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An update on artificial induction of lactation in domestic animals

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Abstract

Artificial induction of lactation (AIL) is an advanced biotechnology that enables milk production in non-pregnant animals through controlled hormonal and management interventions. This technique has gained significant importance in modern dairy production systems, where reproductive inefficiency remains a major economic constraint. AIL serves as a strategic tool to utilize genetically superior but infertile or repeat-breeding animals, thereby preventing involuntary culling and maintaining herd productivity. It can bypass the gestation lag and is utilized to test the milk of transgenic animals as early as 13 months of age. In mares it is used when foaling results in an orphan foal, to find an alternative milk source via nursing mare. In dogs and cats, it is used when milk production is absent or inadequate and lactation disorders like agalactia or hypogalactia.

Mammary gland development (mammogenesis) involves an isometric growth phase in early life followed by an allometric transition at 2-3 months, where it grows 3-5 times faster than body. This process is regulated by estrogen, leading to ductal elongation and formation of secretory luminal and contractile myoepithelial cells. Lactogenesis begins in late pregnancy with secretory differentiation (Stage I) and is followed by secretory activation (Stage II) at parturition, triggered by declining progesterone. Prolactin and growth hormone then maintain milk synthesis during galactopoiesis phase. AIL simulates endocrine profile of late pregnancy and parturition. Administration of estrogen and progesterone promotes mammogenesis, followed by their withdrawal to trigger lactogenesis, supplemented with glucocorticoids and prolactin-stimulating agents. Adjuncts like reserpine enhance prolactin release by inhibiting dopamine, thereby improving lactation success.

AIL evolved from prolonged steroid protocols (120-180 days) to shorter, welfare-oriented regimens. Wherein using this landmark protocol by Smith and Schanbacher (1973) ^[53] achieved up to 60% success rates. Recent trends emphasize shortened protocols and integration with technologies like automatic milking systems. Most successful protocol in cattle is administering estrogen and progesterone for day 1-7 and then administration of dexamethasone during day 18-20.

Induced lactation typically yields 60-80% of normal milk production and nearly comparable with the natural lactational milk composition. Concerns regarding hormone residues and animal welfare necessitate strict adherence to withdrawal periods and optimized protocols. Non-hormonal approaches such as photoperiod manipulation and phytotherapy are emerging as supportive strategies to enhance lactation while minimizing drug use.

AIL represents a valuable intersection of endocrinology, animal production and biotechnology. With advancements such as nano-encapsulation of hormones, genetic selection and stem cell applications, AIL holds significant promise for sustainable and ethical dairy management in the future. Future advancements aim to refine protocols further through the integration of nano-encapsulated hormones for targeted delivery, the identification of genetic markers for high-response animals, and the potential infusion of mammary stem cells to artificially increase the secretory cell population.

Keywords: Artificial induction, lactation, domestic animals

1. Introduction

In the last decades, genetic selection of dairy cows for high milk yield has negatively affected fertility, increasing the culling rates of animals due to reproductive failure. Infertility is considered one of the main reasons for culling and is among the costliest factors in dairy farms, involving direct costs associated to rearing or purchasing the animals, and indirect costs related to maintenance of unproductive animals in the system (Pritchard *et al.*, 2013) ^[49]. In the

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year 2024-25 India's total milk production was 247.87 million tonnes, *per capita* milk availability of milk was 485 grams/day. During the same year total milk production of Gujarat was 19.28 million tonnes (BAHS, 2025) ^[16]. India remains the world's leading milk producer, contributing 24.76% of global output, yet reproductive inefficiency remains the primary silent economic drain (PIB, 2025) ^[48]. The annual growth rate of milk production is declining since last 5 years (Graph 1, BAHS, 2025) ^[16].

