Growth and Dietary Pattern of Rats Fed Self-Selection Diets Following Whole-Body Irradiation

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Animals living in their natural environment instinctively select diets adequate enough to maintain growth and reproduction. The laboratory rat also has demonstrated the ability to select an adequate diet from a variety of nutrients offered in separate containers (Osborne and Mendel, '18; Richter et al., '38).

Cravings for various foods by animals are often attempts to overcome certain nutritional deficiencies or disorders. For example, rats supplied with diets deficient in either thiamine, riboflavin, or pyridoxine will tend to select those diets containing the respective vitamins (Scott and Quint, '46). Increased nutritional demands during pregnancy and lactation also elicit abnormal cravings for calcium and protein (Richter and Barelae, '38).

The present study was designed to investigate further the apparent ability of rats to voluntarily select a diet according to the needs of the body and to detect possible metabolic derangements or deficiencies resulting from exposure to moderate doses of x-irradiation.

EXPERIMENTAL

Male rats of the Sprague-Dawley strain were obtained at weanling age from the Naval Radiological Defense Laboratory's (NRDL) pathogen-free colony and used in this study. Each of the 44 rats was individually housed and fed in large, wire-bottom cages. All animals initially were fed a basal diet composed of the following in per cent: crude casein, 24; corn oil, 10; sucrose, 57; dried brewer's yeast, 4; mineral mix, 4; and cod liver oil, 1. Following a 14-day adjustment period, 28 rats were placed on a self-selection regimen and the remaining 16 rats continued to be fed the basal diet. The rats on the self-selection regimen were offered the above ingredients and distilled water ad libitum in separate containers except the corn oil and cod liver oil which were combined in a 10:1 ratio. The dry ingredients were offered in pint-size, wide-mouth mason jars that were converted to feeding containers. The corn oil-cod liver oil and distilled water were offered in glass vials and bottles, respectively, with glass drinking tubes. The jars and bottles were rotated in the cages every other day in a random, predetermined manner in one-half of the rats supplied with self-selected diets. The rats receiving basal diets also were allowed ad libitum quantities of the basal, premixed diet and distilled water. Daily measurements of food and water intakes and body weights were obtained.

Following a 21-day period on the experimental regimen, all the rats receiving self-selected diets and one-half of the rats maintained with the basal diet were exposed to a single dose of 375-rad x-irradiation1 and three weeks later, to a second 375-rad dose.

The relative proportions of nutrients consumed were converted to calories using the average physiological fuel values of 4, 9, and 4 Cal. per gm of protein, fat and carbohydrate, respectively.

RESULTS

During the pre-irradiation period, two rats obviously were unable to select an adequate diet; and two other rats died quite

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1 The opinions and assertions contained herein are those of the author and are not to be construed as official or reflecting the views of the Navy Department.
2 Salt Mixture, H.M.W., Nutritional Biochemicals Corporation, Cleveland.
3 X-rays, 250 kvp, 15 ma, filters; 0.5 mm Cu + 1 mm Al (HVL, 1.4 mm Cu), target distance, 40 inches; dose rate, 28 rad per minute.
SELFOSELECTIONOD DIETAFTEERADEIATION

TABLE 1

Variability in average daily food intake of an individual rat and in a group of rats on self-selection diets during pre-irradiation period

<table>
<thead>
<tr>
<th>Animals</th>
<th>No. of animals</th>
<th>Casein gm/day</th>
<th>Yeast gm/day</th>
<th>Sucrose gm/day</th>
<th>Fat gm/day</th>
<th>Minerals gm/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual</td>
<td>1</td>
<td>3.0±0.8</td>
<td>1.3±0.9</td>
<td>13.3±1.8</td>
<td>0.1±0.1</td>
<td>0.4±0.4</td>
</tr>
<tr>
<td>Range</td>
<td>(2.0-5.0)</td>
<td>(0-3.0)</td>
<td>(10.0-16.0)</td>
<td>(0-0.4)</td>
<td>(0-1.0)</td>
<td></td>
</tr>
<tr>
<td>Group</td>
<td>18</td>
<td>4.0±2.0</td>
<td>3.6±1.5</td>
<td>6.8±3.0</td>
<td>1.0±1.0</td>
<td>0.2±0.2</td>
</tr>
<tr>
<td>Range</td>
<td>(1.1-7.5)</td>
<td>(1.4-6.5)</td>
<td>(1.4-11.5)</td>
<td>(0.1-3.7)</td>
<td>(0.1-0.7)</td>
<td></td>
</tr>
</tbody>
</table>

