economic value, profitability and the number of calf could be produced along the life of the cows [17, 18]. In this case, the reproductive performance could be controlled by endogen hormone and injection of exogenous prostaglandin F2 alpha to stimulate the regression of corpus luteum and gives effect on the new estrus behavior. Other possibility is by inducing the estrus by stimulation of the function of hypothalamus and anterior pituitary that for long time remain inactive following the partus or called as anestrus post-partum. The inactive hypothalamus and hypophysis can be stimulated by inducing low electrical voltage of Laserpuncture. The most animals became showing estrus behavior 1 to 3 days following laser induction [19].

The reproductive performances are closely affected by breeds and environmental condition, such as the nutrition, micro-environment temperature and relative humidity [20, 21]. In the view, might be the influence of the endogen reproductive hormone should interact with the environmental factors. While the first mating and first calving ages, and service per conception was significant higher in the high land than in the low land areas, the days open and calving intervals were similar in the two altitude areas [16].

In small ruminant, such as goat and sheep, the indicator of efficient reproduction performances includes litter size, birth weight, ratio male:female kids and weaning weight for both male and female kids are normally important considered [22, 23]. This is because the small ruminant has the prolific type that possible to produce multiple kids per birth. The success to produce higher litter size and healthy kids at partus are the beneficial for the farmers [22]. The rearing or management system might influence on the physiological status and hormonal mechanism of the small ruminant. However, the goat reared under farmer condition showed similar reproductive performances to those under intensive condition either in company or government's goat farming. This might be the goat were fed under optimum standard of quantity and quality in both management types [23].

In the male, the principle selection for bull candidate is based on the body performance, reproductive organs function and healthy, and the potential of semen production. The semen production of PO-bull is influenced by the scrotum size or volume, body weight and age of bull[8].In Bali bull, the semen production is optimum from the bull with the age of 3 years throughout until 10 years. The semen production increased by increasing the body weight from 260 kg to 784 kg [24, 25]. In the tropical country like Indonesia with two main seasons dry and rainy season, Suyadi et al (2020) split the months in the year into four groups, and reported that higher semen production semen of PO cattle was observed higher in the period of Oct – Dec and Apr – Jun than the others [26].

Although it was noted that reproductive parameters have commonly low heritability value lies form low to medium (0.047 – 0.2122), recent study reported that all steps of reproduction process are regulated by genetic mechanism, although some of them are by hormones. Almost all of the reproduction process is controlled by the genetic mechanism, both in male and female. It is shown by the significant increase of the reproductive traits following genetic selection in domestic animal. In dairy industry, the genomic selection could significantly improve the rates of genetic gain, particularly for traits with low heritabilities, such as fertility and longevity. Our analysis of the US national dairy database found that generation intervals have decreased dramatically over the past 6 y, and selection intensity for lowly heritable traits has increased considerably. Genetic trends rapidly increased for fertility, lifespan, and udder health. These results clearly demonstrate the positive impact of genomic selection in US dairy cattle, even though this technology has only been in use for a short time. This progress in US Holsteins will have a favourable impact on other populations worldwide due to the widespread dissemination of US germplasm [27].

4. Genetic Control of Reproduction

The reproduction shows very complex mechanism. Some factors involve in this mechanism from genetic aspects (breed of animal and genetic constitution), environmental condition, feed and nutrition, diseases, and management or treatment. These factors influence the physiological status, biochemical process, healthy status, body condition score, and genetic material works i.e. DNA in the cell nucleus and RNA in the mitochondria and other cell organelles.

The genetic molecular's work will be expressed on the action of hypothalamus-hypophyseal-gonad axis as hormone glands to synthesize and secrete the reproductive

condition score and their influences on the reproductive behavior and performances as follows (proposed model):

