counted a little. Further studies are going on in this respect.

By retting mechanically decorticated bark in water, most parts of the plant will be recovered in the soil, i.e. 90% of N, 88% of P_2O_5 and 85% of K_2O are to be recovered respectively.

(5) Amounts of inorganic elements recovered

The amounts of inorganic elements recovered per 1 ha of land are calculated from the above results (Table 5). By whole plant water-retting, recovery of each element is nill. Assuming xylem and pith are recovered 12.6 kg of N, 3 kg of P_2O_5 and 52.6 kg of K_2O will be recovered as shown in the parenthesis of the table. By retting defoliated stems in water, recovery amounts to 31 kg in N, 6.4 kg in P_2O_5 and 40 kg in K_2O so far as farmers use such defoliation. Assuming further that the xylem and pith are also recovered, N will be 47 kg, P_2O_5 9.5 kg and K_2O 91.5 kg.

By retting only the bark parts which are decorticated mechanically, every part of the plant other than the fibrous part, i.e. leaves, xylem and pith and non-fibrous part of the bark, may certainly be left in the soil, which amounts to a substantial volume including 52 kg of N, 10.7 kg of P_2O_5 and 110 kg of K_2O.

Although jute is originally a fertilizer-consuming plant, nearly all or more than half of the nutrients are usually lost in the traditional manufacturing process of fibers in the Southeast Asian countries. Hence, if the traditional process were replaced by the mechanical decortication and then by the retting of only the bark part in water, most parts of nutrients absorbed by the plant could be recovered and fed back into the soil. Furthermore, the mechanized process would enhance efficiency of decortication and decrease the amount and space for water used for retting. In this process the machine breaks the xylem and pith parts so small that the pieces are readily available as green manure or as materials for compost.

Conclusion

Based upon the above results, the writer proposes that the decorticator should be introduced in the very process of production of jute and allied fibers, and suggests that the decorticator should be profitably used by a joint utilization by groups of farmers.

Table 5. Amount of recovery of mutrient influenced by the different preparation of jute.

preparation	N	P_2O_5	K_2O
whole plant retting	0 (12.6*)	0 (3.0*)	0 (52.6*)
defoliated stem retting	34.8 (47.4*)	6.4 (9.4*)	38.9 (91.5*)
decorticated bark retting	51.9	10.7	110.3

note: *This value is in the case of recovered xylem and pith.

Pathogenicity and Aetiology of *Pasteurella multocida*

I. With special reference to hemorrhagic septicemia and fowl cholera

S. NAMIOKA

Chief, 1st Laboratory of Bacteriology, 1st Research Division,
National Institute of Animal Health, Kodaira, Tokyo

In the latter part of the last century, similar bacilli of Gram negative were frequently isolated from the septicemic material of various kinds of animals and fowls. They were characterized by bipolar stainability. As the interrelationship among a group of these similar bacilli derived from the various animals was not clear at that

time, 'zoological classification' had been advocated by Lignières in 1900 was widely used, under which species was named after the deriving animal. Thus, bacilli derived from cattle, fowl and pigs were called *Pasteurella boviseptica, P. aviseptica* and *P. suiseptica* respectively. It was not of cause entirely without objection against this classification system. In 1939, after examining a group of similar bacilli (approx. 30 strains) derived from various animals from the aspect of biochemical properties, Rosenbusch and Marchant[1] declared that there were no appreciable difference among those bacillus strains and suggested that all groups of bacilli which had been classified according to the zoological clasification should be called *P. multocida* collectively. Their suggestion has still being supported.

Since 1920, a number of researchers have attempted to clarify the serological properties of the Pasteurella groups and the relationship between each serotype and the kind of the deriving animal or the type of the disease, but as each researcher's methods varied it was relatively difficult to make clear the relationship between the serotype and the kind of the deriving animal or the type of the disease. One of the reasons for these failures may have been due to the colonial dissociation, which in turn causes complex changes in antigen and in biochemical properties with their respective variation processes. Hence the variation phase to place the standard of serological reaction became difficult to determine.

