“BLACK-QUARTER” IN SHEEP.

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AT the beginning of 1902 I was asked to investigate the nature and causation of a disease of sheep, locally termed “struck,” with the hope of finding some suitable form of preventive treatment.

I was told that the mortality was very heavy, especially during March, April, and May, and that in one part of the Romney Marsh district a skin dealer had been known to collect 1400 or 1500 skins in a single week, practically the whole of which had been removed from “struck” sheep.

It was further stated as a well-known fact that with many Romney Marsh graziers the losses were equivalent to the death of their entire flocks, once every 16 or 17 years, from this cause alone. The disease was most common in Romney Marsh, but was also met with in other marsh-lands of Kent, and occasionally even in upland districts.

The term “struck” did not convey much meaning to me, a stranger to the locality, but I soon found that, although the term may be applied occasionally to any case of sudden death, yet there was one disease which was chiefly recognized under this name.

Various theories are held by the flock-owners of the district as to the true nature of the disease; some feared an investigation, lest the disease should be declared to be “anthrax,” others described it as “acute indigestion” and “hoven,” and blamed the young grass of spring-time as the cause. It is also spoken of as “inflammation of the bowels,” “apoplexy,” &c., but the prevailing opinion seems to be that in some way the new growth of grass in the spring is responsible for the heavy mortality at this period.

The disease certainly is the cause of many deaths in March, April, and May, but sporadic cases occur at all seasons of the year.

Sheep of all ages are attacked, but it is generally said that the best animals in the flock are most likely to suffer.

Soon after my enquiry was begun Mr C. Gillard, M.R.C.V.S., of Ashford, gave me the opportunity of seeing several cases in in-lamb ewes which were said to be "struck." As the outbreak proved to be of a severe character, 60 ewes dying in a few weeks out of a flock of 200, a carcase was sent by Mr Gillard to Professor M'Fadyean, who declared that death was due to "black-quarter."

This outbreak occurred in a district at some elevation above sea-level, where the loss from "struck" sheep was said to be usually slight.

As it had been known for many years that sheep suffered from "black-quarter" in some parts of Great Britain (Steel's *Diseases of Sheep*), I determined to find out whether sheep in Romney Marsh, which were said to be "struck," showed any of the lesions of that disease.

On post-mortem examination of a "struck" sheep it is usual to find some portion of the body greatly swollen, and the skin of a dark purple colour. Well-marked crepitations are discovered on palpation of the swellings. The swellings are frequently found on the inside of the hind-limb, extending from the hock to the groin and even along the abdominal wall; in the fore-limb extending from the knee upwards to the shoulder, and the muscles of the neck and back.

On removal of the skin the swollen parts are seen to be black or dark red in colour, and the subcutaneous connective tissue and the muscles are saturated with a blood-stained fluid which rapidly drains away when an incision is made.

Bubbles of gas escape from the surface of the section, and a well-marked odour of sour milk is easily distinguished.

In the internal organs the chief lesions are congestion of the lungs and the presence of bloody serum in the pleural and peritoneal cavities. These lesions seem to be identical with those of "black-quarter."

On making a microscopical examination of the fluid squeezed from the diseased flesh numerous rod-like organisms with rounded ends are to be found. These bacilli closely resemble those of "black-quarter." They are also to be found in the blood and in the pleural and peritoneal fluids.

A "struck" sheep rarely shows signs of ill-health. Generally the sheep is found dead in the pasture, although it may have been seen

apparently in good health a short time earlier. Sometimes the animal is seen to stagger, to fall to the ground, and to die in a few minutes.

More rarely death is delayed for some hours, and the sheep is seen standing with its four feet close together, its back arched, and breathing rapidly. There may be a frothy, blood-stained discharge from the nostrils, and a blood-stained diarrhoea. The animal moves unwillingly, and when made to do so exhibits considerable stiffness of the limbs. Soon it falls to the ground and quickly dies.

Owing to the rapid onset of the disease and the suddenness of death it is very difficult to say whether any marked swellings are to be detected during life. The thickness of the wool also makes the detection of the swellings more difficult while the animal is alive.

