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pH RESISTANCE OF FOOT-AND-MOUTH DISEASE VIRUS AND ITS COMPLEMENT-FIXING ANTIGEN (*)

by

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SUMMARY

Foot-and-mouth disease (FMD) virus may retain very low degrees of infectivity when exposed to low pH levels (2.8 to 5.1) for 5 minutes; such retention was most marked with type A virus. When exposed to low pH for 30 minutes, unmodified tissue-culture (TC) virus of types A, O, and S.A.T. 1 completely lost infectivity below pH 5.6. There was no significant difference in this respect among the viral types.

High passage virus in baby hamster kidney (BHK 21; C-13) cells developed decreased acid resistance, and this decreased resistance in type A virus was not associated with lowered heat resistance.

Complement-fixing (CF) antigen of types A, O, and S.A.T. 1 viruses became ineffective when exposed to pH between 2 and 3 on the acid side and pH 11 and 12 in the alklaine range. There was no indication that FMD virus of types A and S.A.T. 1 was divided into smaller antigenic units ("soluble antigen") at moderately acid pH values. Such division of type O virus, however, could not be completely excluded. In most tests, the maximal serologic activity lay when the virus was kept in the moderately alkaline zone, between pH 8 and 10. Thus, it was often possible to increase the CF titer of TC virus by moderate alkalinization.

The pH resistance of FMD virus has been the subject of many reports. The virus is extremely sensitive to acid, unlike that of some other picornaviruses, but relatively stable in the presence of weak alkali.

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The earlier literature was reviewed by Randrup.[9] According to more recent work by Bachrach *et al.*,[2] FMD virus of type A was most stable at pH 7.0 to 7.5. Below pH 4, the virus was totally destroyed within a few seconds. At pH 5 and 6, there was also more or less rapid inactivation of most of the virus. However, a small amount of infective residual virus remained which was very resistant to further inactivation for at least 30 minutes. Bachrach *et al.*,[3] were unable to isolate an acid-resistant variant from this resistant population, but Mussgay[6] reported the isolation of such a variant (type O) in cultures with acid medium (pH 6.0.). In the alkaline range, a slow reduction of infectivity occurred even at pH 8 (90% within 3 weeks), a more rapid one at pH9 (90% within 1 week), whereas 90% of the infectivity was lost in 14 hours at pH 10.[2] It is known, from the older literature and practical experience, that 1 or 2% NaOH (as disinfectant) will destroy the infectivity of FMD virus almost instantaneously.

According to Randrup,[9] pH resistance of the "soluble" CF antigen,[11] which has a smaller particle size (7 mμ) than complete virus (22 m μ),[7] is greater than that of the infectious virus and the immunizing antigen. The titer of the CF antigen decreased slightly at pH 6.0 to 6.2 during 30 minutes and was reduced to between a fourth and a half of the original value at pH 3.2, but it was quite stable at pH 9.0 to 9.1. On the whole, reported data on pH resistance of the CF antigen are rather fragmentary.

Randrup concluded that, at slightly acid pH, FMD virus divided into smaller units, which presumably represented the "soluble antigen." Mussgay[7] confirmed Randrup's conclusions specially for type O virus. He observed an increase of the CF titer in fluorohydrocarbon-treated preparations of complete virus that were exposed to pH 6.0 for 20 minutes and then readjusted to pH 7.2. According to Mussgay's[8] theory, in acid environment FMD virus was split. Infective ribonucleic acid was liberated but immediately inactivated in tissues or crude viral suspensions by free cellular ribonuclease. The results that Bachrach[1] obtained with type A virus did not support this hypothesis. When acidified to pH 4.1, the virus did not seem to split off infective ribonucleic acid.

The purposes in this experiment were (1) to compare the acid resistance of different serologic types of FMD virus, unmodified and modified by serial passage in BHK cells; and (2) to test the pH resistance of CF antigen of 3 viral types, unmodified by passage, to determine which pH levels would yield the highest antigen titers.

Materials and Methods

Viral Strains.—The field strains used belonged to serologic types A, O, and S.A.T. 1 and originated from epizootics in Iran. The 2 type A strains (Teheran and Tabriz had serologic differences and may be considered as 2 distinct variants of type A. The same was true for the two O strains (Rey and Sepahpoor) used, although the serologic difference between them, as indicated by results of CF and

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* Passage strains developed by Dr. E. Traub and Mr. G. K. Kanhai from the Near East Animal Health Institute, Razi Serum and Vaccine Institute, Teheran, Iran.

