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UNIVERSITY OF NEBRASKA COLLEGE OF AGRICULTURE
AGRICULTURAL EXPERIMENT STATION

Research Bulletin 147

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Pig Typhus

(*Salmonellosis suis*)

by L. Van Es

SALMONELLOSIS SUIS or pig typhus, also designated as pig typhoid, infectious necrotic enteritis, or "necro," is an infectious disease among young pigs. It constitutes a major factor in the mortality of juvenile swine, and as such must be regarded as a more or less perennial hazard in swine production.

Historical Considerations. The terms "typhus" or "typhoid" as applied to disorders of swine appeared early in the annals of veterinary history. Schmidt (83) in 1862, Murray (62) in 1864, Klein (45) in 1877, and Osler (66) in 1878 so designated pig diseases which came under their observation. In these early years, before bacteriology could bring clarity in the differentiation of various swine maladies, it is quite probable that these terms may not always have been applied to the disorder with which this publication is concerned.

Long before the true cause of hog cholera, an ultramicroscopic virus, was discovered, this disease was attributed to a microbe, frequently found to be present in the organs of swine affected with this malady. This discovery by Salmon and Smith of the Bureau of Animal Industry apparently determined that the so-called hog cholera bacillus, *Salmonella suipestifer,* was the cause of hog cholera and for many years (1885-1903) the results of their initial experiments were generally accepted.

When this micro-organism was inoculated into healthy swine, a disease was produced which very closely resembled hog cholera as it occurs on farms, and it presented symptoms and lesions which at the time were deemed to be pathognomonic of this malady.

However, in the course of further experimental efforts certain results were obtained which could not be interpreted readily. This induced de Schweinitz and Dorset (18), and Dorset, Bolton and McBryde (19) to extend their investigation. They observed a striking difference between the promptness with which hog cholera developed after swine were injected with the blood of affected animals and the difficulty often found in producing the disease by the subcutaneous inoculation of cultures of the "hog cholera bacillus."

It was also noted that, whereas the disease acquired by natural exposure was extremely contagious and the blood of swine affected with cholera was always highly virulent, this was not the case in hogs which were made sick by the inoculation of cultures of the bacillus. What-

ever the disease induced in this manner, it commonly had a milder character than hog cholera, and such inoculations might even fail to give rise to manifest illness.

Swine treated in this manner failed to develop immunity for true hog cholera, and when they were placed in contact with healthy swine, the latter did not contract the disease. On the other hand, field cases which had survived in outbreaks became endowed with a lasting immunity.

In addition, it could also be determined that *Salmonella suipestifer,* although frequently found in cases of hog cholera, was not always present. The injection of blood from animals which became sick after the administration of cultures of so-called "hog cholera bacillus" failed to cause sickness in any of the eleven hogs inoculated in this manner. Of this number ten were exposed to natural infection; nine of them became sick and seven died.

That the "hog cholera bacillus" is not constantly associated with hog cholera was also shown by Uhlenhut and associates (97), who made careful bacteriologic examinations of 178 cases of hog cholera among which *Salmonella suipestifer* could be demonstrated in 76 animals.

From the results obtained by the authors mentioned, it appears that they were confronted with two distinctly different diseases, namely: (1) Hog cholera, caused by an ultramicroscopic virus, and (2) Infectious necrotic enteritis caused by *Salmonella suipestifer.*

The latter disorder is the subject of the present publication.

Etiology. The etiology of pig typhus may be regarded as a process of a more or less complex nature, in which some factors may be more dominant than others. It is not always possible to determine precisely which of these contributory factors may be most active in the causation of disease.

The etiologic factors which operate in bringing about the disease under consideration may be divided into two distinctive groups. One of these is the microbic cause; the other one pertains to certain influences which are apt to predispose the animals to the specific action of the biologic agent already mentioned.

Pig typhus or infectious necrotic enteritis is primarily caused by bacteria included in the colon-typhoid group of micro-organisms. Among these, the one designated as *Salmonella suipestifer* can be accepted as the microbe most commonly implicated in the etiology of the disease as it occurs in Nebraska. Other microbes closely allied to the one mentioned may also have to be considered. As a rule these may be regarded as varieties of suipestifer bacillus, which was discovered and described as the "hog cholera bacillus" by Salmon and Smith in 1885.

The pig typhus bacillus has been frequently recovered from the organs of healthy swine, a fact to be regarded as of considerable importance in seeking potential sources of mischief. Dale (13) states that although relatively few normal hogs harbor this organism, it has been found in a sufficient number to indicate that there may be a carrier

type in which the microbe is present without causing appreciable injury. Lütje (49) reported that among 600 healthy swine of the Berlin abattoir the suipestifer bacillus was found to be present in 8.9 per cent of the animals examined. Trawinski (95) made bacteriologic examinations of the intestinal contents of 500 butcher hogs, and isolated not less than 26 strains of microbes which apparently could be classified as colon-typhoid intermediates.

The occurrence of the pig typhus bacillus in healthy hogs may serve as an explanation for the early acceptance of this microbe as the cause of hog cholera. No doubt the latter disease may have been quite favorable to the concurrent development of the suipestifer bacillus. That such may be the case is indicated by the findings of ten Broeck (93) who, working with hog cholera, isolated the organism from 16 per cent of the cases. Beller and Henninger (6) recovered the microbe from 40 out of 144 (27.7 per cent) cholera cases examined by them.

The casual relation of the suipestifer bacillus and its varieties has been too firmly established by numerous investigators to justify any doubt. The studies of Murray, Biester, McNutt, and Purwin (8, 63, 64) brought results which placed the etiology of infectious necrotic enteritis in a clear light. These authors found that *S. suipestifer* is the primary etiologic factor and that the necrophorus bacillus (*Actinomyces necrophorus*) appeared constantly as a secondary invader. They induced the disease experimentally by the feeding of broth cultures of the suipestifer microbe which then could be re-isolated and in turn passed through successive series of pigs, producing typical lesions in their subjects.

Their investigations disclosed further that *S. suipestifer* could be isolated from 100 per cent of the field cases examined. The organisms thus isolated were fed to more than 100 young swine with positive results in practically all the experimental subjects.

It was also established that membrane formation as found in the early stages was observed 56 hours after the feeding of broth cultures of *S. suipestifer,* and that 64 hours after experimental feeding, caseous or diptheroid membrane formation of a diffuse and more advanced character was evident.

The deep invasion by the secondary factor, the necrophorus bacillus, seemed to be directly responsible for the formation of a caseated membrane, which was considered as establishing an anaerobic environment favorable to this microbe. The suipestifer bacillus could be recovered from the mesenteric lymph nodes prior to 32 hours after the experimental feeding.

