ENZYMATIC CONVERSION OF INDOLE ACETALDEHYDE AND NAPHTHALENE ACETALDEHYDE TO AUXINS

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(WITH TWO FIGURES)

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Introduction

A neutral substance, convertible to an acid auxin, is present in various plant extracts (5, 9) and chemical preparations (9). As indicated by a number of biological tests, the neutral substance is in all likelihood 3-indole acetaldehyde and will for convenience be designated by this name in the present paper.

In a previous paper (11) it was shown that 3-indole acetaldehyde is rapidly converted to indoleacetic acid in excised Avena coleoptiles and in fresh, but not in boiled, coleoptile juice. It was concluded that the conversion is caused by an enzyme system present in the coleoptiles. The indole acetaldehyde used in those experiments was prepared from tryptophan and isatin using a method described previously (9, p. 85).

GORDON and NIEVA (5, 6), using indole acetaldehyde extracted from pineapple leaves and purified via the bisulphite addition-product, demonstrated the presence of an enzyme system, capable of converting indole acetaldehyde to indoleacetic acid, in breis and protein preparations obtained from pineapple leaf bases. WILDMAN et al. (17) failed to obtain any conversion of indole acetaldehyde to indoleacetic acid by enzyme preparations from spinach leaves, although such preparations produced indoleacetic acid readily from tryptophan. As already pointed out by GORDON and NIEVA (6), however, the synthetic preparation of indole acetaldehyde used by WILDMAN et al. (17) probably contained very little, if any, of the desired aldehyde.

Since indole acetaldehyde seems to be the immediate precursor of indoleacetic acid in the biosynthesis of this auxin, a method for the determination of indole acetaldehyde in plant extracts would be highly desirable. This aldehyde, however, has not yet been prepared in the chemically pure state; so we are unable to construct a standard activity curve, relating biological effect, such as curvature in the Avena test, to actual concentration of indole acetaldehyde. Amounts of indole acetaldehyde have been expressed in terms of amounts of indoleacetic acid obtained after treatment of the preparation or extract with soil (5, 6, 9, 10, 15). Owing to losses occurring during the treatment this procedure is unsatisfactory. Since indole acetaldehyde does produce curvatures in the Avena test these curvatures can be compared with curvatures produced by pure indoleacetic acid. As an arbitrary, biological unit of indole acetaldehyde was proposed the \( \gamma \)-equiva-
lent” (11), defined as the amount of aldehyde which has the same effect in
the Avena test as one γ of indoleacetic acid when tested at such a dilution
that the resulting curvatures are ≤15° (or with water-cultured test plants
≤5°).

In the previous study of enzymatic conversion (11), it was found that
treatment of one γ-“equivalent” of indole acetaldehyde with coleoptile juice
gave rise to the formation of approximately 5 γ of indoleacetic acid. (Ind-
oleacetic acid is not inactivated by coleoptile juice.) This means that one
γ-“equivalent” of the aldehyde weighs at least about 5 γ, but since it is
unknown what losses of aldehyde may have occurred the 5 γ is a minimum
value. The main purpose of the present study was to estimate the absolute
weight of one γ-“equivalent” of indole acetaldehyde through a determina-
tion of the amount of acid growth substance which can be recovered from
a known amount of aldehyde after treatment with coleoptile juice. Because
pure indole acetaldehyde is still unavailable, crystalline naphthalene acet-
aldehyde was used as a model substance. Naphthalene acetaldehyde has
been shown previously to be active in the Avena test (10), the pea test (14,
p. 298), and a root-inhibition test (1). Ashby (1), working in this labora-
tory, showed that juice expressed from roots of Artemisia absinthium con-
tained an enzyme system capable of converting naphthalene acetaldehyde
to naphthaleneacetic acid.

