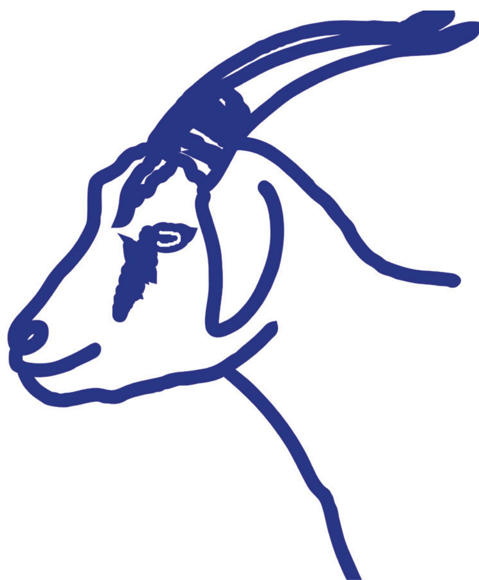
Manual for

Artificial Insemination

in the Goat

(including semen collection and fresh semen processing)



This manual was prepared for training workshops at
Egerton University, Nakuru, Kenya
and
Lilongwe University of Agriculture & Natural Resources (Bunda Campus), Lilongwe, Malawi
in support of
India–Africa–US Trilateral Partnership for Food Security
funded by the
US Agency for International Development
administered by the
USDA Foreign Agriculture Service

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Artificial Insemination in Goats

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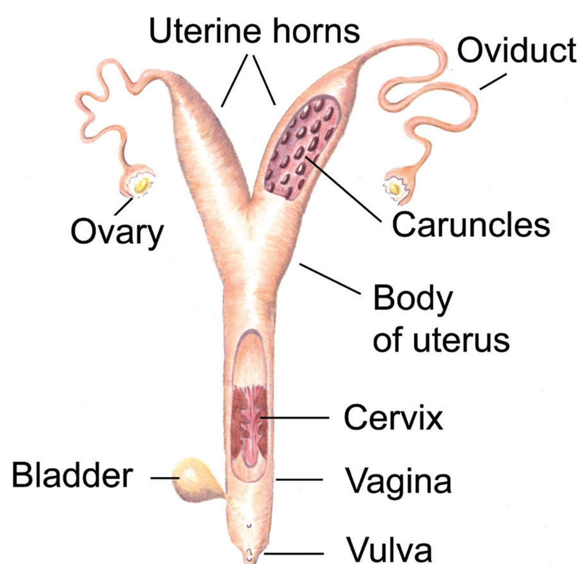
Introduction

Genetic improvement in livestock entails the selection of the animals with the "best" set of genes and allowing only them to reproduce. However, the "best" animals may not be available locally within the goat producer's herd or may be deceased. Artificial insemination using frozen semen can overcome these two obstacles. Artificial insemination using fresh semen can overcome the first obstacle but not the second. Artificial insemination using either frozen or fresh semen can preserve biosecurity measures so that disease transmission from animal-to-animal or farm-to-farm is minimized. Artificial insemination is a relatively simple tool to employ but requires some technical knowledge. The objective of this manual is to provide that knowledge.

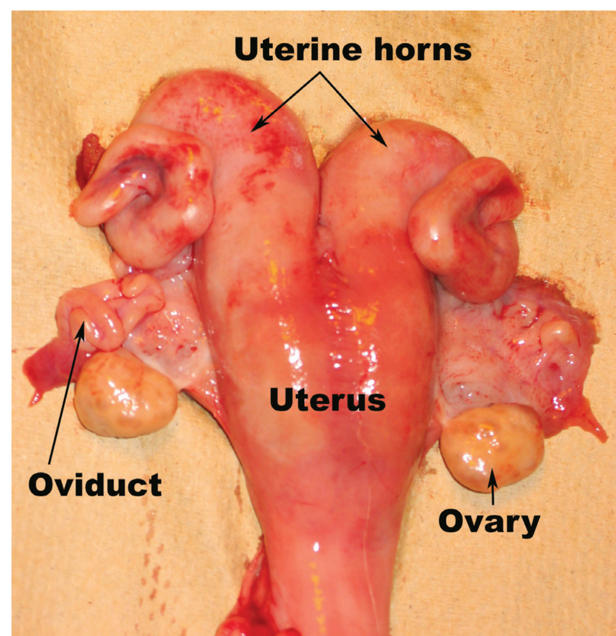
Basic Female Reproductive Anatomy and Physiology

The average length of the estrous cycle length of goats is 21 days, with a normal range from 19 to 23 days. Estrus or heat is the period of time in which the doe (female) is sexually receptive to the buck (male). Does are in estrus for approximately 24 hours and ovulate at the end of estrus.

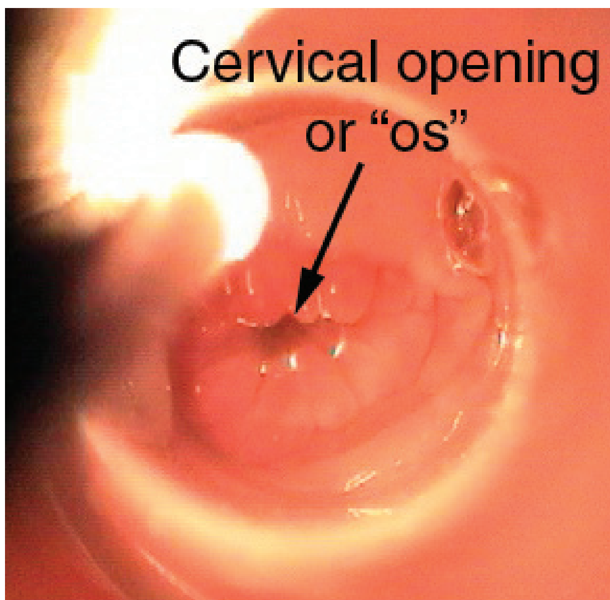
The reproductive tract of the female goat consists of several structures. Starting at the anterior (toward the head), the first structure are the ovaries, which are the primary sex organs of the female. The function of the primary follicles on the ovaries is to produce ova (eggs) and secrete a female reproductive hormone (estrogen). The next structure are the oviducts or fallopian tubes. The funnel-shaped end of the oviducts is called the infundibulum and nestles the ovaries. The oviducts are the site of fertilization. The function of the oviducts is to transport the ova, sperm, and zygote (fertilized egg) via ciliated action and muscular contractions to the next structure - the uterus. As with the ovaries and oviducts, there are two uterine horns but they connect to a single uterine body. The function of the uterus is to be the site of embryonic implantation and embryonic/fetal development. The next structure is the cervix, which is a muscular body consisting of several cervical rings made of cartilage. The opening in the cervix is called the os cervix, or os for short. The function of the cervix is to be the gateway to the uterus. During estrus, the cervix secretes a thin, clear mucus that changes consistency, elasticity, and color as estrus progresses. The next structure is the vagina and is the female organ of copulation. Thus, the function of the vagina is to receive semen during natural mating, usually in the anterior portion, which



Cut-away drawing of female reproductive tract.
Drawing by K. Williams.



Female reproductive tract.



Os cervix.

is also called the fornix. The posterior third of the vagina is called the vestibule and has both a reproduction and urinary function. The urethral orifice opens onto the floor of the vagina; thus, the vestibule is also a pathway for voiding urine. One must use caution when passing a speculum as to avoid damaging the urethral orifice. The external structure is the vulva, which is the doorway to the vagina, and consists of two vertical lips, or labia, located just below the anus.

Hormones Involved in the Estrous Cycle

The estrous cycle is controlled by hormones secreted by the hypothalamus, the pituitary, and the ovaries. Changes in day length and the presence or absence of bucks are external stimuli that can affect the estrous cycle. Primary follicles on the ovaries develop in successive waves and some will continue to become mature, rupture (ovulation), and release the ovum (egg). The released egg travels into the oviduct to join with spermatozoa, while the ruptured follicle transforms into a corpus luteum.

GnRH

Gonadotropin-releasing hormone (GnRH) is produced in the hypothalamus of the brain and controls the release of two gonadotropic hormones from the pituitary gland.

FSH

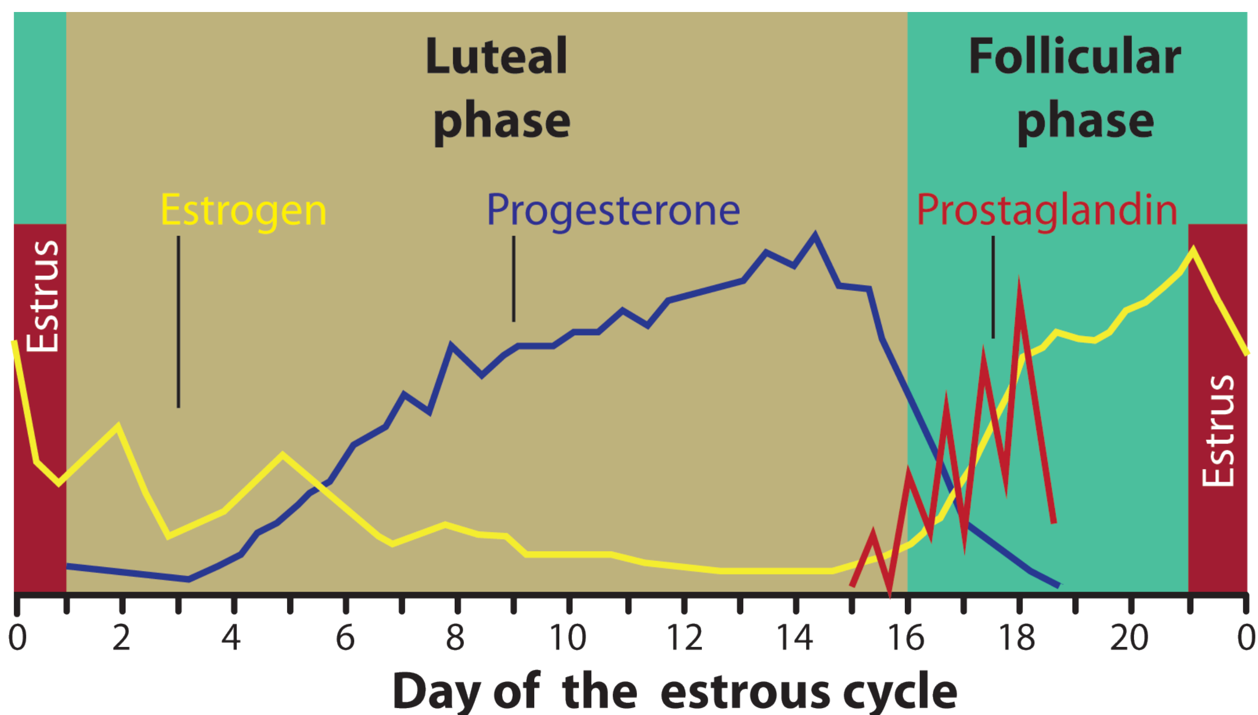
Follicle-stimulating hormone (FSH) is produced by the pituitary gland and stimulates follicle development and estrogen production.

LH

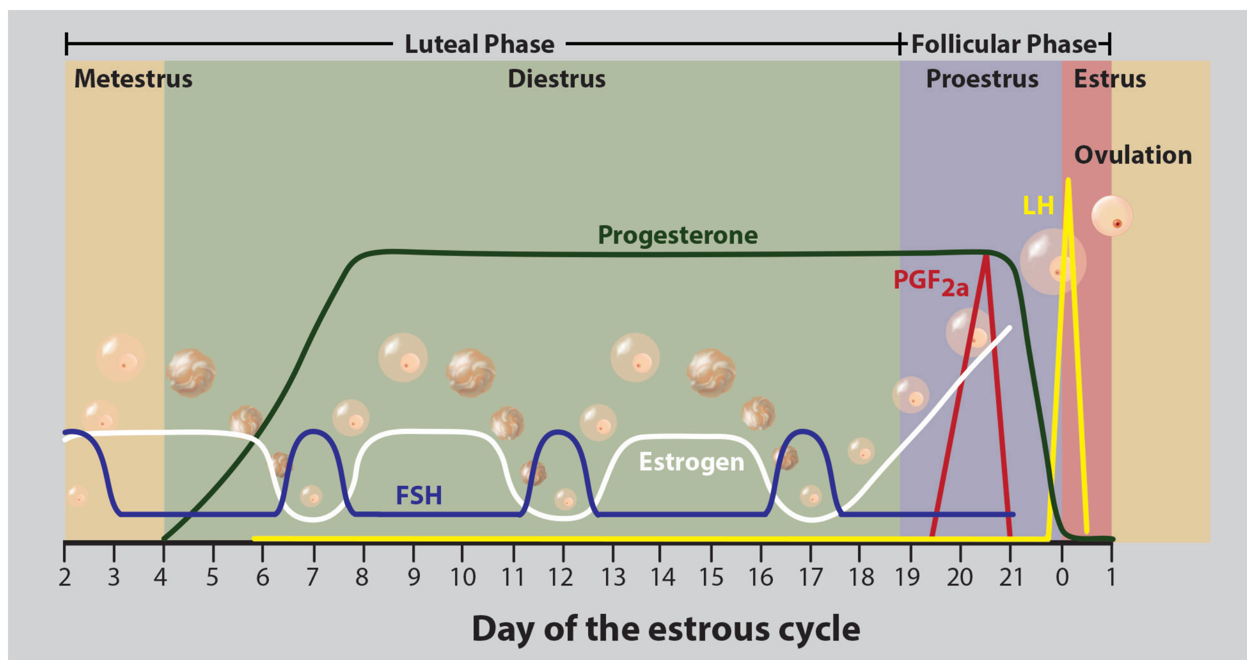
Luteinizing hormone (LH) is produced by the pituitary gland and triggers ovulation and is necessary for development and maintenance of the corpus luteum.

Estrogen

Estrogen is produced by the ovarian follicles, causes sexual excitability, increases fluid production and muscular contractions of the reproductive tract, and triggers increased release of LH.



Patterns of major hormones and the two phases of the goat estrous cycle.
Drawing by K. Williams.



Follicular waves during the estrous cycle; adapted from Simoes et al. 2006. Follicular dynamics in Serrana goats. Animal Reproduction Science 95 (1-2):16-26.
Drawing by K. Williams.

Progesterone

Progesterone is produced by the corpus luteum, prevents further estrus during pregnancy, and maintains pregnancy.

PGF$_2$a

Prostaglandin is produced by the uterine wall and causes regression of the corpus luteum when pregnancy doesn't occur.

Estrous Cycle

Estrus

Estrus or heat and is the period when the female is most sexually receptive, due to high levels of estrogen, and lasts 24 to 36 hours. Increased estrogen levels bring about a surge of LH, which triggers ovulation toward end of estrus.

Metestrus

Metestrus is the period when the corpus luteum forms and begins to produce progesterone. Metestrus lasts 2 to 3 days.

Diestrus

Diestrus is the period when the corpus luteum is highly active in its production of progesterone. If pregnancy occurs, the corpus luteum is maintained and further estrus is inhibited. If pregnancy does not occur, prostaglandin from the uterine wall causes regression of the corpus luteum. Diestrus lasts 15 to 19 days.

Proestrus

Proestrus is the period between the regression of the corpus luteum and estrus, when follicular development is occurring, and estrogen production is increasing. Proestrus lasts 2 to 3 days.

Estrus Detection

The timing of insemination is the most-important factor in determining the success of artificial insemination and timing is dependent upon successful detection of estrus. Under natural mating, the buck is the best indictor of the receptiveness of the doe. The buck will commonly exhibit a Flehmen reaction when assessing the mating receptiveness of the doe. The Flehmen reaction is when the buck curls his upper lip and inserts his muzzle into the urine stream of a female.

Buck exhibiting Flehman reaction (curling of lips) when detecting whether a doe is in estrus.

Mucus that is thick, highly elastic, and cloudy, which is indicative of proper timing for insemination.

He will often hold this position for several seconds. The Flehmen reaction is an olfactory mechanism for identifying the reproductive state of females based on pheromones in the female's urine. In addition, the doe will exhibit "standing" heat at which time she will allow the buck to mount. Otherwise, she will move away from the buck. The inseminator does not possess these advantages and must rely upon other signs/indications of estrus and for the determination of proper timing of insemination.

Signs of estrus

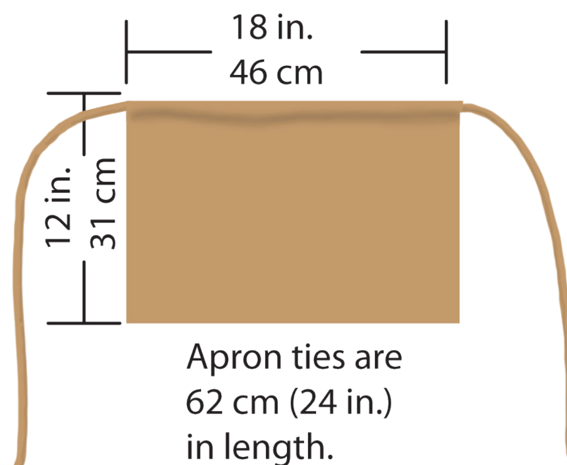
Most does exhibit easily recognized signs of estrus such as:

1. fence walking.
2. tail wagging or flagging.
3. swollen vulva.
4. homosexual activity (mounting or allowing pen mates to mount).
5. increased urination.
6. increased vocalization.
7. increased restlessness and head butting with other females.
8. increased vaginal mucus discharge.
9. decreased appetite.
10. decreased milk yield.
11. other personality changes.

For artificial insemination, possibly the most important sign is the change in consistency, elasticity, and color of the vaginal mucus and is assessed by examining the mucus located in the anterior portion of the vagina, also called the fornix. A speculum and light source are required for this assessment. Upon passing a speculum and examination of the mucus, the mucus should be thick, highly elastic, and cloudy. Mucus that is thin, water-like, and clear is an indication that the doe is too early in estrus for a properly timed insemination. Mucus that is thick, pasty, and white or pale yellow is an indication that the doe is past her proper time.

If possible, the inseminator should keep records on each doe to determine her regular cycle. Good records are a key element in good herd management and are important in the accurate determination of standing heat and also the entire length of her estrous cycle. Does remain in estrus for approximately 24 hours,

Drawing of buck outfitted with a mating apron. Drawing by K. Williams.