1 Including standard deviation.

suddenly of unknown causes and are, therefore, excluded from the results to be presented. The remaining 24 rats on the self-selection regimen were able to select a diet that resulted in growth equal to that of rats fed the basal diet. Rotation of the food and water containers did not influence the selections or growth rates. Statistical analysis of growth rates, total food intake and efficiencies of food utilization prior to the irradiation showed no significant differences between rats fed basal or self-selected diets. In general, the patterns of food intake were quite variable between rats but relatively consistent for any given animal, particularly for the casein and sucrose, as shown in table 1.

Within 4 days after the initial 375-rad x-irradiation, 4 rats had died. Gross findings upon autopsy indicated that two died with urethral proteinaceous plugs and two with internal hemorrhaging. By the 14th day post-irradiation, two additional rats died, presumably from the effects of radiation. All rats that had died was supplied with self-selected diets and 5 of the 6 were, at one time or another, high-fat consumers, selecting as much as 75% of their total calories as fat. The apparent appetite for fat, however, may have reflected a dislike for casein or the other ingredients.

The mean differences in body weight between the two irradiated groups and the nonirradiated control group fed the basal diet are illustrated in figure 1. As shown, rats fed the basal diet lost significantly more body weight after both radiation doses than the rats that selected their own diet. It required 7 days for the rats receiving the self-selection diet and 12 days for those supplied with the premixed diet to re-gain the weight observed at the time of the first radiation. The differences in body weight are not attributable entirely to the variance in weight of water consumed between the two groups since they never approached that of body weight differences (fig. 2). The apparent polydipsia depicted in figure 2, one-day post-irradiation, was due primarily to excessive intakes by one or two rats in each group; otherwise, the intake of water was similar before and after the exposure.

The relatively uniform daily food intakes by the nonirradiated group fed the basal diet permitted daily comparisons of nutrient intake and subsequent patterns of intake between the various groups. The relative proportions of nutrient intake expressed in calories are shown in figures 2 and 3. During the pre-irradiation period, the intakes by rats receiving self-selection diets approximated the levels of intake
of the control group only in total calories and calories from sucrose. The intakes of casein, yeast and water were greater, whereas fat (corn oil-cod liver oil) and minerals were considerably below the levels fed rats supplied with premixed diets. After the first irradiation, selection and intake of casein returned to pre-irradiation levels by the third day (fig. 3) and continued to increase during the post-irradiation period. Following the second x-ray dose, the intake again increased subsequent to the initial drop immediately after the irradiation.

The selections of yeast and corn oil remained essentially unchanged during the post-irradiation period. The selection and intake of sucrose following irradiation decreased, however, and never returned to pre-exposure levels. Similar results were noted after the second exposure.

The mean total caloric intakes of the irradiated rats receiving basal and self-selected diets returned to pre-irradiation levels by the 5th day (fig. 2). The mean caloric intake of the rats fed the self-selection diet immediately after the x-ray was greater than similarly treated rats receiv-

