(2) Chemical Composition

(2-1) Spermatozoa

The head of a spermatozoon contains mainly DNA and basic proteins such as protamine and histone that combine with DNA. The middle piece and tail contain phospholipids, which are a source of energy, and enzymes, that are essential in metabolism.

(2-2) Seminal Plasma

Seminal plasma contains reducing sugar, that is, mainly fructose, polyols such as sorbitol and inositol, organic acids such as ascorbic acid and lactic acid, lipids such as lecithin, amino acids such as glutamic acid, nitrogen containing bases such as glycerylphosphorylcholine and ergothioneine, prostaglandins, minerals and enzymes.

Fructose: A large proportion of sugar in livestock semen is fructose which originates from the seminal vesicle. The amount of fructose in semen is related to the level of androgens and, therefore, fructose level in semen can be used to measure the activity of androgen. Fructose is the main source of energy for spermatozoa soon after ejaculation and the pH of semen falls after ejaculation and in vitro if it is not treated since lactic acid accumulates due to the consumption of fructose.

Protein and Amino Acid: Semen contains a large amount of protein and free amino acids. They combine with heavy metals to protect semen from their harmful effects.

Citric Acid: Citric acid in semen originates from seminal vesicles and bovine semen has the largest amount of citric acid compared to other livestock. Citric acid is

controlled by androgen and this can be used to indicate sexual function. Citric acid is largely unused by spermatozoa and is assumed to have the role of maintaining osmotic pressure and act as a buffer in semen.

Phosphatase: Semen shows strong phosphatase activity. Acid phosphatase comes from the prostate gland and alkali phosphatase comes from the seminal vesicle. Alkali phosphatase activity is high in livestock semen.

Hyaluronidase: This enzyme plays an important role in fertilization and is present in spermatozoa. Hyaluronidase activity in seminal plasma is higher in semen containing a high number of spermatozoa. This enzyme leaks from spermatozoa if semen is frozen then thawed and the amount of leaked hyaluronidase is an indicator of the the degree of damage to spermatozoa. This enzyme helps spermatozoa impregnate the ovum by removing the granulosa cells around the ovum.

(3) Factors That Affect the Properties of Semen

(3-1) Age: The volume of semen and number of spermatozoa in old male animals is usually greater and more stable than in young animals. Bulls, for example, produce good semen very stably at about 3 - 6 years of age. Semen collected from much older males shows features such as a decrease in the ratio of living spermatozoa, an increase in the ratio of malformed spermatozoa, and decreased freezability.

(3-2) Nutrition markedly affects the properties of semen.: Poor nutrition may cause effects such as a delay of sexual maturity, decreased sexual drive, decreased spermatogenesis, and an increase in malformed spermatozoa.
Good nutrition, or high calories, may cause effects such as early sexual maturity, decreased sexual drive due to

obesity, and an increase in malformed spermatozoa. A high protein diet causes an increase in the volume of semen and in the ratio of living spermatozoa. A deficiency of vitamin A or carotene may have a bad effect on spermatogenesis, but sufficient feed containing appropriate roughage can prevent this. The addition of substances such as blood meal, bone meal and minerals to feed is beneficial in health management of livestock. Feeding bull with silage is not beneficial.

(3-3) Season

Some female livestock, such as horses, sheep and goats, have a non-breeding season. In males at this time a decrease in the volume and number of spermatozoa in semen, as well as spermatozoal activity are observed. The semen of bulls and pigs, which can breed throughout the year, is of poor quality in summer to early fall. The rate of conception for the animals may be low at these times of year. This is known as summer sterility and if this is extreme, it may cause aspermia in a pig. This is caused by the effect of heat on spermatogenesis so a cool environment is the key factor in raising male livestock.

(3-4) Exercise and Exposure to Sunshine

Exercise and exposure to sunshine increase livestock metabolism and improve circulation of blood throughout the whole body. These factors enhance spermatogenesis. Exercise and exposure to sunshine is also good for general health management by, for example, preventing obesity.