Material and methods

Preparations of tryptophol and 1-naphthalene acetaldehyde were ob-
tained through the courtesy of Dr. K. A. Jensen, Department of Chemistry,
University of Copenhagen. The crystalline sample of naphthalene acet-
aldehyde had been prepared according to method no. 3 of Jensen and Christensen (7, p. 704; cf. also 8). Since only milligram-amounts of the
aldehyde were available, biological tests were used for its determination.
A few milligrams of the aldehyde were dissolved in peroxide-free ether and
the solution shaken out with a sodium bicarbonate solution in order to re-
move possible traces of acid substances. After suitable dilution various
amounts of the aldehyde were transferred to agar squares (weighing 100 mg.
each) by Boysen Jensen’s ether-dropping method (2, 3) and the agar tested
on double-decapitated, soil-grown Avena plants. The activity curve for
1-naphthalene acetaldehyde shown in figure 1 is based on the mean results
of 50 such tests. A similar curve for 1-naphthaleneacetic acid, based on
32 tests, is shown in the same figure. The curves show that the acid is
about 16 times as active as the aldehyde in the Avena test. The Avena
curvatures given by the various fractions obtained in the conversion experi-
ments reported below were converted to absolute units (γ) of growth sub-
stance by means of these standard curves.

Aqueous solutions of naphthalene acetaldehyde needed for the conversion
experiments were obtained by evaporating the ether and extracting the resi-
due with two 5-ml. portions of a freshly prepared 0.01 M KH₂PO₄ solution.

Coleoptile juice was prepared from etiolated Avena seedlings cultivated
as ordinary test plants but one day older. The apical part of the coleoptile, 25 mm. long, was cut off and the leaf pulled out. In general, 65 such coleoptiles, weighing on an average 1.2 gm. (fresh weight), were used. They were crushed in a mortar, and 1.2 ml. of a 0.01 M \( \text{KH}_2\text{PO}_4 \) solution were added. The resulting brei was filtered through a coarse Pyrex fritted glass filter. The amount of filtrate (in general 1.2 ml.) was measured and twice its volume of the above phosphate buffer was added. The diluted filtrate thus contains roughly 15% coleoptile juice.

In the conversion experiments 1-ml. portions of the diluted coleoptile juice were mixed with 1 ml. of the buffer solution in which naphthalene acetaldehyde had been dissolved. The mixtures (pH = 5.8) were incubated in open test tubes at 22° C in the dark. Control experiments were made with aldehyde mixed with buffer solution instead of coleoptile juice. After various periods of time the mixtures were partitioned between ether and water as follows. The reaction mixture was diluted with 3 ml. of water. One half ml. of a saturated (0.95 M) solution of sodium bicarbonate was added. The alkaline solution (pH = 9.4) was shaken with three successive 9-ml. portions of peroxide-free ether. The ether, containing the unconverted aldehyde, was made up to 25 ml. The alkaline, aqueous phase was acidified (to pH = 2.2) with 0.6 ml. 1 N HCl and again shaken with three successive 9-ml. portions of ether which was then made up to 25 ml., constituting the acid fraction. (In control experiments with pure naphthaleneacetic acid 95% was recovered by shaking at a pH-value of 2.2 and 91% at a pH-value of 1.2.) In general three or four aliquots from each ether fraction were tested in the Avena test on different days at concentrations yielding curvatures on the ascending part of the standard curves (fig. 1).

Results

The main results are given in table I which shows that naphthalene acetaldehyde disappears very rapidly when diluted coleoptile juice is added. Simultaneously, a considerable amount of acid growth substance, undoubtedly naphthaleneacetic acid, is formed. If the number of moles of acid formed is divided by the number of moles of aldehyde which have disappeared the figures listed in the last column of table I are obtained. The mean of these figures is 0.48 which means that one mole of acid is formed per two moles of aldehyde which disappear.

A number of control experiments were also made. The auxin content of the coleoptile juice was determined. No neutral growth substance was found; but the juice contained an acid auxin which, when calculated as indoleacetic acid, was present in the amount of 0.011 \( \gamma \) per ml. of undiluted juice, corresponding to \( 1.7 \times 10^{-4} \gamma \) per 25-mm. coleoptile. This figure agrees with values obtained by Thimann (13) and Wildman and Bonner (16). The natural auxin present in 1 ml. of sixfold diluted juice will simulate the effect of 0.017 \( \gamma \) or 0.090 moles \( \times 10^{-8} \) of naphthaleneacetic acid. This amount is negligible as compared with the quantities of growth substance added.

