

Bovine Reproductive Physiology and Herd Management: Protocols for Low-Technology Breeding, Calving Assistance, and Lactation Sustenance

Introduction to the Dual-Purpose Paradigm and Herd Replenishment

The meticulous management of a bovine herd represents a highly sophisticated intersection of reproductive physiology, nutritional biochemistry, and obstetrical intervention. Achieving a steady supply of milk alongside consistent herd replenishment requires a comprehensive strategy that balances the competing physiological demands of the modern bovine.

Dual-purpose cattle—such as the Fleckvieh (German Simmental), French Normande, Shorthorn, and Brown Swiss—are expected to deliver substantial lactation yields ranging from 7,000 to 11,000 kg per lactation while simultaneously maintaining a robust, muscled frame capable of producing offspring with superior daily weight gains¹. In agricultural systems or historical contexts operating without the benefits of cryogenic freezing, advanced veterinary infrastructure, or continuous high-input feed resources, producers must rely on precise, low-technology protocols. This report provides an exhaustive analysis of the bovine reproductive cycle, ambient-temperature artificial insemination methodologies, comprehensive nutritional frameworks for sustained lactation, mechanical dystocia management, and neonatal care protocols necessary for operational success.

The Bovine Estrous Cycle and Ovarian Dynamics

The bovine female is a non-seasonal polyestrous animal, maintaining continuous reproductive cyclicity throughout the year post-puberty, interrupted only by gestation, severe metabolic deficits, or pathological anestrus⁴. The estrous cycle spans from one period of sexual receptivity to the next, averaging 21 days in length, though physiologically normal cycles may range from 17 to 24 days⁴. This cycle is regulated by a complex hypothalamic-pituitary-ovarian axis, characterized by interdependent follicular waves and the cyclical synthesis and regression of the corpus luteum⁸.

Endocrine Regulation and Cycle Phases

The bovine estrous cycle is classically partitioned into the follicular phase and the luteal phase, which together encompass four distinct behavioral and physiological stages driven by systemic endocrine shifts².

Estrus, designated as Day 0 of the cycle, is the period of active sexual receptivity and lasts an average of 18 hours, though it may fluctuate between 6 and 24 hours². This phase is initiated by peak concentrations of estradiol secreted by the dominant preovulatory follicle, which acts on

the central nervous system to induce mounting behavior, increased locomotion, and the secretion of clear cervical mucus⁴. Following the cessation of behavioral estrus, the cow enters metestrus, which persists for 3 to 4 days⁴. Ovulation occurs approximately 24 to 32 hours after the onset of estrus, triggered by a massive preovulatory surge of luteinizing hormone (LH) released from the anterior pituitary². Following follicular rupture, the site of ovulation hemorrhages to form a corpus hemorrhagicum, which rapidly undergoes luteinization under the continued influence of LH to form the progesterone-secreting corpus luteum⁴. Diestrus, spanning Days 5 through 17, constitutes the longest phase of the cycle and is characterized by maximum corpus luteum volume and steroidogenic output⁶. Elevated systemic progesterone levels suppress the frequency of hypothalamic gonadotropin-releasing hormone (GnRH) pulses, which correspondingly prevents the LH surges necessary for subsequent ovulations⁴. This hyper-progestational environment holds the uterus in a state of pregnancy preparedness. If maternal recognition of pregnancy does not occur by the late luteal phase, the uterine endometrium secretes pulsatile prostaglandin F2-alpha⁴. The transport of this hormone to the ipsilateral corpus luteum induces rapid luteolysis, precipitating a steep decline in systemic progesterone⁴. The removal of this negative feedback initiates proestrus (Days 18 to 20), allowing for accelerated GnRH pulse frequency, subsequent follicle-stimulating hormone (FSH) release, and the final maturation of the next ovulatory follicle².

Ovarian Follicular Wave Dynamics

Follicular growth in cattle does not follow a continuous linear trajectory; rather, it manifests in distinct biological waves⁶. Observational tracking via transrectal ultrasonography reveals that more than 95% of bovine estrous cycles are composed of either two or three distinct follicular waves⁸.

Parameter	Two-Wave Cycle	Three-Wave Cycle
Average Cycle Length	19.4 to 20.7 days	21.5 to 23.0 days
Wave 1 Emergence	Day 0 to 2	Day 0 to 2
Wave 2 Emergence	Day 9 to 11	Day 7 to 9
Wave 3 Emergence	N/A	Day 15 to 16
Ovulatory Follicle Origin	Wave 2	Wave 3
Preovulatory Growth Phase	9.8 days	5.0 days

Each wave is initiated by a transient elevation in FSH, which recruits a cohort of antral follicles measuring 3 to 5 mm in diameter⁸. Within 3 to 4 days of emergence, the wave undergoes a physiological process termed deviation, during which one follicle secures dominance via localized insulin-like growth factor signaling and enhanced aromatase activity⁸. The dominant follicle secretes massive quantities of estradiol and inhibin, suppressing pituitary FSH release and forcing the subordinate cohort into atresia⁴.

If a dominant follicle matures during diestrus, the prevailing progesterone environment prevents the requisite LH surge⁸. Consequently, the dominant follicle loses its dominance, enters a static phase, and eventually undergoes atresia, thereby permitting the emergence of a subsequent wave⁸. Only the dominant follicle present during the profound progesterone nadir of luteolysis will survive to undergo final preovulatory maturation¹². The number of waves dictates the overall length of the estrous cycle; three-wave cycles are physiologically longer (averaging 22.5 days) compared to two-wave cycles (averaging 19.8 days)¹². An individual cow is not genetically restricted to a single pattern and may alternate between two-wave and three-wave dynamics throughout her reproductive lifespan, influenced by metabolic status and endocrine feedback¹⁰.

Venereal Pathogens and the Economic Imperative for Artificial Insemination

Historically, bovine reproduction relied entirely on natural service, frequently facilitated by a community-owned herd sire, referred to in historical German agricultural records as the *Gemeindebulle*¹⁵. While natural mating demands minimal daily intervention, it inherently poses severe biosecurity risks, primarily the dissemination of sexually transmitted infections that decimate herd fertility¹⁸.

Bovine Genital Campylobacteriosis and Trichomoniasis

The two most economically destructive venereal pathogens in cattle are the flagellated protozoan *Tritrichomonas foetus* and the gram-negative bacterium *Campylobacter fetus* subsp. *venerealis*¹⁸. Both organisms have evolved to persistently and asymptomatically colonize the epithelial crypts of the prepuce and penis in mature bulls²². Because these pathogens are obligate extracellular organisms that do not invade deep tissue, they provoke negligible systemic immune responses in the male, rendering the bull a lifelong, silent reservoir²⁰.