TABLE 1—Acid Resistance of Low and High Passage Foot-and-Mouth Disease Virus of Type A

Infectivity at pH	Test No. 1				Test No. 2	
	5-minute exposure		30-minute exposure		30-minute exposure	
	3 passages	221 passages	1 + 2	246–248	2	267
pH 8.2	.....	.....	.....	+	.....	.....
8.1	.....	.....	+	.....	+	.....
8.0	.....	.....	.....	.....	.....	+
pH 7.9	.....	+	.....	.....	.....	.....
7.8	+	.....	.....	.....	.....	.....
7.7	.....	.....	.....	.....	.....	.....
7.6	.....	.....	.....	.....	.....	.....
7.5	.....	.....	.....	.....	.....	.....
7.4	.....	.....	.....	.....	+	.....
7.3	.....	.....	.....	+	.....	.....
7.2	.....	+	+	+	+	+
7.1	+	+	.....	.....	.....	+
7.0	.....	.....	.....	+	.....	.....
pH 6.9	+	.....	+	.....	+	.....
6.8	.....	.....	.....	.....	.....	+
6.7	.....	.....	+	+	.....	.....
6.6	+	+	+	.....	.....	Neg.
6.5	.....	.....	.....	.....	+	.....
6.4	+	.....	.....	.....	.....	Neg.
6.3	.....	+	.....	Neg.	.....	.....
6.2	.....	+ *	.....	.....	+	Neg.
6.1	.....	.....	.....	.....	.....	.....
6.0	.....	.....	.....	.....	.....	.....
pH 5.9	+	.....	.....	.....	.....	Neg.
5.8	.....	Neg.	+	.....	+ *	.....
5.7	.....	.....	+	.....	.....	Neg.
5.6	.....	+ *	+ *	Neg.	.....	.....
5.5	.....	.....	.....	.....	Neg.	.....
5.4	+	.....	.....	Neg.	.....	.....
5.3	+	.....	.....	Neg.	.....	Neg.
5.2	.....	Neg.	.....	.....	.....	Neg.
5.1	+ *	.....	Neg.	.....	.....	.....
5.0	Neg.	+ *	.....	.....	Neg.	.....
pH 4.9	.....	.....	.....	Neg.	.....	Neg.
4.8	.....	.....	Neg.	.....	Neg.	.....
4.7	Tr.	.....	.....	.....	.....	.....
4.6	.....	.....	.....	Neg.	.....	.....
4.5	.....	.....	Neg.	.....	Neg.	Neg.
4.4	+ *	+ *	Neg.	.....	Neg.	.....
4.3	.....	.....	.....	.....	.....	.....
4.2	Neg.	.....	Neg.	Neg.	.....	.....
4.1	.....	+ *	.....	.....	Neg.	.....
4.0	Tr.	.....	.....	Neg.	.....	Neg.
pH 3.9	.....	+ *	.....	Neg.	Neg.	.....
3.8	Tr.	Tr.	Neg.	.....	Neg.	Neg.
3.7	.....	.....	Neg.	.....	Neg.	Neg.
3.6	.....	.....	.....	Neg.	.....	Neg.
3.5	.....	.....	Neg.	.....	.....	.....
3.4	Tr.	.....	.....	.....	.....	.....
3.3	.....	.....	.....	Neg.	Neg.	Neg.
3.2	.....	Tr.	.....	.....	.....	.....
3.1	Neg.	.....	.....	.....	.....	.....
3.0	Tr.	Tr.	Neg.	.....	Neg.	Neg.
pH 2.9	.....	.....	.....	Neg.	.....	.....
2.8	Tr.	.....	.....	.....	.....	.....
2.7	.....	Neg.	Neg.	.....	.....	.....
2.6	.....	.....	.....	.....	.....	.....
2.5	.....	.....	.....	.....	Neg.	.....
2.4	.....	.....	.....	.....	.....	.....
2.3	.....	.....	.....	.....	.....	.....
2.2	.....	.....	.....	.....	.....	.....
2.1	.....	.....	.....	.....	.....	.....
2.0	.....	.....	.....	.....	.....	.....
pH 1.9	.....	.....	.....	.....	.....	.....
1.8	.....	.....	.....	.....	.....	.....

* Delayed cytopathogenic effect. Tr. = Trace of cytopathogenic effect only; subcultures were positive.