The stability of naphthaleneacetic acid in diluted coleoptile juice was
Fig. 1. Relationship between concentration and activity in the Avena test of naphthalene acetaldehyde (above) and naphthaleneacetic acid (below). Ordinate: degrees curvature. Abscissa: concentration of growth substance in the agar blocks.

tested. Samples of 2.31 moles $\times 10^{-9}$ of the acid were mixed with diluted coleoptile juice and treated as in the conversion experiments with aldehyde. No neutral growth substance was formed from the acid. The amounts of acid recovered after 60 and 285 minutes were 2.31 and $2.15 \times 10^{-9}$ moles, respectively. It may thus be concluded that only negligible amounts of the

<table>
<thead>
<tr>
<th>Initial amount of aldehyde, *\text{M} \times 10^{-9}</th>
<th>Duration of incubation min.</th>
<th>Aldehyde disappeared, \text{M} \times 10^{-9}</th>
<th>Acid formed, \text{M} \times 10^{-9}</th>
<th>Ratio \text{M. acid formed}</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.8</td>
<td>255</td>
<td>9.1</td>
<td>5.2</td>
<td>0.57</td>
</tr>
<tr>
<td>14.6</td>
<td>15</td>
<td>13.4</td>
<td>5.1</td>
<td>0.38</td>
</tr>
<tr>
<td>14.6</td>
<td>60</td>
<td>12.9</td>
<td>5.7</td>
<td>0.44</td>
</tr>
<tr>
<td>15.2</td>
<td>15</td>
<td>12.9</td>
<td>5.2</td>
<td>0.40</td>
</tr>
<tr>
<td>15.2</td>
<td>60</td>
<td>14.0</td>
<td>6.6</td>
<td>0.47</td>
</tr>
<tr>
<td>25.8</td>
<td>120</td>
<td>20.9</td>
<td>9.5</td>
<td>0.45</td>
</tr>
<tr>
<td>25.8</td>
<td>180</td>
<td>22.7</td>
<td>10.5</td>
<td>0.46</td>
</tr>
<tr>
<td>73.5</td>
<td>60</td>
<td>41.7</td>
<td>23.1</td>
<td>0.55</td>
</tr>
<tr>
<td>103</td>
<td>120</td>
<td>96.2</td>
<td>52.3</td>
<td>0.54</td>
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<tr>
<td>103</td>
<td>255</td>
<td>96.4</td>
<td>49.1</td>
<td>0.51</td>
</tr>
<tr>
<td>139</td>
<td>60</td>
<td>65.4</td>
<td>33.5</td>
<td>0.51</td>
</tr>
<tr>
<td>139</td>
<td>120</td>
<td>107</td>
<td>56.6</td>
<td>0.53</td>
</tr>
</tbody>
</table>

| Mean                                           |                             |                                               |                                               | 0.48                        |

*One mole $\times 10^{-9} = 0.17 \gamma$. 
TABLE II
STABILITY OF NAPHTHALENE ACETALDEHYDE IN BUFFER SOLUTION IN ABSENCE OF COLEOPTILE JUICE

<table>
<thead>
<tr>
<th>Amounts of aldehyde and acid recovered, M x 10⁻⁹</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 min.</td>
</tr>
<tr>
<td>Aldehyde</td>
</tr>
<tr>
<td>---------</td>
</tr>
<tr>
<td>10.2</td>
</tr>
<tr>
<td>10.4</td>
</tr>
<tr>
<td>27.3</td>
</tr>
</tbody>
</table>

acid, if any, are destroyed by the juice within the duration of the experiments. Since indoleacetic acid has been shown to be stable in coleoptile juice (11) it is not surprising that naphthaleneacetic acid is also stable. The stability of naphthalene acetaldehyde in buffer solution in the absence of coleoptile juice was tested using the same methods as in the conversion experiments. The results (table II) show that the aldehyde is stable for at least 4 hours in the buffer solution.

If the conversion of naphthalene acetaldehyde to acid is enzymatic, no conversion should take place in boiled coleoptile juice. Table III shows the results of experiments with diluted coleoptile juice which had been boiled for 20 minutes. Practically no acid was formed; but it was impossible to recover all of the added aldehyde when present at low concentrations. At the highest concentration of aldehyde tested no loss occurred.