I rarely had the opportunity of examining a "struck" sheep during life, but I was able to make a considerable number of post-mortem examinations, and I always found swellings present in some part of the body, and the bacilli of "black-quarter" were always present in the exudate from the diseased muscle.

As it was not possible for me to make a bacteriological examination at the College, I submitted a slide of the bacilli to Professor M'Fadyean, who identified the organism as the "bacillus of black-quarter."

At a later stage of the enquiry Dr Hamilton, of Aberdeen, visited Romney Marsh with me and examined several carcasses of "struck" sheep, and afterwards made a careful bacteriological examination of fluids and tissues then obtained. He informed me that he "found a bacillus quite comparable with that of 'black-quarter,' although he was not as yet prepared to say that they were identical."

I also learned that some years ago the late Mr Alston Edgar, F.R.C.V.S., of Dartford, Kent, had declared that "struck" sheep died from "black-quarter."

In order to prove to the sheep-owners of the district that the disease was not due to any dietetic cause as was popularly supposed, I inoculated a healthy sheep with the serum obtained from the diseased muscle of a "struck" sheep. The fluid was injected deeply into the muscles of the thigh, and the sheep died within 12 to 14 hours after the inoculation. The inoculated sheep presented all the appearances of a "struck" sheep, and a microscopical examination of the exudate showed the presence of numerous bacilli of "black-quarter."

The conclusions I drew from my enquiry were that the term "struck" was chiefly used in reference to sheep which after death presented the lesions above described, that these lesions were identical

with those of "black-quarter" in cattle and sheep, that the "black-quarter" bacillus was invariably present, and that practically the whole of the annual loss from "struck" sheep was due to the presence of the bacillus of "black-quarter."

This bacillus is known to exist in the soil of certain pastures, usually in damp, low-lying situations. Its spores are most tenacious of life. They will resist heat and cold, dryness and moisture, and may remain dormant in the soil for many years.

It is probable that infection occurs through the digestive organs, but it has also been suggested that the spores may enter the body through small punctured wounds¹.

PREVENTIVE MEASURES SUGGESTED.

As soon as I became aware that the disease was identical with "black-quarter" in sheep, I endeavoured to find some means of prevention suitable to the districts in which heavy losses occurred annually.

First, it was pointed out that the usual method of dealing with the carcase of a "struck" sheep was conducive to the prevalence of "black-quarter."

Throughout the Romney Marsh district carcases are flayed and then allowed to lie unburied, to be gradually destroyed by decomposition, or to be eaten by dogs, poultry, rats, &c. In this way the organisms contained by the diseased carcases are allowed to return to the soil, where the spores may live for many years, retaining their power to produce "black-quarter" when again introduced into the body of a living sheep.

Much benefit might be derived in a few years from the general and uniform adoption of some plan for the total destruction of *unflayed* carcases. Cremation would, of course, be the ideal method to be adopted, but the expense of burning a large number of carcases during the spring months would be considerable, and could only be met by the co-operation of a number of sheep-owners. If small kilns or destructors could be erected in suitable situations, arrangements might be made for working them more economically than would be possible for the individual owner. Failing cremation, the carcases should be buried deeply in the ground where practicable; when the character of the soil prevents any but shallow graves being dug, then plots of ground should be fenced off and used only for burial purposes, as suggested by Dr Hamilton for cases of "braxy."

¹ *Annual Report of the Bureau of Animal Industry, U.S.A., for 1898.*

It is certain that the total destruction of unflayed carcasses would ultimately bring about a gradual decrease in the number of cases.

Second, an attempt was next made to show whether protective inoculation against "black-quarter" in sheep was of any value. As is well known, considerable success has attended the adoption of protective inoculation of young cattle against "black-quarter," both in this country and abroad. Mr Gilruth, M.R.C.V.S., the chief veterinarian and bacteriologist to the New Zealand Government, recently reported that in one district alone 2250 calves have been vaccinated as a preventive measure, with a subsequent loss of only two animals. He also mentions that in a district where "black-quarter" is very rife, "if done twice a year vaccination is a great success¹."

I hoped to find that protective inoculation of sheep would prove equally valuable. Unfortunately, I was unable to obtain any vaccines especially prepared for sheep, and I was obliged to try those used for cattle. These vaccines were of the usual type—virulent muscle, dried and attenuated by heat, and then reduced to a powder.