TABLE 2—Acid Resistance of Low and High Passage Foot-and-Mouth Disease Virus of Type O

Infectivity at pH	Test No. 1				Test No. 2	
	5-minute exposure		30-minute exposure		30-minute exposure	
	2 passages	235 passages	1 + 2	235 + 258 + 259	1	282
pH 8.2	.....	+	.....	.....	+	.....
8.1	.....	.....	.....	.....	.....	.....
8.0	.....	.....	.....	+	.....	.....
pH 7.9	+	.....	.....	.....	.....	+
7.8	.....	.....	+	.....	.....	.....
7.7	.....	.....	.....	.....	.....	.....
7.6	.....	+	.....	.....	.....	.....
7.5	.....	+	.....	.....	.....	.....
7.4	.....	.....	.....	.....	.....	+
7.3	.....	.....	.....	.....	.....	.....
7.2	+	+	.....	+	.....	+
7.1	.....	.....	+	.....	.....	.....
7.0	+	+	.....	+	+	.....
pH 6.9	.....	.....	.....	.....	.....	+
6.8	+	.....	.....	.....	+	+
6.7	.....	.....	.....	+ *	.....	.....
6.6	+	+	+	.....	+	.....
6.5	.....	.....	.....	+ *	.....	+ *
6.4	.....	+ *	.....	.....	.....	+ *
6.3	+ *	.....	+	.....	+ *	.....
6.2	.....	.....	.....	.....	+ *	.....
6.1	.....	+ *	+	.....	.....	Neg.
6.0	.....	+ *	.....	+ *	.....	Neg.
pH 5.9	Neg.	+ *	+	.....	+ *	.....
5.8	.....	.....	.....	.....	.....	Neg.
5.7	.....	.....	.....	.....	.....	Neg.
5.6	.....	.....	.....	.....	Neg.	.....
5.5	+ *	.....	.....	.....	.....	.....
5.4	.....	.....	.....	.....	.....	.....
5.3	.....	.....	.....	.....	Neg.	.....
5.2	.....	Neg.	.....	.....	.....	Neg.
5.1	Neg.	.....	Neg.	.....	.....	.....
5.0	.....	.....	.....	Neg.	.....	.....
pH 4.9	Neg.	Neg.	.....	.....	Neg.	Neg.
4.8	.....	.....	.....	.....	.....	.....
4.7	.....	Neg.	Neg.	Neg.	.....	Neg.
4.6	.....	.....	.....	Neg.	Neg.	.....
4.5	.....	Neg.	Neg.	.....	Neg.	.....
4.4	Neg.	.....	Neg.	Neg.	.....	Neg.
4.3	.....	.....	.....	.....	.....	.....
4.2	.....	Neg.	.....	.....	Neg.	.....
4.1	Tr.	.....	Neg.	Neg.	.....	Neg.
4.0	.....	Tr.	.....	.....	Neg.	.....
pH 3.9	.....	.....	Neg.	Neg.	Neg.	Neg.
3.8	.....	.....	.....	Neg.	.....	.....
3.7	Neg.	.....	Neg.	Neg.	Neg.	Neg.
3.6	.....	.....	.....	.....	.....	.....
3.5	.....	.....	Neg.	Neg.	.....	.....
3.4	.....	Neg.	.....	.....	Neg.	.....
3.3	Neg.	.....	.....	.....	.....	Neg.
3.2	.....	.....	Neg.	Neg.	.....	.....
3.1	Neg.	.....	Neg.	.....	Neg.	.....
3.0	.....	Neg.	.....	Neg.	.....	.....
pH 2.9	.....	.....	Neg.	.....	.....	.....
2.8	Neg.	Neg.	.....	Neg.	Neg.	.....
2.7	.....	.....	Neg.	Neg.	.....	.....
2.6	.....	.....	.....	.....	.....	.....
2.5	Neg.	.....	.....	.....	.....	.....
2.4	.....	.....	.....	.....	.....	.....
2.3	.....	.....	.....	.....	.....	.....
2.2	.....	.....	.....	.....	.....	.....
2.1	.....	.....	.....	.....	.....	.....
2.0	.....	.....	.....	.....	.....	.....
pH 1.9	.....	.....	.....	.....	.....	.....
1.8	.....	.....	.....	.....	.....	.....

* Delayed cytopathogenic effect. Tr. = Trace of cytopathogenic effect only; subcultures were positive

TABLE 3—Acid Resistance of Low and High Passage Foot-and-Mouth Disease Virus of Type S.A.T. 1

