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Popular Article

Lactation in dairy cattle

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LACTATION

- *Lactation* refers to the combined process of milk secretion and removal. It includes two processess
  - *Lactogenesis* - initiation of milk secretion.
  - *Galactopoiesis* - maintenance of milk secretion.

Lactogenesis

It is the process of differentiation in which the mammary alveolar cells acquire the ability to secrete milk. Lactogenesis includes two stages:

- Stage I occurs before parturition in which alveolar cells differentiate and acquire a limited capacity for milk secretion
- Stage II begins shortly before parturition and continues for several days postpartum in which the alveolar cells are able to secrete copious amount of milk components. Secretory cells before parturition can secrete caseins and milk fat. Lactose synthesis is the key to the secretion of large volumes of milk

Hormones required for lactogenesis:

- Progesterone of pregnancy blocks lactogenesis. For the synthesis of lactose, α-lactoalbumin, and casein, PRL is required. Progesterone inhibits the binding of PRL with PRL receptors in the mammary gland and prevents synthesis of these components, thereby lactogenesis is blocked.
- Progesterone secretion starts to decline during late pregnancy and mammary gland

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becomes responsive to the lactogenic hormones – insulin, glucocorticoids and prolactin.

- Mammary alveolar differentiation is stimulated by these lactogenic hormones and secretory apparatus develops in alveolar cells
- Insulin and/or IGF-I cause alveolar cell multiplication and seem to be necessary for lactogenesis. Insulin increases glucose uptake by alveolar cells by stimulating glucose transport into the cells which are needed for lactose synthesis and may also increase expression of milk protein genes
- Glucocorticoids secretion stimulated by ACTH are involved in intracellular synthetic machinery development for protein synthesis and are involved in transcription of casein and α-lactoalbumin genes. Mammary glucocorticoid receptors increase late in pregnancy
- Prolactin is also responsible for switch over from 1st to 2nd stages of lactogenesis; PRL receptors and its blood concentrations increase at that time. It synergizes with Insulin and glucocorticoids in transcription of casein and α-lactoalbumin genes, translation of milk protein mRNA and for milk secretion
- Estrogen is indirectly involved with lactogenesis - increase PRL receptors at parturition and control PRL release from pituitary
- Somatotropin has no direct effects and may through IGF-I (somatomedin secreted by liver) -may have PRL-like activity with elevated levels
- Local Factors may also affect lactogenesis probably by working through autocrine or paracrine mechanisms
- Prepartum milking can initiate lactation – neural impulse to hypothalamus initiates PRL and ACTH secretion leading to mammary cell secretion.

Galactopoiesis

It is the maintenance of lactation. It requires hormones and the removal of milk from udder. It involves maintaining the alveolar cell numbers and function After parturition, milk yield increases in cows, which reaches a maximum in 2 to 8 weeks and then gradually declines, which is due to decline in the number of secretory cells.

If milk is not removed frequently from the mammary gland, synthesis of milk will not persist even with adequate hormonal levels.

***Hormones of galactopoiesis*:** Maintenance of lactation requires hormones - GH, ACTH (glucocorticoids), insulin, thyroid hormones, prolactin and PTH.

- Prolactin is the primary component of the galactopoietic complex especially in monogastric animals but it is not necessary for galactopoiesis in ruminants where inhibitors

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of prolactin do not suppress lactation with slight reduction in milk yield in ewes; if given endogenously PRL will increase milk yield

- Suckling or milking induces PRL surge in blood (peak value reached in 30 min) with a decrease in dopamine; this response declines with advancing lactation. Temperature and light also stimulate prolactin - warmer temperatures and artificial lighting in winter and fall can increase mammary development and milk yield
- GH is very galactopoietic in ruminants and necessary to maintain lactation
  The thyroid hormones influence the milk synthesis and duration of secretion.
- Insulin is required for glucose uptake in the mammary gland.
- ACTH releases glucocorticoids which are necessary to maintain mammary cell numbers and alveolar cell metabolic activity. Corticosteroids also Influences expression of casein genes

Milk removal and galactopoiesis

Acute accumulation of milk increases intramammary pressure, activates sympathetic nervous system, decrease mammary blood flow, decreases hormones to mammary gland which will eventually cause cell apoptosis. Nursing stimulus triggers release of galactopoietic hormones especially PRL which may stimulate next round of secretory activity in cows, reproductive cycles restarts even when milk production is high.

Biosynthesis of Milk

- Mammary epithelial cells take precursors for milk synthesis from blood through the basal and lateral membrane and discharge the milk through the apical membrane into the lumen of alveolus.
- Mammary alveolar cells synthesize fats, proteins and carbohydrates
- Fat first accumulates in the basal cytoplasm of the cell, then move to the apex where the droplets protrude into the alveolar lumen.
- Triglycerides constitute 97% of milk fat with rest formed by phospholipids and cholesterol. About 40-50% of the fatty acids used for the synthesis of milk fat by mammary epithelial cells are synthesised from precursors (do novo synthesis). Remaining fatty acids used in the synthesis of milk fat are preformed and taken up from blood by mammary epithelial cells
- Bovine milk fat consists of large proportions of short-chain fatty acids (C4-C16). The fatty acids and glycerol are synthesized in the cytoplasm and the triglycerides are formed in the endoplasmic reticulum of the mammary epithelial cells.