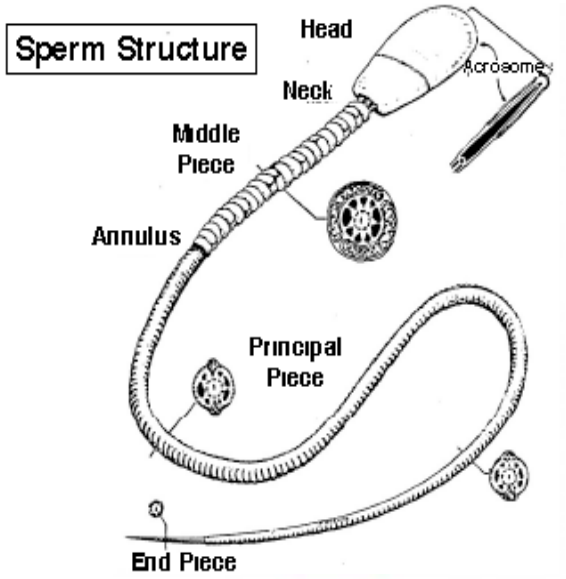
(3-5) Frequency of Ejaculation

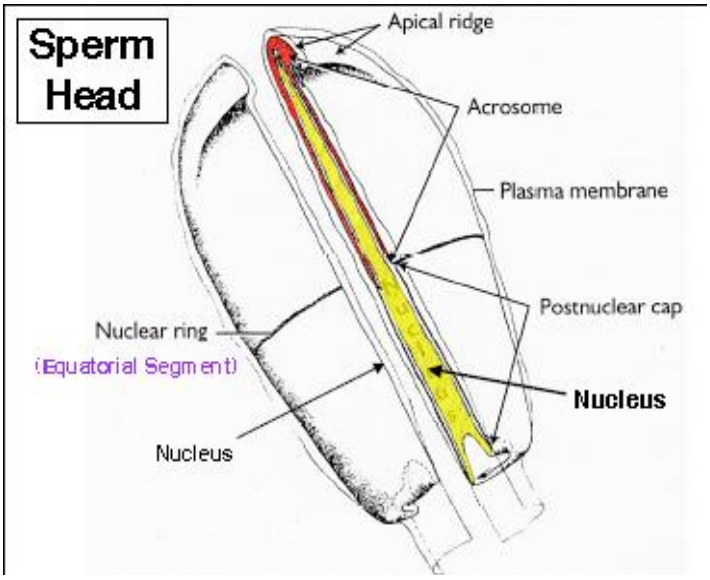
The frequency of ejaculation affects the volume of semen, the number of spermatozoa, spermatozoal activity, and the ratio of malformed spermatozoa. Frequent ejaculation advesely affect these properties. Horses and pigs, which ejaculate a large volume of semen each time, are easily affected by these factor. Bulls and sheep are not so strongly affected since they accumulate semen every day for a week. For the effective use of male livestock such as maintaining reproductive ability for a long time the most appropriate frequency of semen collection for each animal species is as follows;

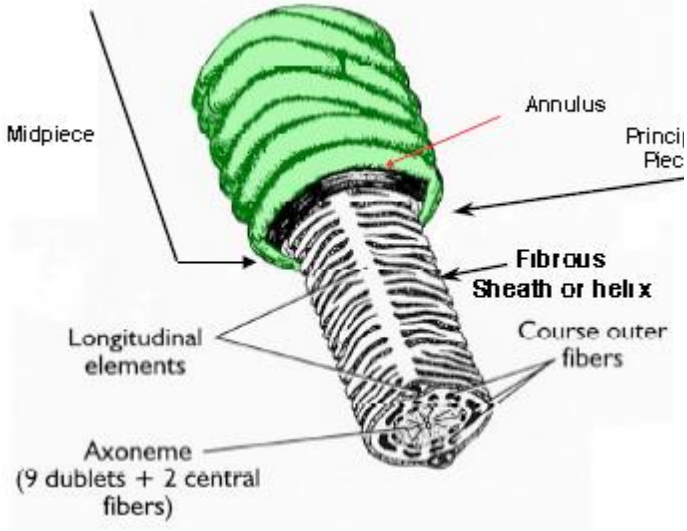
Bull: 2 ejaculations per day, every 2 - 4 days.
Pig: 1 ejaculation per day, every 3 - 4 days.
Sheep and goats: 2 - 3 ejaculations per day with 1 or 2 days rest per week.
Horse: 1 - 2 ejaculations per day with 1 or 2 days rest per week.