Major cause behind this declining growth is reduced per animal milk production. The average yield per animal per day in India is 9.05 kg/day/animal (Exotic/crossbred) and 3.86 kg/day/animal (BAHS, 2025) ^[16]. The surveillance of breedable zebu cattle, crossbred cattle and buffaloes (total 28,815) from 5 different regions of Gujarat revealed reproductive problems in 27.4, 26.6 and 34.5% animals, respectively. Among these infertile animals, the incidence of anestrus was maximum (23.34%) followed by repeat breeding (14.94%), subestrus (14.69%), uterine infection (12.91%), infantile genitalia/pubertal anestrus (9.64%) (Dhami *et al.*, 2022) ^[17]. Over half of the cow population in repeat breeding animals are in productive years, aged 4-6 years, only 44.8% having 1 or 2 offspring(s) (Pongkapadang *et al.*, 2025) ^[47].

As a solution to tackle this condition Artificial induction of lactation (AIL) aims to allow heifers and cows with superior genetic value that fail to conceive to remain in the herd, generating revenue until a new breeding opportunity arises (Busanello, 2025) ^[5]. Artificial induction of lactation is a physiological intervention that uses exogenous hormone treatments to stimulate mammary gland development (mammogenesis) and initiate milk secretion (lactogenesis) in non-pregnant, intact mammals (Noguchi *et al.*, 2020) ^[43]. Artificial induction of lactation with the use of synthetic hormones which are likely natural mainly at the end of the pregnancy, ulating the physiological system of the animal a pregnancy and stimulating milk production (Freitas *et al.*, 2010) ^[18]. Formation of normal colostrum can be achieved by injecting estrogen and progesterone and both the hormones are involved in control of selective transport of serum immunoglobulin into milk (Smith, 1971) ^[54].

Status of artificial induction of lactation

Global status

Globally, Artificial Induction of Lactation (AIL) is primarily utilized to maximize the lifetime productivity of genetically superior dairy cattle, particularly high-yielding breeds such as Holsteins, that fail to conceive following a dry period. Contemporary global approaches increasingly integrate AIL with advanced dairy technologies, including Automatic Milking Systems (AMS), reflecting a trend toward precision dairy management (Busanello, 2025) ^[5]. Standard global protocols commonly involve short-duration regimens, particularly 8-day protocols, often supplemented with Recombinant Bovine Somatotropin (RBST) to enhance lactational performance (Busanello, 2025) ^[5]. Success rates of induced lactation under global conditions generally range between 80% and 100%, with milk production achieving approximately 78-80% of natural lactation yields (Busanello, 2025) ^[5]. Furthermore, reproductive performance following induction has shown encouraging outcomes, with post-induction pregnancy rates reported to range from 41% to 71% (Ramgattie *et al.*, 2014) ^[50]. Recent international research trends indicate a marked transition toward shortened protocols designed to reduce estradiol exposure, minimize treatment costs and improve animal welfare by limiting prolonged estrus-associated behavioral stress (Isola *et al.*, 2024) ^[23].

Status in India

In India, the application of artificial induction of lactation differs considerably from global objectives and is primarily directed toward preventing involuntary culling and addressing the growing stray cattle problem, influenced by cultural values and legal restrictions on cow slaughter (Lakhani *et al.*, 2017) ^[32]. AIL serves as an important rehabilitative strategy for barren and nonproductive animals, restoring them to economic usefulness and converting financial liabilities into productive dairy assets (Inchaisri *et al.*, 2010) ^[21]. Indian protocols generally rely on traditional 7-21- day induction schedules, with hormonal formulations tailored according to breed type. Crossbred cattle are typically managed using an estrogen-to-progesterone ratio of 1:2.5, whereas indigenous cows and buffaloes commonly receive a 1:1 ratio (Lakhani *et al.*, 2017) ^[32]. Reported success rates in India range between 80% and 85%, although buffaloes frequently demonstrate comparatively lower responses to induction protocols. Milk yield following induction generally reaches 60-70% of natural lactation, which has been attributed to uncoupling of the somatotrophic axis during induced lactation. Reproductive outcomes after induction indicate that many repeat-breeder cows regain normal estrous cyclicity, although conception rates remain moderate to relatively low under field conditions.