Dimensions of a mating apron. Drawing by K. Williams.

Teaser buck outfitted with a marking harness.

although this can vary from breed to breed and from doe to doe within breed. Generally, an individual doe will likely repeat the length of her estrus and the length of her estrous cycle on a regular basis.

The assessment of estrus can be facilitated by:

1. introduction of a teaser or intact buck.
2. fence line exposure to a buck.
3. buck jar/bag.

A teaser buck is an epididymectomised or vasectomised males that is often outfitted with a marking harness. An epididymectomy or vasectomy is a surgical procedure to cut and ligate the epididymis or the vas deferens, respectively, and in most countries, requires a licensed veterinarian to preform the surgery. A epididymectomised or vasectomised male is not fertile but will still mate with females. Therefore, venereal diseases can be transmitted from doe to doe or from herd to herd, if proper biosecurity measures are not enforced. An alternative to a teaser is an intact male outfitted with a breeding/mating apron. The apron is made of stiff material, such as canvas, and ties just behind the front legs of the buck. This allows the buck to mount but not to mate with the doe. A teaser or intact male outfitted with a breeding/mating apron is an excellent diagnostic tool for assessing standing heat.

A less valuable tool is fenceline exposure to a buck. This tool will gauge a doe's interest in the buck but will not effectively allow the inseminator to determine if she will stand for the buck. A buck jar/bag can be made by rubbing a rag on the buck's head, which is where the scent glands are located, or by clipping the beard of a buck in rut. The rag or beard is then put in a jar or in a cloth bag and offered to does once a day. A jar will concentrate the buck odor and maintain the scent longer than a cloth bag.

Estrus Synchronization

While artificial insemination can be utilized with a management style that emphasizes naturally-occuring estrus, many goat producers prefer to synchronize does for labor-saving or time-saving considerations. For synchronizing does, several options exist.

Light therapy

In temperate zones, light therapy is a very cost-effective and common practice of bringing a large number of does into estrus; however, this practice in the tropics provides less reliable results. In temperate zones, goats are seasonal breeders; coming into estrus in the fall with declining daylight length. Light therapy is accomplished by manipulating the doe's photoperiod in a controlled environment. Does are housed in a building with adequate ventilation and regular cleaning to maintain good health. However, the design of the building should be light-proof, that is, it should not allow ambient light to penetrate the interior. This light-proofing will enable the goat owner to control the length of time that the goats are exposed to light and darkness. The owner may choose

A mating apron can be made from a simple feed sack.

The presence of a buck can stimulate estrus.

to release the does to enjoy outside, natural light for a controlled period of time, or he/she may choose to control the photo stimulus by simply turning on and off the interior lighting. The same results can be accomplished using either option.

The theory is to mimic the decreasing daylight hours that naturally occur during the fall and winter months in temperate zones. When beginning the program, does could be exposed to perhaps 20 hours of light per day. Over a succession of weeks the hours of light exposure are gradually decreased until an estrous response is induced and breeding can begin.

The following protocol is suitable for employing light therapy:

1. Photo stimulation should be provided using incandescent light intensity equal to 12 to 15 foot candles at the animal's eye level for 18 to 22 hours per day over a 45 to 60 day period. This light intensity can be achieved by using bulbs giving 400 watts of incandescent light for each 4 × 4 square meter block of the barn. This provision of light should bring about an anestrous period in the subjected herd of does.
2. Following the 45 to 60 day period of light stimulus, the does should be exposed to decreasing length of the daily photoperiods. If done correctly, this will mimic the onset of fall and winter daylight hours. Six to eight weeks following the termination of the extended light period, the does should be exposed to bucks in rut. Once the bucks are introduced, fertile estrus can be expected 10 to 20 days later.

Buck effect

Utilizing the buck effect is a very simple and cost-effective means of inducing estrus in the doe earlier than would naturally occur. It is, however, not 100% reliable in its results and is not nearly as effective as light therapy in initiating off-season estrus. This protocol is more useful when the goal is to bring one or several does out of seasonal anestrus and into estrus as many as several weeks earlier than would normally be expected. This can be accomplished with reasonable success by first removing buck(s) of any age from the doe's line of sight and sense of smell for an extended period of time, perhaps as long as several months. Three to seven days prior to the time of desired estrus in the does, a buck(s) should be brought within immediate fence line contact. A young, virile buck, in his prime, will facilitate sensory stimulation by his odor, behavior, and vocal expressions. Within a few days behavioral estrus should begin to be seen in many, if not all, of the exposed does.

Hormonal treatments

Progesterone implants

Progesterone implants provide controlled release of progesterone, thereby preventing the normal estrous

cycle. Once removed and in the absence of progesterone, the normal estrous cycle resumes and estrus can be expected within 24 to 36 hours. Progesterone implants come in a variety of forms and should be used according to veterinary instruction.

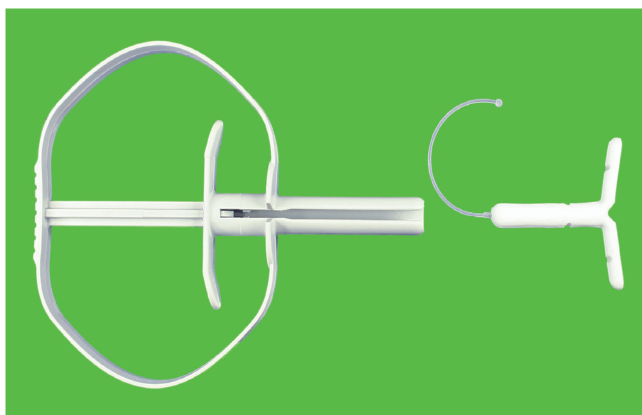
The most popular progesterone implant is known as a Controlled Internal Drug Releasing (CIDR®) device. The CIDR® is made of an inert silicone elastomer that is non-porous and does not readily absorb bodily fluids. The producer is cautioned to only use CIDR®'s designed and sized for use in sheep or goats, not bovines. The CIDR® made for use in sheep delivers 0.3 g of progesterone. A CIDR® designed for small-ruminant use, when used with full-sized goats and according to manufacturer's instruction, can be used both safely and effectively with no vaginal trauma or other negative results. The CIDR® has been found to be the most cost effective device providing ease of use for the producer. It should be inserted using an applicator specifically designed for this purpose.

Once properly inserted deep into the doe's vagina, the CIDR® unfolds into a "Y" like formation that aids in retention. Be aware that it is not uncommon for pen mates to grasp the bulb at the end of the clear plastic string that protrudes from the doe's vulva and will remove the device. Some producer's have found that cutting off the bulb end, helps to avoid pen mates taking notice of the device's existence in the doe. Daily monitoring of the device is advisable to confirm that it has not been inadvertently removed. Some producers running large herds choose to color the clear plastic line with a brightly colored paint or enamel. Although this may draw more attention by pen mates, it enables easy monitoring of the device during routine feeding and as a daily management protocol.

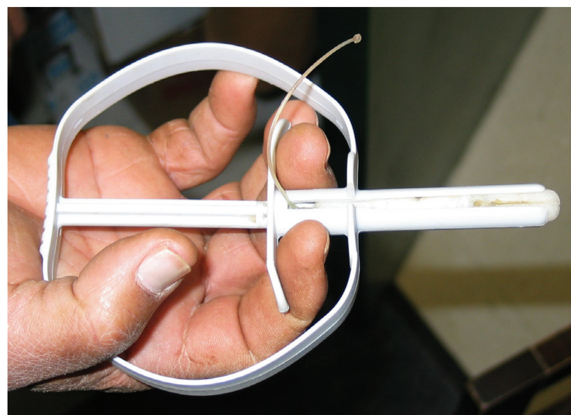
CIDR®s are impregnated with enough progesterone to last approximately 24 days. If used for a short duration (8 to 12 days), then studies have shown that CIDR®s may be reused once. Upon removing the CIDR®s, the producer should clean them with a mild disinfectant, dry them thoroughly, and store them in a ziplock bag in a cool, dark place until they are ready for a second use. After the second use or if used longer than 12 days, then the CIDR®s should be discarded and not used again.

In many countries, a progesterone-impregnated vaginal sponge or pessary, such as Veramix®, inserted into the vaginal cavity is a very easy means for the goat producer to maintain progesterone levels in the doe. The vaginal sponge is a porous sponge-like material that is comfortably retained by the vagina until its time of scheduled removal. The sponge can be properly inserted deep into the doe's vaginal cavity using a well lubricated, large sized speculum or oversized syringe that has been cut off and sanded to smoothness. For removal, depending on the manufacturer, a fine piece of "fish line" type material or string is attached to the sponge and protrudes from the doe's vulva while implanted. The sponge is removed by pulling gently on the string. One disadvantage of the vaginal sponge is the porous material of which it is constructed. Although the texture affords good comfort for the doe, it also acts as a host for bacteria and can trap other debris that may enter the vaginal cavity. Bacterial growth can occur that may cause a potential vaginal or uterine infection. In some cases, fetal abnormalities have been reported when vaginal sponges have been used.

Previously, many producers utilized an implant labeled for cattle, known as Syncro-Mate B™, with good success. Although Syncro-Mate B™ is not currently available in the U.S., it is worthy of consideration in the event the implant again becomes available. This norgestomet implant resembles a small pellet and is "injected" using an applicator made specifically for this purpose. The implant is often cut in half to provide a 3 mg dose (half the bovine dose), and is deposited just under the surface of the loose skin



CIDR and applicator.



Loaded applicator.

found at the side of the tail web of the goat. Though less recommended, it may also be implanted at the base of the ear as is done with cattle. An experienced technician should be employed for both the insertion and the removal of the cylindrical shaped implant. For easy removal it is important that the implant be deposited just under the first layers of tissue, and not deep in the fat that may be present in the tail. If not deposited properly, the implant can migrate deeper into the fatty tissues making removal difficult.

Prior to the implant's removal, a small injection of anesthetic just under the skin is necessary to deaden pain in the surrounding tissue. The implant can then be easily and painlessly removed by way of a small incision made with a sterile scalpel at one end of the implant. Using a forcep or tweezer, the implant should be extracted, and once removed, an antibiotic ointment applied to the small incision.

Whatever form of implant selected, it is best to follow the manufacturer's labeled instruction on its proper use and application. Once the implant is removed, a majority of does will exhibit estrus within 24 to 48 hours. However, insemination should not occur until proper timing is achieved for the technique the producer wishes to use. It should also be noted that intravaginal progesterone delivering devices could lend some additional "color" to vaginal mucus. This can be deceiving to an inexperienced technician unfamiliar with working with such a device and who is using mucus color and consistency to gauge a doe's stage of estrus.

Progesterone feed supplement

Melengestrol acetate (MGA), a progesterone feed supplement, has been used in cattle, horses, and sheep. However, its efficacy in goats has yet to be established. As with any feed supplement, constant monitoring of each animal's intake is necessary and can prove labor intensive for the large producer. In group-fed animals given unrestricted feed access, dominant animals will invariably disrupt each animal from ingesting a proper dose. Individual feeding or other methods of solving this problem may prove impractical for the average producer. However, with proper management and equipment design, a feeding program utilizing a progesterone feed supplement is worthy of consideration.

Prostaglandin treatment

Although not affording the same reliability and consistency of results as progesterone therapies, prostaglandin injections also have proven a cost effective means of producing a synchronized heat for the

Lutalyse® is commercially available prostaglandin product.

producer. The length of time in which the producer can expect an apparent estrus response, if indeed one is even achieved, also varies considerably according to dosage administered, breed of goat, geographic location of the animal, and time of year. Time of year is important to the producer because prostaglandin is only effective if a corpus luteum is present on the doe's ovary. If no corpus luteum exists, the prostaglandin injection is useless in stimulating estrus. Another discouraging result of prostaglandin use can be a showing of behavioral estrus, but no ultimate ovulation. This may be due to a variety of reasons including the lack of sufficient LH (luteinizing hormone) in the doe's system to elicit such a response.

Favorable results using prostaglandin injections have occurred with the following protocol:

1. Day one; 2 cc of prostaglandin administered intramuscular injection (IM).
2. Day eleven; 2 cc of prostaglandin administered IM.
3. Hour 48 to 52; doe shows signs of estrus.
4. Hour 48 to 72; doe is carefully monitored for stage of estrus.
5. When evidence that a proper stage of estrus is apparent (internal vaginal mucus appears cloudy, showing evidence of good elasticity with a viscous consistency and form), doe is inseminated.

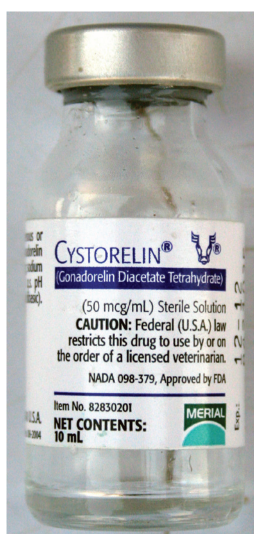
It is good to recognize that prostaglandin in any dosage could cause a fetal abortion in a pregnant animal. Great care and caution should be taken in the exposure of such a product to animals at any stage

of gestation if a termination of pregnancy is not the desired result.

Combinations

Progesterone, prostaglandin, and follicle-stimulating hormones can be used in combination to tighten synchrony. Options are presented in the table below

Event	Prairie View A&M	Langston #1	Langston #2	NC Synch
CIDR	In for 7 days	In for 10 days	In for 6 days	Not used
Prostaglandin (Lutalyse®)	1 ml given 3 days before anticipated AI and at time of pulling CIDR®s	2 ml given 3 days before anticipated AI but 24 hours before pulling CIDR®s	2 ml given when inserting CIDR®s	3 ml given at Days 0 and 14
GnRH (Cystorelin®)	1 ml given when inserting CIDR®s	Not used	Not used	1 ml given at Days 7 and 17
PMSG/eCG (PG-600®)	Not used	2 ml (half-dose) given 2 days before anticipated AI and at time of pulling CIDR®s	2 ml (half-dose) given 2 days before anticipated AI and at time of pulling CIDR®s	Not used
Diagram	CIDR (in) + GnRH CIDR (out) + PGF$_{2\alpha}$ IA 0 7 10 Day	CIDR (in) PGF$_{2\alpha}$ CIDR (out) + PMSG IA 0 9 10 12 Day	CIDR (in) + PGF$_{2\alpha}$ CIDR (out) + eCG IA 0 6 8 Day	PGF$_{2\alpha}$ GnRH PGF$_{2\alpha}$ GnRH + IA 0 7 14 17 Day



Cystorelin® is a commercially available GnRH product.

PG-600® is a commercially available eCG product.

Restraining the Doe for Artificial Insemination

Proper restraint of the doe is necessary to ensure the safety of the doe and the inseminator during the insemination process. The doe should be comfortable and should experience a minimum amount of stress. Excessive stress can have adverse effects upon the success of the inseminating event.

Restraining in a horizontal plane

A metal or wooden stanchion is not essential but provides a steady elevated base for the inseminator and a more comfortable working position for the doe. The head gate should be narrow enough so that the doe cannot escape but wide enough not to cause discomfort. An assistant steadies the doe and maintains the doe on the stanchion. Many inseminators find it helpful if the assistant puts his/her leg under the abdomen of the doe. This will raise the hind feet of the doe, which will minimize movement of the doe and will help elevate the reproductive track making it easier to locate the os. The assistant can hold the tail of the doe to remove any obstacle that it might provide the inseminator.

Assistant with foreleg under doe for added stabilization.

Doe on a metal stanchion.

Restraining in a vertical plane

Without a stanchion, restraining the doe in a vertical plane is a desirable option. An assistant is essential for restraining the doe. The assistant stands with the doe's neck between his/her legs, which act as a head gate. The inseminator lifts the hind legs of the doe and the assistant grabs the cannon bones just below the hock on both hind legs. In twisting his/her hands slightly inwardly, the assistant will allow the stifle of the doe to rest on his/her forearms. The majority of the weight of the goat is then on the forearms of the assistant.

Restraining the doe in a vertical plane.

Artificial Insemination

Artificial insemination is a simple technique that, when performed with skill properly founded on knowledge, offers ease of use and a good level of success. However, results can be discouragingly poor for an inseminator lacking knowledge and the necessary attention to details needed for a successful outcome.

It is good to keep in mind that the success of any artificial insemination program is largely dependent on three primary factors:

1. The use of live/viable fresh cooled or frozen semen.
2. The appropriate timing of insemination in relation to estrus and ovulation.
3. The proper deposition of semen in the doe.

Not every doe is a good AI candidate. Does who do not cycle normally every 17 to 24 days with regularity or who are difficult to determine when and if they are in estrus should be lesser candidates in an AI program.

Cervical vs trans-cervical artificial insemination

Success Rate of AI by % Pregnancy Rate (PR).

Method	PR (%)
Vaginal	< 15-25
Cervical (CAI)	<40-45
Transcervical (TAI)	55-65
Intrauterine (LAI)	80-90

Under natural service (using a buck), the buck deposits the semen in the fornix of the vagina and the success (pregnancy) rate is generally near 95%. If the inseminator deposits semen in the same location, the pregnancy rate is generally less than 25%. If the inseminator is unable to traverse the cervical rings and deposits the semen within the cervix, then the pregnancy will nearly double to 45%. If the inseminator is successful in traversing all the cervical rings and is able to deposit the semen in the body of the uterus, then pregnancy rate can rise to near 65 to 70%.

Proper semen deposition

Many inseminators will check heat once in the early morning and once in the late afternoon with a teaser buck or an intact buck outfitted with a mating apron. Those does found to be in standing heat in the morning are scheduled to be inseminated in the afternoon and does found in standing heat in the afternoon are scheduled to be inseminated the next morning. If a doe is still in standing heat at the next heat check, then a second, or even a third, insemination can be scheduled. This decision is contingent upon the price of the semen and the availability of the inseminator.

Weight of the doe resting on the forearms of the assistant.

Insemination assistants utilizing a vertical orientation for the conduct of artificial insemination.

The mucus consistency, elasticity, and color should be verified on the does scheduled for insemination. If the mucus has the proper properties, then insemination can continue. If not, the doe should be returned to the herd and heat check procedure continued.

