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Vegetable acceptance by infants:

Effects of formula flavors

Julie A. Mennella^{*}, Janice M. Kennedy, and Gary K. Beauchamp

Monell Chemical Senses Center, 3500 Market Street, Philadelphia, PA 19104-3308, United States

Abstract

Individual differences in acceptance patterns are evident as early as the child's first experiences with a particular food. To test hypothesis that the flavor of formula fed to infants modifies their acceptance of some foods, we conducted a within- and between-subjects design study in which two groups of 6- to 11-month-old infants were tested on two separate days. One group was currently feeding a milk-based formula whereas the other was feeding a protein hydrolysate formula, a particularly unpleasant tasting formula to adults that contains similar flavor notes (e.g., sulfur volatiles) with Brassica vegetables such as broccoli. In counterbalanced order, acceptance of pureed broccoli/cauliflower was determined during one test session and pureed carrots on the other. Although there were no group differences in the amount of carrots consumed, hydrolysate infants consumed significantly less broccoli/cauliflower relative to carrots when compared to those who were currently fed milk based formulas ($F(1, 72 \text{ df})=4.43$; $p=0.04$). The mothers of hydrolysate infants were significantly more likely to report that their infants did not enjoy feeding the broccoli/cauliflower (54.2%) when compared to mothers of infants being fed milk-based formulas (28.0%; Chi-Square (1 df)=4.79; $p=0.03$). Such findings are consistent with prior research that demonstrated a sensory specific satiety following repeated exposure to a particular flavor in milk. We hypothesize that when infants are experiencing a flavor in milk or formula, in the short term, the preference that develops is specific to the context it is experienced in (e.g., milk). Over the longer term, the preference may generalize to other contexts such as solid foods. Hydrolysate infants were also significantly more likely to be judged by their mothers as being more active ($F(1, 69 \text{ df})=3.95$; $p=0.05$) and hesitant ($F(1, 69 \text{ df})=6.55$; $p=0.01$) when compared to those infants who were feeding milk-based formulas, a finding that further supports the hypothesis that mother—child dynamics surrounding early feeding impacts upon mothers' perception of their children's temperament.

Keywords

Infant nutrition; Weaning; Flavor; Development; Taste; Formula; Hydrolysate

1. Introduction

Up to one third of American children under the age of two consume no fruits or vegetables on a given day [1]. Because fruit and vegetable experiences during infancy track into childhood and adolescence [2,3], developing strategies to enhance acceptance of these foods early in life are important for long-term health [4]. However, such strategies need to take into account the individual differences in acceptance patterns that are evident as early as the child's first experiences with a particular food [5].

Although the source of such individual differences remains a mystery, prior research has shown that the very earliest flavor experiences, that which occurs in utero and during milk feedings,

^{*}Corresponding author. Tel.: +1 215 898 9230; fax: +1 215 898 2084. E-mail address: mennella@monell.org (J.A. Mennella).

can influence food acceptance at weaning. The degree of acceptance depends on the length of time that has elapsed since exposure to the flavor as well as the sensory context in which the flavor is experienced. For example, breast-fed infants whose mothers consumed a diet rich in carrots exhibited a decrease in their acceptance of carrot-flavored cereal when tested shortly after the exposure period [6,7]. This may be a form of sensory-specific satiety, such that the infants become less responsive to a flavor that they have been extensively exposed to in the very recent past [8].

Over the longer term, exposure to carrot flavor served to heighten its acceptance. That is, infants who were exposed to the flavor of carrots prenatally or during the first months of life in mothers' milk and were tested several months later, were more accepting of carrot-flavored cereal than were infants without such experience [9]. Presumably, learning (e.g., elimination of neophobia, conditioning, "mere exposure") has occurred.

The present study expanded upon these findings to experimentally investigate this issue in infants who are formula feeding. Here we take advantage of the marked differences of commercial infant formulas. In particular, the sensory quality differences between the hydrolysate and milk-based formulas are striking and profound. To most adults, who are tasting these products for the first time, milk-based formulas are described as having low levels of sweetness and tasting >'sour and cereal-like', whereas hydrolyzed protein-based formulas are of a most unpleasant character with a bitter and sour taste profile, unpleasant odor volatiles and a horrible after taste [10-12]. The extreme unpalatability of hydrolysate formulas, which supply infants with protein nutrients in a >'predigested' form, is likely due to both its processing and composition since many amino acids and small peptides taste sour and bitter and is characterized by unpleasant volatile components [13-15]. Because hydrolysate formulas [16] contains similar flavor notes (e.g., sulfur volatiles) with broccoli [17], the present study tested the hypothesis that infants currently feeding hydrolysates would reject broccoli in the short term when compared to a group of infants being fed milk-based formulas.