**DISCUSSION**

If an animal can voluntarily select a diet pattern conducive to normal growth
then, conversely, if normal growth occurs, the diet selected must be an adequate one. The majority of the rats in this study exhibited normal growth and thus, apparently were able to select an adequate diet. As expected, some of the rats were unable to make adequate selections due, in part, to the limited number of foods offered and to unpalatability of one or more of the ingredients. Scott (‘46) also noted that many rats failed to select an adequate diet when offered a limited number of purified foods. He also observed wide variations in appetite between rats as in the present study (table 1). This characteristic prevented the calculation of meaningful averages and standard errors of nutrient intake in the present study but allowed the delineation of average intake patterns. This was accomplished by: (a) converting the intakes of each ingredient to calories; (b) depicting the relative proportions of intake for a group as daily differences from a control group; and (c) by including control values obtained prior to the irradiation, thus, allowing intragroup comparisons. Then, if the general trend of a pattern is modified subsequent to a given stress, the resultant change may reflect certain metabolic derangements or imbalances. Such a change was noted with the mineral and casein intakes. The high intake of minerals on the third day after the first irradiation suggested an increased craving probably aggravated by excess electrolyte loss from the body. This is in accordance with the observations of Jackson et al. (‘58), who noted that the excretion of potassium and sodium increased on the third day after irradiation in fasting rats. It is recognized, however, that the apparent craving in the present study may not represent appetite for either sodium or potassium alone, since the mineral mix also contained other salts. It is perhaps significant that the minerals were voluntarily selected even though the salt mixture was composited for inclusion in a mixed diet and not necessarily for isolated consumption.

The slight and gradual but sustained increase in the intake of casein following irradiation may represent greater demands for protein as growth progressed although such an increase was not observed in similar studies by Richter and Barelare (‘39). The relatively early preference for casein in this study was of interest and may be indicative of an early attempt to replenish loss of protein after the irradiation. That losses do occur after irradiation was clearly shown in studies by Gustafson and Koletsky (‘52) with rats exposed to 660 r x-irradiation and was presumed to be due, in part, to tissue destruction and to probable alteration in metabolism. At any rate, the increase in casein intake would be consistent with experimental evidence that high levels of protein facilitate regeneration of damaged tissues, particularly in situations of concurrent calorie deficit (Pollack and Halpern, ‘52).

The early selection of casein also may be related to the variation in body weight between the rats supplied with self-selected and premixed diets. Another factor to be considered is the greater total intake of protein by the rats selecting their own diet. It is not unreasonable to suppose that under conditions of high-protein intake, loss of weight following irradiation may be modified to some extent by virtue of differences in excretion and retention of water. That rats consume greater quantities of water when fed high-protein diets is well known (Maynard and Loosli, ‘56) and also was observed in the present study (fig. 2). Although an increase in water intake is normally associated with a corresponding increase in excretion, this may not occur in the irradiated animal. The subject invites further investigation with particular attention to the evaluation of weight loss and recovery in rats fed high-protein diets and when fasted for various periods after exposure to a moderate dose of x-irradiation.

The results of this study indicate the applicability of allowing rats free-choice selections of their diets to demonstrate possible metabolic derangements or imbalances following irradiation as revealed by their subsequent patterns of nutrient intake. The technique should also be considered in other studies where nutritional disorders are suspected concomitant with disease.
SUMMARY

The apparent ability of rats to voluntarily select a dietary according to the needs of the body was used in this study to detect possible metabolic derangements subsequent to a dose of 375-rad whole-body x-irradiation. The animals were allowed free choice selections of various foodstuffs offered in separate containers and the relative amounts of food intake as well as body weights were measured daily.

The majority of the rats were able to select diets sufficiently adequate to support normal growth. Upon irradiation at the level used, rats fed a basal premixed diet lost significantly more body weight than similarly treated rats selecting their own diet. In the overall pattern, the proportion of casein selected increased progressively, whereas that of sucrose decreased subsequent to the irradiation. The selections of yeast and corn oil remained essentially the same. On the third day only, after irradiation, the intake of minerals increased to over 5 times the pre-irradiation level. The selection and intake of casein returned to pre-irradiation levels by the third day, whereas the total caloric intake of irradiated rats fed basal and self-selected diets returned to normal levels by the 5th day. Possible explanations for the apparent craving for casein and minerals after the level of irradiation used are discussed briefly.

LITERATURE CITED