Determining the proper time to inseminate is not only critical with regard to the condition of the spermatozoa and ovum (egg) when they come in contact with one another, but also is critical to facilitate proper placement of semen in the reproductive tract. It is necessary that proper timing be achieved to allow the artificial insemination gun to penetrate and traverse the cervix prior to semen deposition. A properly timed procedure should allow for relative ease in manipulating through the cervical rings. However, young or maiden does will prove markedly more difficult and are not advised for the beginning inseminator. Even mature does, if stressed or made uncomfortable due to rough handling, poorly designed or ill-used equipment, can become so tense as to constrict the muscular canal of the cervix rendering its penetration past the os nearly, if not totally, impossible. It cannot be overstressed that artificial insemination should be performed with a slow, determined, but gentle approach with adequate time allowed to follow proper protocols.

Semen should be deposited within an approximation of like timing to the occurrence of ovulation. Ovulation occurs just before or shortly following the end of the doe's standing heat. Once the semen is properly deposited, it is believed that fresh semen can remain viable for over 12 to 24 hours in the doe's reproductive tract. Processed and frozen semen is compromised to some degree and can be expected to have a somewhat shorter time of viability.

Artificial insemination equipment and supplies

Some basic equipment is required for the inseminator to perform cervical and/or trans-cervical insemination effectively. Ultimately the doe's comfort should be in the forefront of the inseminator's mind in the selection of tools to use. Basic equipment necessary for artificial insemination includes:

1. Carrying case.
   - A compact metal or plastic case for the safe and clean storage of equipment.
2. Artificial insemination (AI) gun.
   - A goat length (usually 30 cm) device used for the depositing of semen via a ¼ or ½ cc straw; available in a variety of styles.
3. AI gun sheaths.
   - Disposable, sterile, individually wrapped outer plastic shells which fit over the gun providing a secure seat for the straw. Each AI gun requires a specific style of sheath to accommodate the gun's specific design.
4. AI light.
   - A compact light source which should attach securely to the vaginal speculum. The most easily used light sources are independent of a battery pack, generate little to no heat, and are unobtrusive in design.

AI gun and sheath for goats.

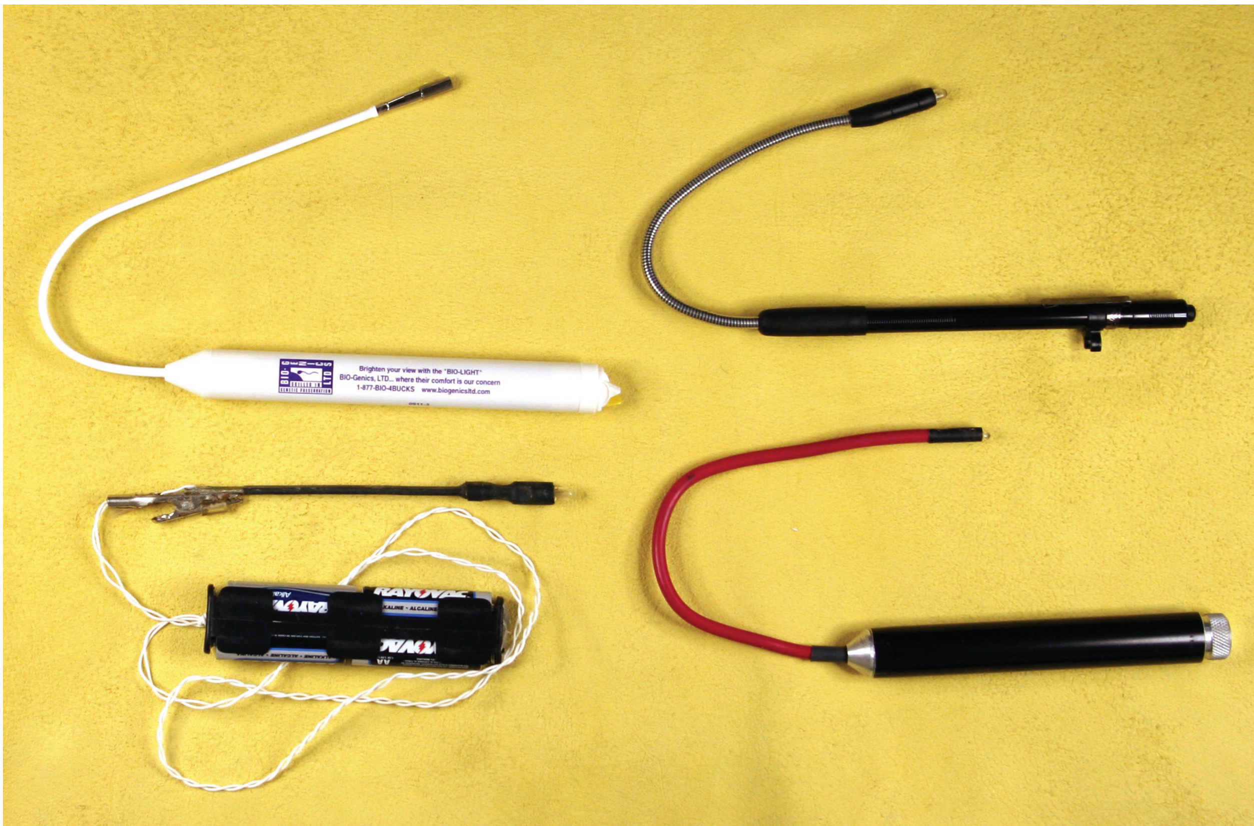
5. Vaginal speculum.
   - When used in conjunction with a light source, enables the clear view of the cervical os.
6. Speculum brush (bottle brush).
   - A soft brush, sized to provide thorough cleaning of the vaginal speculum.
7. Straw cutter or scissors.
   - For proper seating in the AI gun sheath, this device delivers the critical square cut to the end of the semen straw. Scissors will work well as a cutter. However, scissors tend to flatten the end of the straw and the end of the straw needs to be rounded with a gentle roll of the fingers before it is inserted into the gun.
8. Non-spermicidal, sterile lubricant.
   - Used for the lubrication of the vaginal speculum prior to its insertion.
9. Semen thaw unit.
   - A device designed for the proper control of the semen straw's thawing process. The unit should be compact in design, providing optimal thermal protection, complete with a thermometer, as well as both water and dry bath compartments.
10. Straw tweezers.
    - Used for the retrieval of straws from the liquid nitrogen tank and from thaw unit. Available in both 0.25 and 0.5 cc sizes

Other items needed:

- Fresh cooled or frozen semen.
  - Packaged in ¼ or ½ cc straws.

If using frozen semen, additional required equipment includes:

- Liquid nitrogen storage tank.
  - Available in a variety of sizes, storage capacities, and duration of hold times; an over-sized thermos of a sort, to be filled



Different types of AI lights.

A simple light source can be constructed of locally available materials. Here a light source is constructed using an inexpensive flashlight (torch), lamp wire, and a drinking straw.

with liquid nitrogen, for the long term cryogenic storage of semen.

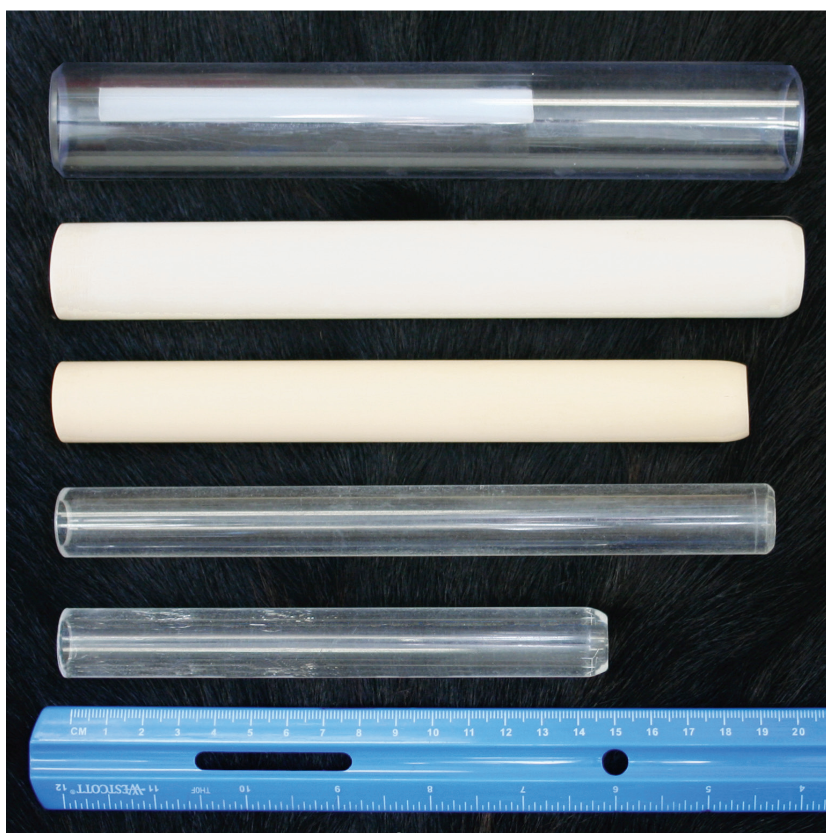
- Liquid nitrogen tank measure stick.
  - For the measuring and accurate monitoring of the volume of liquid nitrogen contained within the storage tank.

Optional equipment includes:

- Microscope.
- Of mid-grade or better quality with a tungsten or halogen light source and capable of examining specimens at a minimum of 100× and 400× magnifications; used for basic thawed semen observations and analysis.
- Microscope slides.
  - The platform on which the thawed semen sample is dispensed for viewing with the microscope.
- Microscope cover slips.
  - A small piece of plastic or glass used to cover the semen sample, allowing its proper viewing.

Goat AI Procedure

1. Assemble equipment.
2. Restrain doe.
3. Wipe dirt from around vulva – no soap is used as this is spermicidal.
4. Put lubricant on the speculum.
5. Insert speculum into vagina and attach light source.
6. Locate os of cervix (opening of cervix).
   a. Evaluate os – does it appear open or closed.
   b. Evaluate mucus – is it clear (early heat) or somewhat cloudy (later heat, more appropriate for insemination).
7. If doe is ready for insemination remove speculum.
8. Thaw semen.
   a. Remove from semen tank and put in thaw jar within 3 seconds.
   b. Thaw jar temperature should be 95°F (35°C).
   c. Thaw semen for approximately 15 – 30 seconds, can be longer.
9. Remove straw from water, wipe off water.
10. Cut the crimped end with straw cutter, do not cut end with plug.
11. Load into insemination gun.



Speculums come in a variety of materials and sizes. The two white speculums are made from PVC plumbing pipe.

12. Put on appropriate sheath.
13. Keep gun warm until needed.
14. Reinsert speculum as described previously.
15. Locate os of cervix.
16. Insert insemination gun into os and try to penetrate into cervix.
    a. Generally there will be 5 cervical rings, count the rings as they are passed.
    b. Do not deposit semen into one uterine horn, deposit inside cervix.
    c. Sometimes will not penetrate and need to deposit inside cervix.
17. Deposit semen slowly over at least 5 seconds, watch the cervical opening to see if any semen "backs up" out of the cervix.
18. Slowly remove the insemination gun to avoid creating a vacuum effect pulling semen out of the cervix.
19. Remove the speculum and record time of mating, buck number, doe number, mucous characteristics, time of mating, inseminator's name, comments on heat characteristics, any further comments.
20. Place the speculum in a bucket of water to wash.
    a. Speculums can later be sterilized by boiling or baking, dried and individually wrapped in paper towels until next use.

Semen Collection

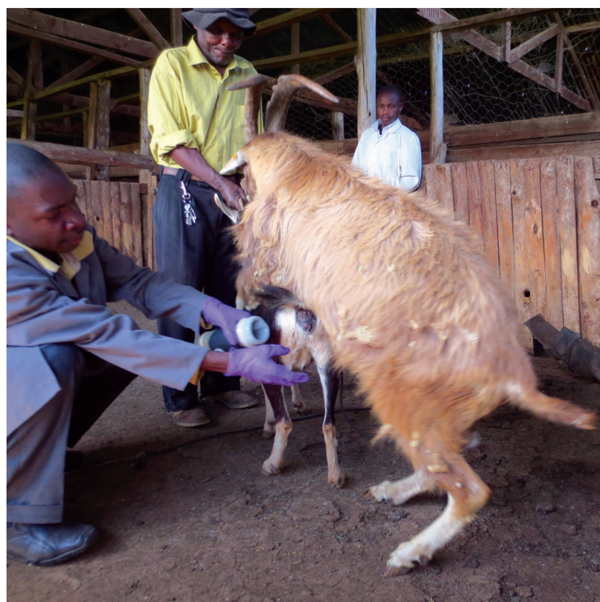
Breeding Soundness Examination

Breeding success depends on the reproductive health of both the female and the male. Because a male is expected to service a number of females, determining the potential fertility of the male is much more important than determining the fertility of any individual female.

A breeding soundness examination (BSE) will not ensure the fertility of a buck but will allow a processor the opportunity to screen bucks.

Physical examination

Evaluation of testicular consistency and scrotal shape, and the examination of the sheath, prepuce, and penis are important parts of the external reproductive examination. Palpation of the testicles can determine consistency. Testis should be firm with a slight spongy feeling. Mushy testis or enlarged epididymis could be a sign of infection or other abnormality. Sperm production only occurs at a temperature slightly lower than the rest of the body. Some scrotal shapes can affect sperm production. A general health examination is the last component of the physical. In natural mating scenarios, the male must be able to walk long distances as well as complete the act of breeding. Physical disabilities such as lameness, arthritis, sole abscesses, and footrot can interfere with mating ability but can also affect sperm production if the male spends a lot of time lying down.



Collecting a buck using an artificial vagina.

Scrotal circumference

Scrotal circumference (SC) is the most controversial component of the BSE. SC is highly correlated to testicular weight which in turn is highly correlated to sperm producing capacity. Generally, each gram of testicle produces 15 million sperm per day. Total sperm production for both testicles averages 6 billion a day. Semen volume and concentration are important factors in determining the number of straws of semen that can be produced from one ejaculate and are discussed in later sections.

Semen characteristics of bucks.	***Average***	***Range***
Daily testicular sperm production (billion, 1×10^9)	6.0	1.0-7.2
Ejaculate volume (ml)	1.0	0.5-1.5
Ejaculate concentration (billion/ml)	3.0	2.0-4.0

Semen collection using an AV.

Semen quality

Semen motility and morphology are very important factors determining the fertility of the buck and are discussed in detail in later sections.

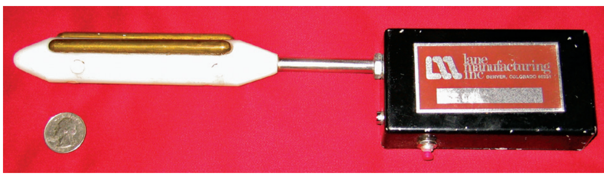
Libido/mating ability

Libido is the sexual desire, or in other words, the eagerness of a male to breed a female and is the component of BSE most difficult to measure. Under natural service, the most common way to evaluate mating ability is to observe a male on pasture with a group of females. However, libido can be easily evaluated during semen collection.

Artificial vagina

The collection of buck semen is accomplished, most commonly, by the use of an artificial vagina (AV). The AV uses thermal and mechanical stimulation to stimulate ejaculation. It is about 20 cm in length and has an inner diameter of about 6 cm. It has an inner rubber liner (containing water at an initial temperature of 42° to 48°C, the AV will cool to the appropriate temperature of 37° to 39°C by the time that it is ready to use) placed between the liner and the wall. A latex rubber collection cone is placed in the AV and a graduated collection tube is placed on the end of the cone. The buck is collected for semen evaluation or processing by allowing him to mount a doe in heat or a wether. The usual procedure is to use a teaser doe (doe showing signs of estrus) which is restrained so that the buck becomes aroused and can mount her. The teaser doe can be in natural heat

Components of an AV.



Electroejaculator.

or one induced by a prostaglandin product. A doe in heat usually stands better for a buck than a wether. She emits a smell when in heat that excites the buck and causes the buck to give a better ejaculate. The doe is usually tied or held and the buck allowed to go through his courting behavior. The buck is allowed a few false mounts, which also gives an increased ejaculate volume.

Generally, it takes two people in close proximity to the buck to perform a collection; one to semi-restrain the doe and one to direct the penis into the AV. The stimulation provided by the AV's warm water bladder, lubrication, and pressure produce an ejaculation. The collection tube containing the ejaculate should be protected from direct sunlight and cold temperatures.

The natural inclination of the buck is to shy away from people in close proximity. Proper training will overcome this natural shy behavior and also will overcome the buck's hesitancy to ejaculate into the AV. The time required to properly train bucks varies and depends upon the personality of the buck. Typically, exposure to a simulated collection event, complete with teaser animal and AV, 2 or 3 times per week with 2 or 3 events per day, which mimics a real collection, will provide satisfactory results in 2 to 3 weeks for even the shyest buck.

Electroejaculation

On occasion, if a buck should refuse to mount or ejaculate into the AV, it may be necessary to collect his semen by way of electroejaculation (EE); however, this is not the preferred method. If not performed with proper technique, expertise, and the use of quality equipment, an ill-performed procedure can be extremely painful for the donor buck and the results of such methods can be less than desirable. Electroejaculators come in a variety of shapes and sizes can be used when the buck is physically unable to mount, or a suitable mount is not available. Most processors have obtained a greater volume of semen but of lower concentration of spermatozoa with EE that with an AV. Some animals do not respond well to the electrical stimulus, especially if a second or third collection is desired. Further, there is some danger of contamination of the semen sample with urine. Greater concentrations of sodium and potassium were found in both the sperm and seminal plasma obtained by EE. The increased volume of seminal plasma obtained by EE appears to reduce the resistance of sperm to cold shock and decreases the post-thaw survival rate of frozen semen.

Limited comparisons of fertility showed that the conception rate at first service was 17% higher when semen was collected with an AV than with EE. However, other reports have not found a significant difference in fertility with semen collected by these two different methods.