Later in 1952 Carter[2] reported that there existed capsular substances in the freshly isolated organisms. He called this fluorescent type (later changed to iridescent type). The capsular substances should be lost through the sucessive incubation on the medium. This was called blue type (lost capsule type). He also conducted precipitin reaction with the antigen of capsular substances extracted by saline. Carter reported these substances could be classified into four kinds of specific serotypes. Later, Carter carried out capsule classification by a hemagglutination test with capsular substances with erythrocyte of human O group. In the report, Carter[2] stated that he had got a hint for the classification by the capsular type of original bacillus from Hoffenreich's report published as early as 1928. Hoffenreich had recognized the existence of capsules and made precipitin reaction by their polysaccharide. Thus, the clear serological classification with capsular antigen of the organisms was made by Carter.[4] The four kinds of serotypes were called types A, B, C and D respectively.

A little earlier than when Carter established his capsular type, Roberts[3] in England conducted protection tests in mice using more than twenty strains of *P. multocida* (*P. septica*) derived from various animals, and found that *P. multocida* could be divided into four types by immunological method; they were called I, II, III and IV respectively. In 1954 Carter[4] examined the relationship between his classification and Roberts's and concluded that his types A, B, C, and D corresponded to Roberts's types II, I, III and IV respectively. Carter considered that the protective ability of *P. multocida* reported by Roberts may due to the capsular substance of the organisms.

Thus, higher reliance has been placed on Carter's serological classification of *P. multocida* than any other method so far known. It has been used internationally; Bergey's Manual, 7th ed. of 1957 uses his system.

Carter says his type A together with type D has the widest geographical distribution. It especially accounts for much of *P. multocida* isolated in the northern hemisphere, notably in the United States and Canada. Also, it derives from a great variety of sources such as fowl cholera, sepsis and pneumonia of various animals and the throat and purulent diseases of man. According to him,[5] a small amount of the organisms belonged types A and D inoculated on fowl was fatal with various routes. Further, 20,000 organisms of Carter's type B inoculated intractaneously was fatal to a buffalo, while 10,000 times the above amount of the same organisms were required to kill a pig.[5] On the other hand, it was reported

Table 1 Relation between Serological type of *P. multocida* and Animal Host (Carter and Bain, 1960)

Animal Host	Type (Capsular) A	B	D	Not typable
Buffalo	2	13	0	0
Caribonu	3	0	0	0
Cat	3	0	1	27
Cattle	88	23	6	47
Chinchilla	0	0	0	7
Chipmumk	0	0	0	1
Deer	0	1	1	0
Dog	0	0	3	14
Fowl	56	0	6	125
Goat	0	0	1	1
Guinea-pig	1	0	2	1
Horse	0	1	1	1
Man	20	0	11	16
Mink	3	0	1	10
Monkey	1	0	0	0
Mouse	0	0	2	3
Muskrat	1	0	0	2
Pig	157	3	118	19
Rabbit	11	0	3	13
Sheep	11	1	9	13
Totals	357	42	165	300

much of Carter's type C derived from dogs and cats, especially from their throats. However, since 1955 he has excluded type C himself on the grounds that the standard organisms of his type C became S-to-R variation and that its distribution is extremely rare. It is also said that his type B derives mostly from hemorrhagic septicemia of cattle. Table 1 shows the distribution of *P. multocida* derived from various animals and classified by Carter and Bain.

In this table, the detail of disease types is not shown, it does, however, illustrate that types A and D isolate not only from fowl alone but from a wide range of animals, as mentioned earlier. It may also be emphasized that about 35 percent of the cultures collected were untypable. This indicates the fact that the organisms lost their capsule very rapidly after isolation. Thus it must be noticed that many untypable organisms may exist resulting from the classification with capsules.

Carter has noted that all organisms belonging to type A has strong pathogenicity against fowl.