Infectivity at pH	Test No. 1				Test No. 2	
	5-minute exposure		30-minute exposure		30-minute exposure	
	3 passages	145 passages	1	198	2	229
pH 8.2	.....	.....	.....	.....	.....	.....
8.1	.....	.....	.....	.....	.....	+
8.0	.....	.....	+	+	+	.....
pH 7.9	+	.....	.....	.....	.....	.....
7.8	.....	+	.....	.....	.....	.....
7.7	.....	.....	.....	.....	.....	.....
7.6	.....	.....	.....	.....	.....	.....
7.5	.....	.....	.....	.....	.....	.....
7.4	.....	+	+	+	.....	.....
7.3	+	.....	.....	.....	+	+
7.2	.....	.....	+	.....	.....	.....
7.1	+	+	.....	.....	+	+
7.0	.....	.....	+	.....	.....	.....
pH 6.9	.....	+	.....	+	.....	+
6.8	+	+	.....	+	+	.....
6.7	.....	.....	.....	.....	.....	.....
6.6	+	.....	.....	+	.....	Neg.
6.5	.....	Tr.	.....	.....	.....	.....
6.4	.....	.....	+	.....	+	.....
6.3	.....	.....	Neg.	Neg.	+ *	.....
6.2	Tr.	.....	.....	Neg.	.....	Neg.
6.1	.....	.....	Neg.	Neg.	+ *	.....
6.0	.....	.....	.....	.....	.....	.....
pH 5.9	Neg.	Neg.	Neg.	Neg.	.....	.....
5.8	.....	.....	.....	Neg.	+ *	.....
5.7	.....	.....	Neg.	.....	.....	Neg.
5.6	Neg.	Neg.	.....	.....	.....	.....
5.5	.....	Neg.	.....	Neg.	Neg.	.....
5.4	.....	.....	Neg.	.....	.....	Neg.
5.3	Tr.	.....	.....	.....	.....	.....
5.2	.....	.....	Neg.	Neg.	.....	.....
5.1	.....	.....	.....	.....	Neg.	Neg.
5.0	.....	.....	.....	.....	.....	.....
pH 4.9	.....	.....	.....	.....	.....	.....
4.8	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.
4.7	.....	.....	.....	.....	.....	.....
4.6	Neg.	.....	Neg.	.....	.....	Neg.
4.5	Neg.	.....	Neg.	Neg.	.....	.....
4.4	.....	Neg.	.....	.....	Neg.	.....
4.3	.....	.....	Neg.	.....	.....	Neg.
4.2	.....	.....	.....	.....	.....	.....
4.1	Neg.	.....	Neg.	.....	.....	Neg.
4.0	.....	Neg.	.....	Neg.	Neg.	.....
pH 3.9	.....	.....	.....	.....	Neg.	.....
3.8	Neg.	Neg.	.....	Neg.	.....	Neg.
3.7	.....	.....	Neg.	.....	Neg.	Neg.
3.6	.....	Neg.	.....	.....	.....	.....
3.5	.....	Neg.	Neg.	.....	Neg.	.....
3.4	Neg.	Neg.	.....	.....	.....	.....
3.3	.....	.....	.....	Neg.	.....	Neg.
3.2	Neg.	.....	.....	.....	Neg.	Neg.
3.1	.....	.....	Neg.	.....	.....	.....
3.0	.....	.....	.....	Neg.	Neg.	.....
pH 2.9	Neg.	Neg.	.....	.....	.....	.....
2.8	.....	Neg.	.....	Neg.	Neg.	Neg.
2.7	Neg.	.....	.....	.....	.....	Neg.
2.6	.....	.....	.....	.....	.....	.....
2.5	.....	.....	.....	.....	.....	.....
2.4	.....	.....	.....	.....	.....	.....
2.3	.....	.....	.....	.....	.....	.....
2.2	.....	.....	.....	.....	.....	.....
2.1	.....	.....	.....	.....	.....	.....
2.0	.....	.....	.....	.....	.....	.....
pH 1.9	.....	.....	.....	.....	.....	.....
1.8	.....	.....	.....	.....	.....	.....

* Delayed cytopathogenic effect. Tr. = Trace of cytopathogenic effect only; subcultures were positive.

neutralization tests, was relatively slight.[12] Of type S.A.T. 1 virus, strain Shiraz (the only strain in our collection) was used.

In experiments on infectivity, acid resistance of low passage (unmodified) virus of strains Teheran (type A), Rey (type O) and Shiraz (type S.A.T. 1) was compared with that of high passage of the same strains in BHK 21 cells.* In these tests, the acid resistance of low passage of type A (3rd and pool of 1st and 2nd passage in test No. 1 and 2nd passage in tests No. 2) compared respectively with that of high passage of the same strain (passage 221 and pool of passages 246, 247, and 248 in test No. 1 and passage 267 in test No. 2).

The acid resistance of low passage of type O (2nd passage and pool of 1st and 2nd passage in tests No. 1 and 1st passage in test No. 2) compared respectively with that of high passage of the same strain (passage 235 and pool of passages 235, 258, and 259 in test No. 1 and passage 282 in test No. 2).

The acid resistance of low passage of type S.A.T. 1 (3rd and 1st passage in test No. 1 and 2nd passage in test No. 2) were compared respectively with that of high passage of the same strain (passage 145 and 198 in test No. 1 and passage 229 in test No. 2). Tissue culture fluid from bovine embryo kidney cells infected with these strains was used in the tests. The maintenance medium in these cultures was VM3, which contains $NaHCO_3$ as the only buffering substance.

