STUDIES ON ATP DEAMINASE

IV. DISTRIBUTION OF ATP DEAMINASE, AND THE PURIFICATION AND PROPERTIES OF ACID-TYPE ADP-DEAMINATING ENZYME

SHIAU-TA CHUNG, KÔ AIDA AND TEIJIRO UEMURA

Institute of Applied Microbiology, University of Tokyo, Tokyo

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The distribution of deaminases active for adenosine compounds was studied and it was found that besides two kinds of deaminases, i.e., non-specific ATP and adenosine deaminases, another acid-type ADP-deaminating enzyme was present in *Aspergillus* species.

Deaminases from *Aspergillus glaucus* and *A. repens* were purified and it was confirmed that they were of the same type of non-specific ATP deaminase which was found in *Microsporum audouini* by the authors.

Non-specific acid ADP-deaminating enzymes were found and purified from the koji cultures of both *A. ochraceus* and *A. melleus*. They deaminate ADP, ATP, adenosine sulfate, adenosine tetraphosphate, 5'-AMP, dAMP, 3',5'-cyclic AMP, adenosine, and 3'-AMP in this order. The optimum pH of ADP-deaminating enzyme obtained from both strains were 3.4 in acetate buffer, and the K_m values of *A. ochraceus* and *A. melleus* were calculated to be 4.0×10^{-5} M and 6.6×10^{-5} M, respectively.

Previously, *Microsporum audouini* was found to form an adenosine phosphate-deaminating enzyme which should be designated as ATP deaminase (EC class 3.5.4) and its purification and properties were described (1). On the other hand, a fungal deaminase, i.e., a non-specific adenosine deaminase which is different in properties from the above deaminase, has been obtained from Takadiastase and investigated in detail by KAPLAN *et al.* (2). Then, it will be of special interest to see whether ATP deaminase or deaminases of another type are also distributed in microbes, especially in *Aspergillus* species or not.

While studying on this subject, not only ATP deaminase and KAPLAN's deaminase but also another adenosine phosphates-deaminating enzyme, i.e., acid-type ADP-deaminating enzyme, was found to be present in *Aspergillus* species. The presence of ADP deaminase (EC 3.5.4.7) was observed in acto-

myosin by DEUTSCH *et al.* (3), but it has not been studied in the isolated form. A partially purified preparation of ADP-deaminating enzyme from *Aspergillus* species is characterized by the acid optimum pH in its action and its purification and properties are dealt with in this paper.

MATERIALS AND METHODS

Microorganism. Microorganisms surveyed for distribution of ATP deaminase were obtained from this Institute (IMA), Institute for Fermentation, Osaka (IFO), Faculty of Engineering, Osaka University (OUT), and Faculty of Engineering, Hiroshima University (HUT).

Cultural method. "Wheat-bran Koji", i.e., culture of the tested microorganisms on wheat bran, was prepared by inoculating each microorganism, except for *Streptomyces*, to sterilized wheat bran, and by incubating for 3 or 4 days at 27°. The enzyme formed on wheat-bran koji was extracted with 5 volumes of water at room temperature for 30 min, and the enzyme extract was subjected to the test of ATP deaminase or other test as described below. *Streptomyces* strains were cultured in the following medium: Glucose 2%, peptone 1%, yeast extract 0.2%, $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$ 0.3%, KH_2PO_4 0.05%, K_2HPO_4 0.05%.

Assay for enzyme activity and detection of each of adenosine-, ADP- and ATP-deaminases. The assay was made in a reaction mixture containing $4 \times 10^{-5}\text{M}$ of substrate and 0.1M acetate buffer in a total volume of 3.0 ml. According to Kalckar's spectrophotometric method, activity was determined with a Beckman spectrophotometer at 265 m μ at 25°. One unit was defined as the amount of enzyme which caused an optical density change of 0.015 per minute at 265 m μ under the condition described above. Specific activity was expressed as unit per mg of protein.

In order to obtain a rough idea on the selective specificity of the enzyme toward adenosine compounds, activity of each crude enzyme solution for adenosine or ATP as substrate was compared. When the enzyme solution showed a higher activity for ATP than for adenosine, it was tentatively assumed that the crude enzyme preparation contained ATP deaminase predominantly; while in the reversed case adenosine deaminase was assumed to be present. ADP-deaminating enzyme in the crude enzyme solution was first recognized when the activity for ADP was higher than that for ATP. It was subsequently confirmed by using a partially purified preparation.