Results more or less comparable with the ones mentioned above were obtained by earlier as well as later investigators. Glässer (28) stated that in the so-called German hog cholera (pig typhus) only the suipestifer microbe could be considered as an etiologic factor. The same author also reported that pig typhus is readily transmitted from pig to pig, and that swine more than four months old proved to be more resistant to the infection.

The above mentioned observations and results were confirmed by workers in various countries and at different times. In this connection the following authors are named: Adsersen (1), Blount (10), Damman and Stedefeder (14), Hagan 33), Haendel and Gildemeister (32), Hindmarsh and Edgar (35), Joest (37), Lesbouyries and Berthelon (47), Levine, Peterson and Graham (48), Lütje (50), Manninger (54), Moussu (60), Pfeiler (68), Pfeiler and Kohlstock (71), Shanks (86), Van Es and Olney (101), and Weidlich (102).

Not in all cases diagnosed as, or suspected of being affected with, pig typhus could the presence of *S. suipestifer* be revealed by bacteriologic examination. McEwen (53) reported that in a herd of swine kept under good sanitary conditions, necrotic enteritis was found to be the most serious disease among recently weaned pigs. In his investigations it could be determined that the disease was not associated with any bacterial infection, nor with parasitic worm infestation, or with infestation by coccidia.

Davis, Freeman and Madsen (15) reported the results covering six experiments in three successive years, which indicated that necrotic enteritis of swine was primarily caused by a nutritional deficiency. However, they mentioned that attempts were made to isolate paratyphus organisms from the lymph nodes of animals apparently free from necrotic enteritis and of those which died from the disease. It was found that in most cases examined paratyphus microbes were recovered, although they were not positively identified as *S. suipestifer* except in one case.

In the experiments of Gwatkin and Moynihan (31), in which 102 pigs were used, the results were the same as in a previous study. They state that since a large number of tests were made with such questionable results, there is need for a new concept of the etiology of the condition usually known as necrotic enteritis, in which until recently *S. suipestifer* had been considered as the specific etiologic factor.

There are few diseases of swine in which a predisponent etiologic factor is more important, more decisive, than in the malady under consideration. Such factors pertain to a number of conditions and circumstances which cause swine to become especially susceptible to infection by the suipestifer microbe and its varieties. Any of these predisposing influences operating singly or in combination commonly determines the fate of a herd of pigs exposed to pig typhus infection.

There is a consensus among veterinarians and investigators that unless pigs are exposed to certain predisposing influences an infection by the suipestifer bacillus is not apt to produce disease. Among these the influence of age appears to be dominant, as pig typhus is particularly a disorder of juvenile swine. The morbidity of pig typhus is most conspicuous in pigs less than four months of age. In older swine it is relatively uncommon although occasionally encountered. This is likely to be observed in cases in which the hog cholera virus and the suipestifer bacillus are simultaneously present.

Dorset (20) stated that the presence of the virus of hog cholera vastly increases the susceptibility of hogs to suipestifer infection. Moussu (60) believes that the causative microbes live in a given environment as saprophytes and as such may exist in the digestive tract of swine. Faulty sanitary conditions, indigestion, irritation of the digestive organs by feed of an inferior quality, or even slight intoxications are apt to reduce the normal defensive powers of the body to such an extent that the infective agent begins to multiply in profusion and becomes progressively more virulent and pathogenic, with infectious enteritis as a result.

Manninger (55) is of the opinion that pig typhus is largely determined by faulty herd management, and believes that *S. suipestifer* alone is not likely to cause disease if pigs are maintained under favorable hygienic conditions. He adds that after the elimination of adverse conditions an outbreak may automatically terminate.

Descazeau (17) subscribes to the opinion that the malady always rages in establishments where hygienic conditions are defective. The filthiness of an environment, faulty or inadequate feeding, as well as the debilitating influences of parasitism are factors highly favorable to the development of infectious enteritis.

Glässer (29) recognizes damp, stuffy, dirty stables, faulty feeding, deficiency of minerals and protein in the ration, the lack of paddocks or pasture occupancy, and atmospheric influences, such as excessive humidity, as important predisposing factors.

Biester and associates (8) observed that the action of *S. suipestifer* was greatly intensified when the microbe was introduced into subnormal subjects affected with ascariasis but free from necrotic enteritis at the time of feeding. The lesions developed more rapidly and were of a more advanced character than those of normal pigs of the same duration of illness, after the pigs were fed with a culture of the primary causative organism.

Miessner and Wetzel (59) remark that the infection is of environmental origin; the infective microbes are expelled with the feces of infected animals and the infection is introduced through the mouth. They further express the opinion that the disease develops only when the resistance of the pigs is depressed by faulty management and inadequate feeding.

Lütje (50) declares that in no animal species are predisposing influences more evident than in swine confronted with an exposure to suipestifer infection. He states that it is always improper maintenance and feeding or other predisponent factors that are responsible for outbreaks of the disorder. Lesbouyries and Berthelon (74) are likewise of the opinion that bad hygienic conditions favor the development of pig typhus by reduction of an organic resistance.

Hutyra, Marek, and Manninger (36) submit that only in pigs in which the capacity for resistance has become reduced by unfavorable conditions may the disorder gain a foothold. In this connection they mention occupancy of stables with an excessive atmospheric humidity,

unsuitable feeding with either a deficiency or an excess of protein, lack of minerals and vitamins, an indoor existence, parasitism, and excessive fatigue incidental to transportation. Saunié (81) points out such predisposing factors as excess protein in the ration, the influence of weaning, as well as marked and sudden atmospheric variations.

Because of the manifest influences which may be instrumental in bringing about suipestifer infection, there is reason to give some of these factors careful consideration. Attention may therefore be called to the fact that many of the quoted authorities emphasize the importance of maintaining young pigs at pasture. Such counsel is based on two good reasons. In the first place, the larger area of pastures as compared with smaller enclosures tends to prevent a concentration of infective material deposited on the surface by affected pigs or by healthy swine which, as already mentioned, may happen to be carriers of the pig typhus microbes. In pastures the causative germs are scattered, whereas in smaller areas the infective agents, in the course of a continuous occupancy, are apt to accumulate to the extent that pigs, by their very eating and rooting habits, may take in such a volume of infective bacteria as may overcome any resistance with which the animals concerned might be endowed. After all, pig typhus is a typical filth-borne disease and will probably always remain so.

Certain observations indicate that, on the whole, pigs are somewhat tolerant to a small volume of the microbic agents taken in, whereas a larger amount of bacilli may not readily be overcome. This may not always be a dependable conclusion because the degree of virulence of the bacteria concerned may prove to be a very disturbing factor.