In CF tests, TC fluids from BHK cells infected with the respective unmodified strains were used as antigens. The pH resistance of CF antigen of modified passage strains was not tested.

pH Adjustments.—Certain quantitites of 0.267 N HCl or 0.267 N NaOH were added to 7-ml. amounts of infectious TC fluid to obtain the necessary pH levels. The amounts of acid and alkali used to obtain the respective pH values were previously estimated in tests with noninfectious TC fluid. A pH meter* was used in all tests. The fluids were kept at the respective PH levels at temperatures between 25 and 26 C. for 5 or 30 minutes. The exposure time in experiments with CF antigen was 30 minutes. Hereafter, the pH was adjusted to the original values by adding appropriate amounts of 0.267 N NaOH or 0.267 N NCL.

Infectivity Tests.—Since all viruses were highly cytopathogenic for ovine embryo kidney cells, infectivity of the acid or alkali-treated preparations was tested in such cells. Primary cultures of ovine embryo kidney were most susceptible;[6] in subcultures, a lesser degree of sensitivity was frequently seen. Fully infective preparations had a complete cytopathogenic effect, whereas others, in which the infectivity was affected by pH, had an incomplete cytopathogenic effect. In such instances, the presence of infective virus was confirmed by transfer to other ovine embryo kidney cultures.

Complement-Fixation Tests.—The method of Traub and Möhlmann [10] with minor modifications,[12] was used. In every experiment, the type specificity of the

* Dynacap, Catalogue No. 11077 W.G. Pye and Company Ltd., Cambridge, England.

antigen was confirmed with homotypic and heterotypic guinea pig immune serum, and the antigens were titrated in dilutions of 2^{2} to 2^{-3} against homotypic serum 1:10 or 1:20, depending on the strength of the serum. The amount of fixation was estimated visually after sedimentation of the unlysed cells.

The "mean fixation" in the range 2^{2} to2^{-3} was calculated by adding the values recorded for successive individual antigen dilutions (4+ = 100%; 3.5+ = 87.5%; 3+ = 75%; 2.5+ = 62.5%; 2+ = 50%; 1.5+ = 37.55%; 1+ + 25%; 0.5 + = 12.5% and trace = 6.25%) and dividing the sum by 4. The volume increase by addition of acid and alkali was considered in the calculation of the cumulative values. The corrected mean fixation values were plotted against the pH values measured.

Results

Infectivity.—Acid-treated TC fluids continued to be slightly infective after exposure to low pH for 5 minutes (Tables 1-3). This occurred more frequently with virus of type A than with the 2 other viral types. Exposure for 30 minutes destroyed infectivity at pH levels below 5.6 in every instance. There were no marked differences in the acid resistance of low-passage strains of different viral types.

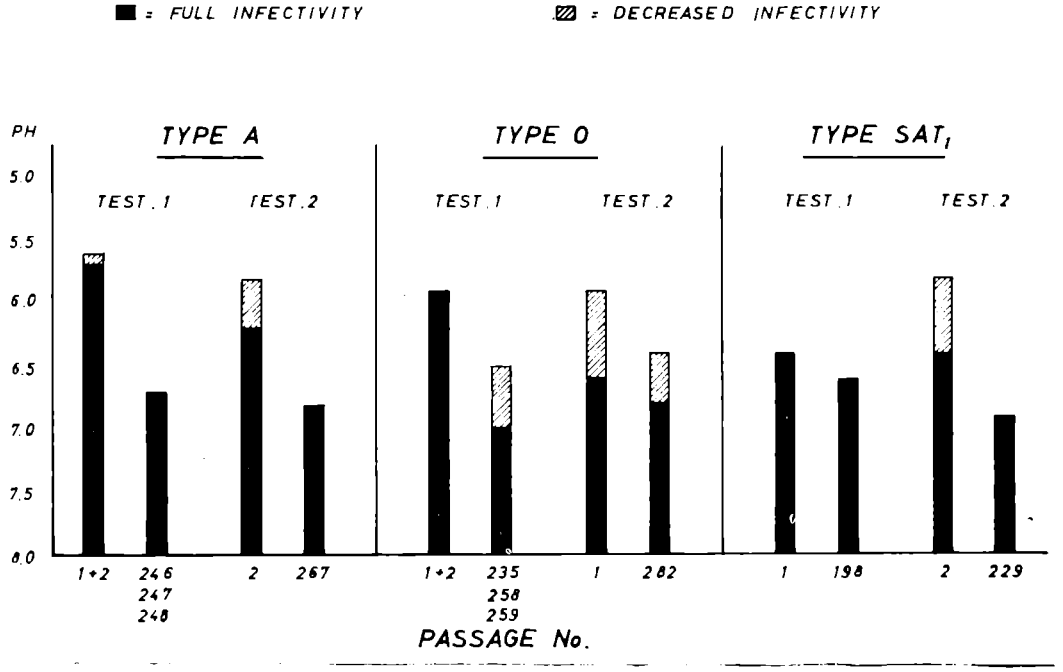

Fig. 1.—Acid resistance of infective foot-and-mouth disease virus of types A, O, and S.A.T. 1.