2. Methods

2.1. Subjects

Women, who were formula feeding an infant, were recruited from ads in local newspapers. The racial background of the mothers was 44.6% Black, African descent, 45.9% White, European descent, 4.1% Hispanic, 2.7% Asian and 2.7% Admixed/Other Ethnic Groups. All infants were born fullterm and were healthy at the time of testing, as reported by their mothers.

Two groups of infants, whose ages ranged from six to eleven months, were formed on the basis of the type of formula they were feeding. Group 1 infants ($N=50$) were feeding a milk-based formula and had never experienced hydrolysate formula (Mean age= 8.5 ± 0.2 months), whereas Group 2 infants ($N=24$) were feeding the protein hydrolysate formula, NutramigenTM (Mean age= 8.9 ± 0.3). As expected, those who were feeding Nutramigen often fed a milk- or soy-based formula during the first months (1.8 ± 0.4 months) of life and then, usually following their paediatrician's recommendation, were switched to hydrolysate for such reasons as the baby was experiencing colic, allergies, or constipation. None of the infants fed milk-based formulas had ever experienced hydrolysate formulas. Six additional infants were tested but were excluded because either the mother did not comply with study procedures ($N=1$) or because the infant in the milk formula group (Group 1) had prior experience with hydrolysate formulas ($N=5$). The study procedures were approved by the Office of Regulatory Affairs at the University of Pennsylvania, and informed consent was obtained from each woman before the start of the study.

2.2. Procedures

A within- and between-subjects design study that controls for time of day since infants were last fed was conducted. To accustom infants to the testing procedures [6], mothers were sent a bib and spoon to use when feeding their infants during the 3 days before the first testing session and throughout the 2-day experimental period. They were asked to refrain from introducing additional foods or beverages to their infants during this time period.

2.3. Foods

All foods used in this experiment were commercially available infant foods from Gerber Products Company (Fremont, MI, USA). The foods were Stage 2 pureed carrots (35 calories/jar) and pureed broccoli/cauliflower (60 calories/jar). The maximum amount of food that could be extracted from one jar was approximately 113 g.

2.4. Monell test sessions

Each mother-infant pair was tested on two days separated by, on average, two days (± 0.3). The infants' weights and lengths prior to feeding were recorded and their Body Mass Indexes (BMI) were determined. To minimize possible effects due to different levels of satiation, the two test sessions took place at the same time of day and infants were last formula fed, on average, 3.9 (± 0.3) h and last fed solid foods, on average, 9.1 (± 1.0) h prior to the testing sessions. There was no significant difference between the groups in the length of time since the infants were last fed ($F(1, 71) df=0.04$; $p=0.95$).

Following a brief period of acclimation, mothers were videotaped as they fed their infants, in counterbalanced order, pureed carrots during one test session and pureed broccoli/cauliflower during the other. Carrots were chosen because it is generally well accepted by infants [5]. The content of three jars was the maximum amount of food offered during each test session. Mothers were asked to refrain from talking during the feeding sessions to eliminate any potential influence of their facial or verbal responses on the infants' behaviors [6,18]. The infants determined the quantity of food consumed; they were fed at their customary pace until they refused the spoonful of food on at least three consecutive occasions. Analyses of the videotapes by trained observers revealed that this was indeed the case for each of the mothers and infants.

The amount of food consumed was determined by weighing each jar of baby food and bib immediately before and after each feed on a Denver Instrument XS-3100 toploading balance (Anada, Colorado) accurate to 0.01 g. The amount of calories consumed by the infant was also determined since the broccoli—cauliflower was more calorically dense than the pureed carrots. Immediately after the feeding session, mothers were asked whether they thought their infants enjoyed the food and to rate their infants' enjoyment of the food on a 9-point scale (1=did not enjoy; 9=did enjoy). Mothers were not told how much food their infants had consumed.