Mechanism of artificial induction of lactation

Artificial Induction of Lactation (AIL) is based on sequential hormonal stimulation intended to induce mammary development, initiate milk secretion and maintain lactation. Although AIL does not perfectly reproduce the endocrine profile of natural pregnancy, it utilizes key hormonal pathways involved in lactogenesis and galactopoiesis. Artificial induction protocols are primarily based on administration of estradiol, progesterone, prostaglandins, corticosteroids and bovine somatotropin.

The initial phase of AIL relies on estradiol and progesterone administration to stimulate mammary gland development. These hormones promote the mammogenic changes necessary for lactation induction. Following this developmental phase, prostaglandins and corticosteroids are incorporated to facilitate transition toward milk secretion. Dexamethasone-based treatments are used during the final stage of induction to stimulate lactogenesis and trigger milk secretion.

Endogenous prolactin release is an important component of the induction process. Stimulation of the mammary gland through massage or milking adaptation is used to promote prolactin release and support initiation of milk production. Busanello (2025) ^[5] notes that mammary gland massage was used specifically for endogenous prolactin liberation and further discusses that prolactin stimulation contributes to milk secretion. Maintenance of lactation after induction depends on continued stimulation of the mammary gland and hormonal support. Bovine somatotropin has been reported to improve milk yield responses through stimulation of epithelial cell proliferation and regulation of apoptosis, thereby contributing to maintenance of milk production. Additionally, increased milking frequency may provide further stimulation to sustain milk yield during induced lactation. (Busanello, 2025) ^[5]

Indications for artificial induction of lactation

Mitigating involuntary culling

Reproductive failure is the leading cause of involuntary culling in Indian herds. In the context of India's record milk production of 247.87 million tonnes (2024-25), but with rising population, need of more production will also rise significantly (BAHS, 2025) ^[16]. That's why using AIL protocols in cows which are in their productive year and not conceiving.

Clinical utility in companion & lab animals

Dogs & Cats: In maternal death, AIL using dopamine antagonists (*e.g.*, Metoclopramide, Domperidone), enables a non-parturient surrogate or the biological dam to produce milk, to synchronize milk production for orphaned neonates in small animals. In swine, employed as a colostrum supplement for large litters and Equines (Nurse Mares): In high-value Thoroughbred breeding, for the creation of "nurse mares" to foster orphaned foals. (Noguchi *et al.*, 2020; Podico *et al.*, 2022) ^[43, 46]

Research and Biotechnological applications

Transgenic animals: AIL is a prerequisite for testing the milk of transgenic animals (*e.g.*, for human therapeutic proteins) as early as 13 months of age, bypassing the long gestation and age at first calving delays. Pharmacokinetic Benchmarking: Provides a controlled physiological model to establish Hormonal Clearance Windows (typically 15-30 days) for public health safety). (Monzani *et al.*, 2024) ^[41]

Other indications: Prevents involuntary culling of high-pedigree animals failing to conceive, Bypasses the 9-month (280-310 day) non-productive gestation lag, Exogenous steroid priming (E2/P4) can reset the hypothalamic-pituitary-ovarian axis. 40-60% of induced cows subsequently conceived, In buffaloes to bypass silent heat and summer infertility, Addresses chronic conditions like Cystic Ovarian

Disease (COD) or persistent anestrus, To study mammogenesis and lactogenesis without the metabolic interference of a developing fetus.

