The Effect of Summer Heat on Spermatogenic Function in the Bull

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There have been many reports on the relationship between the reproductive function and the season in the bull since old times, saying that the semen becomes inferior in quality from summer to autumn. The same phenomenon is known to occur not only in the bull but also in the ram, he-goat, boar and male rabbit and called summer sterility in general.

In recent years experiments have been carried out in an artificially controlled climatic chamber to make clear the relationship between the atmospheric temperature and the seminal character, obtaining the result that the spermatogenesis was remarkably inhibited in the bull by continuous rearing at the environmental temperatures above 85°F.

Based on the result of those experiments, the decline of spermatogenic function in summer is said today to be due to high temperatures. The summer sterility is fairly frequent in the bull in Japan because of high humidity in addition to high temperature in summer. The sterility is an obstacle to the work of artificial insemination and is a cause of a decrease in conception rate in summer. A countermeasure, therefore, is greatly demanded to prevent the sterility.

The following is an outline of the studies carried out on the summer sterility in the last few years.

Importance of the testicular temperature

The testis is contained in the scrotum and kept at lower temperature than the other parts of body in the bull. And the spermatogenesis does not take place in the cryptorchid which is incapable of regulating temperature, showing that a difference in temperature between the body and the testis is essential for the normal spermatogenic function. Peters and Newbound,[23] Schindler[25] said that the temperature of skin was 33.6-34.2°C in summer and 28.6-28.8°C in winter at the scrotum, being lower by 2-4°C than at the groin and abdomen in a bull. And according to the Yamauchi's observation[33] in a bull the difference in temperature between the scrotal skin and the body was more than 5.3°C, and higher by 1°C in summer than in winter.

Glover and Young[5] induced testicular degeneration in guinea pigs by artificial cryptorchidism and reported that the temperature was higher by 4°C in that testis than in the normal one. Male rats were made sterile by infrared radiation at 48°C for five minutes, and in case of male rabbits and male mice, the seminiferous epithelium was damaged within one hour by dipping into hot water at 48°C.

The isolation of the scrotum from the open air by covering also raised the temperature of testes without heating them externally and had a strikingly had effect on the production of spermatozoa in bulls and rams.[8][24] Those facts suggest that the spermatogenic function reacts sharply to a rise of temperature limited to the scrotum irrespective of the method of induction.

Gun et al.[7] reported that spermatogenesis was damaged in rams in case the animals be-

Fig. 1. The black spots on the scrotal skin are small hematoceles originated from the stings of blood-sucking insects. The arrow shows a stable fly.

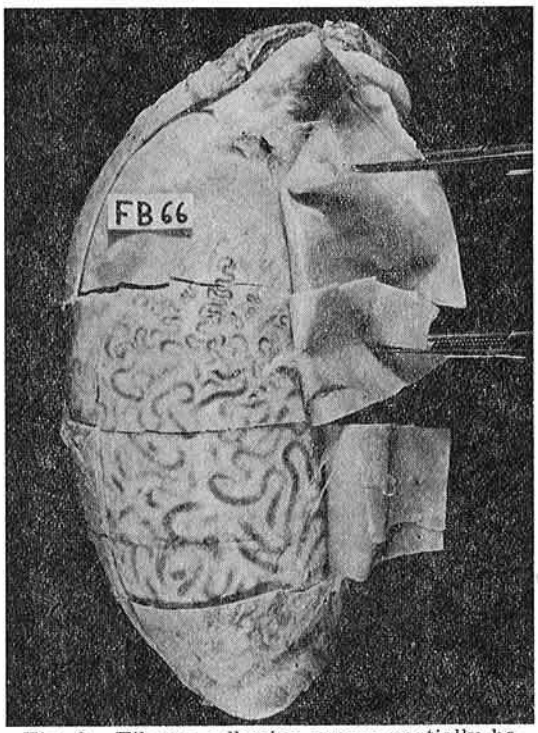

Fig. 2. Fibrous adhesion occurs partially between the tunica vaginalis communis and the tunica vaginalis propria. It is complete especially at the tail of the epididymis, and the tunica vaginalis communis is difficult to be stripped of there.

came feverish owing to the dermatitis caused by the maggots of blowflies hatched from the eggs laid among the wool. The author et al.[20] also observed that originating from the stings of blood-sucking insects many individuals had hyperemia, a large number of hematoceles of 3-5 mm in diameter and scabs in the scrotal skin, and suffered from scrotal dermatitis in summer. The inflammation often spread to the scrotal cavity and gave rise to periorchitis and hydrocele.