Thin-layer chromatography. Reaction mixtures containing 0.1 ml of the above aqueous enzyme extract from each wheat-bran koji were incubated for 1 hr and they were submitted to thin-layer chromatography on MN-cellulose 300 pei developed with the following solvent system: Saturated $(\text{NH}_4)_2\text{SO}_4$: *ter*-butanol: 0.025 N NH_4OH =160:3:40. Spots were detected by ultraviolet ray.

Materials. 5'-Adenosine tetraphosphate (5'-ATPP), 5'-adenosine triphos-

phate (ATP), 5'-adenosine diphosphate (5'-ADP), 5'-adenylic acid (5'-AMP), 3', 5'-cyclic AMP, 3'-AMP, 2'-AMP and deoxyadenylic acid were purchased from the Sigma Chemical Company (U.S.A.). Adenosine was obtained from Tokyo Kasei Kogyo Ltd. 5'-Adenosine monosulfate (Ad-sulfate) was kindly given by Ajinomoto Co., Ltd.

EXPERIMENTAL RESULTS

Distribution of ATP deaminase and other adenosine compound-deaminating enzymes.

It has been found that Takadiastase from *Aspergillus oryzae* contains non-specific adenosine deaminase, which deaminates adenosine most actively but ATP only at a considerably slow rate. On the other hand, ATP deaminase which was found in *M. audouini*, is most active to ATP and deaminates adenosine at the rate of 6.7% of ATP. Then, screening of distribution in fungi and *Streptomyces* of such ATP deaminase as found in *M. audouini* was carried out based on the difference in properties of both adenosine and ATP enzymes as described above.

The presence of deaminase activities in 67 strains of microorganisms belonging to the genera of *Aspergillus*, *Penicillium*, *Mucor*, *Rhizopus* and *Streptomyces* was tested by the use of crude enzyme extract prepared by treating the wheat-bran koji culture of each strain with 5 volumes of water. Their presence was indicated by the formation of ITP or inosine as the deaminated product of ATP or adenosine which was detected by thin-layer chromatography. The presence of these deaminases was found to be distributed widely in *Aspergillus* species, but it was not detected in *Penicillium*, *Mucor*, *Rhizopus*, and *Streptomyces* so far tested (Table 1) and the deaminase activity was assayed as described in the method section. Adenosine deaminase which was demonstrated by its higher activity to adenosine than to ATP was found in *A. oryzae*, *A. flavus*, *A. sojae*, *A. candidus*, and *A. citrisporus*.

The ATP deaminases in the crude extracts were further purified and their enzymatic properties were compared with those of ATP deaminase from *M. audouini* reported previously.

As shown in the following sections, it was confirmed that deaminases from *A. glaucus* and *A. repens* were of the same type of ATP deaminase as that from *M. audouini*, but deaminases from *A. ochraceus* and *A. melleus* belong to another one, i.e., a non-specific acid ADP-deaminating enzyme.

Purification of ATP deaminases and ADP-deaminating enzyme.

Deaminases from *A. glaucus* (IAM 2124), *A. repens* (IFO 4884), *A. ochraceus* (IAM 2022), and *A. melleus* (IFO 4339), all of which showed a higher activity to ATP than to adenosine, were purified according to the same procedure as reported previously (1). Each wheat-bran koji was extracted with 5 volumes of water and the crude enzyme extract was treated with

Table 1. Distribution of adenosine phosphatc-deaminating enzyme.