During coitus, these pathogens are mechanically transferred to the female reproductive tract. In the cow, they ascend through the cervix, colonizing the endometrium and inducing severe inflammatory responses¹⁸. Infections frequently precipitate early embryonic death, mid-term abortions, and the development of purulent pyometra¹⁸. In herds relying on natural service, the introduction of these pathogens can cause pregnancy rates to plummet to 20%, significantly extending the herd's average calving interval and resulting in massive losses in both calf crop and subsequent milk yield¹⁸.

Economic Modeling of Breeding Methodologies

Beyond the absolute necessity of pathogen eradication, the transition from natural service to artificial insemination (AI) represents a profound economic and genetic optimization. Maintaining a natural service bull incurs substantial and continuous ownership costs, including forage, concentrate feed, veterinary care, housing infrastructure, and the inherent financial risk of the animal's sudden death or acquired infertility¹⁷. Comprehensive economic modeling indicates that the annual maintenance and depreciation costs of a herd sire range from \$1,445 to over \$2,100 per year¹⁷.

While AI requires an initial operational outlay for technician labor, estrus detection protocols, and semen acquisition, it eliminates the feed and housing burden of maintaining multiple bulls—a standard natural service ratio necessitates one bull for every 25 to 30 cows²⁷. Furthermore, AI facilitates access to elite global genetics. Although AI can occasionally extend the calving interval by several days due to estrus detection failures, the daughters of highly proven AI sires routinely produce upwards of 900 to 1,000 kg more milk per lactation than their natural-service counterparts¹⁷. The revenue generated by this superior genetic dividend rapidly amortizes the operational costs of AI, establishing it as the most profitable long-term reproductive strategy²⁵.

Low-Technology Artificial Insemination and Liquid Semen Preservation

In contemporary intensive dairy systems, AI is virtually synonymous with cryogenic freezing in liquid nitrogen and the use of disposable plastic sheaths. However, effective genetic transfer can be executed utilizing low-technology equipment and ambient-temperature or refrigerated liquid semen preservation, methodologies that remain highly relevant in resource-scarce environments³¹.

Semen Collection and Non-Cryogenic Extenders

Prior to the standardization of cryopreservation, semen was collected via an artificial vagina and immediately diluted in complex biochemical buffers known as extenders³³. These liquid extenders perform several critical physiological functions: they supply metabolizable energy substrates (fructose or glucose) to sustain flagellar motility, buffer the lactic acid generated by anaerobic sperm metabolism to prevent lethal pH declines, furnish lipoproteins to stabilize the sperm plasma membrane against thermal shock, and deploy bacteriostatic agents to inhibit microbial proliferation³⁴.

When liquid nitrogen is unavailable, semen must be maintained in a liquid state at either refrigerated temperatures (4°C to 5°C) or ambient room temperatures (18°C to 25°C)³¹. At 5°C , the metabolic activity of bovine spermatozoa is depressed to approximately 10% of its physiological basal rate, allowing the semen to be stored for 5 to 7 days while retaining acceptable fertilizing capacity³⁶.

Extender Name	Primary Buffer System	Cryoprotective / Membrane	Metabolic Inhibitor /	Storage Temp
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		Agent	Preservative Mechanism	
Egg Yolk Citrate (EYC)	Sodium Citrate Dihydrate (2.9%)	Fresh Egg Yolk (20%)	Cold suppression of metabolism	4° C – 5° C
Illini Variable Temperature (IVT)	Citrate, Bicarbonate, Chloride	Fresh Egg Yolk (10%)	Hypercapnic arrest via CO_2 gassing (pH 6.3)	18° C – 25° C
Caprogen	Citrate, Glucose, Glycine	Egg Yolk (5%)	Nitrogen gassing + Caproic Acid + Catalase	18° C – 25° C
Coconut Milk Extender (CME)	Natural Coconut Water + Citrate	Egg Yolk (5-10%)	Endogenous sugars and plant antioxidants	5° C – 25° C

Note: Data synthesized from historical and contemporary seminal preservation literature³¹. The formulation of the Egg Yolk Citrate (EYC) extender by Salisbury in 1941 established the foundation for modern semen processing³⁴. The sodium citrate acts as a highly effective chelating agent that disperses the dense fat globules of the egg yolk, permitting accurate microscopic evaluation of progressive motility, while the egg yolk provides the critical lecithin and phospholipids necessary to fortify the sperm membrane against cold shock³⁴. For operations entirely lacking refrigeration, the Illini Variable Temperature (IVT) extender revolutionized ambient storage³¹. By bubbling carbon dioxide (CO_2) gas through the buffered solution until the pH drops to 6.3, the IVT extender exploits the glyoxylate mechanism to reversibly arrest sperm respiration and motility, rendering the cells dormant at room temperature for up to six days³¹. Similarly, the Caprogen extender utilizes nitrogen gassing to displace reactive oxygen species, supplemented with caproic acid and the enzyme catalase³¹. The catalase actively neutralizes toxic hydrogen peroxide (H_2O_2) generated by lipid peroxidation, preventing oxidative damage to the sperm membrane during prolonged ambient storage³¹. In tropical and low-resource environments, boiled green coconut water serves as a

highly effective, naturally sterile extender, rich in complex carbohydrates, vitamins, and minerals that sustain sperm viability with minimal chemical inputs³¹.

Insemination Techniques Without Disposable Plastics

Before the ubiquity of the disposable Cassou gun and sterile plastic sheaths, artificial insemination was routinely and successfully executed using reusable glass pipettes⁵¹.

The vaginal speculum method involves the insertion of a sterilized, lubricated metal or glass tubular speculum into the vagina. Utilizing an external light source, the technician visually locates the external os of the cervix⁵⁴. A rigid glass catheter containing the liquid semen is guided through the speculum and inserted shallowly into the first annular rings of the cervix, where the semen is expelled⁵⁴. While requiring less anatomical dexterity, this method typically yields slightly depressed conception rates compared to deeper deposition techniques⁵⁴.

