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Popular Article

Impact of Minerals on Reproduction of Animals

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Abstract

Infertility in dairy animal is a complex and multifactorial phenomenon. In addition to energy and protein deficiency, minerals play an important role in preventing reproductive problems in dairy animals. Minerals are required for maintaining membrane integrity, hormone production and maintenance of strong immune system which are helpful for preventing reproductive problems in animal. Mineral supplementation strategies are very complex, because differences in mineral status and requirement of all livestock in order to obtain optimum production. Subclinical or marginal deficiencies may be a larger problem than acute mineral deficiency because specific clinical symptoms are not evident to allow the producer to recognize the deficiency. Trace element deficiency may be linked to problems such as retained foetal membranes, abortion and weak calf born. Subsequently mineral deficiency leads to decreased milk production in lactating cows

Introduction

The most critical components of a successful dairy farm are animal productivity and reproductive efficiency for having a successful dairy enterprise with consistent revenue. In India, the key factor affecting reproduction is nutrition, which includes minerals. Therefore, a decent return from cattle requires balanced feeding. Minerals have a vital role in regulating domestic animal production and reproduction. Nutritional deficits are most common in productive animals as a result of excessive production and inadequate feeding. Deficiencies in macro and micro minerals have a significant impact on the reproductive physiology of animals, and their imbalances produce a variety of problems, including decreased reproductive efficiency. Since most roughages, concentrates, and even most commercial diets are lacking in trace minerals, adequate mineral supplementation is essential. Minerals play an important role in immunological function, oxidative metabolism, and feed utilization (Bhalakiya et al., 2019). They are engaged in the growth, production and reproduction directly or indirectly. Currently, the best recommendation is to give a reproductive feeding program that is mineral-balanced and satisfies all needs of the animals. To boost reproductive efficiency, proper mineral feeding at various phases of the life cycle is required.

Minerals as cofactor

Minerals act as cofactor or constituents for several enzymes and hormones that are required for both normal metabolic and reproductive process. Some minerals involved directly to the reproduction are presented in the following table.

Reproductive stage	Enzymes involved at that stage	Minerals associated with the enzyme
Proliferation and Differentiation of cells in zygote	DNA Polymerase	Zn, Mg ,Mn
Capacitation of sperm	c AMP, Tyrosine phosphorylase	Ca, P
Increase fertilizing capacity of sperm and uterine receptivity	Alkaline phosphates	Zn

Mineral act as antioxidant

When there is leakage from electron transport chain in mitochondria during normal cellular metabolism and from peroxidation of polyunsaturated fatty acids in the pathway of conversion of arachidonic acid to prostaglandin and related compound, then it generates free radicals. These free radicals are highly reactive due to incomplete electronic configuration. They damage the cells more specifically rapidly dividing cells like germinal epithelium by disrupting their cell membrane. So antioxidants are required to protect the cells from oxidative damage. These minerals act as natural antioxidants in the body by either inhibiting its formation or by donating electron or hydrogen ion making highly unstable radical to stable molecule (Uniyal *et al.*, 2018).

Antioxidant	Mineral associated with it	Mechanism of action
Selenium	Glutathione peroxidase	Converts H_2O_2 to H_2O
Copper	Cu-Zn superoxide dismutase	Converts O_2^- to H_2O_2
Zinc	Cu-Zn superoxide dismutase	Converts O_2^- to H_2O_2
Manganese	Mn superoxide dismutase	Converts O_2^- to H_2O_2
Iron	Catalase	Convert H_2O_2 to H_2O

Minerals affecting the energy and protein metabolism

During reproductive phase of animal, both gonadal activity and synthesis of sex hormone are proportionately associated with energy and protein metabolism. In animals, the energy metabolism is turned on energetic cost of puberty, pregnancy, lactation *etc.* For example, decrease calorie intake affect ovulation and fertilization rate by impairing secretion of gonadotropin from anterior pituitary gland. Movement of sperms and parturition process is highly energy dependant. Similarly, reduction in protein intake in late pregnancy results in delay in return to estrus cycle. High intake of crude protein particularly rumen degradable protein leads to decrease fertility due to toxic effect of blood urea or ammonia. These reduce the pH of uterine environment during luteal phase of cycle leading to foetal death. Several minerals are actively involved in energy and protein metabolism as a cofactor. So, they are not directly affecting but indirectly influencing the reproduction process in animal.

