Change to a Preference for Maltose from Sucrose over Days in Zn-Deficient Rats Selecting from Maltose and Sucrose Diets

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Summary This paper describes a preference for two disaccharides in the diets of Zn-adequate and Zn-deficient rats. Maltose and sucrose were used as a source of carbohydrate in the diet and the selection patterns of rats were analyzed for 28 d by a two-choice selection method. Diets provided as a set of two either Zn-adequate or Zn-deficient diets were changed in position daily. Control Zn-adequate and Zn-deficient rats both exclusively selected the sucrose diet at days 1 and 2, after onset of the feeding experiment, and then gradually selected the maltose-diet. After changing their preference from sucrose to maltose, the Zn-adequate control rats selected widely from both the maltose and sucrose diets, while the Zn-deficient rats exclusively and continuously selected the maltose diet from the two diets over the experimental period. The level of selection of sucrose-diet on day 28 had a correlation with the intestinal sucrase activity in the control rats. The sum of daily maltose and sucrose diet intake in rats fed a Zn-deficient diet showed a characteristic variation with the cyclic period of 3.6±0.2 d. The daily body-weight change of rats fed a Zn-deficient diet was well synchronized with their own food intake cycle. The day before changing preference from sucrose to maltose in rats fed a Zn-deficient diet represented a trough in their own food intake and body-weight cycles. These results suggest that one sign of a change in preference from sucrose to maltose in Zn-deficient rats is caused by a stage of negative energy balance.

Key Words zinc deficiency, food selection, maltose, sucrose

It is well recognized that food intake is one of the most basal physiological behaviors in animals. Rats fed a zinc (Zn)-deficient diet show reduction of food consumption and growth retardation (1–3). The decreased food intake of rats fed a Zn-deficient diet shows a characteristic cyclic pattern with a 3.5–4.0 d period (4–12). The decreased food intake of rats fed a Zn-deficient diet follows growth retardation (13, 14).

Zn-deficient rats have a preference for increased sodium chloride and sucrose solutions (15, 16), but do not reject a much higher concentration of hydrochloric acid and quinine sulfate solutions (16, 17). Zn-deficiency induces parakeratosis and hyperkeratosis of the oral mucous membranes, and structural disorder of the taste bud cells (17–19). Zn-deficiency also causes a reduction in carbonic anhydrase activity with correlated taste and lingual trigeminal nerve sensitivities (20).

The daily food intake of rats fed a Zn-deficient diet shows a characteristic variation and fits well to a cosine curve (12–14). But force-feeding Zn-deficient rats with 140% of their voluntary intake rapidly induces severe signs of illness (5). When Zn-deficient rats consume a restricted diet, which is the average level of daily food intake of Zn-deficient rats, the food intake cycle disappears (5). The daily food intake of Zn-deficient rats is lower than that of control rats and the reduced food intake is the result of the failure of the rats to eat food and not the result of a reduction in the amount consumed when the rats eat (7). The cyclical variation in food intake in rats was accompanied by a cyclical variation in body-weight in rats fed a Zn-deficient diet, which also occurred in pair-fed control rats (13).

The cyclical feeding pattern in rats fed a Zn-deficient diet changes under various conditions. A reduction of the protein content of the Zn-deficient diet from 20 to 5% results in no effect on food intake and disappearance of the cyclical pattern of intake (5, 7, 21). The value of the amplitude is decreased and the mesor is increased with increasing Zn supplementation by oral feeding (13) and subcutaneous injection (14) in the food intake cycle of Zn-deficient rats. When Zn deficient rats selected a diet from glucose and fructose diets with a two-choice method (22) and from dextrin, maltose and glucose diets with a three choice method (23), some rats changed their preference in the course of the experimental periods but the total daily food intake of the rats continued to show a 3.5–4.0 d-cycle (22, 23). The mechanisms of the cyclical food intake of rats fed a Zn-deficient diet have remained obscure.

Rains and Shay (24) studied differences in macronutrient preferences in Zn-deficient and Zn-adequate rats in a 28-d study using complete macronutrient selection...
by simultaneously providing each animal with three different diets, each consisting mainly of either fat, protein or carbohydrate. The carbohydrate intake of rats fed a Zn-deficient diet decreased in parallel with the reduction in total intake. When dextrin, maltose, sucrose, glucose and fructose are used as a source of carbohydrate in a diet, the food intake of the dextrin group is the highest under either Zn-adequate or Zn-deficient diets, and that of the fructose group is the lowest (25). Using a three-choice method by selection from dextrin, maltose and glucose diets, a decreased preference for the maltose diet is found in Zn-deficient rats (23). These results suggest that rats have preferences for different kinds of carbohydrate and change their preference under Zn-deficiency.