If a mixture of aldehyde solution and fresh coleoptile juice is shaken out with ether immediately after mixing, it might be possible to recover all of the aldehyde, unconverted. Attempts to recover the added aldehyde at zero time, however, yielded results (table III) very similar to those obtained with boiled coleoptile juice. As expected, practically no acid was found at zero time; but it was impossible to obtain a 100% recovery of the aldehyde at low concentrations. The probable causes of the loss will be discussed later. There is no loss of acid.

TABLE III
THE INFLUENCE OF BOILED AND FRESH COLEOPTILE JUICE ON THE RECOVERY OF NAPHTHALENE ACETALDEHYDE

<table>
<thead>
<tr>
<th>Initial amount of aldehyde, M x 10⁻⁹</th>
<th>Boiled coleoptile juice</th>
<th>Fresh coleoptile juice</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Duration of incubation, min.</td>
<td>M x 10⁻⁹</td>
</tr>
<tr>
<td></td>
<td>Aldehyde disappeared</td>
<td>Acid formed</td>
</tr>
<tr>
<td>10.8</td>
<td>155</td>
<td>5.6</td>
</tr>
<tr>
<td>15.2</td>
<td>107</td>
<td>6.8</td>
</tr>
<tr>
<td>25.8</td>
<td>120</td>
<td>3.8</td>
</tr>
<tr>
<td>139</td>
<td>60</td>
<td>(-1.8)</td>
</tr>
</tbody>
</table>
The ratio of one mole of acid formed per two moles of aldehyde suggests that the conversion process may be a dismutation in which equivalent amounts of alcohol and acid are formed. The possible interference with the Avena test of the alcohol thus formed was studied with indole-ethyl alcohol (tryptophol) because naphthalene-ethyl alcohol was not available. Tryptophol, which has been shown previously to have a very slight activity in the Avena test (10) and the pea test (14), was required at a concentration of 200,000 γ/l. to give a curvature of 5° in the Avena test. Hence, the activity of tryptophol is only 0.005% of the activity of indoleacetic acid, or 0.05% that of indole acetaldehyde. The maximum curvature which tryptophol can produce is 8.5°, and 450,000 γ/l. are required to give this angle. Since the activities of naphthalene compounds in the Avena test have always been found to be lower than those of the corresponding indole compounds, there is good reason to believe that naphthalene-ethyl alcohol, if active at all, will show a still lower activity than tryptophol in the Avena test. The growth-promoting activity of the quantities of alcohol possibly formed in the conversion experiments, therefore, is negligible as compared with the amounts of acid and aldehyde involved. Since the neutral and acid growth substances were separated before bio-assay, any alcohol present would interfere only with the determination of the aldehyde, not the acid. The possibility that the alcohol formed might have an inhibitory effect in the Avena test was tested with mixtures of tryptophol and indole acetaldehyde. The concentration of the latter was determined by bio-assay, using the factor of 9 (see later) for a conversion of γ“equivalents” to actual γ. It was found that the admixture of 9100 or 91000 γ/l. of tryptophol to 140 γ/l. of indole acetaldehyde did not change the curvature of 12° given by 140 γ/l. of indole acetaldehyde alone. The experiments with tryptophol give no indication that naphthalene-ethyl alcohol, if formed in the conversion experiments, would interfere with the determination of naphthalene acetaldehyde.

Discussion and conclusions

Upon addition of diluted coleoptile juice to a solution of naphthalene acetaldehyde the aldehyde starts to disappear. Within a few minutes, the formation of an acid growth substance, undoubtedly naphthaleneacetic acid, can be demonstrated. The formation of the acid is evidently an enzymatic process since no acid is formed when boiled juice is added to the aldehyde solution.