The other reason for out-of-door life at pasture is associated with the fact that it promotes the safety of pigs by the wholesome influences of green forage and of exposure to the radiant energy supplied by the sun. Lack of exposure to direct sunshine tends to cause rickets and the subsequent ill health traceable to this disorder. This alone is apt to create a predisposition to disease.

In foreign literature cement floors are often mentioned as the cause of unthriftiness of pigs. In the opinion of the writer it is not the cement floors which are responsible for pig decrepitude, but rather the rickets engendered by an indoor existence. Animals existing exclusively under Nature's care do not, as a general rule, give birth to their young until green foliage and sunshine have become available. Persons engaged in animal husbandry may well ponder this lesson gratuitously taught by Mother Nature.

Pig typhus is not a contagious disease and is not apt to be directly transmitted from pig to pig in the manner of hog cholera. Outbreaks can usually be traced to such common sources as contaminated soil, feed, and drinking water.

The virulence of *S. suipestifer* is subject to variations. In certain instances the bacillus may be avirulent even for pigs. However, its pathogenic qualities may become exalted when it passes through a successive series of pigs. Such a phenomenon may be especially observed

on farms where the farrowing season is unduly prolonged. Thus, wherever successive litters appear in an infected environment, the disease may be relatively mild while later litters may be wiped out by enteritis of a particularly malignant character.

Epizootiology. Pig typhus is encountered in many parts of the world, probably wherever a dense swine population is being maintained, and especially where a more or less permanent occupancy of restricted areas by successive populations of pigs happens to be an established practice. Infectious necrotic enteritis is a common disorder in the hog-raising sections of the United States, in Germany and other European countries, and it has been reported from such far apart regions as Chili and New South Wales.

The character of pig *Salmonellosis* is more enzootic than epizootic, as the malady is usually restricted to individual farms where young pigs are being produced. The disease does not usually spread from farm to farm, although it always remains possible that the infection is carried from place to place by means of markets, public sales, and the like where affected pigs are exchanged.

Clinical Manifestations. Pig typhus may present itself as an acute septicemic disease or as one of a decidedly chronic character. In some swine-producing areas the acute malady may be relatively common, whereas in others its chronic forms may be preponderant.

The development of pig typhus is subject to variations. Some pigs may die within a few days and others may be sufficiently resistant to

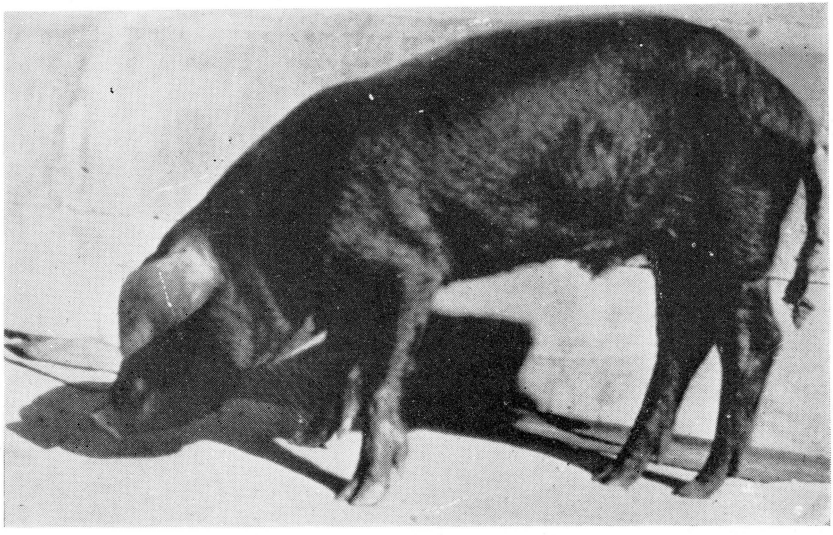

FIG. 1. A subacute case of pig typhus.

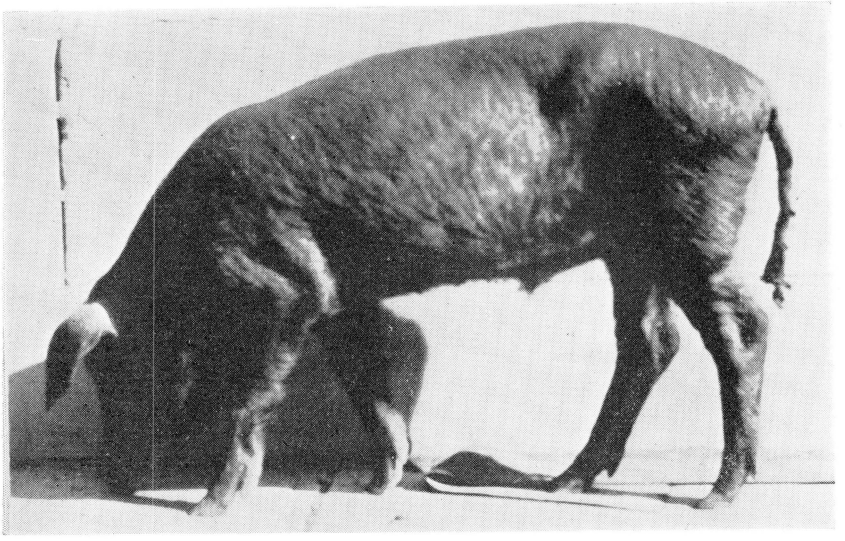

FIG. 2. A subacute type of pig typhus.

maintain themselves in a fair state of health. A few animals may eventually recover, while others become sickly and succumb after a more or less prolonged illness.

Outbreaks on farms are not uncommonly preceded by one or more deaths before the enzootic character of the disease becomes apparent. As a rule it is not possible to determine the length of the incubation period with any degree of accuracy, where the disease occurs under field conditions. It appears to range between 24 hours and eight days in accordance with the severity of the infection.

One of the earliest manifestations of *Salmonellosis* in pigs is a rise of the body temperature which Forgeot (24) found to fluctuate between 105.8° and 107.8° F. Even in the earlier phases of illness the affected animals become languid, remain recumbent, and hide themselves in the litter. The appetite declines, may be completely lost, and the pigs even refuse their dam's milk. The water intake may be continued as long as the pigs are able to move about.

The affected animals lose strength and may no longer be able to remain on their feet. A marked loss of flesh may be observed quite early in the course of illness. The visible mucosa become pale and the bristles become rough and dirty. Prostration is marked toward the end and a state of coma often precedes death.

Diarrhea is a prominent and significant symptom of necrotic enteritis. It is frequently observed that with its appearance a drop in the body temperature follows. The intestinal evacuations are *thin, often* watery, with a light yellow or grayish color. There may be a reddish

tinge because of the presence of blood, and in the more severe cases the feces may be decidedly hemorrhagic.