It seems that such a stimulus by blood-sucking repeated every year will induce the incrassation and induration of scrotal skin, the atrophy of pilosebaceous apparatus and finally the inability of the scrotum to regulate the temperature (Fig. 1, 2 and 3).

However, the damage of spermatogenic function by the temperature is not always due to a local action. In animals reared in an environment of high temperature, the sperm becomes immobile, decreases in number, increases in the malformation rate, and finally the spermatogenic function stops.[3),22)]

Macleod and Hotchkiss[14] described a decrease of sperm concentration in feverish cases of men. The author et al.[19] observed occurrence of spermatogenic dysfunction in bulls suffered from pneumonia and hepatitis purulenta, or several days after the ill-defined pyrexia. Those cases will most frequently be met within boars among the rest.

It seems, therefore, that a spermatogenic dysfunction is induced by a rise of temperature in the part or the whole body above the optimum range for normal enzymatic functions and normal development and differentiation of the cells of the seminiferous epithelium.

Mechanism of the spermatogenic dysfunction caused by high temperatures

Okamoto et al.[21] observed histologically a fall of thyroid function in summer, and

Fig. 3. Thickening of the scrotal epidermis accompanied with elongation of its processes, and vasodilatation and cell infiltration in the stratum papillare. Stained with HE. × 80.

Griffin et al.[6] confirmed a similar tendency by measurement of thyroxin in rams. It was also observed that a loss of sexual desire and deteriolation of seminal character similar to the symptoms of summer sterility in the bull were induced by thyroidectomy or feeding of thiouracil, a thyroidinhibiting agent, in rams and bulls, and their normal function could be recovered by medication of thyroprotein.[1),15),17)] Swanson and Boatman,[29)] Brooks and Ross[2)] and others, however, denied those results.

Shima[26),27),28)] observed that thyroidectomized male rats were lower in the sensitivity to gonadotropin.

Those data may suggest that functions of the thyroid gland and the adrenal gland have some connection with the occurrence of summer sterility.

The production and release of gonadotropin by the pituitary gland are influenced by season, especially by light. It is known that an increase in daylight acts to reduce the production of gonadotropin, and on the contrary, a decrease in daylight promotes the synthesis of this hormone.[30)]

In the early days of study it was reported that artificial cryptorchidism had no specific effect on the secretion of testicular hormone, and Leidig cells rather increased in number, promoting the secretion of this hormone. Recently Clegg[4)] has suggested a decrease in the secretion of testicular hormone in rats with cryptorchids, and Llauradd and Dominguez[13)] have proved that cryptorchidism caused a decrease in the function of enzymes which have connection with the biosynthesis of testicular hormone.

The author et al.[32)] measured the excretion level of urine androgen and the fructose content in seminal plasma in two Japanese black bulls, observing that the amounts of those two substances decreased in parallel with each other in summer.

Hiroe et al.[10)] however, said that they could not observe a definite seasonal change in the amount of fructose in seminal plasma in a bull of the Holstein-Friesian variety, showing a difference from our result.

As mentioned above, there are many unknown facts to be studied in future about the endocrine control of the testis in the bull in an environment of high temperature.

On the other hand, it is considered that the change of testes by heat is due to the lack of oxygen caused by hyperemia and stagnation originated from vasodilatation. Waites and Setchell[31)] have recently investigated the effect of high temperature on the metabolism in rams, and observed that heating of testes at the temperaures above 39°C for 2-3 hours gave rise to moderate or serious degeneration of the cells of the seminiferous epithelium.