The recto-vaginal method remains the undisputed gold standard for bovine AI. The technician inserts a lubricated, gloved arm into the rectum to manually grasp and stabilize the cervix through the highly elastic rectal wall⁵¹. A sterilized, reusable glass pipette—often propelled by an attached rubber bulb or syringe mechanism—is passed through the vulva and vagina⁵¹. The technician utilizes the rectal hand to carefully thread the tortuous, cartilaginous rings of the cervix over the rigid glass pipette, ultimately depositing the semen precisely into the short uterine body⁵¹. In a low-technology paradigm utilizing reusable equipment, immaculate hygiene is paramount; glass pipettes must be thoroughly washed, rinsed with distilled water, and sterilized via boiling or dry heat to prevent the iatrogenic introduction of bacterial pathogens into the sterile uterine environment⁵².

Nutritional Paradigms for Dual-Purpose Herds and Steady Milk Production

Ensuring a steady supply of milk from dual-purpose breeds requires exacting nutritional precision, as these cattle must partition energy between high-volume lactogenesis and the maintenance of significant muscle mass¹. The Fleckvieh and Normande breeds, for example, exhibit unique metabolic plasticity, maintaining body condition significantly better than specialized dairy breeds while yielding high-component milk¹. However, the physiological realities of producing up to 11,000 kg of milk per lactation necessitate the accurate prediction of Dry Matter Intake (DMI)¹.

A mature dual-purpose cow typically consumes between 3.0% and 3.5% of her body weight in dry matter daily, equating to approximately 19.5 to 22.75 kg for a standard 650 kg animal¹. To fulfill the energetic demands associated with this intake, nutritionists must utilize dynamic evaluation frameworks, such as the 2023 standards published by the German Society of Nutrition Physiology (GfE), which transitions exclusively to a Metabolizable Energy (ME) system¹. Under this framework, baseline maintenance energy is calculated mathematically as

$$0.515 \text{ MJ} \times \text{BW}^{0.75}$$

¹. Lactation imposes an immense additional burden, requiring approximately 5.15 to 5.3 MJ ME per kilogram of energy-corrected milk¹. Managing the body condition of these heavy-framed cattle is metabolically expensive; accreting one kilogram of

body tissue requires roughly 32 to 34 MJ of ME, while mobilizing that same tissue during energetic shortfalls yields only 28 MJ of ME¹.

Transition Metabolism and Negative Energy Balance

Despite sophisticated ration formulation, dual-purpose cows invariably enter a state of severe Negative Energy Balance (NEB) during early lactation, as volumetric rumen capacity cannot immediately expand to match the explosive caloric demands of milk synthesis¹. The cow enters a state of homeorhesis, mobilizing substantial adipose reserves¹. Lipidomic profiling of milk during this period reveals deep metabolic shifts: elevated circulating non-esterified fatty acids (NEFAs) from adipose lipolysis are incorporated directly into milk fat, altering the balance of de novo synthesized fatty acids¹. Specific polar lipids, such as Phosphatidylethanolamine (PE 33:1), act as accurate biomarkers of this energetic deficit¹. If this massive fat mobilization is not meticulously managed via a dedicated "close-up" dry cow ration, the liver's oxidative capacity is overwhelmed, inducing endoplasmic reticulum stress and subclinical ketosis¹.

Rumen Health and Mineral Antagonisms

In dual-purpose operations where male offspring are finished for beef, aggressive concentrate feeding poses the severe risk of Subacute Ruminal Acidosis (SARA)¹. SARA occurs when ruminal pH drops below 5.8 for extended periods, destroying the ruminal epithelium and manifesting clinically through the passage of large, undigested feed particles in the feces

(particles > 4 mm exceeding 4% of fecal dry matter)¹. Mitigating SARA requires the precise formulation of physically effective neutral detergent fiber (peNDF) to stimulate rumination and salivary bicarbonate buffering¹.

Furthermore, pastured herds face complex trace mineral antagonisms dictated by soil geochemistry. The presence of excess dietary sulfur and molybdenum in the rumen leads to the formation of thiomolybdates, which bind irreversibly to copper, inducing a severe secondary copper deficiency characterized by achromotrichia, bone fractures, and reproductive failure¹. Simultaneously, the influx of high potassium from lush spring grasses depolarizes the ruminal epithelium, paralyzing active magnesium transport¹. This hypomagnesemia, colloquially known as grass tetany, can be accurately predicted when the

tetany ratio $\frac{K^+}{(Ca^{2+} + Mg^{2+})}$ exceeds 2.2 mEq/kg of dry matter, necessitating prophylactic magnesium oxide supplementation¹.

Agronomic Integration and Winter Fodder

Intensive rotational grazing bridges the gap between animal nutrition and soil health. Paddock geometry must be dynamically adjusted to balance total Animal Unit (AU) demand against real-time vegetative growth, striving to intercept grasses at their nutritional peak while leaving adequate residual leaf area to fuel rapid regrowth¹. The incorporation of deep-rooting multispecies swards, particularly herbs like ribwort plantain and chicory, confers profound drought resilience and provides secondary plant metabolites that enhance protein bypass in the rumen¹.

During winter housing, milk production relies entirely on the biochemical stability of conserved

fodder. A flawless ensiling process is dependent on the rapid, anaerobic fermentation of plant carbohydrates into lactic acid by epiphytic bacteria, precipitating a pH drop to between 4.0 and 4.2¹. Failure to achieve this acidic environment invites proliferation of *Clostridium tyrobutyricum*, which metabolizes lactic acid into foul-smelling butyric acid¹. Beyond devastating dry matter intake, clostridial spores survive passage through the bovine gut to contaminate the milk supply, causing catastrophic "late blowing" defects in cheese production¹.

Postpartum Metabolic Health and Subclinical

Hypocalcemia

The onset of lactation places an unprecedented, instantaneous drain on the cow's calcium reserves. A high-producing cow requires approximately 23 grams of calcium to synthesize 10 liters of colostrum on the first day postpartum—a demand that is nearly eight times the total normal calcium circulating in the plasma pool⁶⁷. While parathyroid hormone (PTH) and 1,25-dihydroxyvitamin D3 are rapidly recruited to mobilize calcium from skeletal reserves and increase intestinal absorption, this homeostatic mechanism frequently lags behind the mammary drain⁶⁸.

When total serum calcium falls below 1.50 mmol/L (6.0 mg/dL), the cow suffers from clinical parturient paresis (milk fever), characterized by flaccid paralysis, an autoauscultatory posture, circulatory collapse, and potentially death if untreated⁷⁰. However, a far more pervasive and economically damaging condition is subclinical hypocalcemia (SCH). SCH is defined by serum calcium concentrations falling below 2.14 mmol/L (8.5 mg/dL) without manifesting outward signs of paralysis⁶⁷.