A catarrhal conjunctivitis, giving rise to a muco-purulent discharge may be observed. As the malady progresses a crusty eczema is apt to make its appearance. Persistent coughing and sometimes respiratory distress is noted; pneumonia may come as a serious complication.

European observers frequently describe erythematous discolorations of the ears, the axillae, the perineum, the belly, and the inner surfaces of the thighs. In uncomplicated cases of pig typhus observed in Nebraska, such cutaneous changes are not encountered. However, in cases in which hog cholera or swine erysipelas are complicating factors, such phenomena may well enter into the clinical picture.

As the malady continues in its course, the pigs involved commonly present a tucked up belly and a motionless dependent tail. The animals progressively lose flesh, show a marked emaciation, become cachectic, and often die in a comatose condition. In some of the cases in which the duration of illness extends over a rather long period, the pigs concerned may show only slight evidence of sickness. To a certain extent the appetite may be fairly good, although somewhat capricious. They remain small, poor in flesh, and may eventually develop a more or less lasting diarrhea. Even this may gradually disappear and the pigs may recover. Or diarrhea may again declare itself to lead to cachexia and death.

Not all pigs in a given outbreak may sicken, although some of the animals which apparently escaped the disorder may nevertheless present slight intestinal lesions after slaughter.

In the more acute cases, death may ensue within a period of ten days, whereas in the chronic form of the malady it is not always possible to determine its actual duration. No doubt, the latter is apt to vary considerably. Some subjects may succumb after less than four weeks of illness, and others may persist in a more or less decrepit condition for a much longer time, in the course of which the state of nutrition continues to decline.

FIG. 3 and FIG. 4
Chronic cases of pig typhus.

The mortality of pig typhus differs in individual outbreaks, apparently under such influences as the virulence of the causative microbe as well as those associated with unfavorable environmental conditions. According to available data, the herd mortality ranges between 25 and 60 per cent. Udall (96) submits the following: for young pigs 40–50 per cent, for feeder hogs 10–20 per cent, and for brood sows 2–5 per cent. However, when the etiologic factor is extremely pathogenic and the environment very unsanitary, the death rate may occasionally closely approach 100 per cent.

Pathologic Anatomy. With the possible exception of the peracute cases, the cadavers of animals dead of pig typhus are commonly marked by a very conspicuous degree of emaciation, often reducing the carcasses to mere skin and bones.

As reported by Biester (8) the earlier pathologic changes consist of an accumulation of inflammatory exudate on the surface of the intestinal mucosa. Subsequently the mucous membrane, as well as the exudate, becomes involved in necrobiotic changes. This process is progressive and is apt to be extended to the gastric and intestinal submucosa.

In the relatively uncommon acute cases, the pathologic manifestations are of a purely septicemic character, and as such they do not differ greatly from the ones encountered in such septicemic disorders as hog cholera and acute swine erysipelas. In a number of acute cases a gastro-enteritis may be observed, which may or may not be marked by superficial crusty erosions that occasionally present hemorrhagic features.

The most characteristic lesions of pig typhus are met with in the gastro-intestinal tract and its lymphatic adnexa. These pathologic changes may vary to a considerable extent under such influences as the virulence of the etiologic factors and the duration of illness.

The gastric mucosa may be hyperemic in the more acute cases and the mucosal rugae may be erose at their projecting portions. In subacute or chronic cases, the partially hemorrhagic gastric mucous membrane may, at the height of the disease, show some superficial eschars.

The duodenum may not disclose definite changes, but from its terminal portions onward superficial, shallow ulcers are not uncommon. Further along in the small intestines these ulcers are more numerous, and near the terminal parts the mucosa is covered by a diptheroid mushy secretion of a pronounced yellow color. In some cases the mucosa is diffusely necrotic and may present a dry, greenish yellow, disintegrated surface.

Not uncommonly a false membranous coat covers the mucosa in its entirety, the latter being covered by flaky crumbs as if sprinkled with ashes or bran. Observed also are caseous deposits at the level of the lymphatic structures of the gut. These may be either separate or confluent and well marked off from the normal areas. On the periphery of these areas the intestinal wall is thickened, the mucosa showing partially detached membranous shreds, or there may be firmly at-

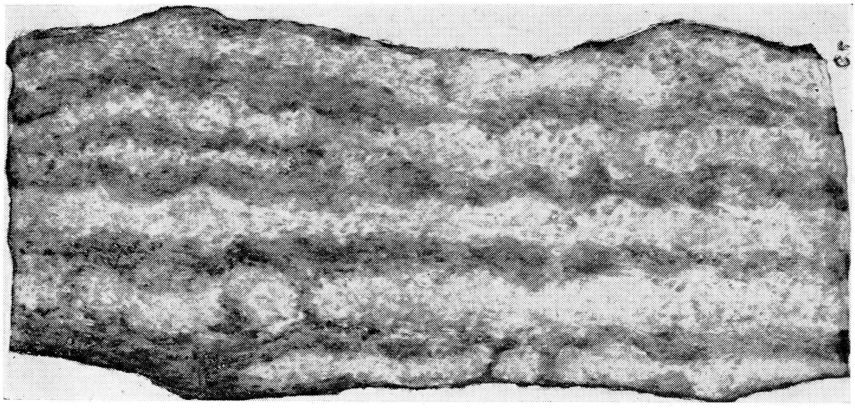

FIG. 5. Small intestine of pig. Lesions induced by intravenous injection of 0.25 cc. of broth culture of *S. Salmonella suipestifer*. Pig was killed four days after the inoculation.

tached crumbly eschars, which after removal bring to light an erose, nipped-out appearance of the intestinal lining.

The ileo-cecal valve projects as a dense, thickened hyperemic or necrotic cone. Its structures may be thoroughly mortified, presenting a dirty brown, torn and broken surface.

The large intestines are commonly the seat of the most characteristic, as well as the most extensive pathologic changes. Above all they are always significant from the standpoint of diagnosis.

When at autopsy the abdominal viscera become exposed, one may observe, especially in the lingering cases, that the large intestines are adhering to the abdominal wall as the result of a dry peritonitis. Connected with this fusion of the tissues involved, the formation of granulation tissue may also attract attention. This adhesive process may develop to such an extent that the intestinal coils are, as it were, soldered together in a compact, solid mass.

The involved intestines may display constrictions as well as dilatations. In regard to the latter, the intestinal wall is relatively normal, although in certain swollen and opaque areas the gut may show a more or less marked rigidity.

Occasionally inclusions of a nodular type may be encountered in the mesentery. They are apt to be quite numerous and often they are caseated throughout. The external aspect of the intestines reveals a slate-colored surface, sometimes yellowish gray with a possible tinge of green. In other instances the exterior of the intestines has a normal appearance, even if their interior may disclose a surprisingly manifest pathologic picture. The mucosa is opaque, somewhat rigid, and the intestinal structures often suggest degenerative changes. The contents of the intestines are usually thin and mushy, with a color resembling that of mustard paste or beaten eggs.

