MULTI-ELEMENTAL MODELS FOR ESTIMATING THE ACUTE RADIOSensitivity OF COCKROACHES AND BLOOD FEEDING INSECTS

R. Levy², H. I. Cromroy, and J. A. Cornell³

Department of Entomology and Nematology
University of Florida, Gainesville, Florida 32611 and
Department of Statistics
University of Florida, Gainesville, Florida 32611

ABSTRACT

Multiple regression models were formulated for 6 species of cockroaches representing the order Orthoptera and 4 species of adult and immature blood-feeding insects representing the orders Anoplura, Diptera, and Hemiptera. Results from multiple regression analyses indicated that the total body concentration of 2 major elements (i.e. K and Na for cockroaches and Mg and Na for blood feeding insects) could effectively be used to estimate or predict the acute (LD₅₀/²⁴ hr) radiosensitivity of insects on a species level.

Data have been presented by Levy et al. (1973) indicating the importance of total body concentrations of several major and trace elements in predicting or estimating the acute radiation mortality (LD₅₀/²⁴ hr exposure) of insects on a species level. Simple regression analyses of these data indicated that statistically significant estimates of species-specific LD₅₀/²⁴ hr exposures could be made when insects were subdivided into groups based on their laboratory diets. The following groups with their associated elemental bioindicator were used: cockroaches, K; blood feeders, Mg; stored product beetles, Cu or Cu/Fe ratio.

Major and trace elements do not always act alone in performing their biological functions (Christian and Feldman 1970, Comar and Bronner 1962, Schütte 1964). There is sometimes an interelemental dependence, and the effects of 1 element may be dependent on the presence and concentrations of another. The simultaneous actions of the alkali metals Na and K, as well as other metals such as the alkaline earths (i.e. Mg), have been shown to be responsible for maintaining a proper balance in cellular metabolism. A physiological relationship has been shown between Mg and Na and K and Na for insects (Chapman 1969).

The current study explores the feasibility of utilizing the importance and interelemental dependence of Na(Na⁺) with other biologically active cations i.e. Mg(Mg²⁺) and K(K⁺), in the physiology of insects to improve the acute (LD₅₀/²⁴ hr) radiation exposure predictions for the cockroach and blood feeders models (Levy et al. 1973). Hence, multiple regression models would be tested using total body concentrations of K and Na for cockroaches and Mg and Na for blood feeders. This multi-elemental approach is hoped to further reduce the variations encountered between the observed and predicted radiation exposures for related species of insects having similar diets.

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²Department of Entomology and Nematology, University of Florida, Gainesville, Florida 32611.
³Department of Statistics, University of Florida, Gainesville, Florida 32611.
METHODS AND MATERIALS

Parts per million Na, K, and Mg for each insect in the cockroach and blood feeder groups (Levy et al. 1973) were determined by atomic absorption spectroscopy (Levy and Cromroy 1973). Acute (LD_{50/24 hr}) exposure data for each species in a model was obtained from previous research by Levy, et al. (in press). Repeated sampling of adult insects from several laboratory colonies indicated that the experimentally observed LD_{50/24 hr} exposures were usually within a 20% error range, probably due to variations in sex and age within an irradiated sample.

Statistical analyses consisted of fitting multiple regression models using the method of least squares (Draper and Smith 1966). Multiple regression analyses of the data were based on the straight line equation, \( y = b_0 + b_1(X_1) + b_2(X_2) \), where \( y \) = the estimated or predicted LD_{50/24 hr} exposure in Roentgens(R), \( b_0 \) = constant, \( b_1, \ldots, b_2 \) = the estimate or measure of the strength of the effect of \( X_1, \ldots, X_2 \) on the response \( y \), where \( X_1, \ldots, X_2 \) = the total body concentration of a specific major element in parts per million (ppm).

To test the strength of a predictor equation, the coefficient of multiple determination (R^2) and F-statistic (F) were calculated for each model. F-test significance at the 0.05 level was indicated for each model. The standard error (SE) for each predicted or estimated LD_{50/24 hr} exposure was also determined. Predicted LD_{50/24 hr} exposures and their respective standard errors were rounded off to the nearest whole number.

RESULTS AND DISCUSSION

Multiple regression analyses of 6 species of adult cockroaches representing the order Orthoptera and 4 species of adult and immature insects representing the orders Anoplura, Diptera, and Hemiptera indicated that there was an excellent correlation between 2 major elements (i.e. K and Na for cockroaches and Mg and Na for blood feeders) and the acute (LD_{50/24 hr}) radiation exposure for insects on a species level (Tables 1, 2).

The biological relationship between Na and K and Na and Mg in the metabolism of insects has been discussed by Chapman (1969). In addition, Levy et al. (in press) have shown the importance and feasibility of utilizing the known relationship between the trace elements Cu and Fe in the form of a Cu/Fe ratio in formulating predictor equations for stored product beetles. Simple regression analyses indicated that this combination of elements (i.e. Cu/Fe) would significantly improve the LD_{50/24 hr} exposure predictions in the stored product beetle model over a model based entirely on copper (Levy, et al. in press).