Semen Evaluation

Immediately after collection, semen should be placed in a water bath at 37°C in order to prevent cold shock and promptly evaluated. The goal of semen evaluation is to assess the semen's fertilizing capability. Semen quality and fertility are a combination of several factors. Even though fertility cannot be accurately predicted, the lack of it can. Deviations from the norm is usually a good predictor of low fertility. The objective in evaluating semen quality should be to identify those samples that have traits pointing to the probability of below normal fertility and therefore discard them. An extension of this thought is to discard those males that continuously produce poor quality semen.

In general, semen quality can be divided into two broad categories: a) the number of sperm cells collected and b) the viability of the collected sperm cells. Quantification of sperm cells can be readily determined with the proper equipment and training. It is simply the product of the ejaculate volume and the sperm concentration. Assessing the viability is a much more difficult task. It is known that viable sperm are capable of swimming in a straight-forward direction (progressive motility), and have an intact sack of enzymes (acrosome) surrounding the top of the head, utilize nutrients from dilutors, and secrete waste products (metabolize) that may alter the pH of the dilutor, and have a characteristic normal shape (morphology).

Volume

The volume of the ejaculate will generally be between 0.5 and 1.5 ml and can easily be measured using a graduated collection tube attached to the AV.

Concentration

The average buck ejaculate usually contains between 1 and 6 billion sperm cells. The accurate measurement of semen is important when semen is to be used in artificial insemination or processed for

freezing. The concentration of buck sperm reported to be necessary for a satisfactory fertilization rate is 40 million sperm per ml when fresh semen is used and 120 million motile sperm when frozen semen is used, although usually twice this number is used by processor when packaging straws. The concentration of sperm in a sample can be determined by the use of a hemocytometer, photoelectric colorimetry, or spectrophotometry.

The concentration of the ejaculate is a function of several parameters. They include the degree of sexual preparation of the buck, the age of the buck, the time of year the collection is made, the amount of sexual rest before collection, the health of the buck, his nutritional state, inherent sperm storage, and the production capacity of the buck.

Most of the factors can be controlled by employing good management practices. The ability of the buck to produce sperm (in the testes) and store sperm (in the epididymis) can be assessed to some extent by palpation and measurement of the testes and epididymis.

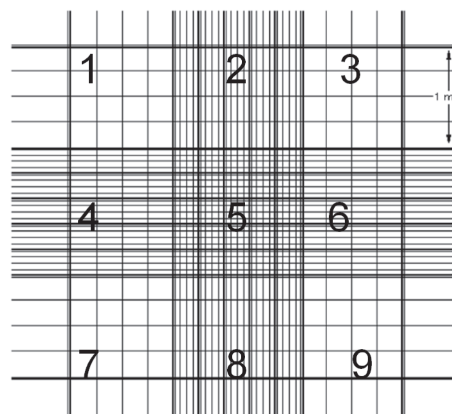
Hemocytometer counting of sperm

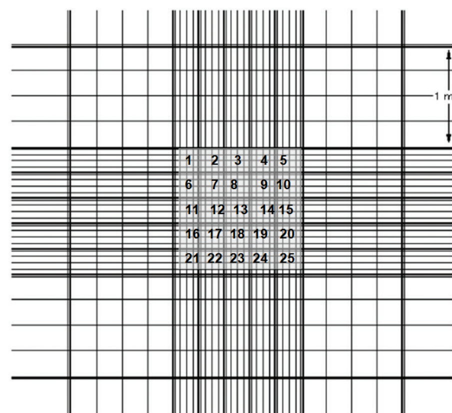
Sperm concentration can be determined by hemocytometer or by spectrophotometry. The procedure for calculating concentration using hemocytometer is:

1. Mix raw semen thoroughly.
2. Dilute semen 1:1000 with an agent that will kill the sperm such as NaCitrate or 1% formalin or water. Example: Add 0.01 ml (10 µl) of raw semen to 0.09 ml (90 µl) of diluent (formalin or NaCitrate) in a test tube labeled #1. Mix thoroughly. Add 0.01 ml (10 µl) of test tube #1 semen to 0.09 ml (90 µl) of diluent (formalin or NaCitrate) in a test tube labeled #2. Mix thoroughly. Add 0.01 ml (10 µl) of test tube #2 semen to 0.09 ml (90 µl) of diluent (formalin or NaCitrate) in a test tube labeled #3. Test tube #3 is now a 1:1000 dilution.
3. Put hemocytometer on a flat surface with cover slip in place.
4. Fill both sides of hemocytometer chamber.

Hemocytometer used for counting sperm.

5. The hemocytometer is divided into 9 large squares or grids. Count all sperm heads in the large center square (grid 5). Grid 5 is divided into 25 squares. Counting sperm heads in each small grid provides an easy way to keep track of counting. The 5 diagonal squares of grid 5 can be counted and the number of cells multiplied by 5. Regarding the heads on the lines of squares, count only those on the left and bottom lines of each square. Don't count those on the right and top lines.





6. Count number of cells on each side of the hemocytometer and average the numbers.
7. Each of the nine squares on the gridhas an area of 1 square mm, and the coverglass rests 0.1 mm above the floor of the chamber. Thus, the volume over grid 5 is 0.1 mm^3 or 0.1 microliter.
8. Multiply the average number of sperm by 10,000 to obtain the number of sperm per ml of diluted sample.
9. Multiply that count obtained by the dilution factor, in this case, 1,000. Therefore, the number obtained will be multiplied by 10,000,000 (ten million) and this will give the concentration of the sperm.

10. The concentration of sperm per ml × the total ml of raw semen = the total number of sperm in the ejaculate.
11. The hemocytometer must be cleaned immediately after use. The hemocytometer will be hard to use accurately if dirty or scratched.
    a. Wash the hemocytometer chamber with mild detergent. Be careful not to scratch the chamber.
    b. Rinse well with warm water.
    c. If possible rinse with distilled or deionized water.
    d. Rinse in alcohol to dry and dry with lens paper or soft tissue.

Store in a dust free container with hemocytometer and coverslip wrapped in tissue to avoid dirt and scratching.

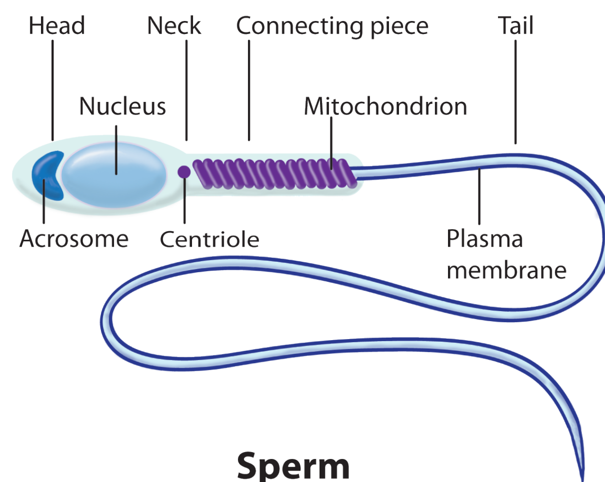
Motility

The progressive motility of the sample is defined as that percentage of the spermatozoa in a sample that swim in a more or less straight-forward direction. Circular or reverse motion often indicate cold shock or media that is not isosmotic with semen. The progressive motility is determined by examining a drop of semen, diluted so that individual cells can be visualized.

Physiological saline can be used as a diluter, but it is better to use a buffered solution containing an energy source such as glucose. Phosphate buffered saline (PBS) with 1% glucose works very well. Other standard buffered solutions (such as Ringers solution, sodium citrate buffer, Tris buffer, and Tyrodes solution) can also be used.

Modified Kreb's Ringer Phosphate Buffer

Ingredients	Millimols	gm/liter
NaCl	120	7.0
KCl	5	0.36
KH_2PO_4	10	1.36
$MgSO_4.7H_2O$	5	1.23
Tris	10	1.21



Parts of a sperm.

Phosphate Buffered Saline with Glucose

Ingredients	Millimols	gm/liter
NaCl	137	8.0
KCl	2.7	0.2
Na_2HPO_4	10	1.44
KH_2PO_4	1.8	0.24
D-Glucose	5.6	1.0

It is extremely important that the solutions, pipettes, and glassware (such as test tubes and slides) be at the same temperature as the semen. It is best to make the motility estimate as soon after the semen is collected as possible. Since good semen handling dictates that the collection tube should be at 37°C at the time of collection, all of the things that come in contact with the semen should be at 37°C. Remember, semen is and never will be any better than the instant it is ejaculated.

Since the motility measurement is subjective (one actually makes an "educated guess" of the percentage of motile sperm), care should be taken to make the sample as "readable" as possible. Ideally, the sample, under the cover slip, should be as thin as possible (one sperm thick) and each field should contain between 10 and 20 sperm. On the average, this can be achieved by mixing 6 to 8 microliters (µl) of semen with 0.4 ml of diluter and transferring 7 µl of that mixture to the slide. A less desirable but more practical approach is to place a drop of diluter

Example of a semen straw. BG is Boer Goat; GRK 126 is the buck ID; collection/processing date is June 25, 2010; processor is RAMSEM (RMS) of Bloemfontein, South Africa.

on a pre-warmed slide and transfer a small amount of semen to the drop with a solid clean glass rod. The rod should be about the diameter of an AI straw or smaller. Mix and then transfer part of the mixture to a clean part of the slide and carefully put the cover slip in place before examining. The sample should be observed under 400×, and at least ten areas of the smear used to estimate the percent of motile sperm. Sperm cells near the edge of the coverslip or near trapped air bubbles do not appear to act "normally". Total motility should be estimated to the nearest five percent. An average motility score of 85% is normal. Semen with an initial motility much below this should probably not be processed.

An alternative method to evaluating motility on raw semen is to evaluate semen in its final extended concentration so that one has a direct comparison with what is seen when a straw is evaluated after thawing.

Morphology

When sperm morphology is evaluated, one usually looks for abnormal shapes of the head and tail. It has become popular to examine the morphology of a portion of the head, the acrosome. Examination of the acrosome requires the use of a fairly sophisticated microscope fitted with either phase-contrast or differential interference optics. Any abnormality is categorized as a primary, secondary, or tertiary abnormality.

Additionally, the sample is scrutinized for the presence of excessive quantities of bacteria, interfering microorganisms, and leukocytes (white blood cells). Such latter findings could indicate possible infection or disease. The presence of excessive microorganisms and/or white blood cells within the sample should eliminate it from further processing, thereby avoiding any possibility of infection or disease transfer from the donor to the intended recipient.

Semen Processing

Once the semen has been comprehensively evaluated, sperm concentration is used so that a proper dilution of cells can be made according to both its packaging and desired means of use. Dilution of the semen is a process which utilizes one of several possible mediums. These mediums traditionally consist of milk or egg yolk, sugars, antibiotics, and buffers to provide a stable environment for the semen, particularly during the transport of the fresh cooled semen. Buck seminal plasma contains an enzyme which can cause coagulation when introduced to an egg-based extender. To overcome this potential problem, semen may be "washed" via centrifugation to separate the seminal plasma from the spermatozoa before further processing. The processor may also elect to quantitatively reduce egg yolk levels in the extender or in some cases substitute with a diluent that utilizes skimmed milk as opposed to egg yolk.

The number of spermatozoa used per dose varies according to the intended use of the straw. The recommended industry standard for spermatozoa packaged for frozen storage and cervical or trans-cervical AI requires 120 million live cells in a ½ cc straw, pre-freeze. Processors in the United States most commonly use a ½ cc straw for packaging, ¼ cc straws are also used but are more common in the international marketplace. Properly marked straws indicate the donor buck's permanent identification, i.e., donor name, registration number, processing company identification, date of collection, and the animal index number assigned by the individual processing company.

Spermatozoa, by nature, are catabolic cells. This means that in the metabolic processes they deteriorate as they use stored energy. With time, they age and slowly die off until all cells are immotile and incapable of fertilization. Likewise, semen subjected to adverse environments will irreversibly deteriorate and become useless. Because sperm have little or no anabolic or healing capacity, anybody working with any stage of semen processing must be attuned to the potentially harmful environments in which semen is placed. The main objective in semen processing is to minimize the catabolism of semen so that the quality of thawed semen is similar to that which was originally ejaculated.

Fresh semen

Generally, when semen is extended and stored at 4°C, sperm cell survival is of a few days duration and sperm fertilizing ability cannot be preserved for more than two days. Sperm cell survival is generally longer than fertilizing capacity and the former cannot be used as an indication of the latter.

Long-term storage (frozen)

Most, if not all, semen is preserved in a frozen state. In order to accomplish this goal, suitable extenders must be used.

Semen Extenders

Semen destined for fresh use or for freezing should be extended. An ideal extender has to meet certain requirements: a) provide nutrients as a source of energy; b) contain constituents that provide protection

against the harmful effects of cooling and freezing; c) provide a buffer to prevent shifts in pH as lactic acid is formed; d) maintain the proper osmotic pressure and electrolyte balance; e) contain antibiotics that inhibit bacterial growth; f) substantially increase the volume of semen so that multiple inseminations can be performed; and g) provide an environment in which metabolic activities of the sperm can continue.

Most extenders for liquid or frozen semen have been either egg yolk or milk or a combination of the two as a basic ingredient. The primary benefit derived from fresh egg yolk is protection of the sperm cell against cold shock by yolk lipoprotein and lecithin. The milk protein, casein, has been established as the agent responsible for prevention of cold shocking with the use of extenders.

Milk extenders

Goat semen has been diluted in saline, sodium citrate, or skim milk. Of these extenders, only skim milk heated at 95°C for 10 minutes satisfactorily preserved the fertilizing capacity of goat spermatozoa. Cow's milk has been used as an extender in routine artificial insemination of goats with good fertility results. A skim milk glucose-glycerol extender has also been used to freeze goat semen.

Recipes for quantities for 100 ml for each dilutor follows:

Dilutor #1.

Dried skim milk powder (11%, w/v); may substitute whole milk powder.	11.0 g
Distilled water	89 ml
• Following thorough mixing, heating at 95°C for 10 minutes and cooling down to room temperature antibiotics are added:	
Penicillin (Na salt)	0.050 g
Dihydrostreptomycine (sulphate form)	0.060 g

Adapted from: Paulenz, H., K. Soltun, T. Ådnøy, K. Anderson Berg, and L. Söderquist. 2005. Effect of different extenders on sperm viability of buck semen stored at room temperature. Small Ruminant Research 59:89-94.

Dilutor #2.

Skimmed cow's milk powder containing less than 1% butterfat	10 g
d- Glucose	0.194 g
Distilled water	100 ml
• Following thorough mixing, heating at 85°C for 10 minutes and cooling down to room temperature antibiotics are added:	
Penicillin (Na salt)	50,000 IU
The conversion factor for penicillin is 1 mg = 1,666.67 IU or 600 mg = 1,000,000 IU.	
Dihydrostreptomycine (sulphate form)	0.050 g

Source: Corteel, J.M. 1981. Chapter 5. Collection, Processing and Artificial Insemination of Goat Semen. In: Goat Production. Academic Press, London, p. 184 [ISBN: 0-12-273980-9].

Dilutor #3.

Fresh 3.5% pasteurized, homogenized whole milk	100 ml
• Heating at 98°C for 10 minutes and cooling down to room temperature in a water bath with the lid on. When the milk is in equilibrium temperature with the water bath, the water condensation on the inside of the lid is shaken back into the milk and antibiotics are added:	
Potassium G crystalline penicillin	25,000 IU
The conversion factor for penicillin is 1 mg = 1,666.67 IU or 600 mg = 1,000,000 IU.	
Crystallin di-hydrostreptomycin sulfate	0.125 g
• Warm this diluter to about body temperature before adding the fresh semen at 19:1 ratio. Place the diluted semen in a water bath at body temperature of 38°C.).	

Adapted from: Haenlien, G.F.W., R. Cacesse, and M.C. Smith. 1984. All about A.I. In: Goat Extension Handbook. D-8.

Dilutor #4 (for fresh and frozen semen).

Skim milk	100 ml
Glycerol	7 ml
Penicillin g potassium	100,000 IU
Streptomycin sulfate	100,000 micrograms

NOTE: The above ingredients are used to make 50 ml each of 2 extenders; PART A - non- glycerolated, and PART B - glycerolated.

1. In a double boiler heat the 100 ml of skimmed milk to 95°C for 10 minutes.
2. Allow the milk to cool to room temperature and divide it into two portions: 50 ml - Part A and 43 ml Part B.
3. Add 100,000 units of penicillin G and 100,000 micrograms of streptomycin to Part A and mix thoroughly. These antibiotics can be bought

from a number of pharmaceutical firms in pre-weighed powdered form.

4. Add 7 ml of glycerol to Part B (43 ml of skimmed milk) and mix.
5. Make sure to label the two parts clearly. During the semen processing, if the wrong one is added first, the sperm may be killed. Both parts can be stored in the refrigerator for a day, so the extender can make up the day before semen collection.

Dilutor #5 (for fresh and frozen semen).

	Diluter A (w/o glycerol)	Diluter B (w/ glycerol)
Milk Powder (g) (1% fat)	50.0	50.0
Glucose (g)	0.97	0.97
Penicillin (units/ml)	1000.0	1000.0
Streptomycin (ug/ml)	1000.0	1000.0
Glycerol (ml)	---	70.0
Distilled H_2O to final volume (ml)	500.0	500.0

Egg yolk extenders

There are two schools of thought regarding the use of egg yolk as a component of a goat semen extender. Semen diluted with egg yolk has resulted in acceptable conception rates for some workers. Goats inseminated with sodium citrate glucose-yolk-glycerol extended semen, conception rates were 60 and 92% with frozen thawed and fresh semen, respectively.

Other investigators believe that egg yolk is toxic to the goat spermatozoa. An enzyme (phosphotidase) produced by the bulbo-urethral glands of the male goat catalyses the hydrolysis of lecithins in egg yolk to fatty acids and lysolecithins, which are toxic to the spermatozoa. The presence of phosphotidase in the seminal plasma of the goat means that media containing egg yolk cannot be used for semen extension.

Seminal plasma has been blamed as a limiting factor of goat semen freezability and fertility. Washing goat spermatozoa in a physiological solution improved the percentage of motile sperm in fresh ejaculates. Post-thaw motility of spermatozoa was also increased.

