Flavor variety enhances food acceptance in formula-fed infants¹–³

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ABSTRACT

Background: Research in humans and animal models suggests that acceptance of solid foods by infants during weaning is enhanced by early experiences with flavor variety.

Objective: We tested the hypotheses that the acceptance of novel foods by formula-fed infants could be facilitated by providing the infants with a variety of flavors at the time when beikost is first introduced and that, contrary to medical lore, infants who had previously consumed fruit would be less likely to reject vegetables when first introduced than would infants without such an experience.

Design: The infants’ acceptance of a novel vegetable (puréed carrot) and a novel meat (puréed chicken) was evaluated after a 9-d exposure period in 3 groups of infants, some of whom had previously consumed fruit. During the home-exposure period, one group was fed only carrots, the target vegetable; a second group was fed only potatoes, a vegetable that differed in flavor from carrots; and a third group was fed a variety of vegetables that did not include carrots.

Results: Infants fed either carrots or a variety of vegetables, but not those fed potatoes, ate significantly more of the carrots after the exposure period. Exposure to a variety of vegetables also facilitated the acceptance of the novel food, puréed chicken, and daily experience with fruit enhanced the infants’ initial acceptance of carrots.

Conclusion: These findings are the first experimental evidence to indicate that exposure to a variety of flavors enhances acceptance of novel foods in human infants. Am J Clin Nutr 2001;73:1080–5.

KEY WORDS Infant nutrition, weaning, flavor, food acceptance, development, taste

INTRODUCTION

Concerns about the timing and order of introduction to solid foods (beikost) represent one of the primary matters discussed by mothers with their children’s pediatricians (1, 2). Parents are often advised to complement milk feedings first with a grain product, such as precooked cereal, and to then gradually introduce other solid foods such as puréed fruit, vegetables, and meats. Although some health professionals recommend that foods can be introduced in no particular order (3, 4), others contend that vegetables should be introduced before fruit because the infants’ inherent preference for sweet tastes (5) will interfere with vegetable acceptance. Ultimately, the goal is to gradually accustom children to a varied diet that meets nutritional needs for growth and development (3).

The transition from an exclusive milk diet to a mixed diet consisting of milk and solid foods can be facilitated by feeding infants a particular food for several days (6) or by providing them with familiar flavors such that they experience the same flavor in the 2 feeding situations (7). However, the exposure needed to enhance acceptance may not require the actual flavor. Rather, research in humans (7, 8) and animal models (9–11) suggests that experience with flavor variety enhances the acceptance of novel foods during weaning. Of interest is the finding that breast-fed infants are more willing to accept a novel vegetable on first presentation than are formula-fed infants (6). One explanation for this finding is that breast-fed infants are exposed to a variety of flavors in mother’s milk whereas formula-fed infants experience a monotony of flavors in infant formula (12).

The present study, which builds on these previous findings, was designed to determine whether the acceptance of novel foods by formula-fed infants could be enhanced by providing them with a variety of flavors when beikost is first introduced. To this aim, we evaluated the acceptance of a novel vegetable (puréed carrot) and meat (puréed chicken) after an exposure period in 3 groups of infants, some of whom were also being fed fruit. One group was fed the target vegetable, carrots, during the exposure period; a second group was fed pureed potatoes, a vegetable that differed in flavor and texture from carrots; and a third was fed a variety of vegetables. Thus, infants were exposed to foods that differed not only in their taste and smell, but also in texture—an important component of flavor.

Three hypotheses were tested. First, we hypothesized that infants who were exposed to either carrots or a variety of vegetables would accept carrots more readily after the exposure period than would infants fed potatoes only. Second, we hypothesized that infants fed a variety of vegetables would accept the meat flavor more readily than would the other groups of infants. Because there is no evidence to support the claim that experience with sweet tastes leads to a generalized heightened sweet preference

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foods were first introduced to these formula-fed infants when they
were asked to refrain from introducing additional foods or bev-
ers to their infants during the past month and planned on introducing
other solid foods during the next few weeks were recruited from
advertisements in local newspapers and from Women, Infant and
Children programs in Philadelphia. To control for potential con-
founders due to flavor experiences in breast milk (12), only
mothers of formula-fed infants were recruited. The racial back-
ground of the mothers and their infants was 45.8% African
American, 39.6% white, 2.1% Hispanic, and 12.5% other ethnic
groups. All infants were born full-term and were healthy at the
time of testing as reported by their mothers. The procedures used
in this study were approved by the Committee on Studies Involv-
ing Human Beings at the University of Pennsylvania.