Selection of Animals

Selection of animals for artificial induction of lactation should be based on several physiological and management criteria to optimize treatment success. *Animals* with a body condition score (BCS) of 3.25-3.75 on a 5-point scale are preferred, as they possess adequate energy reserves necessary for galactopoiesis. Multiparous animals, particularly those in the 2nd to 4th lactation, are considered ideal candidates because they possess more developed mammary ductal frameworks. Dry and non-pregnant animals are preferred to permit adequate systemic recovery before induction. Udder health is another critical criterion, and only animals with clinically healthy quarters, no history of mastitis and somatic cell counts below 200,000 cells/ml should be selected. Anatomical integrity, particularly sound teat morphology, is necessary to ensure effective mechanical milking stimulation. *Animals* should also possess a docile or trainable temperament to facilitate management throughout the treatment period. In addition, candidates should be properly vaccinated, dewormed and free from systemic diseases to support overall health and treatment response. (Lakhani *et al.*, 2017) ^[32]

Protocols

Table 1: Hormonal Protocols for artificial induction of lactation in cattle and buffalo

Protocols	Hormone	Success Rate	Reference
Days 1-7: E2+P4 Day 18: rbST single dose	E2: 0.075 mg/kg/day, SC P4: 0.25 mg/kg/day, SC rbST: 500 mg, SC	28.4 kg/day yield	(Magliaro <i>et al.</i> , 2004) ^[38]
Day 1, 8, 21: rbST Days 2-8: Daily P4 Days 2-15: Daily E2 Days 19-21: PGF2 α	Medroxyprogesterone (MPA): 0.25 mg/kg/day SC, Estradiol Benzoate: 0.071 mg/kg/day SC, rbST: 500 mg SC, PGF2 α : 0.530 mg & Isoflupredone: 10 mg SC	21.9 kg/day yield	(Freitas <i>et al.</i> , 2010) ^[18]
Day 1, 8, 21: Bovine Somatotropin (bST) Day 2-8: Estradiol Cypionate (ECP) + Medroxyprogesterone (MPA) Day 9-15: ECP Day 19: PGF2 α	bST: 500 mg (IM) ECP + MPA: 0.075 mg/kg ECP + 0.25 mg/kg MPA (IM) ECP only: 0.037 mg/kg (IM) PGF2 α : 0.530 mg (IM)	80%	(Freitas <i>et al.</i> , 2010) ^[18]
Day 1, 8, 21: bST Day 2-15: EB (Day 2-8 with Medroxyprogesterone) Day 19: PGF2 α Day 19-21: Isoflupredone	bST: 500 mg (IM) EB + MPA: 0.071 mg/kg EB + 0.25 mg/kg MPA (IM), PGF2 α : 0.530 mg (IM), Isoflupredone acetate: 0.05 mg/kg (IM)	90%	
Day 1-7: 17 β -E2 + P4 Day 1, 10, 20: bST Day 18-20: Dexamethasone	17 β -estradiol + Progesterone: 0.1 mg/kg E2 + 0.25 mg/kg P4 (SC), bST: 500 mg (SC) Dexamethasone: 20 mg/day (IM)	83%	(Macrina <i>et al.</i> , 2011) ^[37]
Day 1, 10, 18: PGF2 α Day 11-17: 17 β -E2 + P4 Day 19-22: Reserpine + Dexamethasone	PGF2 α : 25 mg (IM), 17 β -estradiol + Progesterone: 0.1 mg/kg E2 + 0.25 mg/kg P4 (SC), Reserpine + Dexamethasone: 5 mg IM	78%	(Ramgattie <i>et al.</i> , 2014) ^[50]
Day 1-8: EB + P4 Day 9-14: EB Day 16: Cloprostenol Day 19-21: Dexamethasone Day 1, 8, 15, 22: bST	30 mg EB + 300 mg P4 (IM) EB only: 20 mg (IM) Cloprostenol: 0.56 mg (IM) Dexamethasone: 40 mg (IM) bST: 500 mg (IM)	85 - 100%	(Luz <i>et al.</i> , 2020) ^[36]
Day 1-21: Lactation Induction Protocol Day 5: Norfloxacin + ITS applied to quarters	Standard LIP: (Hormones not re-detailed; utilized standard E2/P4 base) Norfloxacin + Internal Teat Sealant (ITS): 7 mg/kg	83.3%	(Monteiro <i>et al.</i> , 2022) ^[6]
Day -7, 0, 17: Cloprostenol Day 0-6: EB + P4 Day 7-8: EB Day 19-21: Dexamethasone	Cloprostenol: 0.25 mg (IM) Estrogen benzoate + Progesterone: 0.1 mg/kg EB + 0.25 mg/kg P4 (IM) Estrogen benzoate only: 0.1 mg/kg (IM), Dexamethasone: 0.05 mg/kg (IM)	100%	(Isola <i>et al.</i> , 2024) ^[23]
Day 1-7: Estrogen + Progesterone Day 18-20: Dexamethasone	17 β -estradiol (0.1 mg/kg/day) SC, Progesterone (0.25 mg/kg/day) SC, Dexamethasone (20 mg/animal) IM	100%	(Nagaraja <i>et al.</i> , 2026) ^[42]
Day 1-7: Estrogen + Progesterone Day 8,10,12,14: Reserpine	17 β -estradiol (0.1 mg/kg/day) SC, Progesterone (0.25 mg/kg/day) SC, Reserpine 5 mg/animal/day IM	100%	