The ramifications of SCH extend far beyond mineral imbalance; calcium is an essential second messenger for both smooth muscle contraction and immune cell activation⁶⁸. Reduced intracellular calcium severely impairs the phagocytic capabilities of polymorphonuclear leukocytes, rendering the cow highly susceptible to infectious diseases⁶⁸. Epidemiological data demonstrate that cows suffering from SCH are 3.4 times more likely to suffer from a retained placenta, 4.3 times more likely to develop metritis, and 3.7 times more likely to suffer a displaced abomasum compared to normocalcemic herdmates⁷⁰. Managing this metabolic bottleneck via prophylactic oral calcium supplementation or dietary cation-anion difference (DCAD) manipulation is critical to ensuring the cow survives the transition period to produce a steady supply of milk⁷⁰.

The Puerperium, Uterine Involution, and Endometritis

Following a successful gestation of approximately 283 days, the cow enters the puerperium—a highly dynamic postpartum period dedicated to the expulsion of fetal membranes, the physical involution of the uterus, endometrial regeneration, and the eventual resumption of ovarian cyclicity⁵.

Mechanics of Uterine Involution

At parturition, the bovine uterus is massively hypertrophied, weighing up to 10 kg⁷³. Complete macroscopic and histological involution requires 40 to 50 days, though the most dramatic

volumetric reduction occurs within the first 14 days⁷³. Driven by continued, rhythmic myometrial contractions and massive vasoconstriction, the uterus shrinks rapidly⁷³. Simultaneously, the maternal caruncles—the highly vascularized sites of placental attachment—undergo avascular necrosis⁷³. By day 5 postpartum, the necrotic caruncular stalks begin to slough off, generating a normal physiological discharge known as lochia (or secundus)⁷⁴. Lochia consists of blood, cellular detritus, and mucus; it transitions from a bloody, reddish-brown fluid to a yellowish-white discharge over two weeks⁷⁴. By day 25 to 30, the caruncles are fully re-epithelialized, and the entire uterine tract has descended back into the pelvic cavity, rendering the uterine lumen clean and prepared for subsequent embryo implantation⁷⁵.

Subclinical (Cytological) Endometritis

While clinical metritis presents with severe systemic illness, fever, and fetid discharge, subclinical endometritis (SE) is an insidious, localized inflammation of the endometrium that presents with no external clinical signs or palpable abnormalities, yet it drastically depresses conception rates⁷⁸. SE is characterized by a persistent, pathological influx of polymorphonuclear neutrophils (PMNs) into the uterine lumen long after the normal postpartum clearance phase has concluded⁷⁹. In a low-technology setting, a preliminary diagnosis can be achieved via the "White Side Test," wherein cervical mucus is collected and boiled with a 5% sodium hydroxide solution; a color change to deep yellow indicates heavy leukocyte degradation⁸¹. More definitively, endometrial cytology is performed utilizing a cytobrush or uterine lavage⁷⁹. The cellular material is rolled onto a glass slide, stained (e.g., Wright-Giemsa), and evaluated under a microscope to calculate the ratio of inflammatory PMNs to normal endometrial epithelial cells⁷⁸. The diagnostic thresholds for SE are not static; they change dynamically as the uterus heals over time:

Postpartum Interval	Diagnostic Threshold for Subclinical Endometritis
20 to 33 Days	> Polymorphonuclear Neutrophils (PMNs) ⁸¹
34 to 47 Days	> to > PMNs ⁸¹
> 40 Days (Post-Involution)	> PMNs ⁷⁸

Cows breaching these thresholds suffer from impaired embryo survival and significantly extended days open, severely disrupting the operational goal of maintaining a strict 365- to 390-day calving interval⁷⁹.

Calving Assistance Protocols and Dystocia Management

Dystocia, or obstructed labor, occurs when the expulsive forces of the dam are insufficient to deliver the fetus within the physiological timeframes of stage II labor⁶⁵. It affects up to 5.6% of all calvings, with a significantly higher prevalence in primiparous heifers due to maternal-fetal disproportion (where the calf's skeletal dimensions exceed the capacity of the immature maternal pelvic canal)⁶⁴. In mature, multiparous cows, dystocia is more frequently caused by fetal maldisposition—an incorrect presentation, position, or posture⁶⁵.

Proper obstetrical intervention is critical; delayed or overly aggressive extraction profoundly increases calf mortality, compromises passive immunity transfer due to fetal hypoxia, and inflicts severe, often permanent trauma on the dam⁶⁵.

Principles of Mechanical Extraction (Mutation and Traction)

If stage II of labor (active abdominal straining) fails to produce fetal progression within two hours, a sanitized vaginal examination and intervention are mandatory⁸⁴. The clinician must assess cervical dilation and fetal viability, and manually correct any malposture (mutation) before applying traction⁸⁴.

Traction must adhere to strict biomechanical protocols to prevent maternal and fetal injury:

1. **Application of Obstetrical Chains:** Traction must be applied using stainless steel obstetrical chains secured with a "double half-hitch" configuration⁵⁷. The first loop is positioned squarely above the fetlock joint, and a second half-hitch is thrown just below the fetlock, resting above the hoof⁵⁷. This two-point distribution of tension is absolutely critical; utilizing a single loop creates a violent fulcrum effect that routinely fractures the fragile metacarpal or metatarsal bones of the calf under heavy traction⁵⁷. The chain must be aligned along the dorsal (top) aspect of the leg to maintain proper limb angle and protect the cow's delicate vaginal mucosa from laceration⁸⁵.
2. **Force Limitations:** The maximum traction applied should never exceed the force generated by two to three adult humans pulling manually (approximately 600 lbs of force)⁵⁷. Instrumented studies utilizing the Calving Assistance Force Logger (CAF-Log) demonstrate that safe manual delivery generates a mean peak force of 95.4 kg across both legs, whereas mechanical extractors routinely exceed 188.6 kg of peak force, drastically increasing the risk of trauma⁹⁰. The use of motorized vehicles or tractors for fetal extraction is strictly prohibited, as the uncontrollable force will inexorably rupture the uterus, crush the maternal pelvis, and kill the calf⁵⁷.
3. **Vector of Pull:** Traction should initially be applied in a straight, posterior-dorsal direction until the calf's head and shoulders clear the maternal pelvic brim. Once the chest passes through the vulva, the angle of traction must arc downward toward the cow's hocks, mimicking the natural curvature of the birth canal⁵⁷. Pulling alternately on one leg and then the other (walking the shoulders out) helps ease the widest part of the calf's thorax through the narrowest part of the maternal pelvis⁵⁷.