During 1903 I used three vaccines:

A. A double vaccine (English).

B. A single vaccine (foreign).

C. The first dose of the double vaccine A used as a single vaccine.

As will be shown later, none of these vaccines proved quite satisfactory, and, as they were kindly given to me for trial, I have not made known their origin.

In the spring of 1903 I vaccinated a small number of sheep at the College Farm with the vaccines A and B, chiefly with the object of finding which was the most suitable part of the body for the purpose. In some the interdigital space of a forefoot was selected as the seat of the inoculation, in others the inside of the thigh or the axilla. In all cases the skin was first scrubbed with a 2 per cent. solution of lysol.

When the double vaccine was used the first dose was given in a right limb, the second eight days later in a left limb. None of the sheep suffered any inconvenience from the injections, whether given in the feet, or under the skin of the thigh or of the axilla. As the inside of the thigh was found to be the most convenient situation for the injection, it was generally selected in the later experiments.

¹ *Report of the Division of Veterinary Science of the New Zealand Department of Agriculture, 1904.*

From this lot of vaccinated sheep I then selected two, one twice vaccinated with *A*, the other vaccinated with *B*. A third sheep, which was unvaccinated, was used as a control animal. All three were inoculated with virulent "black-quarter" muscle injected deeply into the muscles of the thigh, each animal receiving exactly the same dose. Within 24 hours the unvaccinated sheep and one of the vaccinated (single *B*) sheep were dead, while the third sheep, which had been twice vaccinated (double vaccine *A*) remained unaffected by the dose of virulent muscle it had received. The two sheep which died presented the usual appearance of badly "struck" sheep. The doubly vaccinated sheep was lame for some days owing to the pain caused by the puncture, but no symptoms of "black-quarter" were developed.

From this result I concluded that the double vaccine would prove most efficient in giving immunity against the naturally acquired disease.

In the summer of 1903 I arranged with a number of sheep-owners to vaccinate small lots of sheep in various parts of Romney Marsh during the following winter.

As I fully anticipated the possibility of some slight loss resulting from the inoculations, it was arranged that compensation should be paid for any sheep which died from the action of the vaccine.

Judging from the risks met with in the vaccination of cattle I had no reason to expect that the loss in sheep would be more than 1 or 2 per cent., but of the 308 sheep vaccinated during October, November, and December, 14 died within a few days, and the deaths were evidently due to the vaccination, making a loss equal to $4\frac{1}{2}$ per cent.

Of the 14 deaths only one was due to the foreign vaccine *B*; the remaining 13 deaths were caused by the English vaccines *A* and *C*.

Table I shows the loss caused by each of the three vaccines:

An examination of this table shows that:

1. The foreign vaccine *B* was used on 218 sheep with the loss of one only, or less than $\frac{1}{2}$ per cent. Vaccine *B* may therefore be regarded as practically free from risk when used on sheep.

2. The double vaccine *A* caused a loss of 11 sheep out of 80 vaccinated, or nearly 14 per cent. Of the 11 deaths, one was caused by the first dose, 10 by the second. The deaths were directly due to the vaccination, occurring about 48 hours after the operation. The lesions of "black-quarter" were well marked, and were localized at the seat of the inoculation.

3. The single vaccine *C* was only tried on 10 sheep with a loss of two, or equal to 20 per cent.

The loss of 11 sheep caused by the double vaccine *A* was most

unfortunate, as it compelled me to abandon its use, although I had already shown that a high degree of immunity was to be expected when it was tried on an extensive scale. It is of course possible that had a large number of sheep been vaccinated with *A* the percentage of loss would have been greatly reduced, but I was not in a position to risk any further loss, and was obliged to be satisfied with the small number of sheep (69) which had passed safely through the inoculations.

TABLE I.
DEATHS DUE TO VACCINATION.