On the first day of testing, infants had been eating cereal for a
mean (±SD) of 3.8 ± 0.4 wk, which indicates that complementary
foods were first introduced to these formula-fed infants when they
were 4.0 ± 0.1 mo of age, a finding that is consistent with other
reports (2) and the recommendations made by the Committee on
Nutrition of the American Academy of Pediatrics (3). Although
none of the infants had consumed vegetables or meats before their
enrollment in the study, 32% were fed pureed fruit, fruit juices, or
both at least daily; 16% were fed fruit occasionally; and the
remaining 50% of the infants had never consumed fruit.

Methods
To accustom the infants to the testing procedures (7), mothers
were sent a bib and spoon to use when feeding their infants
during the 3 d that preceded the first testing session and during the
12-d experimental period. Mothers were also given a mask that
covered the nose and mouth area to wear while feeding their
infants (7); the mask was worn by the mothers during testing to
eliminate any potential influence of their facial or verbal
responses on the infants’ behaviors (14) and to minimize the
effects of maternal responses to the food odors. The mothers
were asked to refrain from introducing additional foods or bev-
erages to their infants before and during the 12-d experimental
period. To encourage compliance, each mother kept a daily
record of what they fed their infants, and daily phone contact
was made with each mother during the exposure period.

Food
All foods used in this experiment were commercially avail-
able infant foods (Gerber Products Co, Fremont, MI). The foods
were Stage 1 pureed carrots [1.46 kJ (0.35 kcal)/g], peas [2.05 kJ
(0.49 kcal)/g], potatoes [2.05 kJ (0.49 kcal)/g], and squash
[1.46 kJ (0.35 kcal)/g], and Stage 2 pureed chicken [4.73 kJ
(1.13 kcal)/g]. The maximum amount of food that could be
extracted from one jar was ≈68 g.

Monell test sessions
As illustrated in Figure 1, each mother-infant pair partici-
pated in the study for 12 d. On days 1, 11, and 12, each mother
brought her infant to the Monell Center. To minimize possible
effects due to different levels of satiation, the 3 test sessions took
place at the same time of day that the infants were fed the food
during the home-exposure periods and the infants were last fed
formula 219.1 ± 21.5 min before testing. There was no signifi-
cant difference among the groups in the length of time since the
infants were last fed before the testing sessions.

After a brief period of acclimation, mothers were videotaped
as they fed their infants pureed carrots on days 1 and 11 and
pureed chicken on day 12; the contents of 3 jars was the maxi-
imum amount of food offered during each test session. Mothers
wore a mask identical to that worn at home and were asked to
refrain from talking during the feeding sessions to eliminate any
potential influence of their facial or verbal expressions on the
infants’ behaviors (14). Analysis of the videotapes showed that
none of the infants were distracted by the masks because they had
been familiarized with the masks before the actual testing
occurred. Each mother fed her infant at his or her customary pace
until the infant refused the spoonful of food on ≥3 consecutive
occasions (7). All food that spilled onto the tray or bib was placed
in the bowl before being weighed. The amount of food consumed
was determined by weighing each jar of baby food immediately
before and after each feeding on a top-loading balance (PM 15;
Mettler, Hightstown, NJ) accurate to 1.0 g. Immediately after the
feeding session, mothers rated their infants’ enjoyment of the
food on a 5-point scale (1, extreme like; 5, extreme dislike).

Home-exposure period
As illustrated in Figure 1—although the testing procedures on
days 1, 11, and 12 were identical for all groups—the types of

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<th>Day of experimental period</th>
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<th>Potato group</th>
<th>Variety group</th>
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FIGURE 1. Experimental design illustrating the type of vegetable fed on each day of the 12-d study to 3 groups of infants: carrot group (n = 16), potato group (n = 16), and variety group (n = 16). On days 1, 11, and 12, the infants were fed by their mothers at the Monell Center, whereas on days 2–10 the infants were fed at home. Car, puréed carrots; Chk, puréed chicken; Pot, puréed potatoes; Pea, puréed peas; Squ, puréed squash. The shaded areas indicate the test days on which the infant’s feeding behavior was monitored at the Monell Center.
food fed to the infants during the 9-d exposure period at home (days 2–10) were different. Mothers and infants were randomly assigned to 1 of 3 experimental groups: the carrot group was fed carrots only, the target vegetable; the potato group was fed potatoes only; and the variety group was fed a variety of vegetables that did not include carrots. The length of the exposure period was based on the finding that infants require 8–10 exposures to a new food to increase acceptance (6).