Glycerol is added to extenders to protect sperm against the detrimental effects of freezing. The time, temperature, rate of addition, and concentration of glycerol have been studied with many conflicting reports. Some researchers have added the glycerol before cooling (i.e., at 30°C) and others at 4°C. Since cryo-protective activity of glycerol occurs during the crystallization phase, glycerol should be added at 4°C.

The level of glycerol is generally 4-6% in extended semen. One worker has used 6-9%, and another added 14% glycerol to freeze goat semen.

Dilutor #6 (for fresh and frozen semen).

	Diluter A (w/o glycerol)	Diluter B (w/glycerol)
Tris (g)	12.1	12.1
Citric Acid, monohydrate (g)	6.7	6.7
Glucose or Fructose (g)	5.0	5.0
Penicillin (units/ml)	1000.0	1000.0
Streptomycin (ug/ml)	1000.0	1000.0
Glycerol (ml)	---	70.0
Egg Yolk (ml)	100.0	100.0
Distilled H_2O to final volume (ml)	500.0	500.0

Dilutor #7 (REI for fresh and frozen semen).

	Diluter A (w/o glycerol)	Diluter B (w/glycerol)
Tris (g)	15.1	15.1
Citric Acid, monohydrate (g)	8.5	8.5
Glucose or Fructose (g)	6.3	6.3
Penicillin (units/ml)	1000.0	1000.0
Streptomycin (ug/ml)	1000.0	1000.0
Glycerol (ml)	---	25.0
Egg Yolk (ml)	40.0	40.0
Distilled H_2O to final volume (ml)	500.0	500.0

Semen washing solution

After extension, semen is cooled at 4°C at approximately 0.5°C/min. Semen equilibration time after addition of glycerol has been studied with conflict-

ing results. However, 3 to 4 hours appears sufficient for ram semen and 1½ to 3 hours equilibration time seems adequate for goat semen. Longer equilibration times do not appear to be detrimental.

Semen Washing Solution (Ringer Solution)

Ingredients	(Amount to Make)	
	100 ml	1 liter
NaCl	0.86 gm	8.6 gm
KCl	0.03 gm	0.3 gm
$CaCl_2.2H_20$	0.033 gm	0.33 gm
H_20 to	100 ml	1000 ml

1. Weigh out the ingredients listed above.
2. Add 50 ml H_2O (or 500 ml of H_2O, if making up a liter) to the powdered ingredients.
3. Mix until all the ingredients are dissolved.
4. Add H_2O to bring the total volume to 100 ml (or 1000 ml, if you are making a liter).

Semen washing

1. Immediately after collection, gently mix the semen with 20 parts of Ringer solution (i.e., if the ejaculate volume is 1.2 ml add 24 ml Ringer).
2. Centrifuge the diluted semen at 1000 G for 10 minutes at room temperature.
3. After centrifugation, pour off or aspirate the supernatant (liquid) - being careful not to disturb the pellet of sperm in the bottom of the tube.
4. Add the same amount of Ringer solution used in Step 1 and carefully re-suspend (re-dissolve) the pellet by slowly sucking it up into a pipet and letting it flow out 5 to 10 times.
5. Repeat Steps 2 and 3.
6. Add 1 ml of Ringer solution to the sperm pellet and re-suspend it.
7. Take a 0.05 ml sample of the semen and add it to 10 ml of Ringer. This diluted sample is used for concentration determination. If a hemocytometer is used, multiply the count by 10.05×10^6 to find the concentration.
8. Add 2 ml of Extender Part A (non-glycerolated) to the 1 ml of semen. Both extender and semen must be at the same temperature.
9. When the concentration has been determined and the dilution rate calculated, bring the semen up to exactly ½ the total required volume with Extender Part A.
10. Place the tube with the extended semen in a beaker or Erlenmeyer flask to which 100 ml of room temperature water has been added. This volume of water surrounding the semen will ensure the proper cooling rate.
11. Place the semen, with its water jacket, into a refrigerator or cold room adjusted to 4°C. Also, place the amount of Extender Part B (glycerolated) needed for final extension in the refrigerator. (Equal to the volume of Extender A used).
12. After 1 hour, add Extender Part B to the semen dropwise with a pre-chilled pipet.
13. Package the semen in straws or ampules and seal. Allow the sealed packages to stay in the cold room at 4°C for 4 hours.

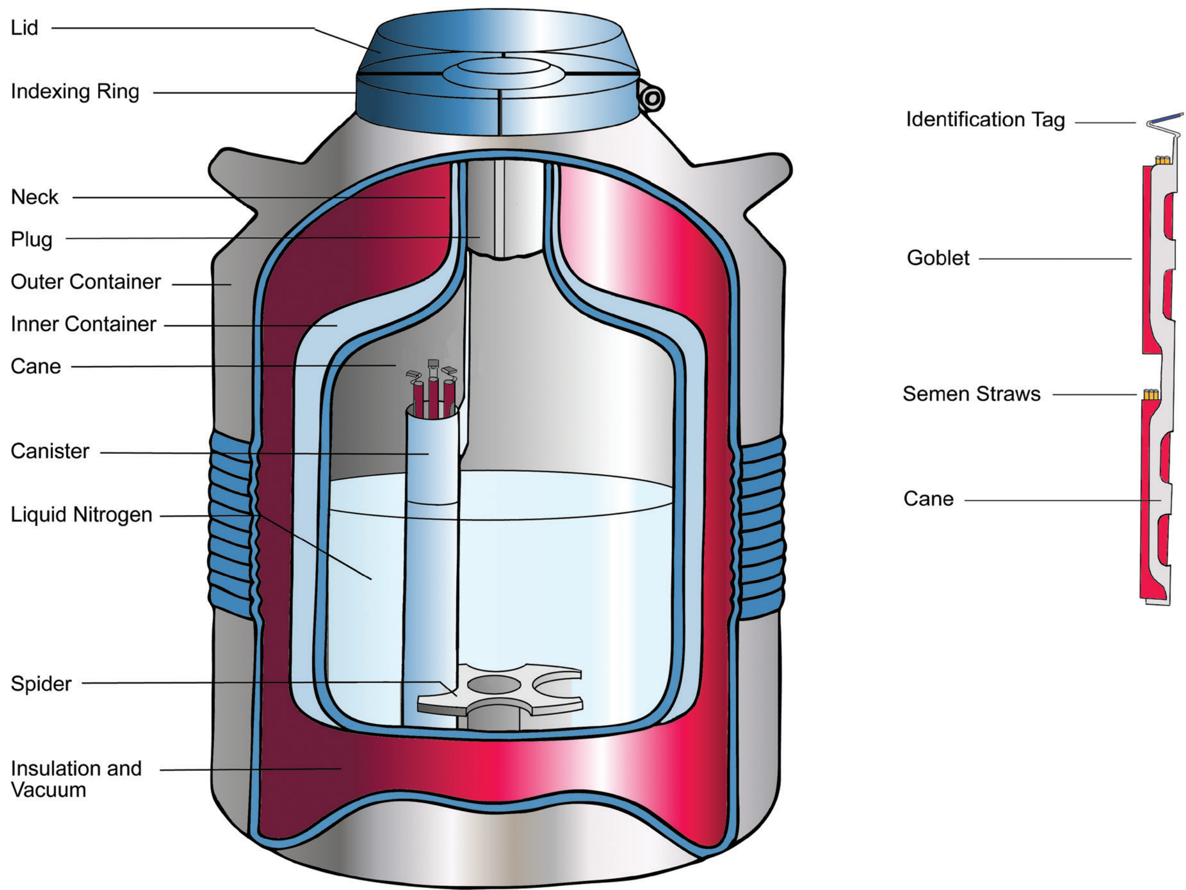
Semen cooling

If washing is not done then once the semen has been extended to the proper dilution, the straws should be filled manually or by machine, sealed, and then the semen is cooled to 4°C at approximately 0.5°C/min. If the semen is destined for fresh use, the semen can be stored in a refrigerator for up to 48 hours; however, studies have shown that fertility is highest if used within 24 hours of collection. If the semen is destined for freezing, then the following procedure should be followed:

1. Place straws on freezing rack.
2. Pour liquid nitrogen into a styrofoam chest to a depth of 5 cm. Let sit for 5-10 minutes covered.
3. Place straw freezing rack containing filled straws into freezing chest so it is suspended 5 cm above the level of the liquid nitrogen. Cover chest, leave for 12-15 minutes.
4. Remove cover and quickly dump straws into liquid nitrogen.
5. Remove a straw and thaw in 35°C water for 1 minute. Open and evaluate.
6. If semen is acceptable, cane up straws and put into storage tanks.

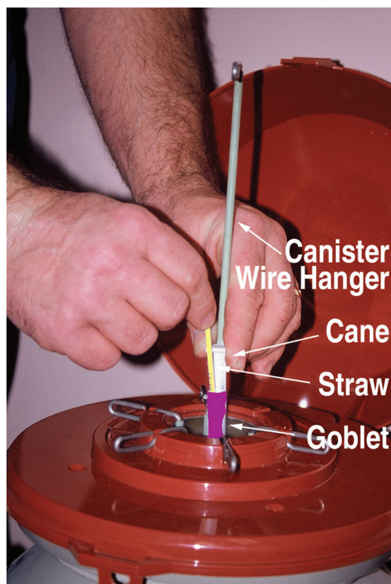
Thawing and post-thaw evaluation

When using frozen semen, proper thawing technique is critical to the resulting post-thaw motility assessment and to the spermatozoa's ultimate fertilization capabilities. It is strongly recommended that each AI technician invest in an inexpensive, good quality microscope capable of magnifying semen cells to such a degree as to ascertain their viability (live vs dead). Depending on the quality of microscope, a minimum magnification of 100× is necessary for

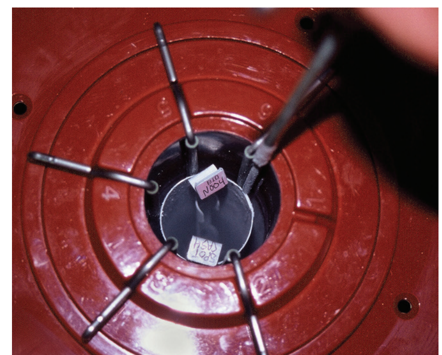


Cut-away drawing of semen storage tank.
Drawing by K. Williams.

Cutout view of a liquid nitrogen semen storage tank showing insulation and canisters.



Parts of a semen storage tank.



Canister pulled up into neck of the tank.

even the most basic observations. More experienced technicians should include cell motility (the way the spermatozoa move/swim) and morphology (normal or abnormal cell appearance) in their assessment. Technicians and producers should understand that no semen sample is entirely void of abnormalities and that freezing semen results in a 5 to 20% loss of viability due to the freezing process. Bacterial contamination can be a primary factor in low conception rates and reproductive problems. In some cases, reduction of sperm motility, acrosome integrity, and sperm cell viability can all be directly related to bacterial contamination that occurred during the processing of semen for fresh or cryogenic storage.

Liquid Nitrogen Storage Tanks

Tanks

Cryogenic storage containers for semen come in a number of designs. The most popular are liquid nitrogen storage tanks, vapor shippers, and even dual-purpose tanks that can provide both storage and a means for the shipping of semen. The tanks are essentially a large vacuum container with insulation inside the vacuum chamber, much like an oversized thermos. The working parts are a lid, styrofoam cork, canisters, the inner chamber that holds the liquid nitrogen, and a "spider" to keep the canisters from moving around. The cork is generally 10 to 15 cm in length with grooves down the sides for the canister hangers. The cork is designed to fit loosely in the neck of the tank, allowing for the evaporating nitrogen gas to escape. If capped too tightly, the gas would build pressure in the tank and cause it to eventually explode.

Hanging from the top/neck of the tank are the canisters, usually six in number, although tanks may contain as few as one or as many as ten. These canisters consist of a long wire hanger/handle used to lift the cylindrical portion of the canister in and out of the tank. The function of the canister is to hold the canes of semen down in the tank for storage and retrieval when necessary.

Liquid nitrogen is at a temperature of -196°C and is a hazardous material. Use caution when handling a liquid nitrogen tank and its contents. It is good to get in the habit of wearing safety glasses for eye protection and clothing covering exposed body extremities such as legs, feet, arms, and hands when working in your nitrogen tank. Gloves made of any cloth-like material should not be worn as they can absorb and trap liquid nitrogen causing a severe burn to the hands and fingers. Rather, gloves should be made of rubber, latex, vinyl, nitrile, or some other tight-fitting, nonabsorbent protective material.

Cryogenic tanks come in a variety of configurations to meet the needs of the producer. Some have a long static hold and working time, generally sacrificing straw capacity; while others have large straw capacities, but sacrifice static hold and working time due to their increased neck size. This increased neck size is necessary to accommodate the larger canister size needed for the additional canes of inventory. A rule of thumb is the larger the neck opening, the easier it is to work in the tank, the more straws it can hold, and the faster the liquid nitrogen will evaporate thereby decreasing the static hold/working time between "charges" (liquid nitrogen refills) of the tank.

Things to consider when purchasing a liquid nitrogen storage tank are straw capacity, initial price, liquid nitrogen availability, static/hold time, and intended use of the tank. For example, a tank that holds 540 straws only has the capacity to hold 54 "canes" of inventory, with ten straws to the cane (an industry standard for ½ cc straws in the United States). Each cane holds two "goblets," each goblet holds five ½ cc straws, totaling the ten straws per cane. If any of the canes has less than ten straws, capacity drops by the number of straws each cane is short of ten. For instance, if one cane is holding only two straws, eight straws of the tank's total storage capacity is lost.

It also costs more to maintain four 540 straw capacity tanks than it does to maintain one 2,100 straw capacity tank. This is in addition to the higher initial cost involved in purchasing four smaller liquid nitrogen tanks as opposed to one larger tank.

A person should check availability and cost of liquid nitrogen to assist in the decision of what model tank to purchase that best suits their use and maintenance budget.

A liquid nitrogen tank measuring stick should be purchased. This is used to monitor the liquid nitrogen level in the tank on a regular basis to ensure the tank's continuous viability and safe storage of its contents.

Liquid nitrogen tanks are somewhat fragile and care should be taken in their handling. Close attention should be paid to the vacuum port. Do not spill nitrogen on it or loss of vacuum may occur rendering the tank useless. Tanks should not be set unprotected on gravel, dirt, or concrete. They should be stored unboxed, in plain view, on surfaces such as clean carpet, wood, cardboard, a rubber mat, etc., to protect the bottom from dents and scratches.

A vapor shipper with its protective shipping cover.

It is essential to recognize the importance of proper product handling, storage, and cataloging of inventory whether it be semen or embryos. The top of each cane should be marked, clearly identifying the cane's contents by the index code assigned to the donor animal by the processor. It is very poor practice to store more than one buck's semen on a single cane. The producer should maintain a current catalog or "map" of the tank's contents and identifying index codes at all times. Any change in inventory within the tank should be noted in the catalog or on the map. Searching for and locating semen by exposing individual straws of inventory to the air, while attempting to read them, is the poorest of practices and will render your inventory ineffective and severely compromised in short order.

When re-caning (dividing or combining canes of semen), a producer or technician should be in the habit of pouring liquid nitrogen into a small, dense styrofoam box known as a "transfer box." The re-caning should be done in the box with straw tweezers while the goblets and the straws they contain are submersed in the liquid nitrogen. The most detrimental element to the long-term viability of straws frozen inside a storage tank is temperature change and fluctuation. If properly stored, frozen spermatozoa can be expected to remain viable for many, many years.

In a perfect world, the frozen inventory would not leave the nitrogen until it is thawed for use. However, this is impractical, so the goal is to move straws as quickly as possible, i.e., the "three second rule."

When semen is being transferred or pulled for thawing and insemination use, the canister must be raised to handle the cane and remove the desired straw. Once raised above the neck of the tank, the cane and canister should be lowered back into the tank or the cane placed in a transfer box within three seconds. This "three second rule" helps to avoid excessive temperature fluctuation within the straws that may compromise spermatozoa viability. Noise and boiling heard when canisters are lowered into the body of the tank indicate a temperature change has taken place; the more violent the boiling the greater the temperature change and the greater the likelihood of viability loss.

When attempting to locate a cane in a specific canister, the canister should remain at the bottom of the tank. To see into the canister simply position it centrally so that an AI light or flashlight shining through the tank's neck will illuminate the tops of the canes. If the cane is properly mapped, marked and positioned, there should be no need to raise the canister into the neck of the tank until you have identified the location of the cane where the desired straw is located. If the canister must be raised into the neck of the tank, remember the "three second rule." After lowering the canister back into the tank because the three seconds have expired, allow it to remain in the nitrogen for 10 to 30 seconds, depending on the nitrogen level in the tank. When pulling straws for insemination, attention should be on the inventory going back into the tank, not the straw you intend to thaw. It is better to pull the canister up three times for three seconds, than one time for nine seconds.

Vapor/dry shippers

Vapor shippers are sometimes referred to as "dry shippers." Their design provides safe transportation of frozen semen and embryos in a classified "nonhazardous" container. Newer models are made of lightweight aluminum and most often have a single canister inside as opposed to the usual six to ten in a "wet" storage model. These newer shipping units contain hydrophobic absorbent material which repels water but absorbs liquid nitrogen. Because of the absorbent nature of the material, should the unit tip during transit the liquid nitrogen will remain absorbed in the "sponge-like" material preventing any spillage. This unique design allows for an exempt status with normal carriers who would otherwise render the container hazardous in nature, further allowing a cost effective means of transport for the shipper and its frozen contents.

When semen inventory is received by way of a vapor shipper, it becomes the receiver's responsibility to verify the contents. When making the transfer from the vapor shipper to the producer's private inventory tank, it is a good idea to quickly glance (remembering the "three second rule") at the goblet and confirm that what has been ordered has been delivered. It is the buyer's responsibility to notify the supplier immediately if there is some discrepancy in the quantity or identification of the inventory received.

Pregnancy

Pregnancy is established after fertilization of the egg by the sperm. Fertilization occurs in the oviduct and requires sperm to be present at the proper time relative to ovulation. Spermatozoa remain viable for only 12 to 24 hours in the female reproductive tract, and the life span of the ovulated egg is limited to 12 hours. A healthy sperm will penetrate the zona pellucida surrounding the egg using enzymes contained in the cap of the sperm head. Fusion of the sperm cell with the egg will prevent penetration of other spermatozoa. Fertilized eggs move from the oviduct towards the uterus and initiate cell divisions within 24 hours. The developing embryo will continue to divide and remain free-floating until it attaches to the uterine wall 15 to 20 days after fertilization, referred to as maternal recognition of pregnancy (MRP).