The amount of aldehyde initially present per test tube in the conversion experiments was determined by bio-assay of a sample of the aldehyde solution to which no coleoptile juice had been added. The amount of aldehyde which had disappeared was computed as the amount initially present minus the amount recovered. The data presented in table I show that at any moment, after 15 minutes have elapsed, there is present in the solution an amount of naphthaleneacetic acid which is very close to one half of the amount of aldehyde that has disappeared. The question now is whether all
of the aldehyde which has disappeared was actually functioning as a substrate for the conversion enzyme. In attempts to recover the aldehyde immediately after addition of fresh coleoptile juice, it was found that part of the aldehyde had disappeared (either instantaneously or during the first shaking with ether, which lasts four minutes) without giving rise to the formation of acid growth substance. The aldehyde showed a similar behavior during a prolonged treatment with boiled coleoptile juice. Various explanations for the loss of recoverable aldehyde may be offered. The loss may in both cases be the result of an adsorption of aldehyde to protein in the juice or of a specific reaction between aldehyde and protein or other constituents of the juice leading to fixation of aldehyde. A highly probable explanation in the case of fresh coleoptile juice is that the aldehyde combines with the enzyme faster than the acid is released and that it is impossible to remove the aldehyde from the enzyme-substrate complex with ether.

It was shown by Stern (12) that catalase and monoethyl hydrogen peroxide form an enzyme-substrate complex within a few seconds after mixing, while the enzymatic breakdown of this complex requires minutes. Chance (4) studied the kinetics of the formation and enzymatic breakdown of the peroxidase-hydrogen-peroxide complex and found (4, fig. 6) that the formation of the enzyme-substrate complex took place in a fraction of a second, whereas the breakdown required several seconds, the actual time depending on the concentration of the oxygen acceptor (ascorbic acid). When the concentration of ascorbic acid was 2.9 M x 10^{-4}, slightly lower than that of the substrate, 50% of the enzyme-substrate complex was still present after ten seconds. If the enzymatic formation of naphthaleneacetic acid from the aldehyde is a dismutation, the aldehyde itself functioning as an acceptor (here hydrogen acceptor), one would actually expect a relatively long life of the (hypothetical) enzyme-substrate complex in the experiments reported here, because the concentration of acceptor was low.

The loss of aldehyde in the experiments with boiled coleoptile juice is perhaps not comparable with that occurring when fresh juice was used, because the aldehyde was incubated with the boiled juice for a prolonged period of time. The possibility exists, however, that the denatured enzyme is capable of forming a complex with the aldehyde, but not to convert it into alcohol and acid.

Figure 2 shows the effect of computing the amount of aldehyde disappearing on the basis of the amount recoverable at zero time. On this basis the molar yield would be decreasing with increasing amounts of aldehyde converted. Such a decrease seems rather unlikely and, together with the above considerations, makes the assumption that all of the added aldehyde was available to the conversion enzyme appear the more probable one.

For further studies of the mechanism of the conversion, the use of partially purified enzyme preparations will probably be advantageous. Such preparations might also be used for routine conversion of indole acetaldehyde to indoleacetic acid before bio-assay of impure plant extracts, a pro-
procedure suggested by Dr. S. A. Gordon, who found that lyophilized coleoptile juice and fractions precipitated by alcohol, acetone or ammonium sulphate contained the active enzyme system (unpublished results).

Even though the results still leave some doubt in regard to the mechanism of the enzymatic conversion they are adequate for the principal purpose of the present study, viz., to determine the weight of one γ-"equivalent" of indole acetaldehyde. The calculation of this value requires only determinations of the actual yields of acid per unit of aldehyde disappearing during the experiment, and these yields are quite constant for a given aldehyde (table I and fig. 2). Except for the use of a more dilute coleoptile juice, the

![Figure 2](http://www.plantphysiol.org)  
**Fig. 2.** Circles and crosses (left-hand ordinate, upper abscissa): yield of naphthaleneacetic acid plotted against amount of naphthalene acetaldehyde disappeared. Aldehyde values based either on amount actually added (circles) or on amounts recovered at zero time (crosses). The line represents the theoretical yield of 1 mole of acid per 2 moles of aldehyde.