Microorganism	Strain No.	Deaminase	Enzyme activity ^a		Most effective substrate ^b
			Adeno-sine	ATP	
<i>Aspergillus clavatus</i>	IAM 2535	—			
<i>A. glaucus</i>	IAM 2124	+	0.020	0.130	ATP
<i>A. glaucus</i> var. <i>minimus</i>	HUT 2038 (HUT 2087) ^c	+	0.015	0.160	ATP
<i>A. glaucus</i> var. <i>nonascus</i>	HUT 2036	+	0.005	0.060	ATP
<i>A. repens</i>	IFO 4884	+	0.010	0.110	ATP
<i>A. chevalieri</i>	IFO 5233 (IFO 4298, IFO 4334)	+	0.004	0.040	ATP
<i>A. citrisporus</i>	IAM 2141 (IFO 4042)	+	0.020	0.000	Adenosine
<i>A. raperi</i>	IFO 6416	—			
<i>A. brunneo-uniseriatus</i>	IFO 6993	—			
<i>A. kanagawaensis</i>	IAM 2583 (IFO)	—			
<i>A. restrictus</i>	IAM 2008	+	0.035	0.000	Adenosine
<i>A. fumigatus</i>	IAM 2400	—			
<i>A. ochraceus</i>	IAM 2022 (IAM 2804 IAM 2806 IFO 4069 IFO 4346 OUT 5034 OUT 5035 OUT 5109)	+	0.010	0.075	ADP
<i>A. ochraceus</i> var. <i>microsporus</i>	IFO 4410 (IAM 2520)	+	0.005	0.060	ADP
<i>A. melleus</i>	IFO 4339 (IFO 4420 IAM 2064 IAM 2066)	+	0.010	0.110	ADP
<i>A. niger</i>	IAM 2533 (IAM 2020 IAM 3010)	—			
<i>A. awamori</i>	IAM 2299 (IAM 2334)	—			
<i>A. usamii</i>	IAM 2185	—			
<i>A. candidus</i>	IAM 2018	+	0.012	0.000	Adenosine
<i>A. flavus</i>	IAM	+	0.016	0.006	Adenosine
<i>A. oryzae</i>	IAM 2024 (IAM 2602 IAM 2610 IAM 2748)	+	0.020	0.011	Adenosine
<i>A. oryzae</i> var. <i>microsporus</i>	IAM 2651	+	0.008	0.005	Adenosine
<i>A. sojae</i>	IAM 2631	+	0.011	0.006	Adenosine

Table 1 (continued)

Microorganism	Strain No.	Deaminase	Enzyme activity		Most effective substrate
			Adeno-sine	ATP	
<i>A. wentii</i>	IAM 2133	—			
<i>A. itaconicus</i>	IAM 2928 (IFO 4336)	+	0.020	0.090	ATP
<i>A. versicolor</i>	IAM 2399	—			
<i>A. nidulans</i>	IAM 2130	+	0.012	0.130	ATP
<i>A. ustus</i>	IAM 2023	—			
<i>A. flavipes</i>	IAM 2523	—			
<i>A. terreus</i>	IAM 3004 (IFO 4100)	+	0.006	0.060	ATP
<i>Penicillium chrysogenum</i>	IAM 7106 (IAM 7320)	—			
<i>P. notatum</i>	IAM 7367	—			
<i>P. citrinum</i>	IAM 7316	—			
<i>Mucor javanicus</i>	IAM 6108	—			
<i>M. racemosus</i>	IAM 6126	—			
<i>M. rouxianus</i>	IAM 6136	—			
<i>Rhizopus japonicus</i>	IAM 6065	—			
<i>R. nigricans</i>	IAM 6070	—			
<i>R. oryzae</i>	IAM 6060	—			
<i>Streptomyces aureofaciens</i>	IAM 0087	—			
<i>S. griseus</i>	IAM 0089	—			
<i>S. venezuelae</i>	IAM 0017	—			
<i>Microsporum audouinii</i>		+	0.008	0.100	ATP

^a Activity is expressed as the change in optical density at 265 m μ per 0.1 ml of crude enzyme solution per minute in a total volume of 3.0 ml of 0.1 M acetate buffer.

^b This indicates the most effective substrate among adenosine, ADP, and ATP under conditions tested.

^c The strain(s) in parentheses was also found to have almost the same activity as the strain described above.

ammonium sulfate, ethanol, acetone, and DEAE-cellulose. Results are summarized in Table 2. Phosphatase activity, found to be present in crude enzyme extract by thin-layer chromatography, was proved to be absent in the purified enzyme preparation.

Some properties of ADP-deaminating enzyme and ATP deaminase.