The uterus requires priming with progesterone for attachment of the embryo and membrane development to occur. In goats, in contrast to sheep, the corpus luteum is the primary source of progesterone throughout gestation. The developing fetus is contained in the placenta, a membrane that facilitates nutrient and oxygen exchange between the maternal and fetal circulation. While the placenta experiences the most rapid growth between 90 to 110 days of gestation, fetal growth increases exponentially during the last trimester of pregnancy. Gestation length in the goat is approximately 150 days, but is affected by breed and sex of kids, and tends to increase with age of doe, but decrease with litter size.

Pregnancy Detection

Once any method of assisted animal reproduction is administered, the producer will want to make some attempt at pregnancy confirmation. There are a number of means in which this can be accomplished.

Bumping

"Bumping" is a method practiced by some producers with a marginal amount of success. The theory behind the technique is to attempt to detect the fetus by way of its "firmness" within the abdomen of the doe. The likelihood of success using this method largely depends on the doe's stage of pregnancy of the doe when the technique is performed, the number of fetus(es) present, and what position the fetus is in at the time the attempt is made. This method is one of the least reliable for an accurate determination of pregnancy.

Vulva examination

Vulva examination is a method widely used by producers with long-term experience working with both pregnant and open (not pregnant) does. Although not easily recognized until late in the doe's pregnancy, the skin in and around the vulva becomes more placid, stretchy, and loose in late gestation. When compared

Transabdominal ultrasonography.

to does of the same general age and size that are not pregnant, it can be very apparent that the vulvar region of the pregnant doe is undergoing changes that will allow for successful delivery of the kid. These vulvar changes are usually coupled with noticeable signs of mammary development. Although certainly not used with any proven reliability until late in gestation, this method is widely practiced and, when asked, experienced producers seem to be of the opinion that the method does work more often than not.

Cervical examination

Producers make some claim that when the cervix of a pregnant doe is examined, a “gray plug” can be seen. This observation has reportedly been made as early as 30 days following conception. An explanation of such an observation may be attributed to the following: The cervix is the “gateway” to the uterus and during pregnancy it has the job of blocking entrance to the uterine body. The claim of a “gray plug” is supported by research proving that during pregnancy, while under the influence of progesterone, the mucus of the pregnant female becomes quite viscous and thick. The mucus can become so thick that during gestation it acts like “glue” holding the folds of the cervix together so that foreign material cannot enter the uterus. This barrier is commonly referred to as the “cervical seal of pregnancy.” Any disruption of this barrier or seal can, and often will, result in abortion. The cause of the abortion is directly related to microorganisms gaining entry to the uterus and causing infection that leads to subsequent embryonic death.

Ultrasonography

For the diagnosis of pregnancy in goats there are three commonly used ultrasound techniques, each with its own, specifically designed piece of equipment. The first and most reliable method is referred to as B-Mode, followed by A-Mode, and finally the Doppler machine. All three methods require that the doe be shaved high on the right side of the abdomen just in front of the mammary gland to remove all hair that may interfere with data received by the ultrasound probe. A coupling gel is used to ensure a clear projection of information to and from the probe.

If the equipment is not owned and operated by the producer, the cost of ultrasound can vary to a large degree depending on the practitioner, distance traveled, and number of animals to be examined. All three ultrasound methods are highly dependent on the experience and technical knowledge of the operator/technician for a correct diagnosis of pregnancy, i.e., openness (not pregnant), or pseudo pregnancy with hydrometra or muco metra (false pregnancy, e.g., uterine development lacking a fetus).

The most popular method and that offering the most accuracy is the use of B-mode or real-time trans-abdominal ultrasonography. This method is commonly performed in some states by licensed technicians and often by licensed veterinarians. Most practitioners find that detection is easiest made when the doe is between 45 and 90 days of gestation. Some well-experienced practitioners can determine identification of a fetus as early as 27 to 30 days, and if examined slightly later, the number of fetuses in the uterine body. Pregnancy can still be identified by means of the caruncles very late in gestation, although actual evidence of the fetus itself may be disrupted by the obstacles in and around the abdominal region of the doe. It is not unusual to see a fetus move about due to the stimulus created by the ultrasonic sound waves. Producers should be aware that there is some minimal risk of fetal abortion if an inexperienced practitioner uses an annular array (transrectal) probe for ultrasound. External sector scanners or linear array (transabdominal) probes offer little to no risk of abortion and are preferred by most technicians.

A-Mode ultrasound, although not nearly as accurate as the linear interpretations used in B-Mode ultrasonography, is an inexpensive means of pregnancy diagnosis with greatest accuracy achieved at 30 to 40 days gestation. The A-Mode ultrasound is designed to detect a large body of fluid within the doe’s abdominal cavity. This method can often produce a misdiagnosis by mistaking a full bladder or fluid filled uterus for a pregnant uterus. The Doppler ultrasound is also used. This machine is designed to detect blood flow by way of a fetal heartbeat. Although cost effective, its degree of accuracy is sometimes less than desirable.

Blood sampling/assay

Although expensive, blood sampling for hormone or protein assay offers by far the greatest degree of safety to the fetus and is one of the most reliable pregnancy detection methods. Results can most often be expected within 5 to 7 days of the sample’s receipt by the laboratory.

The protocol is very simple, a blood draw of at least 5 cc is made into a sterile, gray or red-topped blood tube as early as 26 days after breeding. Once the laboratory receives the sample, it is screened for a protein in the blood that is only produced by the placenta. This protein, PSPB (pregnancy-specific protein B), can only be present if the doe is, or has very recently been, supporting a viable placenta.

Producers should be aware that a possible false positive could be generated in the event of recent embryonic death enabling residual PSPB to still be detected. False negatives occur most commonly when samples are drawn too early for PSPB detection. Enough time must be given, once the doe becomes pregnant, for the body to build sufficient levels of PSPB in the blood for laboratory detection (26 days from the breeding date).

The screening for fetal protein (PSPB) is a highly reliable test and is most probably only compromised by poor timing in the collection or handling of samples and their cross-contamination. The producer should take care in the harvesting of the whole blood so that no mislabeling or cross-contamination between animals occurs.

A test of non-pregnancy through progesterone analysis can also be made. The corpus luteum of the goat produces measurable levels of progesterone throughout gestation. Milk, serum, and plasma may be analyzed for progesterone concentration. If none is detected, the presence of a functional corpus luteum is unlikely thereby diagnosing the doe as not pregnant. Blood serum and plasma are superior to milk for progesterone analysis. It has been reported that commercial on-farm cattle progesterone test kits have been used in goats with good accuracy.

Basic Reproductive Management

Seasonal breeding

In temperate zones, goats are seasonally polyestrus, indicating that they have multiple estrus cycles during the fall and cease cyclic activity in spring. The breeding pattern allows kids to be born in spring when forage resources are abundant to support the nutritional demands of lactation. The environmental cue most dominantly affecting seasonal breeding in goats and sheep is the annual change in day length (short day breeders). As the day length decreases in late summer and fall, does initiate estrous activity and males become more sexually active. Photoperiodic cues are perceived through the retina of the goat and transmit signals to the pineal gland which responds with increased melatonin release during periods of dark. Melatonin in return stimulates gonadotropin releasing hormone and cyclic activity. Hence, melatonin or artificial lighting (or rather extended darkness) can be used to induce estrus in goats.

Differences exist in the onset and length of the breeding season among the various breeds of goats, and even between individual animals within a breed. Geographic location, particularly degree of latitude, has a significant impact on timing and length of the breeding season. At locations close to the equator, tropical breeds of goats cycle throughout the year. However, factors such as rainfall, nutrition, and lactational status can also effect breeding season. Other stressors such as transportation or illness may temporarily stop estrous activity. In seasonally breeding does, the breeding season is framed by transitional periods during which gonadotropin levels are increasing but not to levels that will trigger estrus and ovulation. Often the onset of estrous activity can be hastened through appropriate management techniques (i.e., introduction of males) during this transitional period. Management tools to manipulate the breeding season will be presented later in the chapter. In the male, seasonal breeding is associated with changes in testis size and libido, and the development of a distinct buck odor.

Nutritional considerations

Diets and feed supplies have to be adjusted to account for the physiological stage of production of the goat, particularly in the female (lactation, gestation). Prior to breeding (2 to 3 weeks) does in poor condition should be placed on a gaining plane of nutrition to stimulate higher ovulation rates ('flushing'). The mechanism accounting for this improvement in ovulation rate is not fully understood, nor have results been as consistent in goats as they occur in sheep. It is also not clear if improvements are linked more directly to changes in energy or protein intake, but changes are more pronounced in does where the improved diet results in changes in body condition.

During the early stages of gestation the nutritional demands of does are moderate and only in later stages of pregnancy, at the time of increased fetal growth, should the plane of nutrition be increased. Inadequate nutrition during late gestation can result in abortion, ketosis or pregnancy toxemia, stillborn and weak kids, and also may limit availability of colostrum for the newborn kid. Poor nutrition may also affect the acceptance and bonding of the mother. Late pregnant does should have access to high quality forage, and moderate levels of concentrate feed, as both undernourished or overly fat does are prone to pregnancy toxemia (ketosis) during the late stages of gestation. Does nursing their kids are nutritionally challenged and may require supplemental feed if pastured to ensure adequate milk supply for litters with multiple kids. Nutritional status of the doe can be easily assessed using body condition scoring (BCS), which is a quick method of describing how thin or fat a goat is, using

a numerical score from 1 to 5. A goat may be given a half score. Assigning a BCS cannot be done by looking at the goat, one must feel for muscle and fat cover. An appropriate BCS range for goats is from BCS 2 to BCS 4. Goats that are too thin (BCS 1) may have nutritional or health problems reducing productivity. Overly fat goats (BCS 5) have reduced fertility, increased birthing problems, and health problems.

BCS is commonly assessed in the loin area. Feel the amount of tissue covering the ends of the spinous and transverse processes of the vertebrae. Feel any loin muscle and fat filling the space between the backbone and horizontal bones. In very thin goats the bones can feel "sharp." As the animal gains condition, the thicker tissue covering makes the bone ends feel more rounded and smooth.

Recommendations

- *Does*: BCS between 2.0 to 3.0 at breeding.
- *Bucks*: BCS between 2.5 to 3.0 prior to the breeding season.

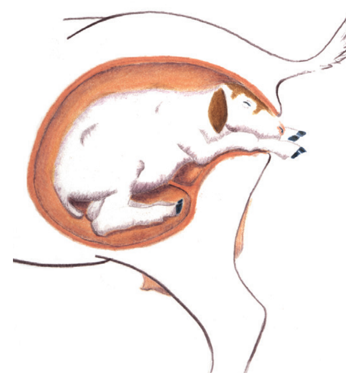
Gestation and parturition

Embryonic losses early in pregnancy are usually much higher than fetal losses at later stages of gestation, and can be as high as 20 to 30%, due to the complexity of events associated with fertilization and implantation. Embryo mortality is also influenced by extrinsic factors such as doe age, and environmental and nutritional stress. Abortions during the early stages of gestation can usually not be readily differentiated from failure to conceive. During these early stages of pregnancy the embryo is sensitive to a variety of drugs and mineral deficiencies.

In goats, in contrast to sheep, the placenta does not provide sufficient progesterone, and is dependent on secretions from an active corpus luteum to support pregnancy. Hence, spontaneous (non-infectious) abortions resulting from luteal insufficiency are more common in goats. Undernutrition, vitamin and mineral deficiencies, toxic plants, and certain drugs can contribute to non-infectious abortions. Late-term abortions at a rate of 2 to 5% can be considered normal; however, multiple late abortions ('abortion storm') usually suggest an infectious cause for the abortion, of which chlamydiosis and toxoplasmosis are the most common sources. To properly diagnose the cause of an infectious abortion, the fetus, portions of the placenta, and a blood sample from the doe should be collected for testing. Abortions should be treated with the appropriate caution. Aborting does should be isolated. All tissues should be handled with protective clothing and those not sent for diagnosis should be carefully disposed to avoid infecting other animals and humans.

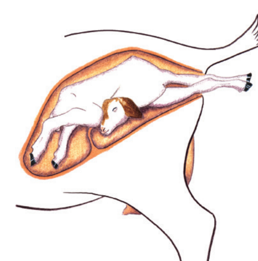
Parturition can be divided into three stages. During the first stage, the uterine content is pushed toward the cervix, causing it to dilate in a process that may last up to 12 hours. In the second stage, contractions increase and the kid(s) move in the birth canal and are expelled in a process that may take up to two hours. In the third stage, the placenta is expelled and uterine involution commences. Parturition can be induced in goats through the use of prostaglandin which regresses the corpus luteum and removes the primary source of progesterone. Does treated with prostaglandin will usually deliver their kids between 30 to 35 hours after injection, and no further ill effects such as retained placenta and reduced subsequent fertility are generally observed. It is imperative that the correct breeding date is available and the doe only be induced by prostaglandin after day 144 of pregnancy to ensure viability of the kid(s). Parturition can also be induced using corticosteroids (i.e., dexamethasone). Treatment with corticosteroids increases estrogen synthesis resulting in prostaglandin production and conversion of progesterone. The advantage of corticosteroids used prior to day 144 of pregnancy is that of ensuring the survival of a fetus. Combination of corticosteroids and prostaglandins are used commonly if the breeding dates are unknown.

Kidding generally should not require human assistance. However, assistance may be needed when



Normal presentation.

Leg-back presentation.



Head-back presentation.

a fetus is not presented properly for delivery, or the cervix is not fully dilated to accommodate a large kid (dystocia). Intervention should be considered once the second stage of labor exceeds more than an hour. In case of failure of the cervix to dilate properly (ring-womb), cautious manual stretching can be applied. Continued failure to dilate may require veterinary assistance and a cesarean section to deliver the kid(s). The normal presentation of kids for delivery is with the head positioned between the front legs. Presentation of the hind legs first may also allow the kids to be born without further assistance. However, abnormal presentations such as the head and leg(s) facing back, and multiple kids entangled during birth, will require manual repositioning of the kids by experienced personnel. Once a kid is positioned correctly assistance may be provided by pulling the legs downward at a 45 degree angle.

Membranes covering the kids will usually rupture during birth and are removed through cleaning by the doe. If membranes cover mouth and nose, and are not attended to by the doe, they need to be removed manually and breathing should be stimulated and the kid(s) dried off. Newborn kids should be nursing within a couple hours of birth to ensure that proper amounts of colostrum are consumed. The udder of the doe should be checked to ensure that milk is present and can be expressed. The navel of the new born kid should be dipped in iodine. In general, handling of newborn kids and does should be limited to allow the proper bond between dam and offspring to form.

The placenta should be expelled within 12 hours of the last kid being born. A retained placenta may indicate an infection or dietary deficiency. Manual removal should not be attempted, but rather the doe be administered oxytocin, and treated systemically with antibiotic.

Newborn kid and doe shedding afterbirth.

Artificial raising of kids

Milk is the principal component of the diet of the pre-weaning kid. Most meat goat kids will nurse their dam until weaning. However, for orphaned kids or for kids of does that have lactation problems it may be necessary to use a milk replacer. If no other milk replacer is available whole cows milk or calf milk replacers can be used. Maintaining milk replacer quality after mixing is particularly important when kids are fed ad libitum (all they can consume).

Under natural suckling, kids consume small amounts of milk at very frequent intervals. Ideally, artificial rearing should mimic natural suckling but the constraint of available labor precludes frequent feeding. Nevertheless, kids should be fed 4 to 5 times daily for the first and second week and 2 to 3 times daily thereafter. Bottle feeding is more labor intensive but kids receive more individual attention and are easier to handle post-weaning than kids that are allowed to suckle does. Pail or pan feeding may reduce labor somewhat but bodyweight loss and need for extra “training sessions” at the beginning must be expected.

Feeding schedule and amount for bottle fed kids.

Age	*Amount of Fluid/Feeding*	*Feeding Schedule*
1 to 3 days	12 centiliter	5 times a day
3 days to 2 weeks	24 to 36 cl	4 times a day
2 weeks to 3 months	48 cl	3 times a day
3 months to 4 months	48 cl	2 times a day

Small, frequent feedings increase digestibility and decrease digestive disturbances. Rapid consumption of large quantities of milk may lead to fatal bloat due to entry of milk into the reticulo-rumen. Rapid passage of milk through the abomasum and small intestines can result in diarrhea or nutritional scours.

Doe raising twins.

The biggest problem with kids bottle fed lamb milk replacer occurs with the feeding schedule. Frequently kids become “pets” and there is a tendency to feed them as much milk as they will consume each feeding. Unfortunately, this may result in bloat and sudden death due to enterotoxemia or diarrhea. A restricted feeding schedule and amount is necessary.

Parts of this section were adapted from:

- **Wildeus, S. 2007. Goat Reproduction in Meat Goat Production Handbook, Langston University, Editors: T.A. Gipson, R.C. Merkel, K. Williams, and T. Sahlu.**
- **Wade, T. 2007. Advanced Goat Reproduction Methods and Techniques in Meat Goat Production Handbook, Langston University, Editors: T.A. Gipson, R.C. Merkel, K. Williams, and T. Sahlu.**

The authors are grateful to Dr. Lou Nuti of Prairie View A&M University for contributions to the sections on Semen Collection, Semen Evaluation, and Semen Processing.

The authors are grateful to Dr. Roger Merkel for photographic contributions to this manual.

Body Condition Scores in Goats

Introduction

Every goat producer has animals that are either too thin (under-conditioned) or too fat (over-conditioned). Failure to recognize these animals and take corrective actions will cost dearly in terms of decreased fertility, increased disease or internal parasite incidence, decreased milk production, and increased operating costs. Thus, goats need to be maintained with a moderate amount of body condition. When overall body condition starts to decrease in the herd, it is a sign that managerial intervention is needed such as supplemental feeding, deworming, pasture rotation, etc. Conversely, when overall body condition starts to increase in the herd, it is a sign that the producer should reduce supplemental feeding. Ignoring an animal's body condition and waiting to intervene until goats become either too thin or too fat may result in production and(or) animal losses or decreased profits from overfeeding. Therefore, producers need to develop skills in assessing body condition of their goats so that a desired moderate body condition can be maintained.