In 1958, on the basis of Carter's method, the authors made the serological typing of *P. multocida* in Japan and bacilli derived from various animals widely distributed in Southeastern Asia. But no sooner had we begun than we came across a problem. Professor Liu of Formosa sent us six bacillus strains derived from pneumonia of pigs. They all belonged to Carter's type A and three of them with less than 100 organisms could kill a three-month old chick within 48 hours. But when we inoculated the other three strains more than 10 million of them could not kill one. Thus it was clearly mentioned that there were at least two types within the organisms belonging to the Carter's type A; the one causes fowl cholera and the other has almost no pathogenicity against chicken. This indicated that Carter's type A included two entirely different types when measured by pathogenicity for chickens. We decided to re-examine the properties of somatic(O) antigens of *P. multocida* independently from the past results. First we collected Pasteurella organisms derived from various animals of foreign countries and received about 100 strains each from Canada, France, Egypt, the Philippines, Burma, Vietnam, Formosa and other countries.

It has already been noted previously that *P. multocida* has rapid colonial dissociation on the medium. The colony of fresh isolated organisms are moist as they have capsules and fluorescence by penetrating ray (iridescent type). But following successive incubation they lose their capsules and became a colorless and transparent colony (blue type) or that of bacilli with lessened fluorescene and increased stickiness (mucoid type). These colony types eventually vary into flat and irregularly edged R-type bacilli. Although the existence of the capsules (K antigen) of organism can also be recognized by capsular swelling reaction with china ink, we succeeded in staining it using Mφller's[6] method. Carter[5] tentatively termed blue type as R type using S^R. However, blue type indicates the loss variation of

capsules; it is not that somatic (O) antigen has become R type. Carter's idea concerning the variation form of colony in *P. multocida*, depends on that of pneumococci by Griffith.[7]

Thus, if *P. multocida* changes to various colonial types from one original strain, accompanying antisera will naturally consist of various antibodies. Further, a complex result may be obtained from serological reaction between these antisera and strains at different stages. This result illustrates one of the reasons why a conclusion could not be reached in a same agreement as far as the relation between the disease type of *P. multocida* and the host is concerned during the period from the 1920's to the 1940's.

Table 2 Agglutiuation tests between antisera prepared with formalinized antigen and the homologous strain treated by various means

Antigen		Antiserum prepared with 0.3% formalinized antigen		
		3397	656	P8497
3397	Capasular type A (mucoid type)			
	Formalinized	0		
	75C, 1 hr	0		
	100C, 1 hr	0		
	121C, 1 hr	160*		
	Alcohol, 37C	0		
	N-HCl, 37C	320**		
656	Capsular type B (Blue type)			
	Formalinized		1,280*	
	75C, 1 hr		640*	
	100C, 1 hr		320*	
	121C, 2 hrs		320*	
	Alcohol, 37C		20*	
	N-HCl, 27C		320**	
P8497	Capsular type D (fluorescent)			
	Formalinized			80§
	75C, 1 hr			160*
	100C, 1 hr			320*
	121C, 2 hrs			320*
	Alcohol, 37C			0
	N-HCl, 37C			640**

* Floccular
** Granular
§Disc-shaped
} agglutiuation

The authors selected the iridescent type, mucoid type and blue type of organisms isolated from various animals. Six kinds of antigen were then produced from these cultures and agglutination tests were carried out with homologous serum. The results are shown in Table 2.

As seen from the table, the results shown by folmalinized or heated treatment reacted in a wide range in each of variational phases of strain. While the antigen treated with N-HCI showed a similar granular agglutination, which was peculiar to somatic (O) antigen, in each variational phase of strain. By heating antigen to 121 C, a common agglutination effect was obtained, but the state of agglutination was floccular and was short of stability shown by O agglutination.

Based upon this original test, serological characteristics of homologous strains were investigated in every aspect. With these studies, it was clarified that constant O agglutination would be able to obtain with the treatment of N-HC1 in any stage of colonial variation. Furthermore, antigens were found to be classified into common and specific ones in a cross absorption test of strains, with the result that the organisms employed were grouped into six O groups.[7][8]

By observing *P. multocida* with capsule and that treated with HC1 through electron microscope, we found that both were ball-shaped, but that the latter was shrinked to 1/5 of its original size. Also, the latter supernatant fluid which included a considerable nucleic acid and succharide. These observations indicates that the HC1 treatment forced not only surface materials but also materials within bacilli to be solved, and size of the organisms to be diminished. Then what substance was left within the cell as angigen? They were conceived to be consisted of lypopolysacchride and protein which is surrounding onto cell wall, in view of the Gram negative bacilli other than Pasteurella.