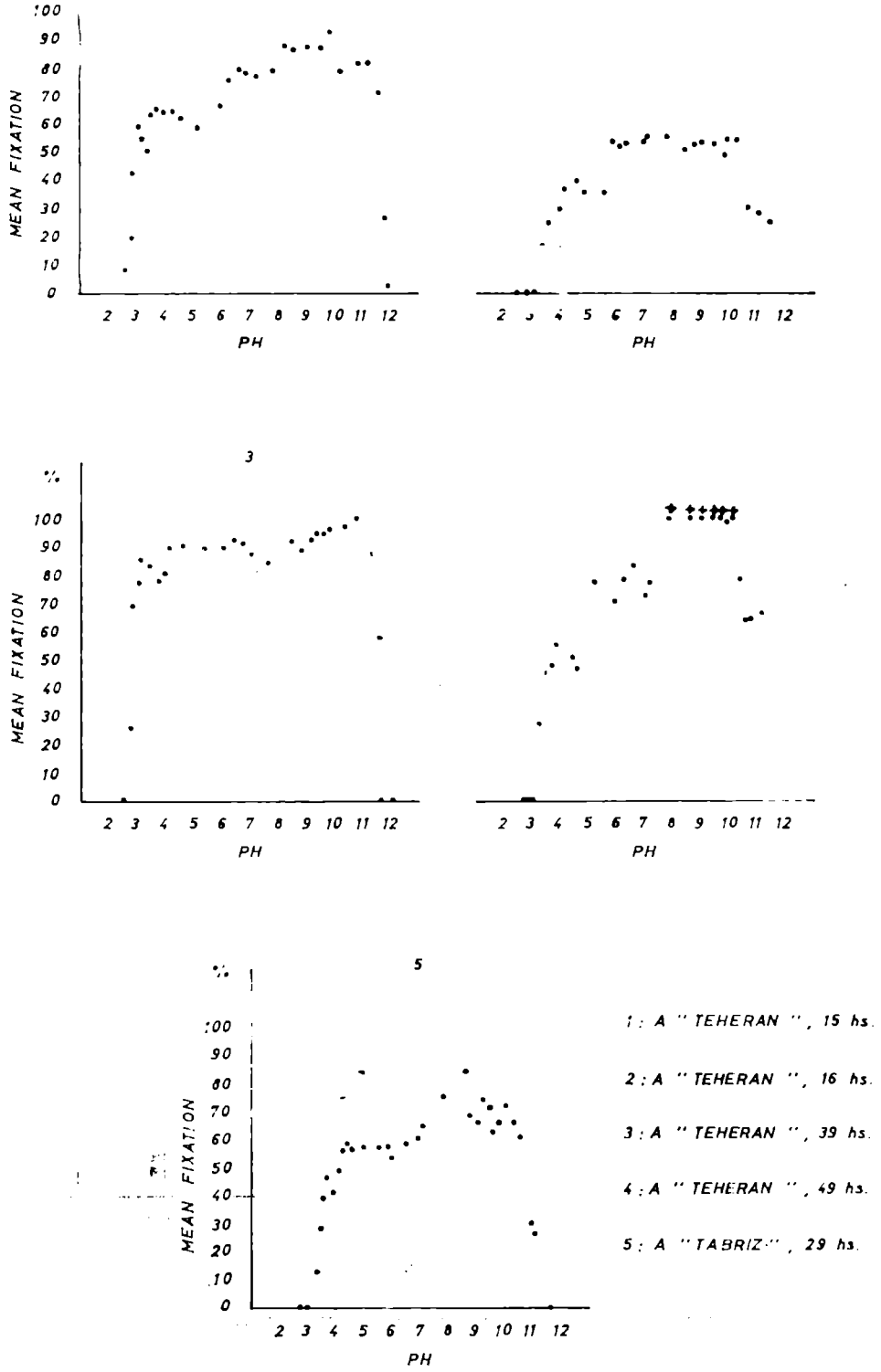

Fig. 2—The pH resistance of complement-fixing antigen of foot-and-mouth disease virus of type A.

High passage strains were usually less resistant to acid than low passage strains when exposed for 30 minutes (Tables 1-3; Fig. 1). The only exception was virus from passage 198 of type S.A.T. 1, which had not been passed often enough to show the difference. The difference, how-ever, is definite with virus of passage 229.