In this paper, we describe the change of preference for carbohydrate in rats with the poor appetite and taste abnormalities induced by Zn-deficiency. With a 2-choice method for selection from maltose and sucrose diets, Zn-deficient rats changed their preference from sucrose to maltose in a trough of their own food intake and body-weight change cycles and continued to select the maltose diet.

MATERIALS AND METHODS

Animals. Male albino rats (Wistar/ST, 4 wk) were purchased from Japan SLC, Inc. (Hamamatsu, Japan) and housed in individual screen-bottomed cages in a room maintained at 23 ± 1°C with 50% humidity, under controlled lighting conditions (lights on from 07:00 to 19:00). The animals were fed a commercial stock diet of Oriental MF (Oriental Yeast Co., Ltd., Tokyo, Japan) and given tap water with free access for 3 d before the experiment to allow acclimatization to their new environment. The rats were given the experimental diet for 4 wk, and killed without fasting after the feeding period by simultaneously providing each animal with three 1.2-cm-diameter holes.

Jar covered with a stainless steel lid containing nine 0.90 and 1.20 mg/kg, respectively, while the contents of Zn in the Zn-deficient maltose and sucrose diets were 31 and 32 mg/kg, respectively. The diet was in powder form and contained in a 9-cm-diameter glass jar covered with a stainless steel lid containing nine 1.2-cm-diameter holes.

Diets. The compositions of the Zn-deficient maltose and sucrose diets, and the Zn-adequate control maltose and sucrose diets are shown in Table 1. The composition of the Zn-deficient diet was the same as that of the Zn-adequate control diets with the exception that ZnCO$_3$ was deleted from the salt mixture. The contents of Zn in the Zn-deficient maltose and sucrose diets from the mean values of three separate experiments were 0.90 and 1.20 mg/kg, respectively, while the contents of Zn in the Zn-adequate control maltose and sucrose diets were 31 and 32 mg/kg, respectively. The diet was in powder form and contained in a 9-cm-diameter glass jar covered with a stainless steel lid containing nine 1.2-cm-diameter holes.

### Table 1. Compositions of the diets (g/kg).

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Control</th>
<th>Zn-deficient</th>
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<tbody>
<tr>
<td>Egg albumin</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>Carbohydrate$^1$</td>
<td>632.486</td>
<td>632.486</td>
</tr>
<tr>
<td>Soybean oil</td>
<td>70</td>
<td>70</td>
</tr>
<tr>
<td>Vitamin mixture$^2$</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Salt mixture (+Zn)$^3$</td>
<td>35</td>
<td>—</td>
</tr>
<tr>
<td>Salt mixture (−Zn)$^4$</td>
<td>—</td>
<td>35</td>
</tr>
<tr>
<td>Cellulose powder</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Choline hydrogen tartrate</td>
<td>2.5</td>
<td>2.5</td>
</tr>
<tr>
<td>tert-Butylhydroquinone</td>
<td>0.014</td>
<td>0.014</td>
</tr>
</tbody>
</table>

$^1$Carbohydrates used were maltose and sucrose.
$^2$AIN-93G vitamin mixture (26) was purchased from Oriental Yeast Co., Ltd. (Tokyo, Japan).
$^3$AIN-93G mineral mixture (26) was purchased from Oriental Yeast Co., Ltd.
$^4$Minerals (−Zn) (g/kg diet): ZnCO$_3$ was omitted from AIN-93G mineral mixture (26).

Chemicals. All chemicals used were of analytical grade and were purchased from Nakalai Tesque, Inc. (Kyoto, Japan) unless otherwise stated. Animal feed was obtained from Oriental Yeast Co., Ltd. Maltose and sucrose were from Nacalai Tesque.

Zn content. A 1 g portion of each test diet was heated for 48–72 h in a muffle oven at 450°C. After the sample cooled, 2 mL of 1 M HCl was added, and the digestates were heated and diluted with double-distilled deionized water. The serum was diluted 1 : 4 with 0.83 M HCl and incubated for 30 min at about 4°C. After brief centrifugation (600 × g for 10 min), the supernatant was removed and used for analysis. The stock Zn and sample solution were analyzed by atomic absorption spectroscopy with a Hitachi Z-5300 Polarized Zeema Atomic Absorption Spectrophotometer (Hitachi Ltd., Tokyo, Japan) at 213.8 nm.