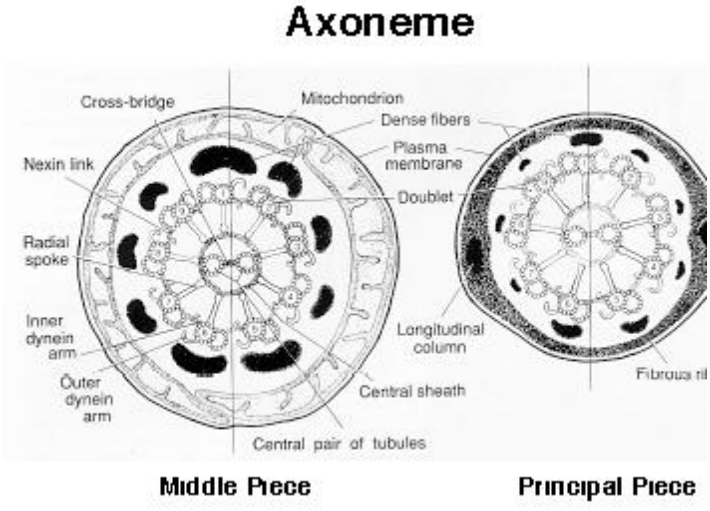
Table 1-3-3 Chemical Composition of Livestock Semen (Mann 1964, 1969)

	Bull	Sheep	Pig	Horse
Total N	440 - 1,170	900	200	150 - 300
Na	150 - 370	103 - 180	280 - 800	257
K	50 - 380	71 - 90	280 - 830	103
Ca	24 - 60	9	2 - 6	26
Mg	8	3 - 6	5 - 14	9
Cl	150 - 390	87 - 180	260 - 430	80 - 400
Fructose	300 - 1,000	150 - 660	3 - 48	< 1
Sorbitol	10 - 136	26 - 120	8	20 - 60
Inositol	24 - 46	10 - 15	380 - 625	19 - 47
Ergothioneine	< 1	< 1	6 - 30	4 - 16
Glycerylphosphoryl choline	110 - 500	1,600 - 2,000	110 - 240	38 - 113
Citric acid	350 - 1,000	300 - 800	36 - 325	10 - 50
Lactic acid	20 - 50	35	20	9 - 25
Zinc	-	-	4	-

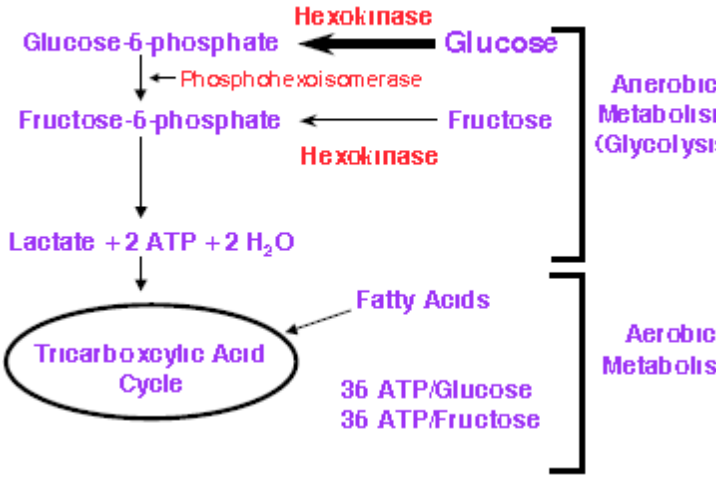








Sperm Metabolism



ATP Utilization in Sperm

- motility (60%)
- substrate cycling (40%)
  - wasted
- maintenance of ionic gradients
  - very small amount
- transcription and translation
  - none after condensation of nucleus and loss of residual body

Sperm Metabolism

- Temperature dependent
  - ATP production increases as temperature increases
- ATP dependent processes are temperature dependent
  - motility increases with increasing temperature

In the case of natural service, semen is deposited in the anterior vagina whereas with artificial insemination it is usual to place it just inside the uterus or in the anterior cervix. Spermatozoa ascend the female tract by both active and passive processes. Active transport involves activity of the sperm tail or flagella, but clearly its interaction with epithelial surface secretions and cilia is also important. Propulsion of spermatozoa through the uterus appears to be quite rapid and the isthmus of the oviduct acts as a spermatozoa reservoir in many species. Recent observations using ultrasound techniques have demonstrated the capacity of the uterus to transport fluids to the vicinity of the oviduct in a matter of minutes. Spermatozoa have been detected in the oviducts as little as two minutes after insemination. The passive transport appears to be due solely to uterine contractions of the female and has been demonstrated to occur even with dead spermatozoa.