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- The fatty acids are synthesized from three major sources
- Acetate and β-hydroxy butyrate–primary source formed in rumen, transported to mammary Biosynthesis of Milk gland. Acetate contributes to C4 toC14 fatty acids of milk. In non-ruminant's acetyl CoA from glucose is the major source for milk fatty acids
- Fatty acids of the triglycerides present in the circulatory system as low-density lipoproteins and chylomicrons are another source. They contribute fatty acids C16 and above. Half of milk fatty acids are derived directly from blood triglycerides
- Cytoplasmic acetyl CO-A from glycolysis and TCA cycle is the third source.
- Glycerol for triglyceride synthesis is derived from glycerol 3-phosphate of glycolytic pathway or from lipolysis of triglycerides in the mammary gland.
- Major milk proteins are (1) caseins (α, β and κ), (2) β-lactoglobulin and α-lactalbumin (3) immunoglobulins (4) Lactoferrin, lysosomal enzymes and other specific proteins.
- Caseins are phosphorylated proteins and present in varying proportions in different species – in ruminants 80% of total milk proteins is caseins, in mares 50% and in human 40%
- Lactalbumins in milk include α-lactalbumin synthesized by mammary epithelial cells and serum albumin transferred from blood.
- Milk immunoglobulins are derived from blood as preformed proteins Milk has lower concentration of IgG while colostrum contains a high level of IgG. IgA and IgM are also present in milk synthesized by plasma cells in mammary gland
- Lactoferrin is milk-specific protein synthesized by mammary epithelial cells and helps to keep iron in bound form in milk. Lysosome enzymes have antibacterial effect.
- Milk proteins are synthesized on the endoplasmic reticulum; the casein molecules pass to the Golgi apparatus for phosphorylation, forms micelles within the golgi vesicles.
- Several genetic variants of milk proteins occur; the genetic polymorphism of milk proteins is useful for genetic identity of the animal
- Lactose, a disaccharide composed of glucose and galactose connected by β-1-4 glycoside bond, is found exclusively in milk. It is synthesized from two molecules of the precursor glucose. One glucose is converted to galactose; lactose synthase catalyses the reaction between glucose and galactose to form lactose.
- The lactose synthase is composed of two subunits–galactosyl transferase and α-lactalbumin. During pregnancy progesterone blocks the secretion of α-lactalbumin, a milk whey protein. At the beginning of lactation, PRL induces synthesis of α-lactalbumin and stimulates lactose synthesis. Lactose is synthesized within golgi vesicles, released in

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conjunction with milk protein. The golgi vesicles fuse with the cell membrane and release protein and lactose by exocytosis.

- During lactation, 70-80% of available glucose is utilized by the udder for lactose synthesis and ruminants are prone to glucose deficiency during peak lactation.

Induction of Lactation

- Lactation can be artificially induced in dairy cattle by the use of variety of hormones when the mammary gland contains sufficient numbers of alveolar cells.
- Subcutaneous injection of a total daily dose of 0.1-mg/kg body weight of oestradiol-17 and 0.25mg/kg body weight of progesterone dissolved in 100% ethanol in divided dose at 12 hours interval for 7 days will initiate lactation in about 60 to 70% of heifers and cows. The percentage of success rate increases to 100% if 5mg of reserpine (a tranquilizer) is administered on day 8, 10, 12 and 14 to increase the prolactin level in these animals.
- Lactation starts between days 14 and 21 after initial injections of estradiol-17 and progesterone.
- ACTH or glucocorticoids in large doses inhibit lactation in ruminants and rats
- GH produces a dose-dependent increase in milk yield in dairy cows. The increase in milk yield by GH is produced by nutrient partitioning from body tissue requirements to milk synthesis.
- Recombinant bovine GH (bST) has been employed to increase milk yield in lactating animals. Injection of GH three times a week stimulates short term increase in the milk production by 10% in early to mid-lactation and up to 40% in late lactation and 15% feed efficiency, whereas reduces the feed intake by 29% in high producing cows.
- Fertility may be altered but does not affect cow's health other than problems associated with high milk production. bST increases synthesis of lactose, fat and protein
- Injection of low dose of synthetic glucocorticoids stimulates milk yield by 14 to 18%.
- Iodocaesin and L-thyroxine have been used to induce milk production. Iodinated casein, (0.5 percent crystalline thyroxine) has been fed to dairy cattle at a rate of 1 to 1.5 g per 45kg of body weight daily, resulting in an increase in milk production of 10 to 30 per cent.
- Extra feed must be provided to prevent weight loss and milk production declines abruptly following withdrawal of thyroproteins. Thyroproteins increase the need for more nutrients, reduces body weight and interferes with the ability to withstand thermal stress.
- Thyroprotein fed to dairy cows at the peak of lactation stimulates milk production by about 10%, whereas during declining phase of lactation it stimulates the milk production by 15

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to 20%. Usually, a greater increase in milk production occurs in high producing cows and older cows. The maximal increase usually occurs during the first 60 days of thyroprotein feeding. However, beneficial effects disappear within 2 to 4 months.

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