The blood stream in the testis showed no distinct change in volume, but the oxygen content in the venous blood of the testis was remarkably low in case the temperature of testes rose to about 37°C. The oxygen uptake of the testis and the epididymis showed an increase of about 70% in amount and their uptake of glucose was higher by about 46%,

though no definite change was observed in the production of lactic acid. Based on those data, they came to a conclusion that such a high temperature as it can do a damage to the spermatogenesis brings a decrease in amount of oxygen in the testis.

Taking the many data mentioned above into consideration, it seems that the temperature has an important connection with the circulation of blood in the gonad including such problems as the supply of essential nutrients to every cell and the utilization of them by the cell.

Genetical factors for summer sterility

From the fact that the same animal suffers repeatedly from the sterility every year, genetical factors must be taken into consideration as to the cause of this suffering, though every year's weather and the age of animals may have relation with it.

According to the investigation by the National Institute of Animal Industry, it is noticed that bulls of certain superior strains tend to suffer from this sterility. However, as the semen of those bulls is in greater demand than that of the others and in frequent use, it is possible that the sterility appears to occur frequently among the progeny of those strains.

The structure of the scrotum seems to have an important role for the maintenance of reproductive function in all animals. For example, it is observed that there is a racial difference between the Short Horn and the African varieties in the distribution of scrotal blood vessels. In addition to this the scrotal skin is thinner in Short Horn than in African, and those differences show that the former is more susceptible to high temperatures than the latter. This fact also suggests that there is a difference in fertilization ability between the two varieties in the environment of the tropics.[18]

It is needless to say that heredity is a very important problem concerning the summer sterility, but it is not easy to get a conclusion about it because of the difficulty in the method of investigation.

Effect of high temperatures on the character of semen

The deterioration of semen quality due to summer sterility is frequent in the period from July to September, but it is often met with in November and December. The affected bull loses sexual desire in general, but shows no change in the amount and pH of semen.

The sperm, however, shows a decrease in number, a high rate of malformation and especially a remarkable decrease in activity and storage life. The affected animals have similar symptoms every year and their conditions tend to become more serious year by year.

Masaki et al.[16] made observation of the seasonal change of plasmalogen in the sperm, showing that it had a tendency to decrease in the July and September period. The sperm was higher in glycolysis in May and June, being lower in August and September, and also tended to be lower in respiration in August and September.

Gustafsson[8] divided an epididymis into five parts after the isolation by covering up the scrotum from the open air for three to eight days and made observation of the malformation of sperms in each part. Malformed sperms gradually increased in number as the part gets near the tail of the epididymis and the malformation rate was so high in the tail as 26 per cent of abnormal-tailed sperms and 32 per cent of free head ones were observed there.

And also there has been noticed that Na and K increased in content and protein did so in concentration in the tail of the epididymis, while glycerylphosphoryocholine (GPC) decreased in content in the end part of its head and protein did so in concentration in the anterior and middle parts of its head and also in the rete testis, suggesting that there occur a fall in secretory function in the epididymis and that in the function of selective absorption in its tail. It is inferred from those facts that the sperm included in the epididymis is most seriously influenced by a rise in temperature.

Kelly and Hurst[12] made a comparison between the samples of deep frozen semen taken in summer and winter from the same bull and showed that the one taken in summer was markedly inferior to that taken in winter irrespective of the season of use. This result indicates that the factor lowering the conception rate in summer is carried by the semen. Accordingly it seems necessary in future to examine the conception rate by the morphologically normal sperms sensitized by high temperature.

Preventive measures against summer sterility

As the summer sterility occurs temporarily in the season of high temperature, from July to September, it is thought that the occurrence can be prevented if animals are reared in an environment below 25°C throughout the year. Hiroe et al.[11] made a fundamental study to make clear this point in the rabbit. They reared the male rabbits which had shown the sterility in the last summer in a cooled condition below 27°C, and recognized a clear preventive effect of cooling against summer sterility in the production, motility and malformation rate of sperms.

Based on this result, some livestock experiment stations have introduced air-conditioning for cooling their stalls.