Body condition score (BCS) has been shown to be an important practical tool in assessing the body condition of cattle, sheep, and goats because BCS is the best simple indicator of available fat reserves which can be used by the animal in periods of high energy demand, stress, or suboptimal nutrition.

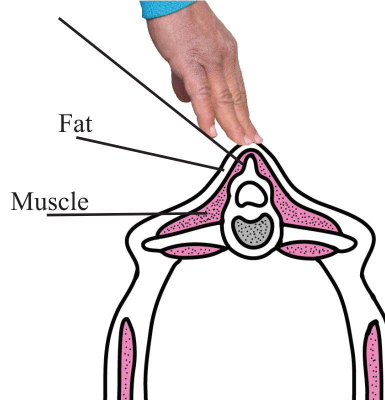
Scoring is performed in goats using a BCS ranging from 1.0 to 5.0, with 0.5 increments. Examples of BCS of 1.0, 2.0, 3.0, 4.0, and 5.0 are given using photographs and written descriptions. Assigning the 0.5 score increment is done when the animal being evaluated is intermediate to the BCS described. A BCS of 1.0 is an extremely thin goat with no fat reserves and a BCS of 5.0 is a very over-conditioned (obese) goat. In most cases, healthy goats should have a BCS of 2.5 to 4.0. BCS of 1.0 , 1.5, or 2.0 indicate a management or health problem. A BCS of 4.5 or 5 is almost never observed in goats under normal management conditions; however, these BCS can sometimes be observed in show goats.

It is important to note that BCS cannot be assigned by simply looking at an animal. Instead, the animal must be touched and felt. The first body area to feel in determining BCS is the lumbar area, which is the area of the back behind the ribs containing the loin. Scoring in this area is based on determining the amount of muscle and fat over and around the vertebrae. Lumbar vertebrae have a vertical protrusion (spinous process) and two horizontal protrusions (transverse process). Both processes are used in determining BCS. You should run your hand over this area and try to grasp these processes with your fingertips and hand. The second body area to feel is the fat covering on the sternum (breastbone). Scoring in this area is based upon the amount of fat that can be pinched. A third area is the rib cage and fat cover on the ribs and intercostal (between ribs) spaces.

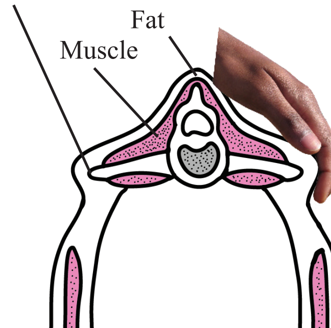
With practice, evaluating the BCS of an animal will only take about 10-15 seconds. By adding BCS as a regular part of your management program, you can more effectively monitor your feeding and herd health program for a healthy and productive herd.

Lumbar Region

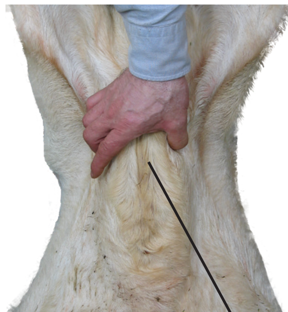
Spinous process

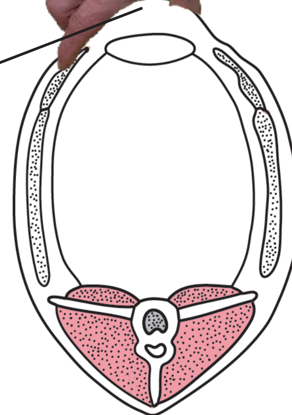


Transverse process



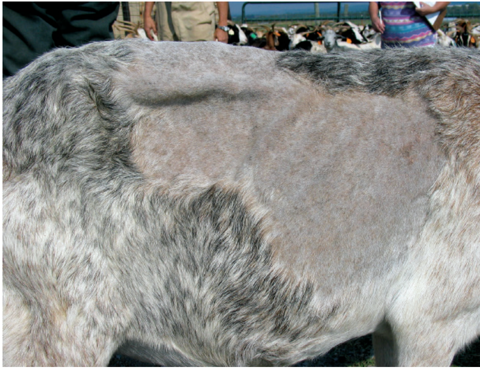
Sternum



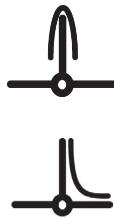


Fat

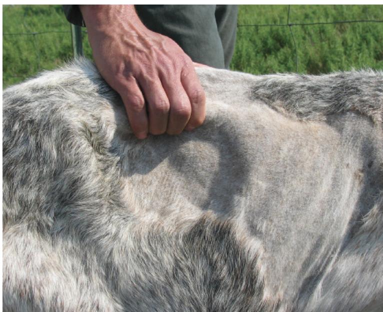
BCS 1.0



Visual aspect of the goat: Emaciated and weak animal, the backbone is highly visible and forms a continuous ridge. The flank is hollow. Ribs are clearly visible. There is no fat cover and fingers easily penetrate into intercostal spaces (between ribs).

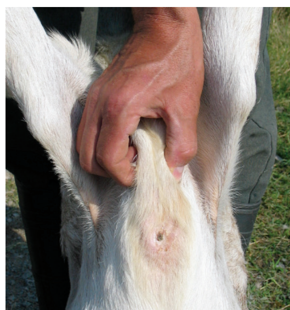


The spinous process of the lumbar vertebrae can be grasped easily between the thumb and forefinger; the spinous process is rough, prominent, and distinct giving a saw-tooth appearance. Very little muscle and no fat can be felt between the skin and bone. There is a deep depression in the transition from the spinous to transverse process.



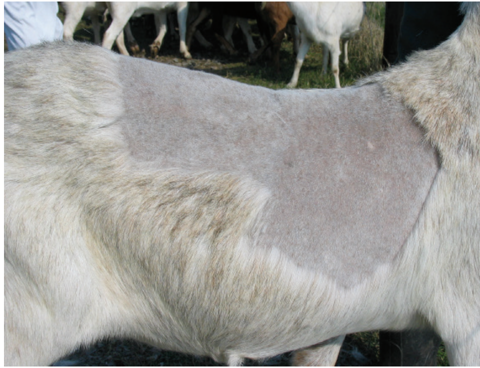
The hand can easily grasp the transverse processes of the lumbar vertebrae which are very prominent. Clearly half of the length of the transverse process is discernible.

Diagrams adapted from Edmonson, et. al, 1989. J. Dairy Science, 72:68-78. Used with permission from the American Dairy Science Association.

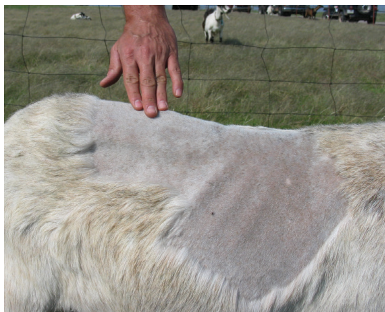


Sternal fat can be easily grasped between thumb and fingers and moved from side to side. The cartilage and joints joining ribs and sternum are easily felt.

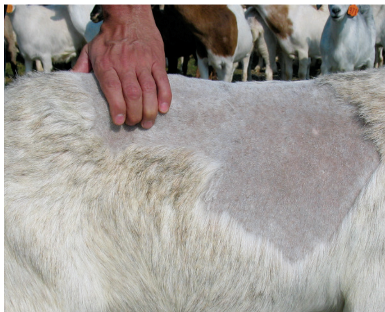
BCS 2.0



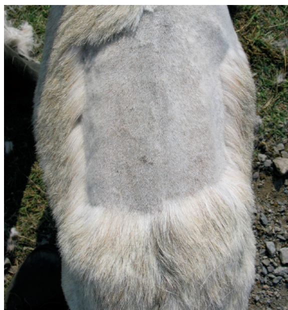
Visual aspect of the goat: Slightly raw-boned, the backbone is still visible with a continuous ridge. Some ribs can be seen and there is a small amount of fat cover. Ribs are still felt. Intercostal spaces are smooth but can still be penetrated.

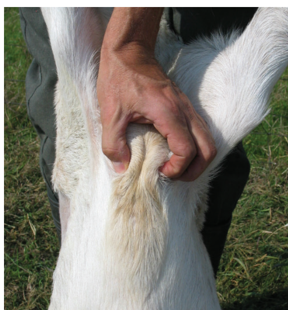


The spinous process of the lumbar vertebrae is evident and can still be grasped between the thumb and forefinger; however, a muscle mass can be felt between the skin and bone. There is an obvious depression in the transition from the spinous to transverse process.



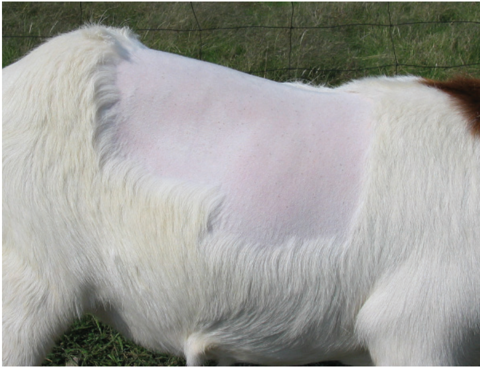
The hand can grasp the transverse process but the outline of the transverse process is difficult to see. About one-third to one-half of the length of the transverse process is discernible.



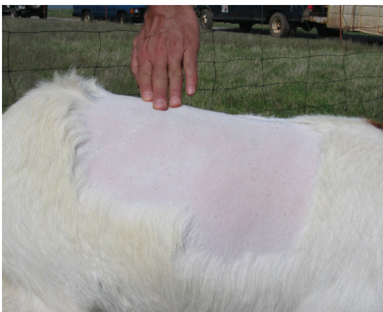


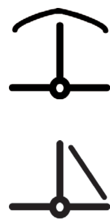
Sternal fat is wider and thicker but can still be grasped and lifted by the thumb and forefinger. The fat layer can still be moved slightly from side to side. Joints are less evident.

BCS 3.0

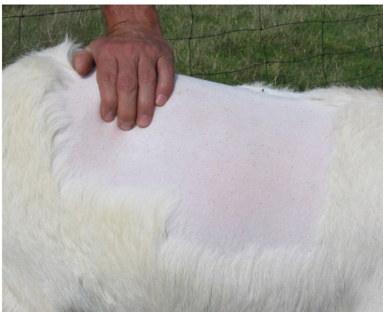


Visual aspect of the goat: The backbone is not prominent. Ribs are barely discernible; an even layer of fat covers them. Intercostal spaces are felt using pressure.

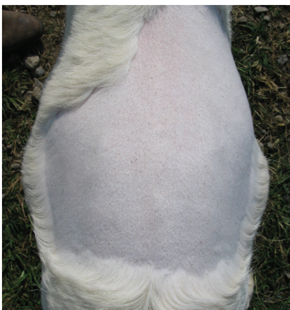


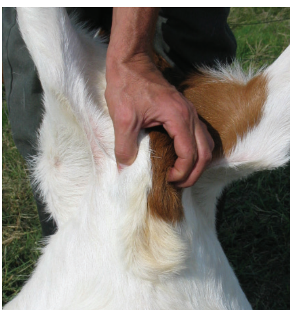


The spinous process of the lumbar vertebrae cannot be easily grasped because the tissue layer covering the vertebrae is thick. When running a finger over the spinous process, a slight hollow is felt. There is a smooth slope in the transition from the spinous to transverse process.



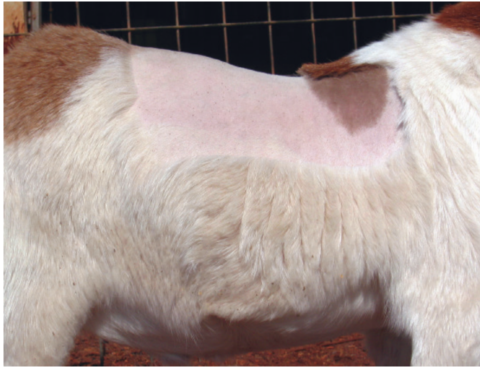
The outline of the transverse process of the lumbar vertebrae is slightly discernible. Less than one-quarter of the length of the transverse process is discernible.



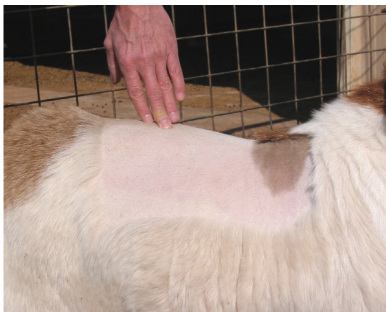


Sternal fat is wide and thick. It can still be grasped but has very little movement. Joints joining cartilage and ribs are barely felt.

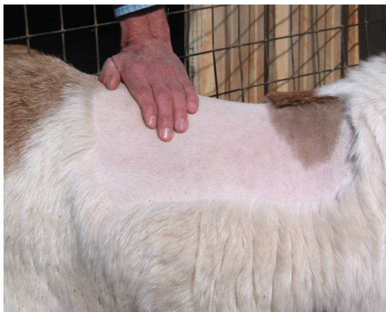
BCS 4.0



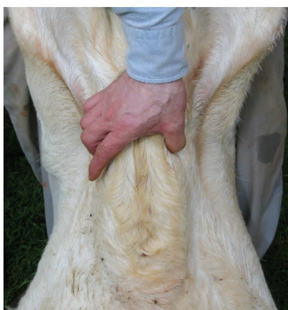
Visual aspect of the goat: The backbone cannot be seen. Ribs are not seen. The side of the animal is sleek in appearance.



It is impossible to grasp the spinous process of the lumbar vertebrae, which is wrapped in a thick layer of muscle and fat. The spinous process forms a continuous line. There is a rounded transition from the spinous to transverse process.

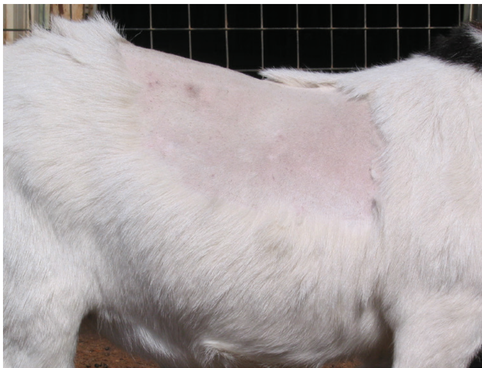


The outline of the transverse process of the lumbar vertebrae is no longer discernible. The transverse process forms a smooth, rounded edge, with no individual vertebrae discernible.

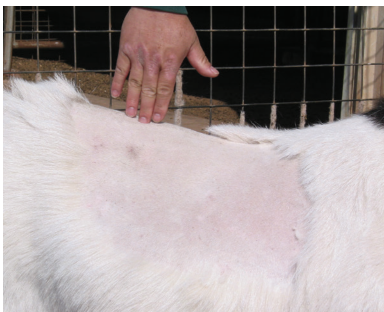


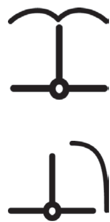
Sternal fat is difficult to grasp because of its width and depth. It cannot be moved from side to side.

BCS 5.0

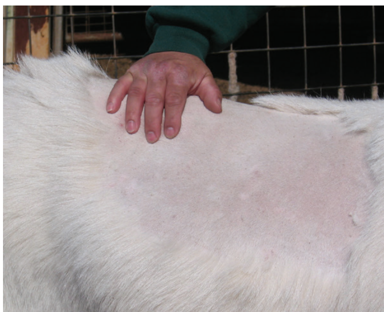


Visual aspect of the goat: The backbone is buried in fat. Ribs are not visible. The rib cage is covered with excessive fat.

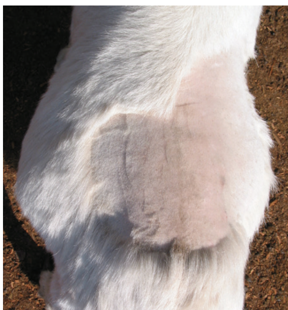


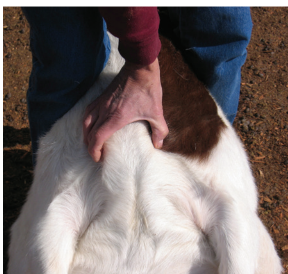


The thickness of the muscle and fat is so great that reference marks on the spinous process are lost. The spinous process forms a depression along the backbone and there is a bulging transition from the spinous to transverse process.



The thickness of the muscle and fat is so great that reference marks on the transverse process are also lost. It is impossible to grasp the transverse process.





The sternal fat now extends and covers the sternum, joining fat covering cartilage and ribs. It cannot be grasped.

Milk Stand / Goat Stand Plans

Brought to you by Fias Co Farm

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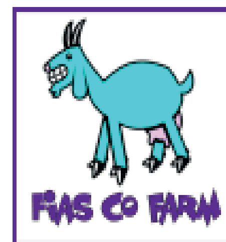


If you construct this stand, please make a donation to the Fias Co Farm web site to help support all the free information it provides.
http://fiascofarm.com/contact.htm#support

Or send a donation check to:

Molly Nolte
4659 Seneca Drive
Okemos, MI 48864

Tools needed:

Saw	Jig Saw	Phillips Screwdriver
Tape Measure	Hammer	Square
Sand Paper/Sander	Drill with bits: 1/8", 3/32", 5/32", 11/32", 11/16	

Hints:

- Note that lumber is not actually the size it is called. For example, a 2X4 is not really 2 inches by 4 inches.
- Read and understand the entire step before actually doing it.
- Predrill holes before screwing using the 1/8" bit.
- When attaching the wood together with your screws, make sure not to hit any screws or tacking nails that you have already driven in from the other side.