Minerals affecting physical condition of body

Physical condition of the animal has a greater impact on reproduction. This physical condition is proportional to the bone and muscle mass, whose major components are mineral like calcium and phosphorous. Low concentration of these minerals results poor body condition, stunted growth,

debilitating condition that severely affect the onset of puberty and future reproductive events. For example, age of puberty of an animal does not depend on age but depends on body weight of the animal. When cattle attain 70% of the adult body then only it will show its 1st heat. High plane of nutrition and low plane of nutrition cause early and delayed puberty in animal respectively. Body reserve also very important during pregnancy as it supplies the nutrient requirement of own as well as growing foetus and nutrient demand of upcoming lactation.

Minerals affecting the activity of rumen microflora

Several minerals like phosphorus, iron, cobalt, manganese etc are having a key role in maintaining rumen environment by either balancing the pH of the rumen or by altering the microbial population in the rumen. When rumen environment is good then utilization of nutrients by microbe is higher consequently it has a positive effect on nutrient demand for reproduction by making available in ample amount. Deficiency of these minerals affect badly on reproductive physiology of the animal. As minerals were affecting all the physiological activities of animals, the effect of some of the important minerals was presented below.

Calcium

Calcium (Ca) is the major inorganic constituents found in the animal body. It is not only the major component of skeletal system of body (provides structural rigidity and strength) but also performs a significant role in muscle contraction, myocardial function, blood clotting, neuromuscular excitability *etc*. It assists during delivery of foetus, muscle contraction, maintaining proper uterine tonicity and uterine involution. GnRH stimulation of LH release from pituitary gland involves Ca dependant pathway. When Ca deficiency occur, then contraction of muscle and rumen function decreases leading to reduced feed intake and energy state of the animal becomes negative. In order to fulfil energy demand fat mobilization increases, animal are prone to fatty liver syndrome and ketosis may occur. This affects the milk production and will impair the fertilization. Deficiency of Ca increases the incidence of difficulty in parturition, retention of foetal membrane and uterine prolapse. Excess calcium impairs the reproductive function by deficiency of P, magnesium (Mg), zinc (Zn) and copper (Cu). Ration containing 0.75-0.80% Ca on DM basis should be provided to lactating animals to avoid this deficiency problems.

Phosphorus

After Ca, phosphorous (P) occupies second major inorganic element in the animal body. Like Ca, P is also the important constituent of bone and teeth. It is involved almost every aspect of metabolism of carbohydrates, protein, fat and other nutrients in the body. As P is a component of

ATP, ADP it plays an important role in energy metabolism. It may induce follicular development or oestrus initiation. It affects the reproduction through impairment of P dependant biochemical reactions. Cyclic AMP and tyrosine phosphorylation is required for capacitation of sperm which must require P. Deficiency of this causes delayed onset of puberty in heifer, anestrus, irregular estrus cycle in cow, low conception rate, increase incidence of cystic follicle. Along this above symptoms it is associated inanition, poor hair coat, decrease appetite. Less than 4mg/100 ml serum shows deficiency symptoms. Ration containing 0.45-0.50% P on DM basis should be supplemented. It is fed through dicalcium phosphate or bone meal or by adding 1% tripolyphosphate or monosodium phosphate in grain ration. Tonophosphan injection is given to anestrus cow to come heat quickly.