Photoperiod Manipulation

Photoperiod manipulation involves the strategic control of daily light and dark cycles to exogenously influence neuroendocrine pathways. In the context of domestic ruminants, the primary clinical and commercial goal is to stimulate, enhance, or restore lactation (galactopoiesis) by manipulating the biological circadian rhythms that dictate hormone secretion, often utilized as a synergistic adjunct to pharmacological artificial induction of lactation (AIL) protocols.

Photoperiod manipulation begins with environmental light exposure, which is detected by intrinsically photosensitive retinal ganglion cells (ipRGCs) in the retina. The light signal is then transmitted through the retinohypothalamic tract to the suprachiasmatic nucleus (SCN) of the hypothalamus, the primary circadian regulator. Activation of the SCN suppresses sympathetic stimulation of the pineal gland, resulting in inhibition of melatonin synthesis. Consequently, circulating melatonin concentrations, the principal biochemical signal of darkness, are reduced. This reduction in melatonin subsequently modulates endocrine pathways, leading to altered prolactin secretion from the anterior pituitary gland and regulation of insulin-like growth factor-I (IGF-I) production through the somatotrophic axis in the liver. (Dahl *et al.*, 2000; Li *et al.*, 2025) ^[14, 33]

Long-Day Photoperiod (LDPP): LDPP typically consists of 16-18 hours of light and 6-8 hours of darkness.

Physiological Effects: Sustained suppression of melatonin secretion. Increased circulating prolactin and IGF-I concentrations.

Results in enhanced metabolic and endocrine signals supporting active milk synthesis. Enhanced metabolic and

endocrine signals supporting active milk synthesis and average increase of 2 to 3 kg/day (Lacasse *et al.*, 2016) ^[30].

Short-Day Photoperiod (SDPP): SDPP typically consists of 8 hours of light and 16 hours of darkness.

Physiological Effects: Increased systemic melatonin concentrations, Reduced circulating prolactin levels.

Upregulation of target-tissue receptor expression, particularly prolactin receptors in mammary tissue. Roughly 40 to 60 days prior lactation. Results in subsequent 3 to 4 kg/day increase in milk yield when transitioned back to LDPP (Crawford *et al.*, 2015) ^[12].

Phytotherapy

Phytotherapy involves the use of plant-derived compounds (herbal galactagogues) to stimulate, maintain or augment milk production. With the rising global demand for organic dairy products and the strict regulation of synthetic galactopoietics like recombinant bovine somatotropin (rBST), phytotherapy offers a viable, non-hormonal and cost-effective alternative that leaves no toxic pharmacological residues in the milk (Patel *et al.*, 2017) ^[45].