Owner	THE DOUBLE VACCINE (A)	
	No. of Sheep Vaccinated	Deaths due to Vaccination
Mr E. Lord	30	1 (2nd dose)
Mr A. Finn	50	10 (1 due to 1st dose, 9 due to 2nd dose)
Total	80	11 total loss (nearly 14 per cent.)
	THE SINGLE VACCINE (B)	
	No. of Sheep Vaccinated	Deaths due to Vaccination
Mr E. Lord	40	0
Mr A. Finn	40	0
Mr L. J. Pankhurst	20	0
Mr T. J. Pearson...	49	0
Mr Geo. Neve	69	1
Total	218	1 total loss (less than $\frac{1}{2}$ per cent.)
	THE SINGLE VACCINE (C)	
	No. of Sheep Vaccinated	Deaths due to Vaccination
Mr T. J. Pearson...	10	2 (loss 20 per cent.)

This vaccine had been used on a small number of sheep with perfect safety at the College Farm in the spring, but when used in October in Romney Marsh the result was disastrous, 11 sheep out of 80 being killed by it. In the spring the sheep used in the experiment were well protected from bad weather during the critical period following the inoculations. In October the sheep used in the experiment were living in the open, and were exposed to adverse climatic conditions.

It seems possible that exposure to bad weather during the 48 hours following the inoculations may be a cause of loss. Anything which would lower the vitality of the sheep might give the organisms contained

in the vaccine the upper hand, and allow them to produce the actual disease instead of merely rendering the animals immune. This theory is supported to some extent by what occurred in connection with the loss of nine sheep due to the second dose of vaccine *A*.

Two lots of sheep in different parts of Romney Marsh were given the second dose of vaccine *A* on the same day, the same dose being used for all the sheep.

In one lot not a single sheep suffered any inconvenience, in the other nine sheep died from the inoculations during the next three days.

For the 48 hours following the inoculation of the two batches of sheep the weather was most unfavourable, for a strong south-westerly gale was blowing, with heavy rainstorms. The sheep in which the loss occurred were near the coast, and were absolutely without shelter, exposed to the full force of the gale. The other lot, in which no deaths occurred, were several miles further inland and in a much less exposed situation, some shelter being provided by trees, hedges, buildings, &c.

Later, the first dose of the double vaccine *A* was tried on 10 sheep as the single vaccine *C*, but in a reduced dose. Two out of the 10 sheep died within 48 hours. On enquiry it was found that the weather had again proved unfortunate during the critical period, the nights being very cold with sharp frost¹. It should be mentioned that before this loss occurred altogether 90 sheep had been given the first dose of vaccine *A* with the loss of one sheep only, yet a reduced dose used in cold weather caused the loss of two out of 10 sheep.

The sheep which had passed safely through the vaccination, together with a number of unvaccinated sheep, were pastured on land well known to be dangerous. The whole of the sheep, about 550 in number, were kept on the dangerous pastures until June, 1904, and careful records were kept of the number of "struck" sheep in the two classes.

From these records the following tables were prepared, showing the number of sheep which were "struck" up to the conclusion of the experiment. It was impossible for me to examine all the sheep which were "struck," but from time to time samples of diseased muscle were sent to me for examination, and in these I was able to detect the presence of the "black-quarter" bacillus.

In the tables below the losses in "struck" sheep in vaccinated and unvaccinated animals have been compared by reducing the figures to a percentage, but of course with such small numbers percentages are

¹ It is interesting to note that sheep owners insist that more sheep are "struck" on frosty nights in spring than at any other time.

not altogether satisfactory. Very different results might be obtained even with the same vaccines if used on a much greater number of animals.

TABLE II.
THE DOUBLE VACCINE A.

Time of Vaccination	Owner	No. of sheep vaccinated	No. of sheep "struck"	Percentage of loss in vaccinated sheep	No. of unvaccinated sheep	No. of sheep "struck"	Percentage of loss in unvaccinated sheep
October, 1903 ...	Mr E. Lord, jun.	29	0	0	111	2	1.80
October, 1903 ...	Mr A. Finn	40	1	2½	50	9	18
		69	1	1.44	161	11	6.83

TABLE III.
THE SINGLE VACCINE B.