The Peyer's patches and solitary lymph follicles are not always conspicuous, although the small number of the first section of the cecum may be quite prominent and enlarged. Here and there submucosal hemorrhages are seen and a thin fibrinous membrane loosely attached to the surface may be observed.

In connection with an inflammatory hyperplasia of the lymph follicles, necrosis and caseation may attract attention. From such follicles the necrosis is apt to be extended to the adjacent parts of the mucosa. The serosa covering such areas is often hyperemic and may be marked by vascular injection.

As revealed by palpation, nodular elevations are encountered. These are hard, firm, and when close together they may convey the impression that the internal surface of the gut was changed to plaques, substantial enough to prevent collapse of the intestinal wall.

Throughout the large intestines, the mucosa has a grayish blue or slaty color and may not always show thickening of their wall. In other cases there is evidence of thickening in certain sections, and there the mucosa is apt to display a degree of disintegration. Such areas are commonly circular in outline and when they become confluent may give rise to an extensive ulceration of the mucous membrane. In their central portions these ulcers may disclose a villous, broken-down mass of a yellowish color in which darker colored particles can be discerned.

After removal of this necrotic material, the subjacent tissue is often marked by hemorrhages and a central depression. Caseation is commonly observed near their periphery and this is rather adherent and

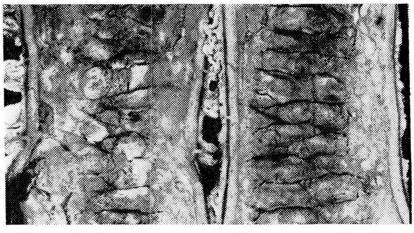

FIGURE 6.

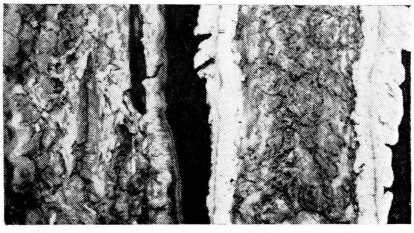

FIGURE 7.

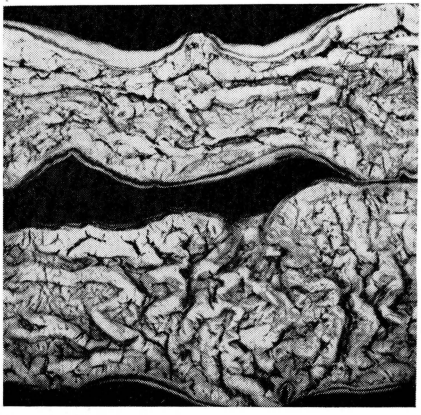

FIGURE 8.

Intestinal lesions in chronic pig typhus.

moist. In certain locations these changes give rise to transverse annular zones, marked by thickening and rigidity of the intestinal wall. Upon cross-section of such areas, a central depression with an elevated margin may attract attention. The cheesy debris of such ulcers may extend as far as the serous coat and this is usually accompanied by an inflammatory reaction.

In the more slowly advancing cases a diphtheroid, ulcerous, and cicatrizing process is frequently apparent. In the rapidly developing forms of the disease, the mucosa is swollen, more or less hyperemic, and marked by traverse folds and ridges seemingly caused by a cellular infiltration of the mucosa and submucosa.

The old ulcers are often surrounded by a reddened elevated ridge of demarkation, of which the thickness increases as the cleansing of the ulcers proceeds. Such ulcers are likely to show a concentrically advancing, dry, leathery consistency. They may be circular, elliptical, or oval in outline, and frequently show eschars. As a rule the latter are firmly attached and may finally involve large intestinal areas.

At the margins of the disintegrating tissues there may be observed a delimiting productive inflammation leading to sclerotic changes and the formation of a weal-like tissue proliferation in the depth of the intestinal wall. In a number of the more chronic cases a demarkating inflammatory process develops, resulting in the formation of granulation tissue, and healing may eventually take place.

With the completion of the cicatrization, a constriction of the intestinal lumen may be a result, or cellular proliferation, in which the granulation tissue becomes displaced gradually by scar tissue, causes the intestinal wall to become sclerotic. Thus there comes about a thickening of the wall, which then becomes rigid and unyielding to pressure, and eventually the gut is transformed into a rubber-like stiff tube.

In connection with the discoid ulcers which commonly follow the elimination of the necrotic materials, it is frequently observed that the marginal portions tend to rise above the surrounding surface by the retention of the eschars, which often appear to be arranged in concentric layers. As a result there develops a button-like structure, still often accepted as pathognomonic for hog cholera. In this process the necrophorus bacillus apparently is a causative factor. However, as such button formations may be encountered in uncomplicated cases of pig typhus, even in cholera-immune animals, as well as in peracute cases of hog cholera which die very early in the disease, the pathognomonic significance of the so-called "hog cholera buttons" may well be questioned.

In pig typhus the spleen may be found to be decidedly hyperplastic, This is especially observed in the more acute cases and somewhat less in the subacute forms of the malady, whereas in the chronic cases the enlargement of this organ may not be conspicuous. The manifestly hyperplastic spleen has a rather dark color, more or less marked by a tinge of blue, and is usually quite resilient to the touch. The con-

sistency of the spleen pulp as a rule approaches that of a normal organ. On the cut surface the enlarged follicles can be readily observed. In general the organ is not softened, although in the case of the more chronic cases the spleen may be somewhat flabby.

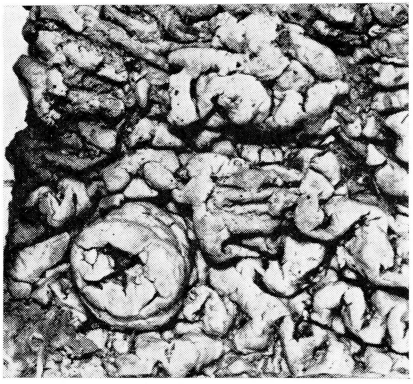

FIG. 9. Lesions of the cecum in chronic pig typhus.

The various lymph nodes, and especially the ones which receive the lymph drain of an involved intestine, frequently show pathologic changes. Even such more remotely situated structures as the pelvic, inguinal, and post-pharyngeal lymph nodes occasionally present evidence of participation in the infection process. Affected lymph nodes are commonly enlarged, edematous, perhaps somewhat hyperemic.

In such nodes caseation is a relatively common phenomenon, but they never show evidence of calcification. The cut surface of the pathologically altered mesenteric lymph nodes may present induration or a partial or total necrosis and caseation. In the rather slowly developing cases, the caseous masses may become encapsulated and evidence of healing may be observed. The cheesy material as a general rule is homogeneous, smeary, showing a color ranging between grayish yellow and grayish green.