Obstetrical Nerve Paralysis (Calving Paralysis)

The most severe consequence of fetopelvic disproportion and prolonged, aggressive traction is severe nerve damage to the dam, clinically diagnosed as calving paralysis⁹¹. As a large calf is mechanically forced through the birth canal, it physically crushes the maternal nerves against the bony ridges of the ilium and sacrum⁹².

The obturator nerve, which courses along the medial shaft of the ilium, is highly vulnerable to compression by the fetal greater trochanters, especially during "hip lock"⁹². Damage to this nerve destroys its ability to innervate the adductor muscles of the thigh (the obturator externus, pectineus, and gracilis)⁹⁴. Affected cows exhibit a wide-based stance and are unable to adduct their hind legs. If placed on slippery surfaces, the legs violently abduct laterally, causing the cow to "do the splits" (a frog-sitting posture), which frequently results in fatal hip dislocation or severe tearing of the adductor musculature⁹¹. Furthermore, damage to the L6 nerve root or the sciatic nerve (and its peroneal and tibial branches) causes loss of motor function to the distal limb, characterized by a dropping of the hock and severe knuckling of the fetlock joint, forcing the cow to walk on the dorsal aspect of her hoof⁹¹. In rare instances of extreme traction on an oversized calf, the calf itself may suffer brachial plexus injury, resulting in a dropped elbow and a knuckled forelimb⁹¹.

Neurological recovery mandates immediate, intensive nursing care. Cows must be moved to deep-bedded, high-traction flooring to prevent slippage⁹³. The hind legs must be bound together using wide canvas or nylon hobbles placed above the fetlocks, restricting the limbs to a maximum spread of 45 cm to prevent catastrophic abduction while the nerves slowly regenerate over weeks⁹¹.

Fetotomy (Embryotomy)

In cases where the fetus is confirmed dead and is too large, emphysematous, or severely malpositioned to be delivered via traction and traction, a fetotomy is the procedure of choice⁹⁶. A fetotomy involves the systematic amputation and extraction of the dead fetus in sections, bypassing the need for a highly invasive and high-risk cesarean section in an already contaminated, toxic uterine environment⁹⁷.

Fetotomy is performed using highly specialized, manual instrumentation:

- **Thygesen's Fetotome:** A double-barreled tubular instrument that guides the wire saw and protects the maternal vaginal and uterine mucosa from the violent cutting action of the wire⁹⁷.
- **Obstetrical Wire Saw:** A flexible, interwoven, multi-strand steel wire (often 27 interwoven wires in a 3x3x3 configuration) that slices through fetal bone and soft tissue via friction generated by rapid to-and-fro sawing motions⁹⁷.
- **Krey-Schöttler Hook:** A heavy-duty, double-jointed steel obstetric hook¹⁰⁰. When limbs or the head have been amputated, leaving no extremities to attach a snare to, the Krey-Schöttler hook is driven deeply into the fetal spinal column or pelvic bone, allowing the obstetrician to apply massive, secure traction to the remaining torso⁹⁹.

A standard anterior fetotomy involves progressive, calculated cuts: decapitation (looping the wire dorsally behind the ears and mandible), amputation of the forelimbs (threading the wire

between the elbow and chest, behind the cartilaginous border of the scapula), and finally a transverse bisection of the fetal trunk⁹⁷. The procedure requires copious amounts of obstetrical lubricant pumped directly into the uterus to replace lost amniotic fluids, facilitating the safe maneuvering of the wire and the atraumatic extraction of the severed parts⁹⁸.

Neonatal Immunity and Colostrum Management

Following a successful delivery, the survival of the neonate—and thereby the successful replenishment of the herd—hinges entirely on the immediate transfer of passive immunity¹⁰³. Due to the synepitheliochorial structure of the bovine placenta, there is an absolute anatomical blockade preventing maternal immunoglobulins from crossing into the fetal bloodstream in utero¹⁰³. Consequently, the calf is born entirely agammaglobulinemic, possessing a fully naïve and vulnerable immune system¹⁰⁵. The calf's survival is entirely dependent on the immediate ingestion of high-quality maternal colostrum—the first lacteal secretion produced by the mammary gland, which is highly concentrated in energy, growth factors, and predominantly Immunoglobulin G (IgG)¹⁰³.

The Mechanics of Enterocyte Pinocytosis and Gut Closure

The bovine neonatal intestine possesses a transient, highly specialized physiological window during which the epithelial enterocytes of the small intestine can absorb massive, intact IgG macromolecules directly from the lumen into the lymphatic system and bloodstream¹⁰³. This absorption is mediated by non-specific endocytosis, specifically pinocytosis¹⁰⁸.

However, these enterocytes rapidly mature and alter their cellular structure in response to enteral feeding and the mere passage of time—a phenomenon known biologically as "gut closure"¹⁰⁵. The efficiency of IgG absorption is highest immediately after birth but declines logarithmically; by 12 hours postpartum, absorptive capacity is severely blunted, and by 24 to 36 hours, gut closure is absolute, and intact immunoglobulins can no longer traverse the intestinal barrier¹⁰³.

Failure of Passive Transfer (FPT) is diagnosed when a calf fails to achieve a serum IgG concentration of $> 10 \text{ g/L}$ within the first 24 to 48 hours of life¹⁰³. To prevent FPT, rigorous neonatal protocols dictate that calves must be fed a minimum of 3 to 4 liters (approximately 10% of their body weight) of high-quality colostrum (defined as containing $> 50 \text{ g/L}$ of IgG) within the first two hours of life, followed by a second feeding at 12 hours¹⁰³. Recent studies have demonstrated that the addition of micronutrients can augment this process; supplementing the colostrum with 3.0 ppm of selenium at the first feeding has been shown to rapidly activate enterocyte pinocytosis, increasing the total absorption of IgG into the calf's bloodstream by up to 42%¹⁰⁹.

Conclusion

The successful, profitable management of a bovine herd transcends basic animal husbandry; it requires a highly integrated, systems-level approach that harmonizes reproductive endocrinology, advanced nutritional biochemistry, and precise obstetrical intervention. Mastery of ovarian follicular wave dynamics allows for the accurate timing of artificial insemination

protocols, utilizing biochemically stabilized, non-cryogenic semen extenders to circumvent the devastating biosecurity risks and economic burdens of natural service. Following conception, adherence to modern nutritional evaluation frameworks protects the heavy-producing cow from the severe metabolic consequences of negative energy balance and subclinical hypocalcemia, ensuring persistent, high-volume lactation. During parturition, strict adherence to biomechanical traction protocols and the judicious application of fetotomy prevent catastrophic neurological injuries to the dam. Finally, the meticulous management of colostrum feeding exploits the narrow biological window of intestinal pinocytosis, ensuring the successful transfer of passive immunity and securing the vitality of the next generation.