Evaluation of food intake and body weight changes. Daily food intake and body weight change data from Zn-deficient rats were analyzed by the Cosinor method (12–14). Food intake (F) and body weight change (ΔB) on day t were determined using the following equation:

\[ F(\text{or } \Delta B) = M + A \cos(2\pi t/\tau + \phi) \]

Where M, A, τ and ϕ represent the mesor (the rhythm-adjusted mean), amplitude (maximum and minimum values of the adjusted mean), period (length of one complete cycle) and acrophase (phase of minimum value), respectively. The experimental data were fitted to the above equation by the nonlinear least-squares method (27), and the four parameters, M, A, τ and ϕ, were calculated using subroutine analysis (28).

As the data from Zn-adequate rats were not fitted to the above equation, comparisons among groups were evaluated between the mean variation of daily food intake and the body weight change. The variation was calculated for each rat with the standard deviation of the estimate of the day-to-day variation in food intake and body weight change for 28 d, and the group means are presented.
Maltase and sucrase. Mucosa was removed from the intestines and homogenized in 10 volumes of 0.9% (w/v) NaCl solution. The homogenate was used to assay enzyme activity. The maltase and sucrase activities were determined by measuring the rates of formation of glucose from maltose and sucrose, respectively. The concentration of D-glucose was determined using the Glucose C2 kit (Wako Pure Chemical Industries, Ltd., Osaka, Japan).

The standard reaction mixture for the estimation of maltase activity contained 75 mM sodium acetate, pH 6.0 and 1.0 mM EDTA, and 0.14 M maltose in a final volume of 2.0 mL. The mixture was incubated in a water bath at 25°C for 60 min. The reaction was stopped by heating at about 100°C for 3 min.

The standard reaction mixture for sucrase activity contained 63 mM sodium acetate, pH 4.65 and 0.09 M sucrose in a final volume of 1.6 mL. The mixture was incubated at 25°C for 60 min. The reaction was terminated by the addition of 0.4 mL of 0.3 M Tris buffer, pH 7.0.

Statistical analysis. Values for food intake, weight gain and weight change are expressed as mean±SD, except where otherwise indicated. Data were analyzed by the paired Student’s t-test to evaluate the significance in each group. For comparison between the two groups, the non-paired Student’s t-test was used. The relationship between value of cosine and phase of food intake and body-weight change cycles of rats fed a Zn-adequate diet was evaluated using a nonparametric one-sample t-test and considered significant at p<0.05.

RESULTS

Weight gain of rats fed a Zn-adequate diet and a Zn-deficient diet

The initial average body weight of the control rats was 146.7±4.0 g and was the same with the Zn-deficient rats. The Zn-deficient rats showed typical symptoms of Zn-deficiency such as alopecia, dermatitis of the paws, and anorexia with growth retardation. Figure 1 shows the average weight gain with the standard deviation. The weight gain of the Zn-adequate control rats, which simultaneously and continuously selected diets from the separate maltose and sucrose diets, progressively increased, while that from the Zn-deficient rats was retarded, and repeatedly rose and fell throughout the experimental periods. After 28 d, the weight gains of rats fed Zn-adequate and Zn-deficient diets from the two-choice method were 101.6±11.6 and 22.8±8.0 g, respectively (p<0.01).

The mean Zn concentrations of the serum at 28 d in the control and Zn-deficient rats were 2.4±0.3 and 0.6±0.2 μg/mL, respectively (p<0.01).

Selection of diets from maltose and sucrose diets in Zn-adequate and Zn-deficient rats

Daily selected food intake values from maltose and sucrose diets for 28 d in either two representative Zn-adequate rats or all of the Zn-deficient rats are shown in Figs. 2 and 3. Rats fed a Zn-deficient diet as well as a Zn-adequate diet predominantly preferred the sucrose diet on the first and the second day and then gradually selected the maltose diet (Figs. 2 and 3. Table 2). On day 28, the Zn-deficient rats preferred maltose to sucrose, while the Zn-adequate rats selected the maltose diet half as often as the sucrose diet (Table 2). Although the two diet jars of the maltose and sucrose diets were replaced daily, the rats fed a Zn-adequate and Zn-deficient diet

Fig. 1. Weight gain over time in rats fed a Zn-adequate diet (○) or a Zn-deficient diet (●). Each rat was simultaneously and continuously provided with two diets, one containing maltose and the other containing sucrose.