Pneumonia is a frequent complication in pig typhus. The pathologic changes in the lungs show the characteristics of a catarrhal pneumonia often confined to the front and lower lobes. These parts may be somewhat increased in volume and they, as well as the bronchial lymph nodes, often show a more or less extensive caseation.

In the cases of pig salmonellosis in which the duration of illness is prolonged, such organs as the liver and kidneys may present evidence of necrobiotic changes, such as cloudy swelling and perhaps also of fatty infiltration.

Diagnosis. In any attempt to ascertain the nature of an outbreak of disease among swine, a survey of the environment in which pigs are forced to exist may be an aid to diagnosis. Furthermore, the history of a given outbreak, if at all obtainable, should not be neglected. In connection with pig typhus it should be remembered that this disease is always filth-borne, and that it usually depends on unsanitary conditions and perhaps also on inadequate feeding. The prior introduction into a herd of swine of new purchases, and the occurrence or non-occurrence of sudden deaths should also be given consideration.

In the diagnosis of pig typhus, the fact that this disorder is practically limited to pigs less than four months of age is of considerable

importance even if, now and then, some older swine may also be involved. Another characteristic of diagnostic importance is that the malady is not usually confined to a single animal, but is always apt to involve a considerable number of the pigs on a given farm.

As a general rule the diagnosis of pig salmonellosis is not difficult; although in parts of the country where hog cholera and swine erysipelas are also prevalent, their presence may constitute a problem. Thus in the case of swine erysipelas the age factor, which is important in the diagnosis of pig typhus, may lose some of its significance because erysipelas in young pigs is by no means uncommon in Nebraska.

In the differential diagnosis between pig typhus and swine erysipelas only the acute form of the latter enters into the problem. This is especially the case when pig typhus occurs in its acute forms. The latter, however, are far less common than in the subacute or chronic forms of the disease.

Acute swine erysipelas above all is distinguishable from pig typhus by its sudden appearance, its rapid evolution, and its relatively high mortality. In such cases a marked pyrexia, and body temperatures as high as 108° F. are frequently noted. Typical in swine erysipelas is the evenly distributed erythema and the redness of the subcutaneous adipose tissue. However, in the case of the pigmented breeds of swine these phenomena may be easily overlooked.

In the case subjected to autopsy for the purpose of differentiation between pig typhus and swine erysipelas, the latter may reveal a moderately hyperplastic spleen, with a color more approaching a reddish brown than is commonly found in pig typhus. The spleen enlargement in suipestifer infections may be less marked than in erysipelas although on the whole these differences are not very stable features.

Swine erysipelas, furthermore, differs from pig typhus by its more pronounced gastritis which is apt to extend even into the small intestine. On the other hand, in pig typhus the intestinal lesions have a more diphtheroid character and the cecum and the colon are more apt to show marked pathologic changes than may be found in swine erysipelas. In the latter malady the kidneys often show evidence of nephrosis, combined or not with renal hyperemia.

Pneumonia, a frequent complication in pig typhus, is but rarely observed in swine erysipelas.

Differing from acute septicemic swine erysipelas, hog cholera causes affected animals to show evidence of illness for a longer period before death ensues. In cholera there is also a marked fever, although as a general average the body temperature does not reach the height attained in acute erysipelas.

In hog cholera the lymph nodes are commonly very hemorrhagic and enlarged, and it is frequently noted that the body lymph nodes may be similarly involved. In both swine erysipelas and pig typhus the pathologic changes in the lymph nodes tend to be confined more to the ones associated with definitely diseased organs or tissues. In

pig typhus the lymph nodes are apt to show caseation, a change which is not observed in uncomplicated swine erysipelas.

Attention must be called to the fact that in part of the cases of hog cholera, intestinal and lymph node lesions may also be encountered. Such lesions are similar if not identical to the ones found in pig typhus. In such cases there is reason for the conclusion that such phenomena must be attributed to the simultaneous presence and action of the hog cholera virus, the suipestifer bacillus, and probably also of the necrophorus microbe. In cases of uncomplicated hog cholera caused by the ultramicroscopic virus alone, ulceration of the large intestines is not apt to be encountered, although a hemorrhagic enteritis caused by the virus must be accepted as a possibility.

In the writer's opinion the ulcerous lesions occasionally observed in the intestines of swine which died of hog cholera and which closely resemble the ones pathognomonic for pig typhus are the result of the combined action of suipestifer bacillus and the necrophorus bacillus and should not be accredited to the virus. As stated before, this pertains also to the so-called "hog cholera buttons."

Although diarrhea may be part of the clinical picture presented by hog cholera, as a general rule it is not as regularly observed as in the subacute and chronic cases of salmonellosis in which it must be accepted as clearly pathognomonic.

In uncomplicated cases of hog cholera, the spleen is not enlarged but such a hyperplasia may be a pathologic development when the suipestifer bacillus is also implicated.

Such a typical pathologic manifestation as the so-called "turkey-egg kidney" of hog cholera is not seen in pig typhus or swine erysipelas.

Hog cholera always has a distinct epizootic character whereas pig typhus is a typical enzootic disease. Hog cholera is particularly distinguished by its almost infallible contagiousness which always exceeds that of swine erysipelas and is lacking in pig typhus.

Hog cholera can be excluded in a given outbreak of suspected pig typhus when adult hogs present in the same herd which are susceptible to hog cholera fail to become sick. Hog cholera has no respect for age, sex, or breed and will be transmitted promptly to non-vaccinated swine by direct or indirect contact.

In the type of cases in which clinical and pathologic-anatomic findings do not permit a definite diagnosis, it may become necessary to have recourse to bacteriologic examination combined or not with inoculation experiments.

Economic Importance. Pig typhus can be held accountable for the greater part of the mortality of pigs less than four months of age. However, accurate data pertaining to such losses are not available, because at present there is no public service pertaining to the vital statistics of the diseases of farm animals. Precise information regarding this subject would be very helpful in any attempt to bring about adequate measures of prevention. In this respect we still persist in sailing on uncharted seas.

Of course, from time to time estimates have been made. These are largely based on guesses and as such they cannot be dependable. Such guesses range between 25 and 45 per cent of the pigs farrowed in a single year which fail to reach the terminal markets, and they usually pertain to combined losses from all causes.

The losses caused by disease not only may seriously affect farm income but they also must have a marked influence on the status of the national food supply. If the latter is to be maintained at a desirable level from year to year, an extra number of brood sows would be required in order to compensate for the number of pigs eliminated by disease. If such losses were adequately prevented, such extra brood sows would find their way to the slaughtering establishments of the country.