With absorbed factor sera and HCI treated antigen, 100 or more strains came from various countries were typed serologically, and these cultures devided more than ten

Table 3. Relation between Pasteurella sero types of Capsule and Somatic and Host Animals

O gronp	Capsule	Sero type	Process of desease	Animals	Strain examined
1	A	1 : A	Pneumonia	Swine	9
			Septisemia	Mouse	2
	D	1 : D	Pneumonia	Swine	1
	—*	1 : —	Pneumonia	Swine	1
				Sheep	2
				Cattle	2
2	D	2 : D	Pneumonia	Swine	12
3	A	3 : A	Pneumonia	Swine	3
	D	3 : D	Pneumonia	Cat	1
4	D	4 : D	Pneumonia	Swine	2
			Pneumonia	Sheep	2
5	A	5 : A	Fowl cholera	Fowl	13
			Pneumonia	Swine	3
	—	5 : —	Fowl cholera	Fowl	21
			Pneumonia	Swine	1
			Local Wound	Men	1
6	B	6 : B	Hemorchagic Septisemia	Cattle	6
	E	6 : E	Hem. Sept.	Cattle	1
	—	6 : —	Hem. Sept.	Cattle	10
7	A	7 : A	Septisemia	Cattle	5
	—	7 : —	Septisemia	Cattle	2
8	A	8 : A	Fowl cholera	Fowl	1
9	A	9 : A	Fowl cholera	Fowl	7
10	D	10 : D	Pneumonia	Swine	1
11	B	11 : B	Local Wound	Cattle	1

* No Capsule was possessed.

Table 4 Relation between Carter's Capule and O group (Namioka and Murata)

Carter's Capsule group	O group
A	1
	3
	5*
	7
	8*
	9*
B	6§
	11
D	1
	2
	3
	4
	10
	12
E	6§

* Pathogen of fowl cholera
§ Pathogen of hemorrhagic septicemia

O group. Thus, by combining O group with Carter's capsule type, 120 strains employed were classified into 15 sero types.[9] The results are shown in Table 3.

As shown clearly in the table, Carter's type A has six O groups, type B two O groups type D six O groups and type E one respectively. The results were summarized as shown in Table 4.

By the representation of the serotypes of *P. multocida* with the combination of O and capsule group the authors should like to make some review concerning the relationship between serotypes and hemorrhagic septicemia.

First, as was previously described, there are several O groups in Carter's type A in which only certain O groups can produce fowl cholera against chickens while another O group can not in spite of belonging to Carter's type A. 5:A and 9:A, are pathogenic against fowl, while 1:A, 3:A and 7:A, for instance, may not cause fowl cholera for

chicken but may cause pneuemonia for hogs, cattle, sheep and so forth. Heddleston[11] has recently applied bivalent vaccine for preventing fowl cholera. He uses 70-X and P 1,059 strains isolated from fowl cholera in the U.S. for producing vaccine. He also points out that these two kinds of strains are different immunologically and states that with heterologous strains the protection did not occur. The strains of two kind of serotypes were forwarded by Dr. Heddleston to our laboratory and they were termined as follows: 70-X was as 5:A and P 1,059 as 8:A. These strains also have strong pathogenicity for fowl. It is interesting that type 8:A and 9:A are pathogenic in turkey rather than in chicken, and for type 5:A, vice versa. Still more important findings are that sero types 5:A, 8:A and 9:A, though they are all classified in the same capsule type, i.e., type A, and also cause fowl cholera in chicken, do not protect fowl with heterogenous strains. In other words, vaccination with 8:A does not protect animals against infection by 9:A or 5:A does not protect infection by 8:A or 9:A. These findings call for a complete reshuffle of aetiology for *P. multocida* conceived so far around capsule type. They also suggest that with only capsular substance the complete protection does not occur against infection. Thus there are at least three serotypes with which fowl cholera are produced.