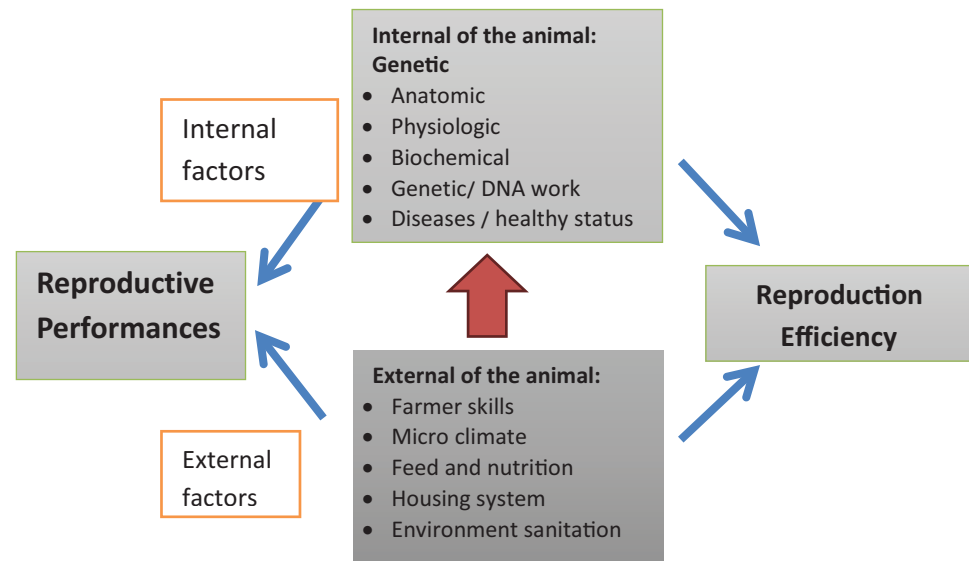


Figure 3: The interaction of some factors resulting the reproduction performance. See – genetic factor is one of the many factors affecting it. However, the genetic factor is an important one.

4.1. Genetic control of male reproduction

primary male sex determination signal is produced by specific SRY (Sex determining Region of the Y chromosome) gene, located at the distal end of short arm of Y-chromosome. Other genes like SOX9 (19th chromosome), DMRT1, (18th chromosome), WNT1 (5th chromosome), AMH (7th chromosome), F1 (29th chromosome), DAX1 (X chromosome), GATA4 (8th chromosome) and aromatase (10th chromosome) are also involved in the sex-determining pathway. Male genital tract development is regulated by several genes like androgen receptor gene, estrogen receptor (ESR1, ESR2) genes, relaxin-like factor (RFL) and insulin-like factor 3 (INSL3) that associated to the success of testes descendance. While the spermatogenesis process is regulated by genes like GnRH-R, FSH-R, LH-R, TGF β -R, and bPRL-R genes [29].

4.2. Genetic control of female reproduction

Müllerian duct development is at least regulated by 13 genes as reported by some authors, some of them are Lim1 (a.k.a. Lhx1), Pax2, Emx2, Wnt4, Wnt9b, Tcf2, Dach1 and Dach2 genes. Furthermore, the genetic complex mechanism of female reproduction has been explored from nucleic DNA encoded traits to mRNA expression analysis

(transcriptomics) involving at the level of ovary, tubal, uterine, placenta, and other reproductive disorders associated with the genetic control. In conclusion, the most reproduction process both in male and female are controlled by the genetic mechanism from the step of organ development, gametogenesis, hormonal synthesis and action, fertilization, embryogenesis and during pregnancy in the female [30].

In the application area, Fortes et al. (2018) searched the association between characterized genetic marker, candidate mutations, and reproductive traits by using Single Nucleotide Polymorphisms (SNP) in Brahman and Tropical Composite cattle. After quality control, 29 SNP were first investigated individually for their association with female reproductive traits and then used as a panel for genomic predictions. The reproductive traits studied were age at first corpus luteum (AGECL; days), post-partum anoestrus interval (PPAI; days), and a binary trait that described if the cow had ovulated before weaning the first calf or not (PW, 0-1). Single nucleotide polymorphisms in six genes (FOXA2, TRAF4, IRF2, IRF1, BPTF, and CPEB1) were found to be significantly associated with reproduction traits [31].

Furthermore, Ortega (2018) stated that in many cases, identification of the causative mutation is difficult because an associated genetic marker can be in intergenic regions and can be in linkage disequilibrium with variants in several nearby genes. Another approach is to identify candidate genes using knowledge of the biological pathways controlling a trait to search for single nucleotide polymorphism (SNP) in genes in those pathways. This should reveal putative causative markers responsible for genetic variation in biological function, and it is expected that the marker will be more strongly associated with a trait than one in linkage disequilibrium. An example of how a series of candidate gene studies demonstrate that identification of markers in genes involved in reproductive processes can lead to discovery of additional markers associated with genetic variation in reproductive traits is presented. In addition, the inclusion of candidate markers for fertility can improve reliability of genetic estimates for fertility traits, and the repeatability of the effects across a separate population of animals gives confidence that association elucidated by this set of markers is likely to be real. More importantly, the use of candidate genes can provide insights into the biology underpinning genetic variation in fertility, and that this understanding can lead to physiological interventions to improve reproductive function [32].

5. Concluding Remarks

The reproduction is one of the important factors determining the success of breeding and farming program in the level of company and farmer. It involves complex mechanisms due to the many factors both internal and external factors contribute in the reproduction process from genetic control in the cell nucleus or in the mitochondrial organelles as the DNA or RNA forms, environment factors, nutrition of feed, and the management factors. Due to the many factors outside of genetic factor affecting the performance of reproduction, the heritability values of the almost of reproductive traits are low range. The selection based on the genetic consideration results the significantly improve the reproductive performance in domestic animals. Hormonal action is more dominant factor regulate the reproduction behaviour and performances. However, genetic factor especially at the molecular genetic level play an important role through the encoding for synthesizing and releasing the peptide reproductive hormones. According to that, the development of accurate and simple techniques for searching genetic marker that showing closed association with the reproductive performances is urgently needed.

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