(1) Effect of pH on enzyme activity:

Optimum pH was determined in 0.1 M acetate buffer as shown in Fig. 1. Deaminases obtained from *A. ochraceus* and *A. melleus* were active at rather

Table 2. Purification of ADP-deaminating enzyme and

Type of deaminase	Microorganism	Crude extract		(NH ₄) ₂ SO ₄ (55-75%)	
		T.U. ^a ($\times 10^{-4}$)	S.A. ^b	T.U. ($\times 10^{-4}$)	S.A.
ADP-deaminating enzyme	<i>A. ochraceus</i>	2.4 (100) ^c	2.5	1.78 (74)	24.1
	<i>A. melleus</i>	4.9 (100)	6.0	4.6 (94)	58
ATP deaminase	<i>A. glaucus</i>	1.7 (100)	1.9	0.85 (50)	34
	<i>A. repens</i>	8.0 (100)	9.5	7.6 (95)	57

^a Total units^b Specific activity^c Yield (%)Table 3. Substrate specificity of ADP-deaminating enzyme and ATP deaminase from *Aspergillus* species.

Type of deaminase	Source	Substrate			
		ATP	ADP	AMP	Adeno- sine
ADP-deaminating enzyme	<i>A. ochraceus</i>	0.102 ^a (100) ^b	0.130 (127.4)	0.065 (63.8)	0.007 (6.9)
	<i>A. melleus</i>	0.125 (100)	0.14 (112)	0.092 (73.6)	0.009 (7.2)
ATP deaminase	<i>A. glaucus</i>	0.137 (100)	0.125 (91.2)	0.095 (69.3)	0.012 (8.8)
	<i>A. repens</i>	0.118 (100)	0.108 (91.6)	0.067 (56.8)	0.014 (11.8)
	<i>Microsporum audouini</i>	0.133 (100)	0.102 (76.6)	0.062 (46.6)	0.009 (6.8)

^a Activity of deaminase; the numeral expresses the change in optical density at 265 m μ per minute at optimum pH in a total volume of 3.0 ml containing 0.01 ml of purified enzyme solution.

^b Numeral in parentheses shows the relative activity. The activity for ATP was arbitrarily taken as 100.

ATP deaminase from *Aspergillus* species.

Ethanol (33-66%, (v/v))		Acetone (20-50%, (v/v))		DEAE-cellulose	
T.U. ($\times 10^{-4}$)	S.A.	T.U. ($\times 10^{-4}$)	S.A.	T.U. ($\times 10^{-4}$)	S.A.
1.54 (64)	64.3	0.7 (29)	272	0.36 (15)	2,300
2.5 (51)	186	2.1 (43)	590	0.93 (19)	6,200
0.59 (35)	48	0.31 (18)	285	0.13 (8)	3,300
7.2 (90)	445	6.8 (85)	723	2.4 (30)	7,700

Table 4. Substrate specificity of ADP-deaminating enzyme.

The reaction mixture (3 ml) contained 0.1 M acetate buffer of pH 3.4, 0.01 ml of purified ADP deaminase, and 4×10^{-5} M of the substrate and incubated at 25°.

Substrate	Activity ^a		Relative activity	
	<i>A. ochraceus</i>	<i>A. melleus</i>	<i>A. ochraceus</i>	<i>A. melleus</i>
5'-ADP	0.130	0.140	100	100
5'-ATPP	0.083	0.073	63.8	52.1
5'-ATP	0.102	0.125	78.5	89.4
5'-AMP	0.065	0.092	50	65.7
3', 5'-cyclic AMP	0.010	0.014	7.7	10
3'-AMP	0.006	0.007	4.6	5
2'-AMP	0.000	0.000	—	—
dAMP	0.013	0.020	10	14.3
Adenosine	0.007	0.009	5.4	6.4
Ad-sulfate	0.083	0.101	63.8	72.2

^a Activity is expressed as the change in optical density at 265 m μ per minute.

Fig. 1. Optimum pH of ADP-deaminating enzyme and ATP deaminase from *Aspergillus* species.

The reaction mixture (3 ml) contained 0.1 M acetate buffer of various pH values, 4×10^{-5} M substrate, and 0.01 ml of the enzyme solution. Temperature, 25°

acid pH, i.e., pH 3.4, for both ATP and ADP. On the other hand, deaminases from *A. glaucus* and *A. repens* were most active at about the same pH as that from *M. audouini*, i.e., 4.8 and 5.3, respectively.

(2) Substrate specificity:

At each optimum pH, substrate specificity of these deaminases was determined. As shown in Table 3, deaminase from *A. glaucus* and *A. repens* had the same substrate specificity as that of the ATP deaminase from *M. audouini*. Deaminases from *A. ochraceus* and *A. melleus*, however, were

Table 5. K_m values of ADP-deaminating enzyme and ATP deaminase from *Aspergillus species*.