Recently, Murata et al.[12] have studied pathogenicity of *P. multocida* (using 1:A and 5:A) against fowl and mice. As against chicken, 5:A alone proves pathogenicity, while both 1:A and 5:A are pathogenic in mice, though with some difference in intensity among the two. By immunizing chicken with 1:A infection is not prevented for the challenge of 5:A, and the same is true with mice.

Thus, it was clarified in our experiment that the immunizing capacity of *P. multocida* much depends on somatic(O) antigen as well as capsule. In comparing, however, pathogenicity of strains among its iridescent type and blue type, the former no doubt affects the same host heavier than the latter. The situation may be interpreted in the same way as *Salmonella typhosa,* when provided with Vi antigen, shows highly pathogenic than Vi loss variant.

It is therefore considered that the role of somatic (O) antigen of *P. multocida* is very important to clarify the aetiology and immunology of the organisms. We have, therefore, made a proposal that type A by Carter should be substituted by group A, or serotype of *P. multocida* should be expressed in a combination of capsular type and O group.[8] In cases when designates type A by Carter, those bacilli divided different serotypes just as group B in Salmonella contain various kind of serotypes. For example, group B in Salmonella include not only *S. paratyphi B,* a bacillus causing paratyphoid for man, but also *S. typhimurium,* so that the cause and effect relationship between these bacilli and diseases are to be ultimately determined by serotype consisting of a combination of O antigen and H antigen. Another interesting example is that 5:A is recovered from pneumonia of hogs as is shown in Table 3. 5:A may cause a different disease by different animals; strains classified as 5:A do not cause hemorrhagic septicemia for hogs in the same way as *S. enteritidis,* a strain causes typhoid for mice, do not cause typhus for man but cause gastroenterities.

In the second place, according to Carter's results, that type B strain by him is so far consisted of simple sero type (6:B) and they are all derived from hemorrhagic septicemia of cattle. Recently, however, we have in hand an report by Bain et al.[13] as follows: one *P. multocida* (Australian type) was isolated from local wound of cattle in Australia. It is primarily classified as type B by Carter but unable to cause hemorrhagic cepticemia even on an experimental basis. It is seemingly isolated in South East Asia and thus to be classified as a strain different from type B (Asian type) which cause hemorrhagic septicemia for cattle on an experimental basis. Bain et al., however, have not found any difference among characteristics of capsule in both. Then they

tried to make a distinction in both in the following process: capsular substance is moved; the residual substance, which are assumed to be somatic (O) antigen, is extracted by phenol according to method by Westphal et al. Lipopolysaccharides thus obtained are then analyzed with the result that Asian type of bacillus contains a little more aldoheptose than Australian type. They conclude from those findings that the prevailing classification by capsule type alone is not fully competent a distinction in connection with Pasteurella aetiology.

We are subsequently provided from Bain with Australian strains (strain 989) and have studied their serotypes. The results are as follow: these bacilli have entirely different somatic (O) antigen from that in O group 6.[10] These results have provided workers to study the relationship between O group of *P. multocida* and aetiology with valuable and up-to-date information. For instance, not all of the organisms belonging to Carter's type B are causing hemorrhagic septicemia unless it is classified as O group 6. Here again a closer aetiologic relationship with *P. multocida* by O group is clearly endorsed. This is as similar an example as that we already quoted: although 1:A and 3:A may not cause fowl chlolera, 5:A and 8:A may cause it. Thus, Bain[10] has sustained the fact that cattle immunized with Australian type (11:B) may not be fully protected against hemorrhagic septicemia infected with Asian type (6:B).