Squares (right-hand ordinate, lower abscissa): yield of indoleacetic acid plotted against γ-"equivalents" of indole acetaldehyde disappeared [data from (11)]. The line represents a yield of 5 γ of acid per γ-"equivalent" of aldehyde.

experiments with naphthalene acetaldehyde were carried out in the same manner as the experiments with indole acetaldehyde previously reported (11), which showed that one γ-"equivalent" of indole acetaldehyde yielded on an average 4.9 γ of indoleacetic acid by identical treatment (compare fig. 2). Again the yield is based upon bio-assay of the amount of aldehyde added, not on the amount recoverable at the so-called zero time. The amount of 4.9 γ is equivalent to 28 moles \( \times 10^{-9} \) of indoleacetic acid. Making the reasonable assumption that 2 moles of either of the two aldehydes yield one mole of acid under the influence of the enzyme system in coleoptile juice, it may be concluded that the 28 moles \( \times 10^{-9} \) of indoleacetic acid origi-
nated from $56 \times 10^{-9}$ moles or $8.9 \gamma$ of indole acetaldehyde. One $\gamma$-“equivalent” of indole acetaldehyde, therefore, has a weight of approximately $9 \gamma$; or in other words, on the above assumption approximately $9 \gamma$ of indole acetaldehyde are required to give the same effect in the Avena test as $1 \gamma$ of indoleacetic acid.

Indole acetaldehyde thus has an activity in the Avena test of 11% of that of indoleacetic acid. A comparison of the relative activities of two other acid growth substances and their corresponding aldehydes is made in table IV. A similar comparison, made previously (10), was based on a somewhat less sensitive modification of the Avena test. The concentrations required for a $5^\circ$ curvature, as listed in table IV, therefore, are somewhat lower than the ones previously reported. In the case of naphthalene acet-

**TABLE IV**

**ACTIVITIES OF THREE ACID GROWTH SUBSTANCES AND THEIR CORRESPONDING ALDEHYDES**

<table>
<thead>
<tr>
<th></th>
<th>Avena test</th>
<th></th>
<th>Artemisia root test (1)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Concentration required for 5° curvature, $\gamma$/L.</td>
<td>Relative activity (acid = 100)</td>
<td>Concentration required for 50% inhibition, $\gamma$/L.</td>
</tr>
<tr>
<td>3-Indoleacetic acid</td>
<td>10.5</td>
<td>100</td>
<td>35.5</td>
</tr>
<tr>
<td>3-Indole acetaldehyde</td>
<td>95*</td>
<td>11.0†</td>
<td>114</td>
</tr>
<tr>
<td>1-Naphthaleneacetic acid</td>
<td>80</td>
<td>100</td>
<td>20.0</td>
</tr>
<tr>
<td>1-Naphthalene acetaldehyde</td>
<td>1250</td>
<td>6.4</td>
<td>2240</td>
</tr>
<tr>
<td>Phenylacetic acid</td>
<td>$1.9 \times 10^4$</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Phenyl acetaldehyde</td>
<td>$26 \times 10^4$</td>
<td>7.3</td>
<td></td>
</tr>
</tbody>
</table>

*3-Indole-ethyl alcohol: 200,000.
†3-Indole-ethyl alcohol: 0.005.

aldehyde, however, the main reason for the low activity reported in the previous study was the presence of impurities in the preparation.

If the activity of each of the acids is set at 100, the activities of indole-, naphthalene-, and phenyl-acetaldehyde are 11, 6, and 7, respectively. Although not identical, these three figures are of the same order of magnitude. The activities of indoleacetic and naphthaleneacetic acids and their corresponding aldehydes in inhibiting the elongation of Artemisia roots were determined by Ashby (1). His results, computed on the same basis as the results obtained in the Avena test, are given in table IV for comparison. In the Artemisia test the relative activities, measured after 24 hours, proved to be of the same order of magnitude as in the Avena test. When measured after four hours, on the other hand, the relative activities of the two aldehydes are quite different. Veldstra and Booij (14) found naphthalene
acetaldehyde to be nearly as active as naphthaleneacetic acid in the pea test.

In view of the 50% yield of acid in the conversion experiments, the question arises as to why the concentration of aldehyde in the agar blocks has to be 9 to 16 times as high as that of the acids in order to produce the same curvature in the Avena test. It must be assumed that the rate of conversion of the aldehydes increases with their concentration. Part of the answer to the above question, therefore, is probably that only at concentrations several times those required for the acids will the rate of conversion become sufficient to build up the necessary amount of the active acid. In addition, differences in transportability of aldehyde and acid may play an important role.

Summary

1. Curves showing the relationship between concentration and activity in the Avena test of 1-naphthalene acetaldehyde and 1-naphthaleneacetic acid were constructed.