Type of deaminase	Source	K_m value ($M \times 10^{-5}$) ^a
ADP-deaminating enzyme	<i>A. ochraceus</i>	4.0
	<i>A. melleus</i>	6.6
ATP deaminase	<i>A. glaucus</i>	1.7
	<i>A. repens</i>	2.2

^a K_m value was measured in 0.1 M acetate buffer each optimum pH (3.4 for *A. ochraceus* and *A. melleus*, 4.8 for *A. glaucus*, and 5.3 for *A. repens*) at 25°, and ADP served as a substrate for ADP-deaminating enzyme and ATP for ATP deaminase.

Table 6. K_m value and relative V_{max} of ADP-deaminating enzyme from *Aspergillus melleus*.

Substrate	Relative V_{max} ^a	K_m value ^a ($M \times 10^{-5}$)
5'-ATP	100	3.2
5'-ADP	157	6.6
5'-AMP	105	7.2
Adenosine	26	12.5

^a K_m value and V_{max} were measured in 0.1 M acetate buffer of pH 3.4 at 25°.

Table 7. Effect of inhibitors on the activity of ADP-deaminating enzyme from *Aspergillus melleus*.

Inhibitor	Concentration (M)	Activity ^a	Inhibition (%)
None	—	0.105	—
pCMB	1×10^{-4}	0.054	49
ICH ₂ COOH	1×10^{-3}	0.105	0
Fe ³⁺	5×10^{-5}	0.059	44
Ag ⁺	1×10^{-3}	0.047	55
Zn ²⁺	2×10^{-2}	0.067	36
Ca ²⁺	2×10^{-2}	0.072	31
Mg ²⁺	1×10^{-2}	0.069	34
Hg ²⁺	1×10^{-3}	0.064	39

^a The reaction mixture (3 ml) contained 0.1 M acetate buffer of pH 3.4, 4×10^{-5} M ADP, and 0.1 ml of enzyme solution.

Table 8. Effect of inhibitor on ADP-deaminating enzyme and ATP deaminase.

Type of deaminase	Source	Inhibitor	Concentration (M)	Activity ^a	Inhibition (%)
ADP-deaminating enzyme	<i>A. ochraceus</i>	Ag ⁺	— 1×10 ⁻⁴ 3.3×10 ⁻³	0.092 0.077 0.039	— 16 58
		pCMB ^b	— 1×10 ⁻⁴	0.100 0.055	— 45
	<i>A. melleus</i>	Ag ⁺	— 1×10 ⁻⁴ 1×10 ⁻³	0.110 0.083 0.049	— 25 55
		pCMB	— 1×10 ⁻⁴	0.098 0.045	— 54
	<i>A. glaucus</i>	Ag ⁺	— 1×10 ⁻⁴	0.100 0.015	— 85
		pCMB	— 1×10 ⁻⁴	0.080 0.017	— 79
ATP deaminase	<i>A. repens</i>	Ag ⁺	— 1×10 ⁻⁴	0.110 0.038	— 65
		pCMB	— 1×10 ⁻⁴	0.098 0.024	— 76
	<i>M. audouini</i>	Ag ⁺	— 1×10 ⁻⁴	0.120 0.026	— 78
		pCMB	— 1×10 ⁻⁴	0.105 0.036	— 66

^a Activity is expressed as the change in optical density at 265mμ per minute.

^b Activity was measured with 0.1M Tris buffer of pH 7.2.

most active for ADP (Table 3) and showed higher activity for ADP than ATP at all pH ranges tested (Fig. 1). Detailed substrate specificities of deaminases from *A. ochraceus* and *A. melleus* are shown in Table 4. They deaminated ADP, ATP, 5'-adenosine monosulfate, adenosine tetraphosphate, and AMP. Adenosine was deaminated at a considerably slow rate.

(3) K_m value:

K_m values of these deaminases are shown in Tables 5 and 6. Relative maximum velocity (V_{max}) was also determined by the use of deaminase from *A. melleus* and it was the largest to ADP (Table 6).

(4) Inhibitor:

The effect of inhibitors on the activity of ADP-deaminating enzyme from *A. melleus* is summarized in Table 7. Similarly as in the case of ATP deaminase, pCMB and Fe³⁺ strongly inhibited the activity. However, the effect

Fig. 2. pH stability of ADP-deaminating enzyme and ATP deaminase from *Aspergillus* species.