Mechanism of action: Phytoestrogenic Effects: Steroidal sapogenins structurally mimic endogenous estradiol. Bind to estrogen receptors, prompting proliferation of mammary epithelial cells & ductal branching (Kumar *et al.*, 2014) ^[29], Rumen Kinetics and Nutrient Partitioning: Saponins stimulate anaerobic fermentation in the rumen, modifying the volatile fatty acid (VFA) profile. This increases the post-ruminal availability of bypass proteins and gluconeogenic precursors required for milk lactose and protein synthesis (Li *et al.*, 2023).

Table 2: Phytotherapy protocols for Artificial induction of lactation

Herb	Active components	Effectiveness
Shatavari (<i>Asparagus racemosus</i>) (Chaudhary <i>et al.</i> , 2024)	Shatavarins I and IV: Acts via pituitary-adrenal axis to release ACTH & prolactin.	Increases alveolar cellular proliferation; total milk, solids, fat and lactose
Fenugreek (<i>Trigonella foenum graecum</i>) (Revathi <i>et al.</i> , 2020) ^[51]	Galactomannans, Diosgenin, Trigonelline: Potent phytoestrogenic activity.	Increases daily milk volume & elevates fat and protein percentages.
Anise (<i>Pimpinella anisum</i>) Fennel (<i>Foeniculum vulgare</i>) (Iommelli <i>et al.</i> , 2025) ^[22]	Anethole (phytoestrogen) Inhibit dopamine receptor. Increase serum prolactin levels & stimulate lactogenesis.	Included in commercial polyherbal galactagogue formulations such as Payapro and Galactin Vet.
Moringa (<i>Moringa oleifera</i>) (Kholif <i>et al.</i> , 2016) ^[27]	Rumen-bypass protein, essential amino acids: Enhances rumen microbial protein synthesis & improves nutrient availability for milk production.	Dried moringa leaves Moringa leaf extract increased milk yield by 65%

Table 3: Milk yield and Composition

Parameter	Natural Lactation	Induced Lactation	Scientific Rationale
Fat (%)	3.0	4.58	Influenced by breed, management, and lactation stage; levels remain within standard parameters.
Protein (%)	2.9	3.50	Milk begins with high protein (6.80% at Day 21) due to its colostrum-like nature before stabilizing.
Lactose (%)	4.3	5.20	Lactose is the main osmotic factor responsible for production; initial IL levels are very high (10.18%).
Somatic Cell Count	< 300 (x1000/ml)	133 (x1000/ml)	Reflect initial mammary epithelial desquamation, which normalizes as lactation stabilizes.
Water (%)	87.54	86.5	Induced lactation yields fewer cells, producing lower alveolar volume and more concentrated milk.
Peak Yield (L/day)	40.5	31.3	----
Consistency	Normal	Thick & Yellow (Day 1)	Initial secretion is colostrum-like due to high initial solids; normalizes in 3 to 5 day
Initial Yield (L/day)	17.3	8.2	Induction protocols don't reach to parturition signals as natural lactation
Persistency (Wood's c)	0.0034	0.0039	More days of peak yield
Total 305-d Yield (L)	10,521	8,239	78-80% Milk yield of natural lactation

Sheep and Goat

Indications for AIL in Sheep and Goat: High-Value Genetics: Superior genetic potential for milk production kept in herd rather than culled, Orphan Rearing: Production of

artificial colostrum in non-pregnant animals, Economic Continuity: To maintain a steady milk supply and Research and Model Development: To study mammary gland development & the specific hormonal triggers

Table 4: Hormonal and pharmacological protocol for induction of lactation in sheep and goats (Ovine/Caprine)

Duration	Hormones & Drugs	Dosage (Ovine/Caprine)
Days 1-7	Estradiol + Progesterone	Estradiol Cipionate: 0.1 mg/kg BW/day Progesterone: 0.25 mg/kg BW/day
Days 8-14	Estradiol Only	Estradiol: 0.1 mg/kg BW/day (Removes P4 inhibition of milk protein genes)
Days 18-20	Glucocorticoids	Dexamethasone/Flumethasone: 16 mg/head/day (Mimics fetal cortisol surge)
Days 19-21	Galactagogues	Metoclopramide: 100 mg/animal (Dopamine antagonist to surge Prolactin)
Day 21+	Oxytocin	Oxytocin: 1-5 IU (Induces milk let-down reflex)

(Mellando *et al.*, 1996)

Mare: Foaling sometimes results in an orphan foal. To raise an orphan foal, it is necessary to find an alternative milk source such as bottle-feeding or acquiring a nurse mare.