Meat Poisoning in Man. The micro-organisms belonging to the suipestifer or paratyphus groups are pathogenic for humans and they are implicated as the cause of illness in man. The latter can usually be attributed to pork products.

Human paratyphus arising from this cause is relatively uncommon in this country but in countries such as Germany, where raw pork is commonly consumed, such pork-borne infection appears frequently enough to constitute a more or less serious problem. Such infections are ordinarily described as "meat poisoning" and may terminate fatally.

In this connection Demnitz (16) reported that in 50 per cent of the hams which apparently caused sickness in 25 persons, suipestifer bacilli could be bacteriologically demonstrated. Standfusz (89) found that 61.1 per cent of cases of meat poisoning were of animal origin and Neukirch (65) reported an outbreak in Anatolia which was marked by a 50 per cent mortality among the persons involved.

It is therefore not surprising that in Germany, where animal-borne paratyphus seems to be most common, the bacteriologic examination of pork products has become an important function of the meat inspection services. It may be pointed out here that the most effective prophylactic measure is the thorough cooking of all forms of pork.

Therapy. Perhaps there are few animal diseases in which therapeutic efforts have been and are still being made so assiduously as in the case of pig typhus. They may include the administration of alkaline solutions added to oats, preparations containing lactic acid, the addition of copper sulfate to feed and drinking water, oats soaked in an alkaline solution to which common salt was added at the rate of one pound per bushel, intravenous injections of proflavine and acriflavine, formalin, and in one instance the feeding of stale bread was mentioned as a cure. Of course, the injection of bacterins is not overlooked.

As reported, any of these therapeutic interventions have on occasion been accredited with favorable results. However, no evidence was presented that such conclusions were based on controlled observations. Hence one cannot know whether pigs recovered by the action of the agents used or merely by the grace of Providence. Disappointing results are apparently not being reported. Thus, on the whole, it seems

probable that any claim pertaining to the value of medicinal treatment should be accepted with a considerable degree of reservation.

A number of authors even go much farther than this: Dale (13) states that no known medicinal preparation has sufficient merit to be recommended as a specific treatment. In the opinion of Hutyra, Marek and Manninger (36) treatment is not promising and they were not convinced of the value of specific anti-serum. Glässer (29) remarks that as far as medicinal treatment is concerned, little of a reliable nature has become known. Lesbouyries and Berthelon (47) as well as Moussu (60) believe that no specific treatment of infectious necrotic enteritis exists, and Udall (96) adds that the use of bacterins or vaccines is of doubtful value.

On the other hand it was reported by Davis, Freeman and Madsen (15) that liver, yeast, and especially nicotinic acid have been fed with remarkable results. Apparently Dale (13) leans to the same opinion.

Whether the action of such substances is of a therapeutic nature or that of a corrective for certain vitamin deficiencies cannot be readily ascertained. In this connection, attention may again be directed to the fact that faulty feed or feeding occupies a prominent place among all-important predisposing influences in the etiology of pig typhus.

Within the last four years a more logical approach to a dependable therapy of salmonellosis of pigs has been made with reference to some of the sulfonamides. Kernkamp and Roepke (39) experimented with sulfaguanidine as a therapeutic agent in the treatment of pig typhus. In their investigations, experimental animals were obtained from herds in which the pig typhus morbidity ranged between 25 and 80 per cent. They found that sulfaguanidine is not toxic when administered in therapeutic dosages. The latter varied between 0.75 G. to 1.5 G. per 10 pounds of body weight, daily for five days, administered morning and evening, either in capsules or mixed with a small amount of feed.

Kernkamp and Roepke (40) in a later report stated that the results of their experiments indicate that sulfaguanidine possesses considerable merit as a therapeutic agent in the treatment of the infectious enteric complex. They state, however, that such treatment should be supplemented by sanitary measures in order to prevent reinfection. A few animals treated with sulfaguanidine showed remissions due to causes unknown at the time. At a still later date, Kernkamp (41) again reported good results of the sulfaguanidine treatment.

Favorable results were also obtained with sulfasuxidine, the daily dose of which should not be less than 1.0 G. to 1.5 G. per 10 pounds body weight, given for at least six to eight days. The results obtained with sulfathalidine were very encouraging and the best results were obtained with daily doses ranging from 0.65 G. to 1.0 G. per 10 pounds body weight.

Cameron (11), also experimenting with sulfaguanidine, found a comparison of mortality prior to and following the use of this drug to be in favor of the latter. In several of his cases recovery was apparently complete, but a relapse occurred in from six to eight days after treat-

ment was discontinued. The resumption of treatment again resulted in recovery. In Cameron's opinion, it appears desirable to maintain animals on a minimum dosage for several days following recovery, so that a concentration of the drug may remain in the intestinal contents, since the effect is apparently due to the bacteriostatic action of sulfaguanidine.

More recently Graham and associates (30) reported on experiments in which the determination of the therapeutic value of sulfathalidine was the objective. In these experiments 707 pigs, affected with clinical enteritis in field outbreaks, were treated with this drug in doses varying from 0.11 G. to 1.10 G. per 10 pounds body weight per pig per day. It was found that 88.8 per cent of the subjects made satisfactory recoveries and 11.2 per cent either died or remained unthrifty. Of the 96 pigs affected with the disease but not treated in order to serve as controls, 43.7 per cent recovered whereas 56.3 per cent died or survived in an unthrifty condition.

Of 101 sulfathalidine-treated pigs affected with clinical enteritis, complicated by pneumonia, 17.8 per cent recovered and 82.2 per cent died or failed to recover fully. The same proportionate figures were obtained in 45 untreated control animals in the same herds.

Of 539 apparently healthy pigs belonging to herds in which outbreaks of swine enteritis occurred and which were treated with sulfathalidine, 95.6 per cent remained healthy and 4.1 per cent died or became unthrifty. Graham et al (30) concluded that the drug has merit in the treatment and control of swine enteritis. They further expressed the opinion that sulfathalidine has merit as a prophylactic against pig typhus when administered to apparently healthy animals.

Garlick (26) also experimented with sulfathalidine as a treatment for infectious necrotic enteritis. He administered the drug in doses ranging from 0.5 to 1.0 grains per pound body weight per day, either as one dose or as divided doses, added to the feed. He likewise obtained good results.

It appears from the evidence thus far presented that the sulfonamides may have a place in the treatment of pig typhus. Notwithstanding the favorable results mentioned, it seems quite advisable that studies such as the ones reported be continued on an even larger scale before arriving at final conclusions. Above all, any failures encountered in the treatment should be given serious consideration, in order that by carefully controlled experimentation the possible causes of unfavorable results can be definitely ascertained and corrected, if such should be possible.