On the other hand, simple and practical prevention tests are being performed as follows:

1) Cooling of the scrotum

The cooling of the scrotum with running water can not be expected to be effective for the maintenance of a normal spermatogenic function, but it can prevent to some extent the sperms completed and stored in the epididymis from the bad sensitization by high temperatures.[17),22),34)] (Fig. 4, Fig. 5.)

2) Effect of the administration of medicines

Medication tests have been carried out to prevent the sterility and to make affected animals recover from it with thyroxin, testicular hormone, gonadotropin, vitamin E,C,A,D, and amino acids, but the effects are variable, obtaining no definite results.[11),20),22),34)]

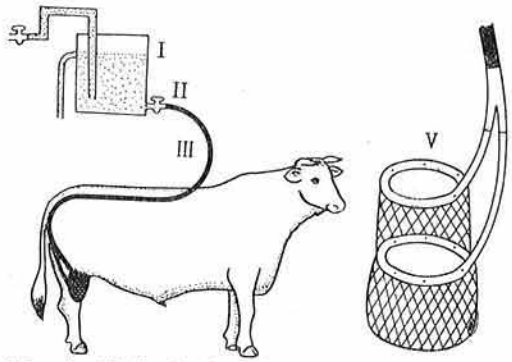

Fig. 4. Method of cooling scrotum:
I. Water tank.
II: Control cock:
III: Vinyl pipe. (diameter 8 mm)
IV: Towel sack.
V: Vinyl rings with six pin holes.
Remark: Water temperature, 24~25°C.
Running water volume, 100~200 cc per minute.

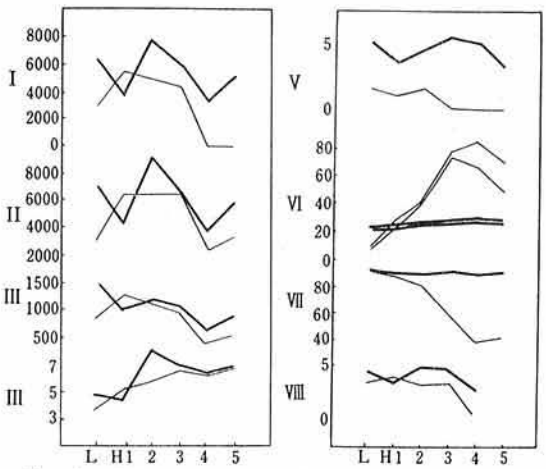

Fig. 5. Differences in semen quality:
I: Total spermatozoa with strong foreward movement per ejaculation. (million)
II. Total spermatozoa per ejaculation. (million)
III: Concentration per cubic centimeter. (million)
IV. Volume: (cc)
V: Days in which spermatozoa more than 50% have a foreward movement. (days)
VI. Percentage of abnormal spermatozoa. (The space between two lines is percentage of spermatozoa with protoplasmic drops.)
VII. Initial motility: (motility index of spermatozoa)
VIII. Ascorbic acid in seminal plasma. (mg/dl)
Remark: —Treatment. —Check.
L: Low temperature period.
H: High temperature period.
Cited from Okamoto et al.[20)]

3) Prevention by care

With an intention to cool the stall for lowering the body temperature of animals, irrigation and blowing by means of an electric fan, a shower, a spray or a pool are being tested. It is also desirable to feed much hay of good quality to animals in the hot summer season, reducing the amount of fresh grass to prevent the active generation of heat by fermentation in the rumen.

It is commonly thought that the introduction of bulls from a cool region to a hot district is undesirable.

4) Utilization of deep frozen semen

The deep frozen semen taken in the season from winter to spring was reported to be used in summer with a high conception rate.[9)]

In short, there may be no good method at present for prevention of summer sterility but keeping the environmental temperature optimum. It is important to keep animals in good health maintaining their normal physiological functions under the optimum environmental conditions not only for the prevention of summer sterility but also for the long use of superior bulls. It must be taken into consideration that ordinary cares result in a difference in heat-resistance of animals. It is also important to diagnose whether the bull considered as suffering from summer sterility is complicated with another kind of damage in spermatogenesis by other cause or not.

Remark: Only a part of the references were cited here for want of space.

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