It is possible that the lessened infectivity in samples of treated virus failing to have a complete cytopathogenic effect (marked by asterisks in the tables or hatching in Fig. 1) was due to acid-resistant viral particles.

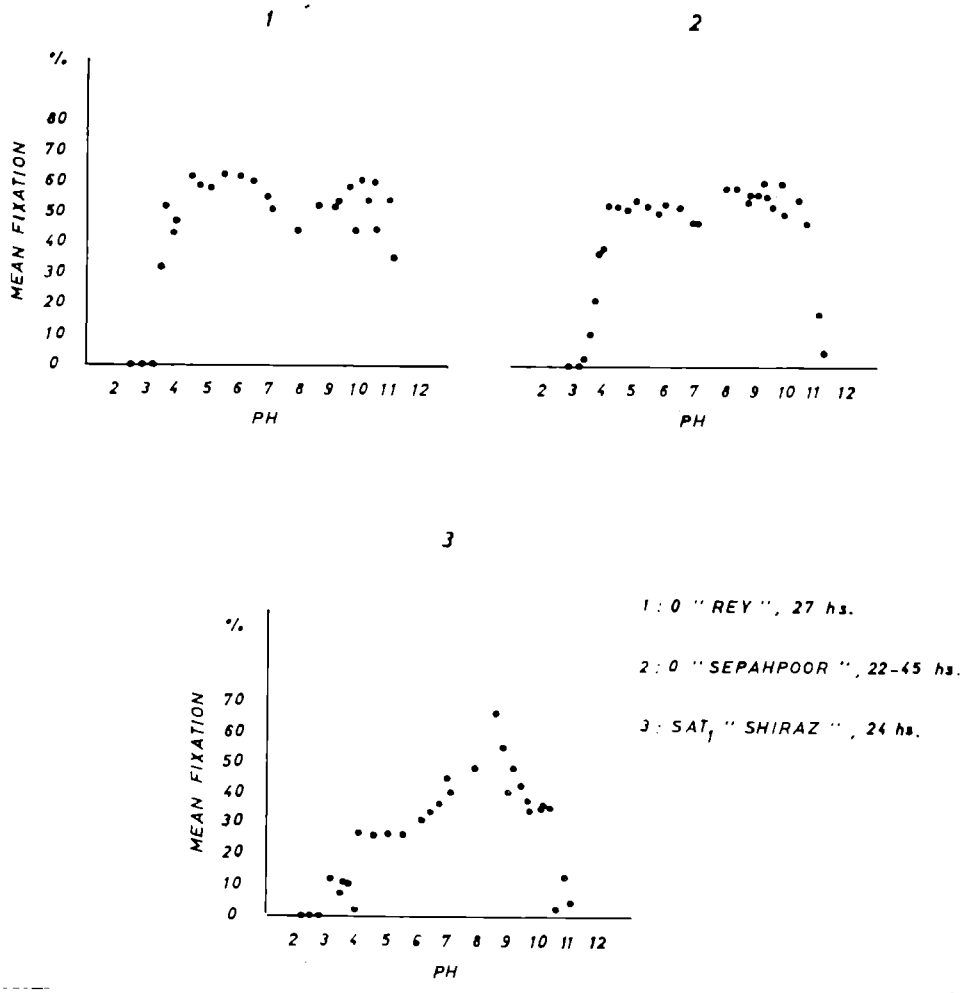

Fig. 3—The pH resistance of complement-fixing antigen of foot-and-mouth disease virus of types O and S.A.T. 1.

Complement-Fixing Antigen.—Since the antigen preparations used in the CF tests were not purified, they undoubtedly contained large (22 mμ, infective) and small (7 mμ, noninfective) particles. It can not be stated, therefore, how much of the CF recorded (Fig. 2, 3) was due to either size of particle. The values represent the total CF activity at the pH levels tested.

The results obtained were not quite uniform (Fig. 2, 3). The CF antigen usually became ineffective between pH 2 and 3 and between pH 11 and 12, most of the curves rising steeply and falling sharply. In several instances (Fig. 2; curves 1 ,3, 4, and 5; and Fig. 3; curves 2 and 3), the peaks of activity were in the alkaline region, usually between pH 8 and 10. The plus signs (Fig. 2, curve 4) indicated that end points were not reached there. The time of incubation of the infected cultures before removal of material for CF tests did not seem to influence the results uniformly.