Works cited

1. 43 Dual-Purpose Cattle Nutrition Plan.pdf
2. Part 1 Endocrinology of the Estrous Cycle - The Bovine Practitioner, <https://bovine-ojs-tamu.tdl.org/bovine/article/view/1409/1403>
3. Oestrous cycles in Bos taurus cattle - PubMed, <https://pubmed.ncbi.nlm.nih.gov/20875708/>
4. the bovine estrous cycle - LSU, http://therio.vetmed.lsu.edu/the_bovine_estrous_cycle.htm
5. The Estrous Cycle of Cattle | Mississippi State University Extension, <https://extension.msstate.edu/publications/the-estrous-cycle-cattle>
6. Estrus Cycle in Cows - Partners In Reproduction, <https://www.partners-in-reproduction.com/reproductive-physiology/cattle/estrus-cycle/>
7. The reproductive cycle of cattle - Herbavita, <https://herbavita.com/en/blog/insights/the-reproductive-cycle-of-cattle/>
8. Bovine Female Reproductive Tract: Ovarian Cycles and Hormonal, <https://www.zubairkhalid.com/knowledge/veterinary-medicine/veterinary-anatomy-physiology/bovine-female-reproductive-tract-ovarian-cycles-hormonal-control>
9. Ovarian Follicular and Luteal Dynamics in Cattle | Veterian Key, <https://veteriankey.com/ovarian-follicular-and-luteal-dynamics-in-cattle/>
10. Follicular Dynamics during Estrous Cycle of Pubertal, Mature and, <https://www.mdpi.com/2076-2615/12/9/1208>
11. Ovarian follicular dynamics in cattle: a comprehensive review, <https://clinicaltheriogenology.net/index.php/CT/article/view/12843/20788>
12. Ovarian follicular activity and hormonal profile during estrous cycle, <https://pmc.ncbi.nlm.nih.gov/articles/PMC194861/>
13. The Bovine Estrous Cycle - LSU AgCenter, <https://www.lsuagcenter.com/articles/page1678995149005>
14. and three-follicle wave interovulatory intervals in Holstein heifers, <https://cdnsiencepub.com/doi/pdf/10.4141/A03-094>
15. Tierische „Angestellte“ - Westfalen/Lippe - historisch, <https://hiko.hypotheses.org/3043>
16. Gemeindebulle - Wikipedia, <https://de.wikipedia.org/wiki/Gemeindebulle>

17. (PDF) Comparison of artificial insemination and natural service cost,
https://www.researchgate.net/publication/221973090_Comparison_of_artificial_insemination_and_natural_service_cost_effectiveness_in_dairy_cattle
18. Trichomonas foetus & Campylobacter fetus Diagnostics,
<https://envirocarelab.co.za/understanding-trichomonas-foetus-and-campylobacter-fetus-hidden-threats-to-bovine-reproductive-health/>
19. Recommendations for control and prevention of Campylobacter and,
<https://nre.tas.gov.au/Documents/Beef%20Trust%20Appendix%20Recommendations.pdf>
20. The History of Bovine Genital Campylobacteriosis in the Face of,
<https://www.mdpi.com/2306-7381/10/12/665>
21. (PDF) Prevalence of Tritrichomonas foetus and Campylobacter fetus,
https://www.researchgate.net/publication/328020321_Prevalence_of_Tritrichomonas_foetus_and_Campylobacter_fetus_subsp_veneralis_among_bulls_slaughtered_in_the_state_of_Minas_Gerais_Brazil
22. 2014: Rediscovering the silent enemy in cattle reproduction health,
https://cdn.ymaws.com/www.therio.org/resource/collection/DB0508BA-DE64-46F0-BE6B-2CE2A338D52C/2014_v3_023.pdf
23. Prevalence of bovine genital campylobacteriosis and trichomonosis,
<https://pmc.ncbi.nlm.nih.gov/articles/PMC3751741/>
24. Bovine trichomoniasis: A hidden threat to reproductive efficiency,
<https://pmc.ncbi.nlm.nih.gov/articles/PMC11682740/>
25. Comparison and economic analysis of artificial insemination and,
<https://tbf.peerjournals.net/comparison-and-economic-analysis-of-artificial-insemination-and-natural-service-practices-in-murrah-buffalo-a-comprehensive-field-study/>
26. Artificial Insemination vs Natural Breeding in Cattle: Which Is Better,
<https://accuvanceindia.com/blog/artificial-insemination-vs-natural-breeding-in-cattle/>
27. Economic Impact of Artificial Insemination vs. Natural Mating for Beef,
<https://extension.msstate.edu/publications/economic-impact-artificial-insemination-vs-natural-mating-for-beef-cattle-herds>
28. Comparison of Fixed-Time Artificial Insemination vs. Natural Service,
<https://www.beefresearch.ca/fact-sheets/comparison-of-fixed-time-artificial-insemination-vs-natural-service-in-beef-cows-reproductive-efficiency-and-system-cost/>
29. Costs of Bulls Versus AI - Drovers,
<https://www.drovers.com/news/costs-bulls-versus-ai>
30. Comparative Study of Artificial Insemination and Natural Service,
<https://journal.interbull.org/index.php/ib/article/download/1031/1031/2063>
31. Ambient Temperature Semen Diluents | 18–25°C Semen Extenders,
<https://www.vetscraft.com/ambient-temperature-semen-diluents/>
32. Comparison between liquid and deep-frozen semen for artificial,
<https://www.fao.org/4/u6600t/u6600T0m.htm>
33. The history of artificial insemination: Selected notes and notables1,