Copper

Copper (Cu) is required for the synthesis of haemoglobin and maturation of erythrocytes. It is an integral part of many metalloenzymes such as cytochrome C oxidase, lysyloxidase, tyrosinase, uricase, plasma amino oxidase *etc*. it is also the main component of superoxide dismutase, lysyl oxidase, thiol oxidase that eliminate free radicals and protects from oxidative damage. Recent studies show that progesterone synthesis from luteal cell is regulated by superoxide dismutase which involves both Cu and Zn. Cu enhances both release of PGE_2 from astrocytes and binding with the receptor that in turn stimulates GnRH production automatically increases FSH and LH synthesis. It also activates plasminogen that helps rupture of matured follicle. It is associated with the synthesis and secretion of releasing hormone that modulate the extent of secretion of LH. Its deficiency leads to anestrus, sub estrus, poor pregnancy rate, early embryonic death, dystocia, retention of placenta, necrosis of placenta, increased calving interval, low fertility associated with anaemia, lack of appetite, loss of condition (Harley and Doare, 1989). Anaemia causes decrease in blood and oxygen supply that results inactive ovary and depressed oestrogen synthesis. Cattle fed diet with less than 3mg/kg Cu show this symptom. Indirect deficiency has been observed in animals due to excessive Mo or S intake.

Zinc

Zinc (Zn) act as cofactor for number of enzymes (carbonic anhydrase, alcohol dehydrogenase, alkaline phosphatase *etc*) and directly involved in many metabolic reaction occurred in avian and mammalian species. Zn acts as a biological antioxidant having component of superoxide dismutase. Zn is constituent of thymidine kinase enzyme which is essential for spermatogenesis. It also involved in motility of sperm, membrane stability and tail morphology through involvement of ATP. It decreases the asthenozoospermia in male by reducing oxidative stress. Maintenance and repair of

uterine epithelium after parturition is controlled by Zn which causes early involution. Synthesis of prostaglandin from arachidonic acid has a greater effect on reproduction and maintenance of pregnancy that process is incomplete without Zn. The binding of steroid receptor complex to DNA must require Zn fingers that are present on nucleic acids. Zn increases plasma ß- carotene concentration that results improved conception rate and cleavage of embryo. At cellular level, Zn effects on pregnancy by modulating the action of insulin like growth factors (IGFs). IGFs are known as potent stimulator of tissue differentiation and cell proliferation. Deficiency of Zn effect spermatogenesis, quality of the semen detoriated, size of testes and libido in bulls decreased. This causes atrophy of tubular epithelium in buck and lambing difficulty in ewes. Recommended dose for dairy cattle is 40 ppm according to the feeding standard NRC (2001).

Manganese

The metabolism of carbohydrates, protein, fat and nucleic acids involve Mn as an activator of several enzymatic processes. It is also thought to be involved in oxidative phosphorylation. It has ubiquitous role in steroid synthesis (Two limiting enzymes during cholesterol synthesis *i.e*. mevalonate kinase and farnesyl pyrophosphate both require Mn as a cofactor). Cholesterol synthesis is prime necessary for synthesis of steroids hormone. It is having antioxidant role and helps in gluconeogenesis process occurred in the animal body. Deficiency results insufficient steroid production leads to decrease circulating concentration of the reproductive hormone causes irregular estrus cycle in female and abnormal sperm in males. Its insufficiency leads to anestrus, poor follicular development, delayed ovulation, silent estrus, and decreased conception rate. Dairy cow shows anestrous after parturition has proven to be increased conception rate when supplemented with Mn.

Selenium

Selenium (Se) and vitamin E synergistically show as a protective biological antioxidant system in the body by removing free radicals. Se is essential for normal spermatogenesis process in male. The phospholipid hydroperoxide glutathione peroxidase (PHGPx/GPX_4) system must involve Se as a component. Glutathione peroxidase catalyses removal of peroxide and prevent stress in animals. The structural protein which contributes normal sperm motility involves PHGPx. A variant of this protein is necessary for condensation of chromatin and formation of head of spermatozoa. The behaviour and function of spermatozoa is regulated by incorporation of Se with sperm mitochondria capsule. It may regulate growth of granulosa call and 17 ß estradiol biosynthesis in ovaries. It is believed that Se is important dietary mineral that have direct link to uterine involution. It also affects iodothyronine deiodinase that converts T4 to T3. Se deficiency results in impaired

reproductive performance in males by reducing viability of semen. Reproductive problems associated with Se deficiency included retained placenta, abortion, birth of premature, weak, dead ones, cystic ovaries, metritis, erratic or silent heat and poor fertilization. In sub clinical Se deficiency there is increased services per conception and mastitis. In males, there is reduction in both semen quantity and quality. Impaired motility with flagella defects localised primarily to the mid-piece has been a consistent feature of Se deficiency animals. Research indicates that both Se and vitamin-E combination decrease incidence of retention of placenta, cystic ovarian degeneration, mastitis and metritis. Se supplementation also improves the conception rate.