The R^2 values and F-statistics for the cockroach and blood feeder models (Tables 1 and 2) indicated that the addition of the major element Na significantly decreased the variation encountered between the observed and predicted LD_{50/24 hr} exposures on a species level, and therefore improved the prediction capability of each model over its corresponding simple regression predictor model (i.e. \( y = 18.5882 + 0.0056(K) \), R^2 = 0.8797 for cockroaches and \( y = 172.2073 - 0.0147(Mg) \), R^2 = 0.8798 for blood feeders) (Levy et al. in press). This could indicate the biological importance and interaction of Na(Na^+) in the mechanism(s) involving the acute radiosensitivity of insects (Levy et al. 1973).
TABLE 1. The Use of Potassium and Sodium as Bioindicators of Acute Radiation Sensitivity of Adult Cockroaches.\textsuperscript{*} Predictor equation\textsuperscript{**}: $y = 18.0819 + 0.0046(K) + 0.0047(Na)$

<table>
<thead>
<tr>
<th>Species</th>
<th>Total body K (ppm)</th>
<th>Total body Na (ppm)</th>
<th>Observed LD\textsubscript{50/24 hr} (kR)</th>
<th>Predicted LD\textsubscript{50/24 hr} ± SE</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Periplaneta brunnea</em> Burmeister</td>
<td>16263</td>
<td>4653</td>
<td>97</td>
<td>109 ± 7</td>
</tr>
<tr>
<td><em>Periplaneta americana</em> (L.)</td>
<td>6194</td>
<td>1569</td>
<td>52</td>
<td>54 ± 9</td>
</tr>
<tr>
<td><em>Blatella germanica</em> (L.)</td>
<td>10956</td>
<td>2438</td>
<td>91</td>
<td>79 ± 6</td>
</tr>
<tr>
<td><em>Leucophaea maderae</em> (F.)</td>
<td>18904</td>
<td>2473</td>
<td>118</td>
<td>116 ± 9</td>
</tr>
<tr>
<td><em>Nauphoeta cinerea</em> (Olivier)</td>
<td>20293</td>
<td>6174</td>
<td>146</td>
<td>139 ± 10</td>
</tr>
<tr>
<td><em>Periplaneta fuliginosa</em> (Serville)</td>
<td>16225</td>
<td>2309</td>
<td>96</td>
<td>103 ± 7</td>
</tr>
</tbody>
</table>

\textsuperscript{*}Diet consisted mainly of Purina\textsuperscript{®} dog chow.
\textsuperscript{**}R$^2 = 0.9266$; F-test value ($F = 17.3986$) highly significant at the 0.05 level.

TABLE 2. The Use of Magnesium and Sodium as Bioindicators of Acute Radiosensitivity for Blood Feeding Insects.\textsuperscript{*} Predictor equation\textsuperscript{**}: $y = 134.6404 - 0.0117(Mg) + 0.0131(Na)$

<table>
<thead>
<tr>
<th>Species</th>
<th>Total body Mg (ppm)</th>
<th>Total body Na (ppm)</th>
<th>Observed LD\textsubscript{50/24 hr} (kR)</th>
<th>Predicted LD\textsubscript{50/24 hr} ± SE</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Cimex lectularius</em> L.</td>
<td>368</td>
<td>2108</td>
<td>155</td>
<td>158 ± 3</td>
</tr>
<tr>
<td><em>Pediculus humanus humanus</em> L.</td>
<td>487</td>
<td>3280</td>
<td>175</td>
<td>172 ± 3</td>
</tr>
<tr>
<td><em>Culex pipiens quinquefasciatus</em> Say</td>
<td>1885</td>
<td>1810</td>
<td>140</td>
<td>136 ± 3</td>
</tr>
<tr>
<td><em>Stomoxys calcitrans</em> L.</td>
<td>3987</td>
<td>2160</td>
<td>115</td>
<td>117 ± 4</td>
</tr>
<tr>
<td><em>Pediculus humanus</em> ††</td>
<td>487 ‡</td>
<td>3280</td>
<td>170</td>
<td>172 ± 3</td>
</tr>
</tbody>
</table>

\textsuperscript{*}In most cases diet consisted of human, rabbit, citrated or defibrinated blood.
\textsuperscript{**}R$^2 = 0.9843$; F-test value ($F = 62.7649$) highly significant at the 0.05 level
\textsuperscript{†}Mainly females.
\textsuperscript{‡}Nymphs—all other species analyzed in the adult stage.
\textsuperscript{‡‡}Based on same potassium content as adults due to analysis of the 2 stages in a mixed sample.

**ACKNOWLEDGEMENTS**

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LITERATURE CITED


THE HUMAN USE OF INSECTS: EXAMPLES FROM YUK-PA—(Prepublished abstract) Entomophagy often plays an integral and complementary role in the diet of autochthonous groups in tropical South America where it helps to compensate for the general deficiency of animal proteins and other vital “protective” products. Most studies have regarded insect-eating as an archaic trait which is gradually disappearing owing to the steady encroachment of more modern subsistence systems. Among the Yukpa-Yuko Indians of Venezuela and Colombia, however, insect foods have retained their importance in the less acculturated communities. Cultural ecological research was conducted among this tribe between 1969 and 1971. Specimens for identification were procured in the areas exploited for subsistence purposes by the Irapa, Maraca, and Rionegro subgroups. The collection and use of insects belonging to 22 genera and 7 orders is discussed. (Biotropica, 1973, 5(2):94-101; K. Ruddle, University of California, Los Angeles 90024).