Material list:

Lumber (note: we do not use pressure treated lumber)

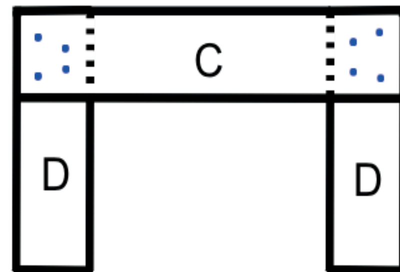
1" x 8" x 10'	parts A	Cut into three 36" pieces
(2) 1" x 4" x 6'	parts B & F	Cut into four 36" pieces
1" x 4" x 8'	parts C & E	Cut into two 20 1/2 " pieces & two 18 ½" pieces
1" x 4" x 8'	parts G & H	Cut into four 21 ½" pieces & two 4 ½" pieces
2" x 2" x 6'	parts J	Cut into three 20 ½" pieces
2" x 4" x 6'	parts D	Cut into four - 14" pieces*

*Parts D are the legs and their length may be adjusted, longer or shorter, if desired. The legs may be made from pressure treated wood if you wish.

Material list continued:

Box 2” Exterior “deck” screws
(4) 3” Exterior “deck” screws
A couple dozen 1 1/2” Exterior “deck” screws
(2) 3” Corner Brace with screws (also called corner brackets)
(1) ¼” x #20 x 2 ½ slotted round head machine screw
(1) ¼” wing nut
(1) ¼” x #20 hex nut
(2) ¼” flat washers
(1) 4” hook and eye latch with extra eye
Handful of 1” finish nails (for tacking)

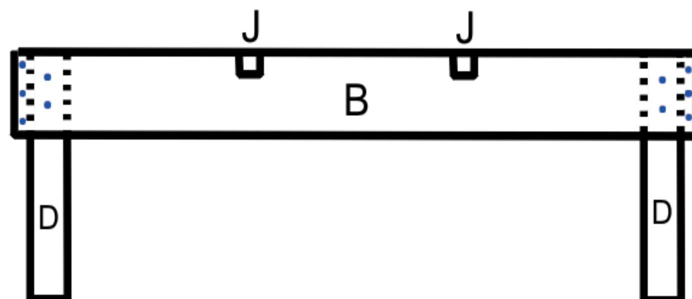
Fig. 1



Constructing the Base:

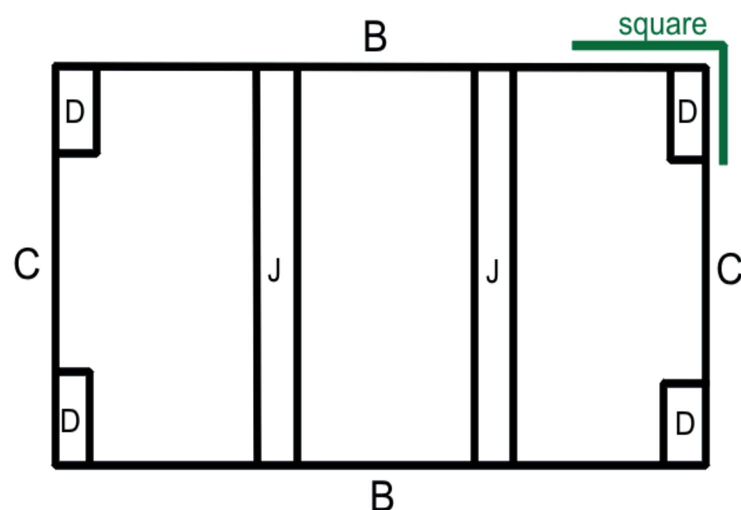
1. Lay 2 legs (2” x 4” x 12”) part (D) (Fig. 1) down with one 20 1/2 “ end piece (C) across the top, flush with the top ends. Secure with 2” screws. Repeat process for opposite end.

Fig. 2



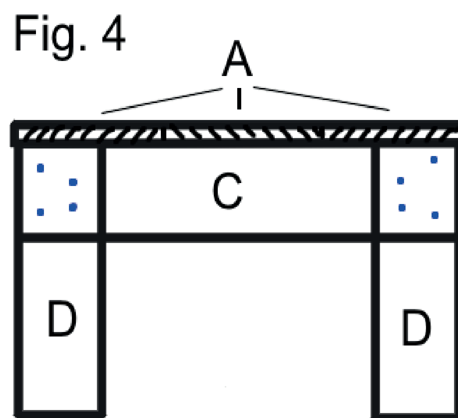
2. Attach both sides (B) 1” x 4” x 36” (Fig. 2) with 2” screws.

Fig. 3 (Underside of base)



3. Attach braces (J), 2” x 2” x 20” to the 1” x 4” sides (parts B) (see Fig. 2 & 3) flush with the top of parts (B) and 12” apart using 2” screws through parts (B) into parts (J).

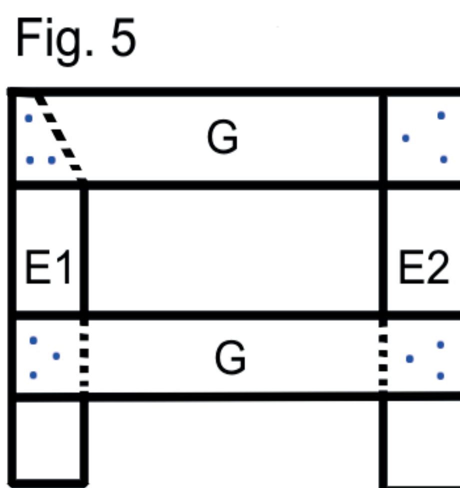
4. Check base for square (Fig. 3). Adjust if necessary.



5. Screw three 1” x 8” x 36” pieces (A) to base (Fig. 4) . Keep square as you go. Screw around edges and to the braces using the 1 ½” screws.

6. Sand all edges and round off corners.

Constructing the Head Gate:

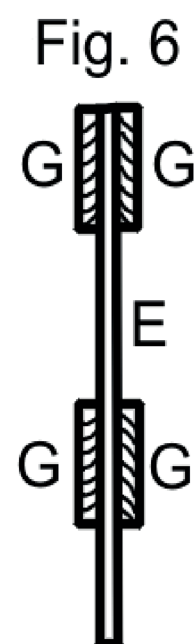


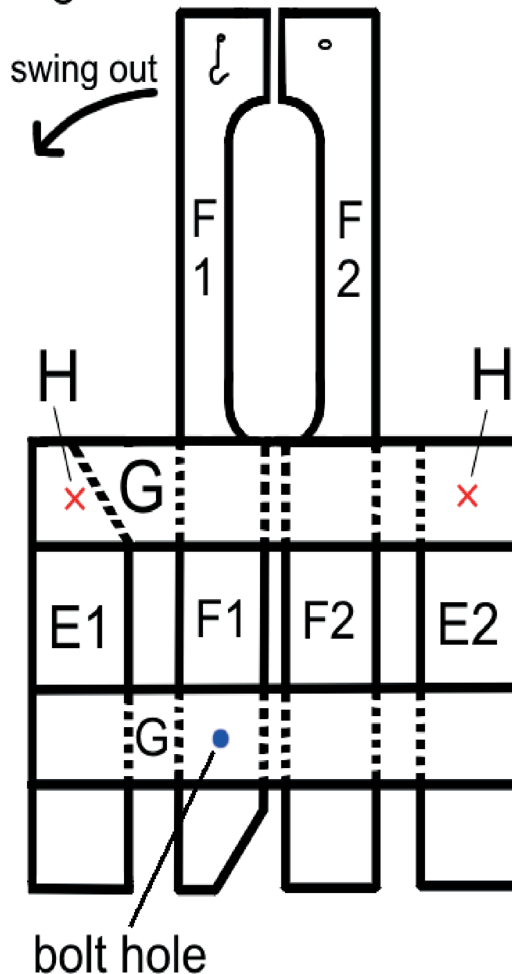
1. Cut one 18 ½” piece (E1) as follows: From one corner, measure over and mark the width at the top at 3”. From the same corner, measure down the length 5 ½” and mark. Draw a line from the first mark to the second and cut. See Fig. 5 left side part E1 has a black dotted line indicating this angle cut.

2. Lay out the two 18 ½” pieces (E1 & E2) and place two 21 ½” pieces (G) across, with top flush and bottom 4” from ends of part (E) (Fig. 5). Use 1” finish nails to tack structure in place without going through the other side. Turn over and put two more 21 ½” pieces (G) into place in the same manner. In effect “sandwiching” the (E) parts.

   See Fig. 6 – This is what it should look like.

   Secure with 2” screws from both sides - Indicated by blue dots is Fig. 5. NOTE: Use an opposite triangle pattern on the reverse side so you do not hit the screws coming from the other side.





3. Cutting the “Head hole”: (Refer to Fig. 7.) Cut a notch in two of the 1” x 4” x 36” (F1 & F2) beginning 4” from the top and down 13 ½” from the first cut with a depth of 1 ½”. Cut entrance and exit in a curve that will not bind your jigsaw

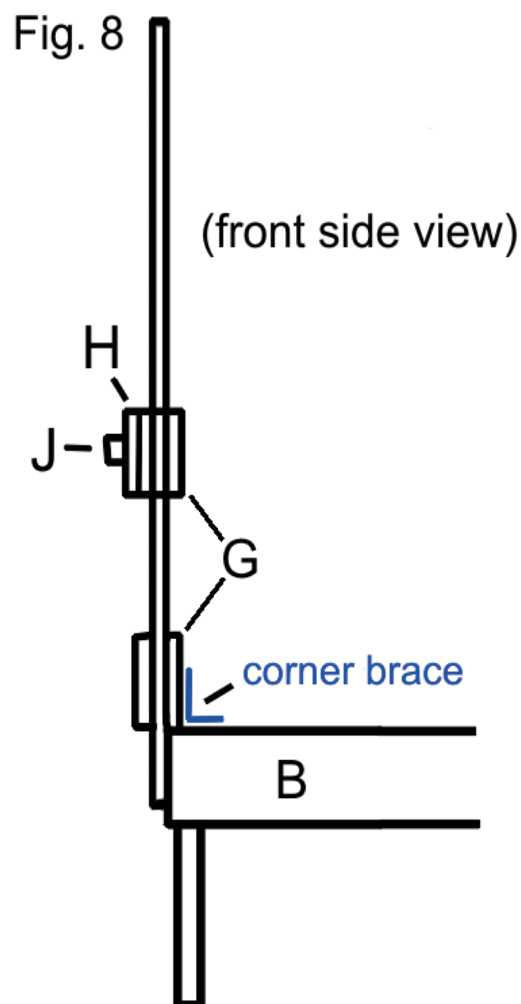
4. Cut the bottom of (F1) as follows: From the inside corner (same side as the head hole- see Fig. 7), measure 3” across width and mark. From the same corner measure up the length 4 ½” and mark. Draw a line from mark to mark and cut. This piece (F1) is the movable portion of the head gate. Sand well so no splinters are present and parts move easily.

5. Insert and slide the part (F2) (not cut at an angle on the bottom) between parts (G). Place ½” from center on (G) and 4” below bottom part (G). Secure with 2” screws.

6. Slide part (F1) into the head catch (see fig. 7). Make sure it has been sanded enough to allow free movement within the head gate. Line up part (F1) 1” from part (F2) already installed.

7. Drill a hole with a 11/32” bit through the lower part (G), (Fig. 7), part (F1) that moves, and part (G) on opposite side. Use a 13/16” bit to enlarge the hole on both sides on both sides no more than ¼” deep. This allows ¼” x 20 x 2 ½” slotted round screw with ¼” x 20 hex nut to be recessed. Install the bolt: place one ¼” washer on the 2 ½” slotted round crew, place screw though bolt hole, place another washer on the screw and then the hex nut. Tighten.

8. Attach 1” x 4” x 4 ½” (H) to upper part (G) (Fig. 7) at the “X” marks that will face away from the base of the stand. Predrill holes to keep these parts from splitting and attach with 2” screws.



9. Attach parts (J), 2” x 2” x 20 ½”, to parts (H) (Fig. 8). Center and attach using two 3” deck screws on each end. This will hold the removable feeder. See photo below.

Note: We found that eventually we needed to add a thin furring strip to (J) so the feeders we used would fit a little more snuggly. You can adjust later to suit your needs.

10. Sand all edges and round off corners

Attach Head Gate to Base:

Refer back to Fig. 4. Enlist the aid of a helper.

1. Hold the head gate with the feeder holder facing away from the base, so that the bottom of part (G) rests on the base surface (A).

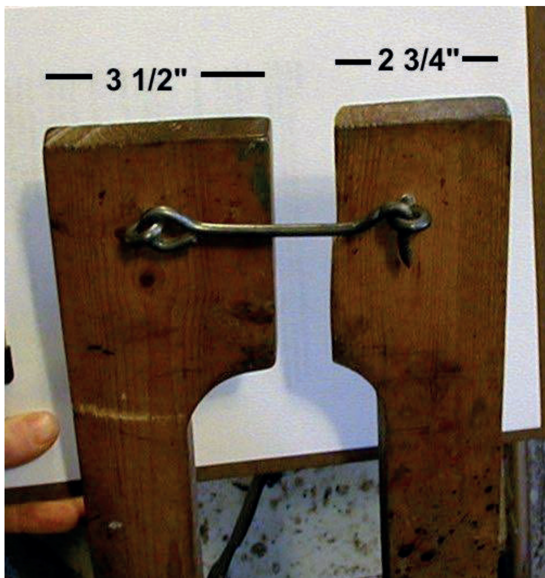
2. Attach assembled head gate onto base using 2” screws though parts (E1, E2 & F2). DO NOT put screws through (F1).

3. Attach the Corner Braces to the head gate and base by as shown in photo .

Install Head Gate Closure:

Attach 4” hook and eye latch to head gate side facing toward the base. Normally, the closed position allows the tops of the head gate (F) to touch. Additional eyes can be installed for thicker necked animals (like bucks and wethers). See photos.

Adjusting to suit your needs:
We removed some of the wood from one (F) piece so that it would close even tighter to accommodate younger kids (two months old). In this case, when using the stand for kids, the gate is secured closed by wrapping a bungee cord around it.



NOTES:

1) ALL CONNECTIONS ARE TO BE WELDED.
2) RUBBER MATTING MAY BE USED OVER METAL FLOORING.
3) DIMENSIONAL INFORMATION FOR BUCKET ATTACHMENT WILL VARY DUE TO TYPE/SIZE OF BUCKET USED.

48"
EXPANDED METAL OR GALV. SHEET
20"
1½" x 1½" IRON

PLAN
SCALE: 1"=1'-0"

1" x ⅛" FLAT STOCK
* SEE BUCKET ATTACHMENT DETAIL
1" x 1" TUBING
1" x 1" IRON
EXPANDED METAL OR GALV. SHEET
1½" x 1½" IRON
4' 4"
1" x 1" IRON
1" x 1" TUBING
16"

SIDE VIEW
SCALE: 1"=1'-0"

20"
1" x ⅛" FLAT STOCK
1" x 1" TUBING
1" x 1" TUBING
*SEE BUCKET ATTACHMENT DETAIL
1" STEEL PLATE W/ BOLT THROUGH FOR HINGE
EXPANDED METAL OR GALV. SHEET
8" 8" 8" 8"
1" x 1" IRON
1" x 1" IRON
1" x 1" TUBING

FRONT VIEW
SCALE: 1"=1'-0"

STEEL PLATE W/ BOLT
1" x 1" TUBE

SECTION B
SCALE: 1"=1'-0"

⅝" x ⅛" LATCH
3/16" BOLT
SUPPORT WASHERS
DRILL ¼" HOLES

VIEW A

⅛" FLAT STOCK
¼" x ¼" NOTCH
¼"
¾"
3/8"

VIEW A W/OUT LATCH

NOTCH FOR LATCH
1/4"
¼"
1" x ⅛" FLAT STOCK

VIEW B

LATCH, CUT FROM 1" x ⅛" FLAT STOCK
½"
3/16" HEX BOLT
⅛" LATCH SUPPORT

VIEW C

DRILL 1/4" HOLE
1" x ⅛" FLAT STOCK
¼"
5/16"
¾"
5/8"

VIEW C W/O LATCH

5/8"
1/2"
½" R
DRILL ¼" HOLE
¼" R
1"

CROSS SECTION VIEW C AT LATCH

LATCH MECHANISM DETAIL
FULL SCALE

1" x 1" TUBING
VIEW B
VIEW C
VIEW A
1" x ⅛" FLAT STOCK STOP BAR
LATCH MECHANISM (DETAIL THIS SHEET)

TOP VIEW
SCALE: 1/2"=1'-0"

48"
6"
1" x 1" IRON
1½" x 1½" IRON
4'-4"
6"
8"
1" x 1" IRON
8"
8"
16"
1" x 1" TUBING

SECTION A
SCALE 1-1/2"=1'-0"

FEED BUCKET HOLDER
1" x 1" IRON
EXPANDED METAL OR GALV. SHEET WRAP-AROUND BUCKET SUPPORT
1" x ⅛" FLAT STOCK

PLAN
SCALE: 1"=1'-0"

BUCKET WRAP-AROUND
1" x 1" IRON

SIDE VIEW
SCALE: 1"=1'-0"

SEE LATCH DETAIL THIS SHEET
STOP BAR
BUCKET RETAINER
BUCKET STAND

FRONT VIEW
SCALE: 1"=1'-0"

GOAT MILKING STAND - METAL

FL '88	6399	SHEET 1 OF 1

Inches to Centimeters Conversion

centimeters × 0.394 = inches

inches × 2.54 = centimeters

1 metre is equal to 39.4 inches.

US	Metric
(inches)	(mm)
5/32	3.97
	4
3/16	4.76
	5
13/64	5.16
7/32	5.56
15/64	6.05
	6
1/4	6.35
17/64	6.75
	7
9/32	7.14
5/16	7.94
	8
11/32	8.73
	9
3/8	9.53
	10
	11
7/16	11.11
15/32	11.91
	12
1/2	12.7
	13
17/32	13.49
	14
9/16	14.29
	15
19/32	15.08
5/8	15.88
	16
21/32	16.67
	17
11/16	17.46
	18
	19
3/4	19.05
25/32	19.84
	20
13/16	20.64
	21
	22
7/8	22.23
	23
29/32	23.02
15/16	23.81
	24
31/32	24.61
	25
1	25.40
	26
1 1/16	26.99
	27
	28
1 1/8	28.58
	29
	30
1 3/16	30.16
	31
1 1/4	31.75
	32
	38
1 1/2	38.10
	39
	50
2	50.80
	51

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