Discussion

Data in the present report on acid resistance of unmodified FMD virus are generally in agreement with those reported by other investigators, although the rapid inactivation at low pH levels as reported by Bachrach *et al.*[2] was not seen. The latter difference may be due to the fact that Bachrach *et al.* worked with a TC passage strain which may have differed in some respects from unmodified field virus. Serial passage in BHK cells resulted in the decrease of acid resistance of the virus. The decrease was most marked with type A virus. This finding is in agreement with similar observations reported on the pH resistance of FMD virus modified by serial passage in bovine kidney cells.[4, 13] As in other instances, it may have practical use to differentiate modified and unmodified strains. Baby hamster kidney high-passage virus of type A had exactly the same degree of heat resistance as the unmodified strain.* Other genetic markers of modified strains have not been studied.

Systematic tests of pH resistance of the CF antigen of FMD virus were prompted by our failure to obtain an increase of the CF titer of TC antigen of type A by moderate acidification and subsequent reneutralization. If what Randrup reported were to occur for all FMD viral types,[9] one would expect increase in titer in such an instance. The data given (Fig. 2; curves 1, 2, 4, and 5, and Fig. 3; curve 3) indicate that this theory does not relate to types A and S.A.T. 1. There was no increase of CF titer in the slightly acid region, but in several instances a definite maximal increase at moderately alklaine pH. Starting with an about neutral preparation, the CF titer can often be increased by moderate alkalinization. According to the data given (Fig. 3; curves 1 and 2), a slight titer increase by acidification seems possible only with type C antigen. Both kinds of particles are known to react as antigens in the CF test.[5]

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* Shafyi, Abbas, Razi Serum and Vaccine Institute, Teheran, Iran: Unpublished data, 1966.

Increase of CF titers by pH change may be due to disaggregation of antigen particles rather than division of complete virus into smaller antigenic units at certain pH levels.

References

1. Bachrach, H. L.: RNA of Foot-and-Mouth Disease Virus: Its Preparation Stability and Plating Efficiency on Bovine - Kidney Cultures. Virology, 12, (1960); 258.
2. Bachrach, H. L., Breese, S. S. Jr., Callis, J. J., Hess, R., and Patty, R. E.: Inactivation of Foot-and-Mouth Disease Virus by pH and Temperature Changes and by Formaldehyde. Proc. Soc. Exptl. Biol. & Med., 95, (1957): 147.
3. Bachrach, H. L., Pledger, R.A., and Patty, R.E.: Physico-Chemical Inactivation of Foot-and-Mouth Disease Virus and Virus Variants. Proc. IV Internat. Cong. Biochem., Vienna, Austria (1958), Abstr. Sectional paper 15-2: (1960): 188.
4. Bengtsson, S., Dinter, A., and Philipson, L.: Genetic Markers Associated with Virulence of Foot-and-Mouth Disease Virus. Proc. Soc. Exptl. Biol. & Med., 113, (1963): 1019
5. Bradish, C. J., Brooksby, J. B., Dillon, I. F,, and Norambuena, M.: Ultracentrifugal Studies of the Infective and Complement-Fixing Components in the Virus System of Foot-and-Mouth Disease. Proc. Roy. Soc. London S.B., 140, 1952): 107.
6. Mussgay, M.: Gewinnung einer pH-stabilen Variante des Virus der Maul-und Klauenseuche und ihre Vermehrung in Gewebekulturen mit sauerem Medium. Zentralbl. Bakt., 175, (1959): 183.
7. Mussgay, M.: Trennung zweier spezifischer Einheiten des Virus der Maul-und Klauenseuche mit einem Fluor-Kohlenwasserstoff. Ztschr. Yyg., 146, (1959): 48.
8. Mussgay, M.: Ueber den Mechanismus der pH-Inaktivierung des Virus der Maul-und Klauenseuche. Monatsh. Tierheilk., 11,)1959): 185.
9. Randrup, A.: On the Stability of Bovine Foot-and-Mouth Disease Virus Dependent on pH: Investigations on the Complement-Fixing and the Immunizing Antigen as Well as on the Infective Agent. Acta path. et microbiol. Scand., 35, (1954): 388.
10. Traub, E., and Möhlmann, H.: Typendifferenzierung bei Maul-und Klauenseuche mit Hilfe der Komplementbindungsprobe. Zentralbl. Bakt., 159, (1943): 289.
11. Traub, E., and Pyl, G.: Untersuchungen über das komplementibindende Antigen bei Maul-und Klauenseuche. Ztschr. Immunitätsforsch., 104, (1943): 158.
12. Traub, E., Shafyi, A., Kesting, F., and Ewaldsson, B.: Serological Variation of Foot-and-Mouth Disease Virus in Iran (1963-1966). Bull. Off. internat. Epizoot., 65, (1966): 2035-2050.
13. Witmann, G., and Ahl, A.: Genetische Merkmale attenuierter Maul-und Klauenseuche-Virusstämme. Bull. Off. Internat. Epizoot., 61, (1964): 579.