- https://www.researchgate.net/publication/285423683_The_history_of_artificial_insemination_Selected_notes_and_notables1
34. Refrigerator Temperature Semen Diluents | 4-6°C Semen Extender,
<https://www.vetscraft.com/refrigerator-temperature-semen-diluents/>
 35. Artificial insemination history: hurdles and milestones - PMC,
<https://pmc.ncbi.nlm.nih.gov/articles/PMC4498171/>
 36. Semen extenders: An evaluative overview of preservative ... - PMC,
<https://pmc.ncbi.nlm.nih.gov/articles/PMC8243668/>
 37. Male Fertility & Artificial Insemination,
<https://cvet.tu.edu.iq/images/vetmednew/files/new-24-25/5th/male%20fertility%20maytham%20abdulalah/semen%20storage%202.pdf>
 38. Semen Extenders: Types and Guidelines | PDF - Scribd,
<https://www.scribd.com/presentation/747896238/05-Lecture-13-Extenders-1>
 39. Short-Term Storage of Rooster Ejaculates: Sperm Quality ... - MDPI,
<https://www.mdpi.com/2079-6382/12/8/1284>
 40. Evaluation of Chilled Dog Semen Extended With Sperm Activator,
<https://www.frontiersin.org/journals/veterinary-science/articles/10.3389/fvets.2021.764750/full>
 41. Semen Preservation Techniques and Extenders | PDF - Scribd,
<https://www.scribd.com/document/681581512/Andrology-Notes>
 42. Spermicidal Factors in Milk Extenders | PDF | Semen | Oxidative Stress,
<https://www.scribd.com/document/423356391/Extenders-Chilling-and-Room-Temperature-Preservation>
 43. evaluation of nguni bull semen extended in tris egg yolk,
<https://univendspace.univen.ac.za/bitstreams/7c337bc6-277c-4258-9483-65ffa5c408b3/download>
 44. QJAAS_26[4]_1969_pp659-664_singleton&josey.pdf,
https://era.dpi.qld.gov.au/id/eprint/11732/1/QJAAS_26%5B4%5D_1969_pp659-664_singleton%26josey.pdf
 45. International Journal of Veterinary Science - CABI Digital Library,
<https://www.cabidigitallibrary.org/doi/pdf/10.5555/20210435290>
 46. US7674576B2 - Semen extender composition and methods for,
<https://patents.google.com/patent/US7674576B2/en>
 47. The effect of amylase, catalase, and a decapacitating preparation on,
<https://www.semanticscholar.org/paper/The-effect-of-amylase%2C-catalase%2C-and-a-preparation-Macmillan/53ef600d298418e2e2023d56508aa7c8eb7a2ecf>
 48. Coconut water combined with purebred chicken egg yolk as an,
<https://e-journal.unair.ac.id/OVZ/article/download/53825/29927>
 49. (PDF) The Effects of Water-Based Coconut Extenders on Semen,
https://www.researchgate.net/publication/370382675_The_Effects_of_Water-Based_Coconut_Extenders_on_Semen_Preservation_A_review
 50. THE POTENTIALITY OF USING BULL SEMEN AT ROOM,
<https://tvj.sua.ac.tz/vet2/index.php/TVJ/article/download/426/258/1267>
 51. Livestock:: Cattle:: Artificial InseminationAnimal Husbandry :: Home,
https://agritech.tnau.ac.in/animal_husbandry/animhus_cattle_AI.html

52. Glass Pipettes | SYNGA for IVF, <http://www.synga.cz/index.php?p=glass&lang=en>
53. The history of assisted reproductive technologies: from prohibition to, https://www.researchgate.net/publication/356984564_The_history_of_assisted_reproductive_technologies_from_prohibition_to_recognition
54. Artificial Insemination (AI) in Animals - Vetscraft, <https://www.vetscraft.com/artificial-insemination-ai/>
55. Techniques of Artificial Insemination in Cow, Doe, Ewe and Chicken, <https://www.slideshare.net/slideshow/techniques-of-artificial-insemination-in-cow-doe-ewe-and-chicken/92790800>
56. A.I. Technique in Cattle - Select Sires, <https://www.selectsires.com/article/ss-blog/2020/11/10/a.i.-technique-in-cattle>
57. Stage 3 labor, or expulsion of the fetal - Beef Skillathon, <https://beefskillathon.tamu.edu/wp-content/uploads/sites/44/2015/10/beef-assisting-difficult-calving.pdf>
58. Hormonal Control of Estrus in Cattle - Management and Nutrition, <https://www.merckvetmanual.com/management-and-nutrition/hormonal-control-of-estrus/hormonal-control-of-estrus-in-cattle>
59. (PDF) Effectiveness of Coconut Water as Boar Semen Extender, https://www.academia.edu/30617414/Effectiveness_of_Coconut_Water_as_Boar_Semen_Extender
60. Canine sperm vitrification with nonpermeable cryoprotectants and, <https://www.scielo.br/j/ar/a/ddznyMYdmX6sKmFtQsYSKBr/?lang=en>
61. Effects of coconut (Cocos nucifera) water with or without egg-yolk on, [http://www.cbpa.org.br/pages/publicacoes/animalreproduction/issues/download/13/v13n2/p057-062%20\(AR724\).pdf](http://www.cbpa.org.br/pages/publicacoes/animalreproduction/issues/download/13/v13n2/p057-062%20(AR724).pdf)
62. Veterinary Andrology I Semen dilution and its preservation I Liquid I, <https://www.youtube.com/watch?v=PXxQ4NeG9CM>
63. Calving Assistance Guidelines, <https://www.vet.cornell.edu/animal-health-diagnostic-center/programs/nyschap/modules-documents/calving-assistance-guidelines>
64. Assisting the Beef Cow at Calving Time - MU Extension, <https://extension.missouri.edu/media/wysiwyg/Extensiondata/Pub/pdf/agguides/ansci/g02007.pdf>
65. Dystocia Prevention and Intervention - Iowa Beef Center, <https://www.iowabeefcenter.org/calving/dystocia.html>
66. Effect of Extender, Storage Time and Temperature on Kinetic ... - PMC, <https://pmc.ncbi.nlm.nih.gov/articles/PMC8389670/>
67. Determination of the impact of subclinical hypocalcemia on milk, <https://pmc.ncbi.nlm.nih.gov/articles/PMC12483406/>
68. Subclinical Hypocalcemia in Dairy Cows, https://ijvst.um.ac.ir/article_29243_68af83d83cb54e85516c85738930a2bc.pdf
69. The Influence of Subclinical Hypocalcemia on Production and, https://ijvm.org.il/sites/default/files/subclinical_hypocalcemia.pdf
70. Associations between subclinical hypocalcemia and postparturient, https://www.researchgate.net/publication/318297310_Associations_between_sub

[clinical_hypocalcemia_and_postparturient_diseases_in_dairy_cows](#)