During each day of exposure, mothers offered their infants the contents of one jar of commercially prepared infant food until they refused the spoon on ≥3 occasions. The original labels were removed and replaced with another that indicated the date on which the contents of that particular jar should be fed. Mothers then rated their infants’ enjoyment of the food, resealed the jar, and stored it in a freezer until they returned to the Monell Center. All but 1 mother returned every jar and all but 5 mothers completed the rating scales during each day of the home-exposure period.

Questionnaire

Mothers were queried about the frequency with which they ate carrots and chicken since their baby’s birth and throughout the 9-d exposure period. In addition, all but one completed an 8-item scale that measured their variety-seeking tendency with respect to foods (15).

Data analyses

For each infant during each test session, we determined the total intake of food (g), the duration of feeding (min), the rate of feeding (g/min), and the mother’s perception of their infants’ enjoyment of the food. To determine whether there were significant differences among the 3 groups in the infants’ relative acceptance of carrots, a proportional score for each of these indexes was calculated by dividing the infant’s response to carrots after the exposure period (day 11) by the response on day 1 plus that on day 11. Thus, absolute differences possibly due to other factors were eliminated and differences in relative responses were compared (16). Arc sine transformations were conducted to stabilize the variance before a one-way analysis of variance (ANOVA) with exposure group (carrot, potato, and variety groups) as the grouping factor. A separate one-way ANOVA was also conducted to determine whether the 3 groups differed in their acceptance of the novel food, chicken. Separate two-factor repeated-measures ANOVAs were conducted to determine possible group differences in the infants’ intake of vegetables and the mothers’ ratings of their infants’ enjoyment of the foods during the 9-d exposure period.

The between-subjects factor was group and the within-subjects factor was day of the experimental period. Significant effects in the ANOVAs were analyzed with paired t tests. When multiple comparisons were conducted, a Bonferroni correction was applied. All summary statistics are expressed as means ± SEMs.

To determine whether prior consumption of fruit hindered vegetable acceptance, we conducted a one-way ANOVA on the amount of carrots consumed on day 1 with frequency of fruit consumption (daily, occasionally, or not at all) as the grouping factor. Note that day 1 of testing occurred before the exposure period and was the first time each infant in the present study was fed carrots. Those infants who had previously consumed fruit began doing so when they were 13.2 ± 0.9 wk of age. STATISTICA (1998; StatSoft, Inc, Tulsa, OK) was used for the analysis.

RESULTS

Subject characteristics

The characteristics of the 3 groups of mother-infant pairs are listed in Table 1. There was no significant difference in age among the groups of mothers or infants, nor were there any significant group differences in the infants’ weight and length or in the number of weeks they had been fed cereal.

Effect of exposure on acceptance of carrots

As shown in Table 2, the infants’ relative acceptance of carrots was affected by the type or types of vegetables fed during the home-exposure period (P = 0.02). The carrot (paired t_{15 df} = 3.63, P = 0.002) and variety (paired t_{15 df} = 3.46, P = 0.003) groups ate significantly more carrots after the 9-d exposure period than before. There was no significant difference in the proportional increase in carrot acceptance between these 2 groups. On average, these 2 groups consumed 189.5 ± 76.1% more carrots after the exposure period than before.
period. In contrast, the amounts of carrots eaten by the potato group before and after the exposure period were not significantly different. Although there were no significant differences between the 3 groups in the length of time that the infants spent eating carrots during the test sessions at the Monell Center, the groups differed significantly in the rate at which the infants ate carrots \( (P = 0.01) \). That is, the carrot (paired \( t_{15} = 2.23, P = 0.04 \)) and variety (paired \( t_{15} = 3.52, P = 0.003 \)) groups ate carrots at a faster rate after the exposure period than before.

The mothers’ perception of their infants’ relative enjoyment of the carrots also differed significantly among the groups \( (P = 0.007) \). Mothers who fed their infants a variety of vegetables reported that their infants enjoyed carrots more after (paired \( t_{15} = 2.54, P = 0.02 \)) than before the home-exposure period. The significant correlation between these 2 measures \( (r_{44} = -0.46, P = 0.001) \) indicated that the mothers’ rating did reflect how much their infants ate. That is, the more positive the mothers’ rating of her infants’ enjoyment of the foods, the higher the intake.