Iodine

Among all the trace minerals only iodine is very much essential for the synthesis of thyroxine hormone in thyroid gland which is a metabolic and mitochondrial regulator. When thyroxin concentration is increased automatically it stimulates hypothalmo-pituitary gonadal axis thereby affecting oestrus cycle. Thyroid stimulating hormone (TSH) has a synergistic effect with follicular stimulating hormone (FSH) in promoting proliferation of granulosa cells. On the other hand, thyroid hormone regulates FSH stimulation in follicle and prevents their apoptosis. Iodine has a positive effect on TSH secretion which in turn causes more prolactin secretion that influence length of oestrus cycle. It plays an important role in implantation and early development of foetus by regulating the invasion of trophoblastic villi against matrix. Supplementation of iodine to ewes before mating increases twinning rate. Congenital abnormality is one of the most outstanding consequences of reduced thyroid hormone concentration. Deficiency symptoms occur in animals supplemented with iodine less than 1mg/kg DM. Deficiency of iodine results in

1) Hairless, weak/dead young, brain development impaired
2) Embryonic death, abortion ,still birth or weak goitoric calves.
3) Depressed libido and defective semen quality in bull.
4) Non specific poor growth, irregular estrus
5) Goitrogenic substances (present in lentils, soyabean, linseed) leads to anestus in heifer.

Cobalt

Cobalt (Co) is the major component of vitamin-B_{12} or cyanocobalamin. Vitamin B_{12} acts as cofactor for the synthesis of methionine synthase, leucine mutase, malonyl coA mutase. This is required when propionate gets converted into glucose (carbohydrate metabolism) and folacin metabolism. Co plays a vital role in thymine synthesis which is essential for synthesis of nucleic acid required for cell growth and reproduction. Its deficiency leads to hamper carbohydrate and folic acid

metabolism. In cobalt deficiency along with anaemia, animal is associated with the reproductive problems like increased number of silent oestrus, delayed puberty, anestrus, poor pregnancy rate, increased calf mortality, irregular inter estrus interval.

Iron

It is the most abundant micromineral found in the biological system. It is a constituents of pigments like haemoglobin, myoglobin enzymes like cytochrome C oxidase(electron transport chain), peroxidase, catalase etc. its deficiency causes negative energy state (as ATP production is disrupted) and less oxygen supply to tissue level (as haemoglobin synthesis is hampered) and more prone to free radical damage (catalase and peroxidase act as natural antioxidant in the body). Due to iron deficiency animal suffer anaemia, decrease appetite, poor body condition. Deficient animal may have chance to show repeat breeding, increased services per conception or may abort occasionally.

Molybdenum

The relationship between molybdenum (Mo and Cu are antagonistic in nature means deficiency of Cu occur when there is high Mo and reverse. Therefore, a proper balance in feeding Cu and Mo must be followed to avoid reproductive problems. Molybdenum toxicity results copper deficiency thereby affecting reproduction. At higher quantity, it affects the hypothalamus-pituitary axis, LH pulse reduced hampering the reproductive cycle of the animals. Reproductive problems associated with Mo toxicity shows lack of libido and damage to germinal epithelium in bull calves, delayed puberty in heifer, failure of estrus in cow.

Chromium

Chromium (Cr) mainly effect on reproduction by release of pregnancy specific protein from endometrium of uterus that prevent early embryonic death. It has got remarkable influence on maturation of follicle and LH release. It is highly concentrated in nuclear protein thus a role in gametogenesis and for healthy foetal growth. Its deficiency leads to oligozoospermia and decreased fertility and influences foetal growth and development.

Conclusion

Though minerals are required in very minute quantities, but they are created a significant position in reproductive life of the animal by involving each and every step directly or indirectly. So now time is coming to emphasize and giving similar weightage to minerals in feed just like other major nutrients like energy and protein.

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