The induction of lactation can offer practical and economical advantages. Lactation can be induced in non-parturient mares that have foaled in previous years using a treatment that includes estrogen, progesterone and a dopamine D2 antagonist (sulpiride or domperidone). The diet should contain a higher proportion of concentrate. These mares were not previously pregnant, so their physiological adaptation differs from normal postpartum mares. They may not consume large volumes of feed like postpartum mares. Increasing dietary concentrate helps meet energy and nutrient demands (Daels, 2006) ^[13].

Selection of mares: Mare must have given birth and successfully nursed a foal at least once in their life, Mares that have raised several foals tend to have a mammary gland that is more developed and a more predictable maternal behavior, Mares must be in good body condition (BCS 5-6 on 1- 9 scale), free of disease and mammary abnormalities, gentle and calm, must be willing to stand confined behind a contention bar for prolonged periods of time and have a history of being a “good mother”, The success does not seem to be influenced by the age of the mare nor by the interval since the last foaling (Daels, 2006) ^[13].

Pre-treatment Management: Mare should be fed as a natural nursing mare from Day 1 of treatment, Before initiating

hormonal therapy maintain mare under artificial photoperiod for ~8 weeks (14.5 h light, 9.5 h darkness) Purpose: Advance cyclicity Improve prolactin response to sulpiride (Korosue *et al.*, 2012) ^[28]

Adoption: Introduction to foal

- 1. The discipline method:** The disciplinary action is a ple action-reaction technique by which the mare is discouraged to act against the foal. Gradually the actions shift from physical action to voice cues and within hours mares were conditioned not to react when the foal attempted to nurse.
- 2. Vaginal method:** The foal held near the mare's head while vaginal-cervical stimulation performed through vigorous massage of the external cervix with slight dilation attempts. This was done twice for two minutes at a ten-minute interval. During and after stimulation, the foal remained close to the mare's head and shoulder to allow sniffing and licking.

Sow: Inducing lactation in non-pregnant pigs is explored as a way to manage modern production challenges, such as Large Litter Sizes: Genetic selection has increased litter sizes beyond the capacity of a single sow's natural colostrum supply. Piglets require at least 200g of colostrum in the first 24 hours, it can reduce culling rates and replacement costs due to reproductive failure. (Noguchi *et al.*, 2020) ^[43]

Table 5: Hormonal Protocols for Induction of Lactation in Dairy Animals and Their Success Rates

Protocol	Schedule	Success Rate	Reference
Estradiol dipropionate (EDP): 5-10 mg (IM)PGF2α: 12 mg (IM)	Day -10 or -5: EDP InjectionDay 0: PGF2α InjectionDay 1: Start Milking	53.8%	(Noguchi <i>et al.</i> , 2020) ^[43]
Estradiol cypionate (EC): 10 mgLong-acting progesterone (P4): 300 mgProstaglandin F2α analogue (PGF): 0.53 mg IM, two doses, 12 hours apart	Day 0 (last day of estrus expression): Estradiol cypionateDay 26:Estradiol cypionate (EC)Long-acting progesterone (P4): 300 mgDay 36: Prostaglandin F2α analogue (PGF)	100%	(Cordeiro <i>et al.</i> , 2022) ^[11]

Dogs and Cats: Artificial induction or pharmacological stimulation of lactation is required when milk production is absent or inadequate during the neonatal period. The neonatal stage in dogs and cats is critical for survival, growth, and immune protection. In carnivores, early neonatal immunity and development depend heavily on maternal mammary secretions. Failure of normal lactation therefore becomes a clinically significant reproductive and neonatal management problem. Postpartum lactation disorders may occur in small animals, including agalactia (absence of milk secretion), hypogalactia (insufficient milk production). In such situations, pharmacological stimulation of lactation may be required to

support neonatal survival and reduce dependence on artificial rearing (Jensen, 2016) ^[25]. Continued milk production therefore requires adequate hormonal stimulation and suckling stimulus. (Orfanou *et al.*, 2010) ^[44].