Fig. 2. Daily intake of Zn-adequate maltose- and sucrose-diets over time. Rats were simultaneously and continuously provided with two Zn-adequate diets, one containing maltose (▲) and the other sucrose (○). Representative selection patterns of rats 5 and 8 from ten rats are shown.
continuously selected one diet or maintained a trend for preference. All rats fed a Zn-adequate diet and a Zn-deficient diet could discriminate between the maltose and sucrose diets.

The feeding pattern in the two-choice method showed a characteristic difference between the Zn-adequate and Zn-deficient rats. Although both Zn-adequate and Zn-deficient rats changed their preference from sucrose to maltose, the control rats selected both diets after beginning to select the maltose diet (Fig. 2), while the Zn-deficient rats exclusively and continuously selected the maltose diet (Fig. 3).

Average daily intake of diets by selection from the maltose and sucrose diets, and the total diet intake were calculated. The average total food intakes of rats fed Zn-adequate and Zn-deficient diets were 13.1±0.6 and 9.0±0.7 g/d, respectively (p<0.01). The day-to-day variation in the total food intake of rats fed a Zn-defi-
icient diet from the two choices was 4.0±0.4 g/d and was significantly larger than that of rats fed a Zn-adequate diet 1.3±0.4 g/d (p<0.01). The levels of selection of the maltose and sucrose diets in the Zn-adequate control rats were 3.6±2.7 and 9.5±2.6 g/d, respectively (p<0.01), and those in the Zn-deficient rats were 5.8±3.0 and 3.3±2.9 g/d, respectively (p=0.072). The levels of maltose diet selected from the two diets in the control and Zn-deficient rats were 32.6±25.6 and 61.5±33.2%, respectively (p<0.05). These results show that the ratio of selection of the maltose-diet over 28 d in the Zn-deficient rats was higher than that in the Zn-adequate rats.

**Maltase and sucrase activities in the intestinal mucosa**

The enzyme activities of maltase and sucrase in the intestinal mucosa of rats fed Zn-adequate and Zn-deficient diets were evaluated. Total maltase activities from mucosa of the control and Zn-deficient rats were 48.9±12.0 and 34.2±10.5 μmol/min, respectively (p<0.01) and sucrase activities were 8.3±2.1 and 5.5±2.0 μmol/min, respectively (p<0.01). However, the specific activities of the maltase activity from the control and the Zn-deficient rats were 0.299±0.102 and 0.297±0.089 μmol/min per mg protein, respectively (p=0.963), and those of sucrase were 0.050±0.017 and 0.048±0.020 μmol/min per mg protein, respectively (p=0.799). These results show that the decreased maltase and sucrase activities in the Zn-deficient rats reflect the decreased protein concentrations in the intestinal mucosa.

A good correlation between selection of sucrose and the sucrase activity in the intestine was found in the rats fed a Zn-adequate control diet (Fig. 4). The selection of sucrose means the level of the sucrose-diet selected in the previous 24-h period at day 28. But no relationship between the selection of maltose-diet and the maltase activity was found in the control rats (r²=0.066, p>0.20). We could not calculate the correlation between selection of the sucrose diet and the sucrase activity of the intestine in the Zn-deficient rats, because eight tenths of rats selected the sucrose diet exclusively on day 28 (Fig. 3).

**Food intake and body-weight change cycles of rats fed a Zn-deficient diet, and change of preference from sucrose to maltose**

The Zn-deficient rats selected diets with a two-choice method from maltose- and sucrose-containing diets over a 28-d period. The daily total food intake and body-weight change in the Zn-deficient rats were well fit to a cosine curve. The four parameters of the cycles in each Zn-deficient rat were follows; food intake cycle: M=9.1±0.7 g/d, A=4.6±0.7 g/d, r=2.3±1.1 radian, body-weight change cycle: M=0.8±0.3 g/d, A=6.6±0.9 g/d, r=3.6±0.2 d and φ=2.3±1.2 radian. The values of period (r) and acrophase (φ) in the body-weight change cycles were closely correlated to those in the food intake cycle (r²=0.995, p<0.01 and r²=0.987, p<0.01, respectively). Neither maltose diet nor sucrose diet selected daily in the Zn-deficient rats showed any signs of periodic curves. The sum of maltose and sucrose diet selected in the Zn-adequate rats did not show a cyclical

**Fig. 4.** Correlation between the level of selection of the sucrose diet and the intestinal mucosa sucrase activity in the Zn-adequate control rats. Selection of sucrose diet means the selected sucrose diet in the previous 24-h period at day 28. The activity of sucrase was determined as described in “Materials and Methods.” The relationship for the selection of sucrose-diet with sucrase activity was y=1.001x+0.324 (r²=0.568, df=8, p<0.05).