71. Parturient Paresis in Cows - Metabolic Disorders,
<https://www.msdsvetmanual.com/metabolic-disorders/parturient-paresis-in-ruminants/parturient-paresis-in-cows>
72. Effects of oral calcium on reproduction and postpartum health in cattle,
<https://pmc.ncbi.nlm.nih.gov/articles/PMC11041631/>
73. Physiology and anatomy of reproduction - Puerperal period of cows,
https://www.groupe-esa.com/ladmec/bricks_modules/brick03/co/ZBO_Brick03_7.html
74. Good uterine involution for good reproductive performance | OZOLEA,
<https://www.ozolea.it/good-uterine-involution-for-good-reproductive-performance/>
75. Postpartum Period or Puerperium - Vetscraft,
<https://www.vetscraft.com/postpartum-period-or-puerperium/>
76. Management and Nutrition Tips for Uterine Involution - Virtus Nutrition,
<https://virtusnutrition.com/2025/09/18/helping-cows-bounce-backmanagement-and-nutrition-tips-for-uterine-involution/>
77. The Visual Guide to Bovine Reproduction: Uterine Involution,
https://visgar.vetmed.ufl.edu/en_bovrep/uterine-involution/uterine-involution.html
78. Endometrial cytology of cow with subclinical endometritis.,
https://www.researchgate.net/figure/Endometrial-cytology-of-cow-with-subclinical-endometritis-Wright-Giemsa-staining-Scale_fig1_323945688
79. Diagnosis of Subclinical Endometritis During Postpartum Period on,
[https://idosi.org/jri/6\(1\)15/2.pdf](https://idosi.org/jri/6(1)15/2.pdf)
80. Etiology, Symptoms, and Detection of Subclinical Endometritis,
<https://www.oculyze.net/dairy-cow-health/subclinical-endometritis/>
81. 3 Diagnosis of Endometritis – Management of Infertility in Cattle,
https://openbooks.col.org/managementinfertilitycattle/chapter_3-diagnosis-of-endometritis.html
82. Cytological endometritis in dairy cows: diagnostic threshold, risk,
<https://pmc.ncbi.nlm.nih.gov/articles/PMC5879079/>
83. Diagnosis of Subclinical Endometritis and its Effect on Reproductive,
<https://bovine-ojs-tamu.tdl.org/AABP/article/download/5305/5173>
84. Dystocia in Cattle: Causes, Diagnosis, and Management,
<https://www.zubairkhalid.com/knowledge/veterinary-medicine/theriogenology/dystocia-in-cattle-causes-diagnosis-and-management>
85. Obstetrics - LSU, <http://therio.vetmed.lsu.edu/obstetrics.htm>
86. Important tips for pulling a calf - Grainews,
<https://www.grainews.ca/cattlemans-corner/important-tips-for-pulling-a-calf/>
87. Ten Tips for a Trouble-Free Calving Season,
<https://healthtopics.vetmed.ucdavis.edu/health-topics/livestock/calving-ten-tips-trouble-free-calving-season>
88. Calving chains: Choosing them, using them and more,
<https://www.billpelton.com/calving-chains-choosing-them-using-them-and-more/>

89. Cattle Intel Kirk Ramsey obstetric chains - YouTube,
<https://www.youtube.com/watch?v=Ur6DFkdn4Bk>
90. Quantifying the Forces Applied During Manually and Mechanically,
<https://pmc.ncbi.nlm.nih.gov/articles/PMC7419429/>
91. Calving Part 3 - Nerve Damage | NADIS,
<https://www.nadis.org.uk/disease-a-z/cattle/calving-module/calving-part-3-nerve-damage/>
92. Calving-related intradural avulsion injuries of the thoracolumbar,
<https://pmc.ncbi.nlm.nih.gov/articles/PMC7649543/>
93. Calving Paralysis - Musculoskeletal System - Merck Veterinary Manual,
<https://www.merckvetmanual.com/musculoskeletal-system/lameness-in-cattle/calving-paralysis>
94. Obturator Nerve Paralysis in Cows and Buffaloes - Vetscraft,
<https://www.vetscraft.com/obturator-nerve-paralysis/>
95. Clinical Management of Obturator Paralysis in a Cow,
<https://www.cabidigitallibrary.org/doi/pdf/10.5555/20153154047>
96. Approach to difficult calvings – and the potential sequelae - Vet Times,
<https://www.vettimes.com/news/vets/livestock/approach-to-difficult-calvings-and-the-potential-sequelae>
97. Fetotomy: and its Clinical Application - epashupalan,
<https://epashupalan.com/11355/animal-husbandry/fetotomy-and-its-clinical-application/>
98. Fetotomy - CABI Digital Library,
<https://www.cabidigitallibrary.org/doi/pdf/10.5555/20153154025>
99. Part 3 | Obstetrical Instruments | Paws and Practice - YouTube,
<https://www.youtube.com/watch?v=4loXQfqYWEs>
100. Krey Schottler Obstetric Hook - Concord Surgical Supplies,
<https://concord-surgical.com/products/89>
101. Obstetrical Equipment and Instruments - Vetscraft,
<https://www.vetscraft.com/obstetrical-equipment-and-instruments/>
102. Obstetrical instruments and their uses | PPTX - Slideshare,
<https://www.slideshare.net/slideshow/obstetrical-instruments-and-their-uses/238730391>
103. Passive Immunity Establishment Through Colostral IgG Absorption,
<https://pmc.ncbi.nlm.nih.gov/articles/PMC12609626/>
104. Colostrum: back to basics with immunoglobulins - PMC - NIH,
<https://pmc.ncbi.nlm.nih.gov/articles/PMC7433919/>
105. (PDF) Bovine colostrums and neonate immunity: A review,
https://www.researchgate.net/publication/262562157_Bovine_colostrums_and_neonate_immunity_A_review
106. Effects of colostrum management on transfer of passive immunity,
<https://cdnsiencepub.com/doi/10.1139/CJAS-2020-0149>
107. Keys to Optimizing Output and Uptake of Immunoglobulin G - Frontiers,
<https://www.frontiersin.org/journals/animal-science/articles/10.3389/fanim.2022.914361/pdf>

108. Uptake of Colostral Immunoglobulins by the Com,
<https://d-nb.info/1109351380/34>
109. Selenium Addition to Colostrum Increases Immunoglobulin G,
https://www.researchgate.net/publication/5821988_Selenium_Addition_to_Colostrum_Increases_Immunoglobulin_G_Absorption_by_Newborn_Calves
110. Timing of the Intestinal Barrier Closure in Puppies - ResearchGate,
https://www.researchgate.net/publication/234041271_Timing_of_the_Intestinal_Barrier_Closure_in_Puppies
111. Colostral and foal serum immunoglobulin G levels and associations,
<https://pmc.ncbi.nlm.nih.gov/articles/PMC7316699/>