Prolactin: Primary hormone regulating milk synthesis in mammals, Dopamine: physiological inhibitor of prolactin, Dopamine Inhibitors: increase prolactin concentrations & stimulate milk production, these drugs remove dopaminergic inhibition of prolactin release, thereby stimulating lactogenesis (Jensen, 2016) ^[25].

Protocols Used in Bitches (Metoclopramide protocol)

In bitches, a metoclopramide protocol can be used to stimulate lactation by administering metoclopramide, a dopamine antagonist, at a dose of 0.2-0.5 mg/kg orally or subcutaneously every 8 hours for 5-10 days, or until adequate milk production is achieved; its mechanism of action involves dopamine receptor blockade, which increases prolactin secretion and thereby promotes lactogenesis, while frequent suckling by puppies is necessary to maintain prolactin release, and adequate hydration and nutrition of the dam are essential for successful milk production. (Keller *et al.*, 2018) ^[26]

Milk Residues and Effects on Animals in Artificial induction of lactation

Following artificial induction of lactation, estradiol residues

decline rapidly after treatment cessation and return to physiologic levels, with a Maximum Residue Limit (MRL) of 0.04 µg/kg, while progesterone, an endogenous hormone with no established MRL, may accumulate temporarily in milk fat because of its lipophilic nature but returns to baseline concentrations after protocol withdrawal. Estradiol and progesterone residues generally peak within the first 7 days and decline to baseline levels within 14-21 days; therefore, a milk withdrawal period of 21-30 days after protocol initiation is recommended. Dexamethasone has an MRL of 0.3 µg/kg and is rapidly eliminated, resulting in only short-term concentrations in milk fat, with residues typically declining to safe levels within 72-96 hours after administration (Zanatta *et al.*, 2022; Busanello, 2025) ^[58, 5].

Table 6: Adverse effect on animals

Adverse Effect	Clinical Impact
Reproductive Dysfunction (Gümen and Wiltbank, 2002) ^[20]	Cystic Ovarian Disease (COD): High E2 doses disrupt the LH surge
Metabolic Stress (Churakov <i>et al.</i> , 2021) ^[9]	Negative Energy Balance (NEB): Induced animals lack the gradual metabolic adaptation of late pregnancy, leading to acute spikes in NEFA.
Skeletal System (Abuelo, 2025) ^[1]	Hypocalcemia: a sudden increase in calcium excretion to support colostrum and milk production, straining calcium homeostasis.
Behavioral Changes (Noguchi <i>et al.</i> , 2020) ^[43]	Persistent Estrus (Nymphomania): Exogenous Estrogen Benzoate induces "bulling" behavior, leading to physical injuries or mounting trauma.

Conclusion

Artificial induction of lactation is an effective physiological strategy for initiating milk production in non-pregnant animals through controlled exogenous hormonal manipulation. When combined with appropriate animal selection, it serves as a valuable tool in modern veterinary reproduction, dairy herd management and biotechnological research. Beyond cattle, artificial lactation induction has practical applications in nurse mare programs for foal fostering, management of agalactia in canines and support of orphan rearing in sheep and goats. Adjunctive approaches such as photoperiod manipulation and phytotherapy may further enhance milk yield and lactational performance. Artificial induction protocols can also facilitate production of normal colostrum, while the quality and composition of milk produced are generally comparable to those obtained during natural lactation. Milk yield typically reaches approximately 60-80% of that achieved during natural lactation. Furthermore, potential hormonal residues in milk can be effectively managed through adherence to appropriate withdrawal periods.

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