**Fig. 5.** Correlation between the value of cosine and the phase of food intake (A) and body-weight change (B) cycles. The phase of food intake and body-weight change cycles mean the phase of cosine simulated at the day indicated by an arrow for each Zn-deficient rat in Fig. 2.
variation.

All the Zn-deficient rats preferred sucrose at days 1 and 2 (Fig. 3 and Table 1), and then gradually changed their preference to maltose except rats 15 and 16 (Fig. 3). After changing to a preference for maltose, the Zn-deficient rats predominantly and continuously selected a maltose-diet except rat 14, while the Zn-adequate control rats selected from both diets (Fig. 2). The Zn-deficient rats 11, 12, 13, 14, 17, 18, 19 and 20 changed their preference from sucrose to maltose at days 5, 4, 2, 6, 6, 5 and 5, respectively. The day before changing preference of each Zn-deficient rat is indicated by an arrow (Fig. 3). The values of the phases ($2\pi/\tau + \phi$) of their own food intake and body-weight cycles on the day previous to changing their preference were calculated. The correlations between the value of the cosine and the phase of food intake and body-weight change cycles on the day before changing a preference are shown in Fig. 5. Cosine values of $-0.2$ and $0$ were significantly different ($p<0.05$) from the values of cosine in the phase of food intake and body-weight change cycles, respectively, at the day before changing a preference as shown by an arrow in Fig. 3, based on a static analysis using the nonparametric one sample $t$-test. These results indicate that the day before changing preference was a low point in the food intake and body-weight change cycles of the Zn-deficient rats. Moreover, the average values of the phase on the day before changing preference in the food intake and the body-weight change cycles were $3.24\pm0.91$ and $3.58\pm0.97$ radians, respectively, from Fig. 5. These values are in the same phase to give a minimum value of cosine (3.14 radian) and indicate a trough in the food intake and body-weight change cycles.

**DISCUSSION**

The qualitative and quantitative analyses of selection of foods could provide useful information about anorexia in rats fed a Zn-deficient diet. Using a two-choice method of selection from maltose and sucrose diets, we found a different preference and a selection pattern for carbohydrates between Zn-adequate and Zn-deficient rats.

Recently, the taste receptor T1R1 was identified as the sac gene product (29–32) and the coupled T1R2 and T1R3, which are a heterodimer of two G proteins, function as a sweet-responsive receptor (33, 34). Sucrose is a more potent stimulus than maltose for the responses from the chorda tymani nerve (33, 35). Therefore, Zn-deficient rats as well as Zn-adequate rats may exclusively prefer sucrose to maltose at 1 and 2 d after the beginning of the selection of diets (Table 2).

In the Zn-adequate control rats, selection of the sucrose diet in the previous 24-h period at day 28 was about two times more frequent than selection of the maltose diet (Table 1). The selection of sucrose diet was correlated with the intestinal sucrase activity (Fig. 4). It is well established that fructose is catalyzed by ketohexokinase, induces hepatic insulin resistance (36), increases intrahepatic cellular lipids (37) and stimulates hepatic lipogenesis (37). Many rats preferred sucrose to maltose over 28 d, but the lipogenesis resulting from intake of sucrose might change the selection to maltose. High intestinal sucrase activity may maintain their preference for sucrose (Fig. 4). In fact, two of ten rats fed a Zn-adequate diet predominantly preferred sucrose through 28 d, and the sucrase activities of the two rats were 11.3 and 10.9 $\mu$/mol/min, respectively and were higher than the average intestinal sucrase activity activity (8.3±2.1 $\mu$/mol/min). Maltose is hydrolyzed to glucose by sucrase and isomaltase as well as maltase (38), and we thus could not find any correlation between the selection of the maltose-diet and maltase activity.