2. An enzyme system present in fresh coleoptile juice is capable of converting naphthalene acetaldehyde to naphthaleneacetic acid yielding 1 mole of acid per 2 moles of aldehyde.

3. Using the same methods as in the present study it was shown previously (11) that the arbitrary unit of one \( \gamma \)"equivalent" of indole acetaldehyde yielded \( 28 \times 10^{-9} \) moles (= 4.9 \( \gamma \)) of indoleacetic acid when treated with coleoptile juice. On the basis of the molar yield obtained in the present study of the naphthalene analogue it was concluded that the \( 28 \times 10^{-9} \) moles of acid originated from \( 56 \times 10^{-9} \) moles of indole acetaldehyde. One \( \gamma \)"equivalent" of indole acetaldehyde, therefore, would be equal to \( 56 \times 10^{-9} \) moles or approximately 9 \( \gamma \).

4. A comparison of the activities of indole-, naphthalene-, and phenylacetic acids and their corresponding aldehydes is made. The aldehydes show an activity in the Avena test which is 6 to 11% of that of the acids.

The present work was supported in part by a grant from the Dr. Wallace C. and Clara A. Abbott Memorial Fund of the University of Chicago.

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LITERATURE CITED


LARSEN: CONVERSION OF ACETALDEHYDE TO AUXINS


ERRATA

Volume 26:

Page 521, line 3, liberation of organic phosphate should read liberation of inorganic phosphate.

Page 598, line 29, component may be expressed should read component (solvent or constituent solute) may be expressed.

Page 598, line 30, molal free energy difference per liter of component flux should read molal free energy difference divided by the partial molal volume (at its reference state) of the constituent component subject to flux consideration.

Page 599, lines 23 and 24, $V_2$ in liters should read $V_2$ in liters per mole.

Page 599, lines 27 and 28, $V_2$ is the partial molal volume of the constituent solute in solution, in liters should read $V_2^*$ is the partial molal volume of the constituent solute in solution, in liters per mole.

Pages 599 to 608, factor $v$ should read $V^*$.

Page 600, line 9, delete of solute flux.

Page 603, line 16, equation (27) should read $\text{REE} = \frac{m}{L_t^*} \times \frac{m}{L_t^*} \times \frac{I}{I} \times \frac{l}{m} = \frac{mL^*}{V^*} \times \frac{l}{l}$.

Page 603, line 18, The ratio $V/m$ should read The factor $\Delta \times \bar{V}^* / m$.

Page 603, line 19, delete of solute flux.

Page 603, line 20, RNI is in grams should read RNI is in grams per square centimeter per second.

Pages 655 to 672, factor $V$ should read $V^*$.

Page 657, line 45, delete In other words, flux intensities are not forces per unit area, but rather are forces concerned with the ordered movement of a unit volume of a constituent component of solution through a unit of distance.

Pages 699, 701, 703, 705, and 707, title, Acetaldehyde should read Aldehydes.

Page 787, line 37, in the 5/P and 2/P groups should read in the 5P and 2P groups.

Volume 27:

Page 104, lines 38 and 42, and Page 105, lines 3 and 4, Method 1 should read Method a and Method 2 should read Method b to correspond with designations in figure 3.

Page 109, line 12, affect should read effect.

Page 140, paragraph 2, line 5, non-reducing sugars in non-treated lots should read non-reducing sugars as was in non-treated lots.

Page 463, line 23, $K$, the constant, should read $K$, the constants.

Page 463, line 25, $V^*$ should read $V^*$. 

Page 466, legend for figure 5, interference of Na and Rb uptake should read interference of Na with Rb uptake.

Page 469, Table I, Figure 5 should read Figure 3.

Page 469, Table I, Figure 6 (left) should read Figure 4 (left).

Page 469, Table I, Figure 11 should read Figure 8.

Page 470, line 10, which the un-competitively affected should read which are un-competitively affected.

Page 471, Table II, Figure 6 (right) should read Figure 4 (right).

Page 471, Table II, Figure 7 should read Figure 5.

Page 530, line 5, although specifically should read although not specifically.

Page 530, line 15, adenosine triphosphate should read adenosinephosphatase.