Prophylaxis. Although therapeutic measures have been proposed which may be helpful in the control of pig typhus, the fact remains that hygiene and sanitation are the factors in prophylaxis on which dependence must be placed. In the maintenance of pig health such efforts are especially effective in herds in which the disease has not yet made its appearance. In all attempts at prevention, emphasis must be

placed on the elimination of any environmental conditions which tend to create such predisposing influences as have been enumerated.

The guiding principle in the prevention of filth-borne diseases such as pig typhus consists of keeping the animals concerned out of contact with body wastes, feed, and drinking water contaminated by the disease latter. Of course, this cannot be accomplished with any degree of completeness under farm conditions. Nor is this absolutely necessary. Even if infective material should be deposited on the soil of pastures and other enclosures by older swine, the larger the area occupied by a given number of susceptible pigs the less will be the risk of infection.

Especially, such areas as were continuously populated by swine during considerable periods must be regarded as not safe for young pigs. Such lots should either be left fallow or be devoted to the growing of some cultivated crop so that the soil may be properly aerated. The rotation of hog lots and pastures with intervals of two years between occupancies is a sound practice. However, such enclosures may be used for livestock other than swine if this should be expedient.

There are good reasons for the belief that when the infective microbes are widely and thinly distributed over a relatively large area, the few that are taken in will be overcome by the inherent power of resistance of the pigs. On the other hand, when the animals are confined in relatively small areas, they may there become exposed to such a massive volume of infective material that their natural resistance is overcome with disease as an inevitable result.

It is therefore a sound practice to have the pigs farrowed at such a time of the year that they and their dams can be turned into clean pastures when the young animals are from 10 to 12 days old. There the intake of causative microbes is reduced to a minimum, if present at all. In addition the pigs will then have the benefit of the health-promoting influences associated with green forage and outdoor sunshine. While at pasture the litters and their dams should have the benefit of shelter such as may be provided by the so-called "A" houses, one for each litter, which should not be placed too close together. In connection with the outdoor maintenance of young pigs, Shanks (86) reported that farms on which pig typhus was a problem had been completely freed of the infection hazard by raising pigs out-of-doors.

If supplementary feeding at pasture should be deemed advisable, self feeders constructed so as to render gross contamination of the feed impossible must be provided. The drinking water should likewise be supplied in equipment constructed to exclude befouling with fecal matter. Pertaining to drinking water, consideration should be given to the fact that a given supply is never better than the worst water to which animals may have access. This means that accumulations of surface water always constitute an infection hazard and should not be tolerated.

Pigs should be maintained in a good state of nutrition, because faulty or inadequate feeding is one of the more potent among the predisposing factors toward a possible pig typhus infection.

Elsewhere in this text it was pointed out that the virulence of the pig typhus bacillus may be substantially increased by its passage from pig to pig. Such a factor is always to be feared wherever the infection can be transmitted by the feces of the older pigs to the more susceptible younger ones. Hence, as an additional safeguard, the farrowing in a given year may be planned so that the pigs are born close together. Of course in herds kept under a strict sanitary regime this may not be necessary, although there may be other advantages by having the pigs of approximately the same age or size.

As an additional measure of prophylactic value, Beckett (4) recommends the practice of dividing a herd of pigs into smaller units. Kernkamp (41) mentions cement floors as a factor in the prevention of pig typhus. Such a type of construction will, without doubt, provide a safe environment. It is quite possible that the use of concrete may eventually develop into an important factor in the control of the malady.

However, before concrete construction for pig lots can be recommended for general use, it seems advisable that a comparison be made between the actual cost of pig mortality and costs of cement construction and the labor of maintaining such lots in a sanitary condition. If data should reveal that the monetary losses arising from mortality exceed construction and labor costs, the general adoption of this type of sanitary construction may be expected to materially reduce the pig mortality with which many pork producers are now confronted.

Even in the management of actual outbreaks, the application of sanitary measures has its place. In such a case, very badly diseased pigs, as well as the hopelessly stunted ones, should be destroyed. Such animals only tend to increase the volume of infective material in the lots occupied by them. Furthermore, such pigs are not likely to yield adequate returns for the feed they consume.

Pigs which are not too far advanced in their sickness may be subjected to experimental treatment with some of the sulfonamides. The apparently healthy pigs should be removed to clean ground and there divided into small lots. If a sufficiently large area should be available, they should be moved to new clean ground at brief intervals.

Whether or not protective vaccination of young pigs can be accepted as practicable is as yet very uncertain. Such a possibility cannot be excluded altogether on purely theoretic grounds, even if it seems doubtful that young pigs, perhaps already exposed to the infection, can have conferred upon them a valid immunity early enough to be of benefit. Nevertheless a number of such attempts were made in the past. Pfeiler and Kohlstock (71) reported that in controlled experiments good results were obtained by vaccination, and Stedefeder (91) also mentions favorable results by the use of specific anti-serum.

Glässer (29) and Lesbouyries and Berthelon (47) also mention apparently good results. Saunié (81) stated that vaccination with a formolized culture proved to be very effective. However, because these four authors failed to submit evidence to indicate that their conclusions were based on precise, controlled observations it seems hazardous to

accept their conclusions at their face value. On the whole, reports available in literature do not inspire confidence in the value of alleged immunizing agents as a means to prevent pig typhus.

Dorset (20) who experimented with suipestifer bacterins concluded that there is nothing to indicate that an immunity against pig typhus was established in his experimental subjects. Hutyra, Marek and Manninger (36) remark that, to say the least, the production of immunity against pig typhus is questionable, and Moussu (60) as well as Manninger (56) claimed that vaccine or serum treatment cannot be depended upon to establish immunity against the disorder.

A prophylactic influence by the administration of nicotinic acid is mentioned by Davis, Freeman and Madsen (15). Graham and associates (30) concluded that sulfathalidine has merit as a preventive against swine enteritis when administered to apparently healthy animals in affected herds. On the other hand, Kernkamp and Roepke (40) state as their belief that animals which recovered from infectious enteritis as a result of sulfaguanidine therapy should not be considered as possessing any significant immunity or resistance to reinfection.

It would seem prudent to suspend judgment on the value of sulfonamides or such other chemicals which may later develop as preventives of pig typhus. If this group of drugs or any one of them should prove to have a constant value in prophylaxis by chemotherapeutic action, its chief value may be associated with a possibility of removing the suipestifer bacilli from brood sows, and so removing a definite hazard from their litters.

When at all practicable, houses and pens occupied by suipestifer infected pigs should be disinfected. It appears from evidence submitted by Erdôs and Koppanyi (23) that the causative germs of pig typhus are readily destroyed by the commonly used antiseptics.

Regardless of what the future may bring forth, hygienic management and sanitary equipment are apt to remain as the principal factors in the prevention of *Salmonellosis suis*.

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