The enzyme solution adjusted to the various pH values was incubated for 30 min at 37° and when cooled, the residual activity was measured in 0.1M acetate buffer of optimum pH at 25°. ADP was used as substrate for ADP-deaminating enzyme and ATP for ATP deaminase.

- (1) —○— *A. ochraceus*. —●— *A. melleus*.
 (2) —●— *A. glaucus*. —○— *A. repens*.

of Ag^+ was different from the ATP deaminase in respect to the fact that 10-30 times the amount of Ag^+ was required to obtain the same degree of inhibition (Table 8).

(5) pH stability:

As it has been known that fungal amylases or proteases having acid optimum pH are often acid resistant, the stability of ADP-deaminating enzyme and ATP deaminases at various pH values was compared. As shown in Fig. 2, ADP deaminase is stable between the pH range of 5.0 and 7.0, but unstable at its optimum pH (3.4). ATP deaminase is more stable than ADP-deaminating enzyme.

DISCUSSION

Since the discovery of adenosine compound-deaminating enzyme by SCHMIDT (4) (1928), such deaminases as adenine deaminase (FC 3.5.4.2), adeno-

sine deaminase (EC 3.5.4.4), AMP deaminase (EC 3.5.4.6), and ADP deaminase (EC 3.5.4.7) have been reported in the literature. Recently, *M. audouini*, in addition, was found to produce another type of deaminase, which had the most intensive activity to ATP resulting in the formation of ITP and was designated as ATP deaminase (1), but its distribution in the fungi has not as yet been examined in spite of its presumptive importance in cellular metabolism in respect of its activity to convert ATP to ITP. Through the present investigation, an acid ADP-deaminating enzyme was found also in *A. ochraceus* and *A. melleus*. Thus, it is to be noted that three kinds of deaminase, i.e., ATP and adenosine deaminases and ADP-deaminating enzyme are widely distributed in *Aspergillus* species corresponding to the grouping of *Aspergillus* fungi by THOM and RAPER (5).

The isolation and purification of deaminases from *A. glaucus* and *A. repens* demonstrate that both of them are the same type of ATP deaminase as that of *M. audouini* reported previously, suggesting a more wider distribution of this ATP deaminase in organisms. Non-specific adenosine deaminase was first isolated by KAPLAN *et al.* from Takadiastase which was prepared by employing a strain belonging to *Aspergillus oryzae*, and a considerably wide distribution of this enzyme in *Aspergillus* species was clarified in the present study.

Besides, another adenosine phosphate-deaminating enzyme was distributed in *Aspergillus* species as described above. From the results obtained in the enzymatic studies with the partially purified preparation, it was clarified that this enzyme is different from either non-specific adenosine deaminase or ATP

Table 9. Comparison of ADP-deaminating enzyme with ATP and adenosine deaminases.

Type of deaminase	Source	Optimum pH ^a	K_m value ^b ($M \times 10^{-5}$)	pH-stability ^c	Most effective substrate	Inhibition of Ag^+
ADP-deaminating enzyme	<i>A. ochraceus</i>	3.4	4.0	5.0-7.0	ADP	+
	<i>A. melleus</i>	3.4	6.6	5.0-7.0	ADP	+
ATP deaminase	<i>A. glaucus</i>	4.8	1.7	5.5-6.5	ATP	++
	<i>A. repens</i>	5.3	2.2	5.5-7.0	ATP	++
	<i>M. audouini</i>	5.0	3.3	5.0-7.5	ATP	++
Adenosine deaminase ^d	Takadiastase	6.3	60	—	Adenosine	

^a Optimum pH was measured with 0.1M acetate buffer.

^b K_m value was measured with 0.1M acetate buffer of optimum pH at 25°.

^c Numerals show the range of stable pH.

^d Data from KAPLAN *et al.* (2).

deaminase. It might be included in ADP deaminase which was found in actomyosin by WEBSTER (6) and by DEUTSCH and NILSON (3), but there is some doubt on this point and it was described as ADP-deaminating enzyme throughout this paper.

The properties of ATP and adenosine deaminases, and ADP-deaminating enzyme obtained from *Aspergillus* species are compared in Table 9. ADP-deaminating enzyme from *Aspergillus* species, different from the enzyme observed in actomyosin, should be called non-specific acid ADP deaminase because of its broad substrate specificity and acid optimum pH.

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