**Effect of exposure on acceptance of chicken**

As shown in Figure 2, the infants’ acceptance of chicken was also significantly affected by the type of vegetable consumed during the exposure period. The variety group consumed significantly more chicken than did the carrot group (unpaired \( t_{29} = 2.32, P = 0.02 \)). There were no significant group differences in the duration of feeding, the rate of feeding, or the mothers’ ratings of their infants’ enjoyment of this food.

**Intake during the exposure period**

As illustrated in Figure 3, there were significant group-by-day interactions and differences among the groups in vegetable intake during the course of the 9-d home-exposure period. The carrot and variety groups ate significantly more overall than did the potato group (variety group compared with potato group: unpaired \( t_{29} = 3.64, P = 0.001 \); carrot group compared with potato group: unpaired \( t_{29} = 4.99, P = 0.001 \)), suggesting that potatoes were less preferred by the infants.

There was no significant difference in overall intake between the carrot and variety groups.

There were also day-to-day differences in the amount of food consumed depending on the type of vegetable offered \( (P = 0.001) \). Although the potatoes were less preferred, the potato group ate significantly more potatoes by the end of the home-exposure period \( (P = 0.04) \). Consistent with the findings of Sullivan and Birch (6) that infants require 8–10 exposures to a novel food to facilitate later acceptance, we found that those infants who were repeatedly exposed to potatoes (potato group) ate significantly more potatoes after 9 d of exposure (paired \( t_{15} = 2.1, P = 0.05 \)), whereas there was no significant difference in potato acceptance in those infants in the variety group, who had only 3 d of exposure to potatoes (on days 2, 5, and 8 of the home-exposure period). In addition, the variety group preferred peas and squash to potatoes \( (P = 0.001) \).

That the mothers’ perception of their infants’ enjoyment varied with the type of food offered during the exposure period was evident by the significant group-by-day interactions \( (P < 0.0001) \) and group differences \( (P < 0.0001) \). The mothers of the potato group reported that their infants enjoyed...
the home-exposure food (ie, potatoes) less than did the carrot (unpaired \( t_{28d} = 6.87, P = 0.05 \)) and variety (unpaired \( t_{27d} = 3.89, P = 0.001 \)) groups, whereas the mothers of the carrot group reported that their infants enjoyed carrots more than did the variety group, who were fed peas, potatoes, and squash in addition to carrots (unpaired \( t_{25d} = -3.42, P < 0.005 \)). The mothers of the variety group indicated that their infants enjoyed the potatoes (rating: 3.8 ± 0.3) less than either the squash (1.5 ± 0.1; paired \( t_{12d} = 5.67, P < 0.001 \)) or the peas (2.2 ± 0.2; paired \( t_{14d} = 4.51, P < 0.001 \)). In addition, these mothers reported that their infants enjoyed the squash more than the peas (paired \( t_{12d} = -3.50, P < 0.005 \)).

Relation between experience with fruit and initial acceptance of carrots

Exposure to fruit did not hinder the infants’ acceptance of carrots during their first feeding experience with this vegetable (day 1). There were significant effects of the frequency of fruit consumption (ie, daily, occasionally, or not at all) on carrot intake (\( P = 0.04 \)). As seen in Figure 4, those infants who ate fruit daily (\( n = 16 \)) consumed more carrots than did the infants who ate fruit occasionally (\( n = 8 \); unpaired \( t_{26d} = 1.65, P = 0.05 \)) or not at all (\( n = 24 \); unpaired \( t_{38d} = 2.35, P = 0.007 \)). However, after Bonferroni correction, only the difference between the group who ate fruit daily and the group who ate no fruit was significant.

Questionnaires on mothers’ eating and variety-seeking behaviors

There were no significant differences among the 3 infant groups in the mothers’ frequency of consuming carrots, peas, squash, potatoes, or chicken since the infants’ birth. Nor was there a significant difference in the mother’s frequency of consumption of the test foods (carrots and chicken) during the experimental period or their variety-seeking tendency with respect to foods.