Time of Vaccination	Owner	No. of sheep vaccinated	No. of sheep "struck"	Percentage of loss in vaccinated sheep	No. of unvaccinated sheep	No. of sheep "struck"	Percentage of loss in unvaccinated sheep
October, 1903...	Mr Lord.....	40	0	0	111	2	1.8
October, 1903...	Mr Finn.....	40	8	20	10	1	10
November, 1903	Mr T. J. Pearson	49	2	4	51	2	4
November, 1903	Mr Pankhurst ...	20	1	5	20	2	10
December, 1903	Mr Neve.....	68	3	4.4	65	6	9.2
		217	14	6.45	257	13	5.05

TABLE IV.
THE SINGLE VACCINE C.

Time of Vaccination	Owner	No. of sheep vaccinated	No. of sheep "struck"	Percentage of loss in vaccinated sheep	No. of unvaccinated sheep	No. of sheep "struck"	Percentage of loss in unvaccinated sheep
November, 1903	Mr Pearson	8	1	12½	51	2	4

These tables show very clearly the success or non-success of the vaccines in securing immunity.

TABLE II.

Of the 69 vaccinated sheep only one was "struck," equal to a loss of 1·44 per cent., while of the 161 unvaccinated sheep 11 were "struck," equal to a loss of 6·83 per cent.

But the most remarkable result was obtained in the sheep owned by Mr A. Finn, of Lydd. These sheep, 90 in number, were kept from October, 1903, to June, 1904, on a particularly dangerous pasture at Broomhill.

Mr Finn states that during his occupation of this land he has had 16 to 20 per cent. of sheep "struck" annually.

Out of the 40 vaccinated sheep only one was "struck," or a loss of 2½ per cent., while of the 50 unvaccinated sheep nine were "struck," making a loss of 18 per cent.

It has already been shown that a high degree of immunity can be produced in sheep by the use of this double vaccine—a vaccinated sheep has resisted the introduction of a known quantity of highly virulent material which was capable of killing two control animals in 24 hours. It seems therefore reasonable to assume that the remarkable contrast between the number of sheep "struck" in the vaccinated and unvaccinated animals is due to the effect of the double vaccine *A* which rendered the 40 sheep strongly immune against "black-quarter" and consequently only one was "struck."

It is possible that the suggestion may be made that this result was due to the fact that all susceptible animals were killed off by the doses of vaccine and that the remaining sheep were naturally immune against the disease. Such an objection might equally be made where cattle are vaccinated against "black-quarter" or where cattle and sheep are vaccinated against "anthrax," and it would be difficult to refute the suggestion except by the comparison of losses in very large numbers of vaccinated and unvaccinated animals.

TABLE III.

Of the 217 vaccinated sheep 14 were "struck," a loss equal to 6·45 per cent., while of the 257 unvaccinated sheep 13 were "struck," or a loss equal to 5·05 per cent.

The single vaccine *B* has failed to protect sheep against "black-quarter," but it is possible that different results might be obtained if this vaccine were used nearer to the dangerous spring season. An examination of the table shows that Mr Neve's sheep, vaccinated at the end of December, 1903, seem to have had a slight degree of immunity. Of the 68 vaccinated sheep three were "struck," equal to a loss of 4.4 per cent., while of the 65 unvaccinated sheep six were "struck," making a loss equal to 9.2 per cent. The annual loss on this land was said to be 9 per cent.

TABLE IV.

The single vaccine *C* caused the loss of two sheep out of 10, and its use was abandoned. Of the eight sheep remaining one was afterwards "struck," so that this vaccine was powerful enough to kill and yet failed to give a strong immunity.

The conclusions which may be drawn from these attempts to immunise sheep against "black-quarter" are:

1. That the double vaccine *A* undoubtedly renders sheep strongly immune against "black-quarter."
2. That the double vaccine *A* is uncertain in its action, and under certain conditions may be highly dangerous when used in the field.
3. That a single vaccine may be powerful enough to kill and may yet fail to give a lasting immunity to those animals which survive the inoculations.
4. That none of the vaccines tried in these experiments have proved entirely satisfactory, although enough has been done to show that the loss from "struck" sheep could be greatly diminished by protective inoculation, if a safe and efficient vaccine were available.

It is possible that more favourable results will be obtained in the future by the use of vaccines specially prepared for sheep. Experiments are now being conducted on these lines and the results will be communicated on their completion.