Thirdly, the topic goes back to 1960, when Dr. Perreau, Tropical Veterinary Research Institute, Chad, Central Africa had called on us at the laboratory. He was of the opinion that bacillus originating from hemorrhagic septicemia of cattle did not agree with type B by Carter. Then we tested three strains of bacillus supplied by him and found that they were already of capsule-free blue type, and that they all belong to O group 6 under the O group classification. A little later Carter also had tested strains of bacillus originating from hemorrhagic septicemia of cattle in Central Africa, and recognized a different capsule from the type B. He

Table 5. Relationship between serotype and pasteurellosis

Carter's Capsular groupe	O group	Sero type		Process of disease	Animals	Immunization
A	5	5 : A	Aviseptica	Fowl cholera	Chicken	Do not protect fowl or
	8	8 : A	group		Duck	mice with heterologous
	9	9 : A			Turkey	strains
B	6*	6 : B	Boviseptica	Hemorrhagic	Cattle	Protect cattle§ or mice
E	6	6 : E	groupe	Septisemia		with heterologous strains
A	1**	1 : A		Pneumonia, Local	Various	Do not protect mice
	3	3 : A		Wound, Secondary	animals	with heterologous
	7	7 : A		infection	and men	strains
B	11	11 : B				
D	1	1 : D				
	2	2 : D				
	3	3 : D				
	4	4 : D				
	10	10 : D				
	12	12 : D	(Provisional)			

* Subgroup preseuts in O group 6

§ Protection tests are not complete with some strains, i.e. various protection degrees are seen in some O subgroups in O group 6

** Subgroups present in O group 1

named it type E anew. So we guessed that type E culture by Carter might be of the same origin with strains we were provided from Chad and that type E bacillus would be most likely belong to O type 6. Incidentally, a standard bacillus of type E was sent from Bain and we verified the above assumption, with the result that type E belong to O type 6.[10] Brain's personal communication told that type E bacillus originated from Central Africa (6:E) and Asian type (6:B) might cause immunity for mice reciprocally Then we were faced with such interesting facts that any different capsule may cause the same pathogenicity against a specific host if it belongs to the same O group. Consequently, the significance for capsule has on Pasteurella is to be deemed subordinate to that for O group. These conclusions are summarized in Table 5.

It is inadequate to call *P. multocida* in general hemorrhagic septicemia bacillus, because this group of bacilli have various pathogenicity according to their serotype. This view was proposed by Bain and Ochi[19] and approved at the FAO meeting in 1957.

Lastly, we have to refer to Ochi's classification[14-19] which is as widel used in our country as those by Carter or by Roberts are used in the worldwide circle. Ochi started his study on *P. multocida* in Korea during 1931 to 1935. His collection of strains was confined to limited geographic areas in Korea. His classification was based upon aetiologic or immunologic method and have some defects in the light of serologic method at present. The worst of them was that the standard bacillus in his classification had been missing, so that his method could not be tested in the experiment in comparison with Carter's method nor with ours. However, Ochi's method is referred to in general in the administrative level at present, so our views thereto will be adequately surmarized in the following.

Table 6 Estimated Relationships Between Carter's Capsular type, O group and Ochi's type

Caster's Capsule type 1959	O group 1961	Ochi's type (estimated) 1934
A	1	C
	3	C
	5	A
	7	C
	8	A
	9	A
B	6	B
	12	C
D	1	C
	2	C
	3	C
	4	C
	10	C
	unknown O group	C
E	6	B
P. hemolytica		D

Type A by Ochi is considered pathogenic as well as immunologically singular to fowl alone. We have at present, however, three different serotypes (5:A, 8:A and 9:A) which are pathogenic to fowl. They are moreover different from each other immunologically and are not preventive from infection of fowl from each other.

Secondly, type B by Ochi is considered causing hemorrhagic septicemia for cattle, hogs and sheep. These correspond to certain types of Carter's type B, i.e. two serotypes of 6:B and 6:E.

While type C by Ochi is considered not causing hemorrhagic septicemia for any animal: its pathogenicity is of minor effect; it rather causes chronic pneumonia, secondary infection or local purulent diseases. Thus a part of type A and B respectively, type C and type D by Carter are included in type C by Ochi. Or in reverse, Ochi's type C covers such many sero types made in combining classification by O group with that by capsule type by Carter as; 1:A, 3:A 7:A, ?:B, 1:D, 2:D, 3:D, 4:D, 10:D, ?:D, etc.

Lastly, type D by Ochi falls on *P. hemolytica* and other bacillus groups, not being connected with *P. multocida*. The relationships concerned are summarized in Table 6.

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