DISCUSSION

The present findings provide the first experimental evidence to support the hypothesis that exposure to flavor variety facilitates infants’ subsequent acceptance of novel foods. Infants who were fed a variety of vegetables that differed in taste, smell, and texture ingested more of not only the novel food, chicken, but also of carrots in a manner similar to that of infants who were fed carrots repeatedly. In contrast, infants fed potatoes exclusively showed no such increase in carrot intake, although their acceptance of the potatoes increased as the home feedings progressed. The minimum number of exposures required to enhance acceptance appears to be more than one because infants who were exposed only to potatoes (and thus had only a single exposure to carrots on the first testing day) showed no increase in carrot acceptance. Because there were no significant differences among the 3 groups of infants relative to their mothers’ frequency of consuming the test foods or their variety-seeking scores, the differences observed in the infants’ acceptance of the novel foods did not appear to be due to the mothers’ eating habits or attitudes toward foods.

Three hypotheses could account for these findings. First, infants fed a variety of foods may have increased their intake of carrots because they could not discriminate among the vegetables (17). That is, perhaps peas, potatoes, and squash share similar flavors with the carrots. However, the finding that the infants who were fed potatoes only did not increase their intake of carrots suggests that the infants indeed differentiated between carrots and potatoes. Moreover, the marked day-to-day fluctuations in both intake and the mothers’ perceptions of their infants’ enjoyment of the foods suggest that the infants fed a variety of vegetables clearly discriminated among the vegetables (Figure 3). Such findings are consistent with those of previous studies that showed that infants prefer certain types of vegetables (6, 18).

Second, infants fed a variety of foods may have increased their intake of carrots after the home-exposure period because they were eating more food overall than were the infants fed potatoes exclusively. In other words, the variety effect may be secondary to increased consumption of the more preferred foods. However, this increased intake does not explain why the infants fed a variety of vegetables (variety group) consumed significantly more of the novel food, chicken, than did infants who were fed carrots only (carrot group) during the exposure period. Recall that there was no significant difference in the overall intake during the home-exposure period between these 2 groups of infants.

Third, early experience with a diversity of flavors may have led to an increased readiness to accept unfamiliar flavors. This finding is supported by a study that showed that infants who experienced a variety of differently textured applesauces (eg, puréed, lumpy, and diced) preferred greater texture complexity (19). Moreover, animal model studies suggest that there is a “transfer of diversity” whereby exposure to a variety of foods during early development prepares young animals for diversity later in life (9, 11). For example, weanling rats exposed to a variety of different flavored waters for 12 d were more likely to accept a novel flavor than were rats exposed to a single flavor only (9). Similarly, when the nutritional content of the diet was held constant, lambs preferred to forage in locations that offered a variety of flavors (20). Of interest is the finding that mothers who claimed they exposed their children to greater dietary diversity early in life were less likely to perceive their 2- to 7-y-old children as having feeding problems or being neophobic (21).
In the present study, mothers chose to introduce solid foods to their infants’ diets when the infants were aged 3.3–6.5 mo, but in other cultures and among breast-feeding infants, the timing of this process can be quite variable and prolonged. Whether similar effects would be observed in older infants and how long these effects would last in the absence of continued exposure to variety are unknown. However, we suggest that the present findings support previous findings that breast-fed infants consume more of a novel vegetable than do formula-fed infants (6). Because a variety of flavors consumed by mothers are transmitted to human milk (22), the sensory world of breast-fed infants is very rich, varied, and quite different from that of formula-fed infants. Formula-fed infants experience a constant set of flavors from standard formulas and thus may miss significant sensory experiences that, until recent times in human history, were common to all infants.

The present study also showed that infants who were exposed to fruit daily consumed more carrots than did infants with no exposure. Because we did not randomly assign infants to groups (the mothers decided when and how much they would feed fruit to their infants), this was not a strictly experimental study. Nonetheless, the infant groups appeared to be matched on the basis of age, weight, and prior experience with cereal consumption. How experience with different types of foods and flavors affects acceptance of other solid foods remains an important area for future research.

Research has shown that a greater diversity of social stimulation during early infancy is associated with higher scores on measures of cognitive development in domains such as language, reading, and mathematics (23, 24). The present findings suggest that the beneficial effects of varied food experiences during early development are not limited to cognitive functioning and provide experimental evidence supporting the claim that experience with a diversity of flavors sets the pattern for a diversified diet (3). Because flavor variety is often related to a greater variety in the nutritive content of foods (25, 26), a preference for varied flavors should ultimately increase the range of nutrients consumed and thus increase the likelihood that a well-balanced diet is consumed. In other words, the variety effect may reflect an important adaptive mechanism in the regulation of food intake (25). The findings of the present study indicate that exposure to flavor variety during infancy enhances acceptance of some novel foods. Such information may prove valuable to health care providers and parents in developing strategies for introducing beikost to formula-fed infants.

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