The preference for maltose in this paper was different from the previous study (23). The Zn-deficient rats changed their preference from sucrose to maltose in this paper but from maltose to dextrin in the selection with a 3-choice method from dextrin, maltose and glucose diets (23). This discrepancy may be caused by the use of dextrin. Rats have two types of carbohydrate-taste receptors, one for polysaccharides and one for sucrose and other sugars (39, 40). Moreover, Harper and Scrivey (41) found an inverse relationship between the osmotic pressure exerted by a dietary carbohydrate and food intake. As Zn-deficiency induces structural and functional damage to the digestive organs (42–46), dextrin will weaken the effect of osmotic pressure and rats may thus prefer dextrin to maltose.

The total food intake and body-weight change in the Zn-deficient rats showed a cyclical variation. Both cycles simulated from the average parameters of $M$, $A$, $\tau$ and $\phi$ are illustrated over 4 d in Fig. 6. The level at the top of the food intake cycle of rats fed a Zn-deficient diet was the same as the average food intake in the Zn-adequate rats. The meal size in Zn-deficient rats might not...
be different from that of Zn-adequate control rats as shown by Chesters and Will (7). When the food intake of Zn-deficient rats arrives at the top of the food intake cycle, they may avoid taking food. The top of the food intake cycle may reflect the average maximum energy requirement in all the cells. Thereafter, the level of food intake decreases gradually to the bottom of the cycle, with a half period of 3.6-d. At the bottom of the food intake cycle, the Zn-deficient rats may fall to a negative energy balance and take food again. These feeding patterns were synchronized with the body-weight change cycle (Fig. 6). The amplitude of the food intake cycle is correlated and inversely correlated to the addition of Zn to a Zn-deficient diet (1, 13) and a subcutaneous injection (14), respectively. The level of values (M−A) on the bottom of the feed intake cycles is decreased but the values of the average food intake (M) are increased by addition of various concentrations of Zn (13, 14). These results suggest that the ability to perceive a negative energy balance following action for food intake may depend on the level of Zn in rats and may relate to a retardation of growth in the Zn-deficient rats. The food intake and the body-weight change cycles may affect each other, and may be synchronized as shown in Fig. 6.

The preference for maltose and sucrose in the Zn-deficient rats was different between the short and long terms. At the onset of the two-choice method selecting from maltose and sucrose diets, the Zn-deficient rats exclusively selected the sucrose diet and then gradually changed their preference to maltose. Zn-deficient rats 11, 12, 13, 14, 17, 18, 19 and 20 changed and expressed a preference from sucrose to maltose at days 5, 4, 2, 2, 6, 6, 5 and 5, respectively. A sign of preference to maltose over sucrose might arise on the day previous to changing the preference, and is indicated by an arrow (Fig. 3). The phase of the changing point was a trough in the food intake cycle. The food intake cycle follows the body-weight change cycle. Therefore, the Zn-deficient rats may recognize their negative energy balance as being at the bottom of the body-weight change cycle. Here, the Zn-deficient rats may change their selection from sucrose to maltose, as shown with an arrow in Fig. 3. The change to a preference for maltose in the Zn-deficient rats thus may not merely depend on taste, but may be a sign of initiation of food intake. After changing their preference from sucrose to maltose, the food intake cycle was maintained with a fixed period of 3.6-d. The periods of food intake cycles changed within a narrow range of 3.5–4.0 d following the addition of Zn in the Zn-deficient rats (13, 14). The Zn-adequate control rats also may have a 3.5–4.0 d food intake cycle, but the difference between the top and the bottom of the food intake cycle is very small, and so may not be noticeable. The change of preference for carbohydrate did not affect the food intake cycle. Therefore, the food intake cycle synchronized with body-weight change may be a physiological action acquired from ancient times. Explanation of the food intake cycle of 3.5–4.0 d in rats needs further experiments.

Over 28 d, after beginning to select the maltose diet, the control rats ate widely from the sucrose and sucrone diets, while the Zn-deficient rats selected only the maltose diet (Figs. 2 and 3). With a 3-choice method for selection from dextrin, maltose and glucose diets, Zn-adequate control rats selected the three diets uniformly, while Zn-deficient rats continued to select the dextrin diet or dextrin and glucose diets (2,3). From these results, the preference for carbohydrate as well as food selection and feeding patterns in Zn-deficient rats are different from those of Zn-adequate rats. Kennedy et al. (47) proposed that periods of nutrient deficiencies cause permanent changes in food intake behaviors, either due to learned responses or because of damage to neurons caused by the nutritional deficiency itself. Zn deficiency is a predominant factor underlying a deviated food habit in the selection of carbohydrate, but the mechanism is not clear yet. The further studies of animal models of anorexia induced by Zn-deficiency should be useful for additional insight into its etiology in human populations.

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