2.5. Questionnaires

Mothers were queried about the introduction of solid foods to their infants' diets and the frequency with which they and their infants ate a variety of foods including carrots and broccoli. All but three of the mothers completed a 10-item scale that measured their food neophobia (the propensity to approach or avoid novel foods) and a 8-item scale that measured general neophobia [19]. Mothers also completed a 95-item questionnaire [20] that measured their perceptions of their infants' temperament (i.e., activity, rhythmicity, approach, adaptability, intensity, mood, persistence, distractibility, threshold) since previous research demonstrated mothers who had to switch their infants' formula to hydrolysate during infancy perceived these infants as being more vulnerable several years thereafter [21].

2.6. Data analyses

For each infant, we determined the total intake (g), length (min) and mothers' ratings of their infants' enjoyment of pureed carrots and broccoli/cauliflower. To determine whether there were significant differences between the two groups in the infants' relative acceptance of carrots and broccoli, each infant's responses to broccoli—cauliflower were expressed as proportions: $[\text{response to broccoli/cauliflower} / (\text{response to broccoli/cauliflower} + (\text{response to carrots}))]$. In this way, absolute differences that may be due to other factors were eliminated and differences in relative responses could be compared. Arc sine transformations were conducted to stabilize the variance prior to a one-way Analysis of Variance (ANOVA) with formula feeding history (i.e., milk formula, hydrolysate formula) as the grouping factor. Both the infants' age and sex were included as covariables in the analyses. There were no significant effects of either age or sex, however. Separate one-way ANOVAs were also conducted to determine whether the groups differed in child temperament scores or maternal neophobia scores. Pearson Chi-Square tests were conducted to determine whether the groups differed in the mothers' judgments of whether the child enjoyed the food. All summary statistics are expressed as Mean + SEM and levels of significance were $p < 0.05$.

3. Results

3.1. Subject characteristics

Table 1 presents data on the characteristics of the sample. There were no significant differences between the groups in the infants' age, sex, ethnicity, or body mass index, and mother's parity, age or education level. Neither were there any significant group differences in the age at which carrots or broccoli/cauliflower was introduced into their infants' diets, the frequency at which these infants ate these foods during the past week or maternal measures of food and general neophobia. Infants who were fed milk-based formulas were as likely as those fed hydrolysate formulas to be feeding cereals and a wide variety of fruits (i.e., bananas, applesauce, pears, peaches, apricots) and vegetables (i.e., green beans, peas, corn, potatoes, squash) at the time of testing (all p 's > 0.20). However, hydrolysate-fed infants were significantly more likely to be feeding meats such as chicken when compared to those fed milk-based formulas (77.3% vs. 51.0%; Fisher Exact; $p = 0.03$).

The groups differed significantly in the mothers' perception of their infants' temperament. Hydrolysate infants were judged by their mothers as being more active ($F(1, 69 \text{ df}) = 3.95$; $p = 0.05$) and hesitant ($F(1, 69 \text{ df}) = 6.55$; $p = 0.01$) when compared to those infants who were feeding milk-based formulas. There was also a tendency for them to be judged as more non-adaptable ($p = 0.06$) and more sensitive ($p = 0.06$).

3.2. Food acceptance

Although there were no group differences in the amount of carrots consumed ($F(1, 72 \text{ df}) = 0.28$; $p = 0.60$), hydrolysate infants consumed significantly less broccoli/cauliflower in terms of grams ($F(1, 72 \text{ df}) = 4.43$; $p = 0.04$) as well as calories ($F(1, 72 \text{ df}) = 4.27$; $p = 0.04$) relative to carrots when compared to those who were currently fed milk based formula (Fig. 1 and Table 2). This significant decrease in broccoli/cauliflower consumption was also evident when the data were expressed as intake (g)/infants' BMI (5.7 ± 0.6 versus $3.6 \pm 0.9 \text{ g/BMI}$; $F(1, 72 \text{ df}) = 3.70$; $p < 0.05$). The mothers of hydrolysate infants were significantly more likely to report that their infants did not enjoy feeding the broccoli/cauliflower (54.2%) when compared to mothers of infants being fed milk-based formulas (28.0%; Chi-Square (1 df) = 4.79; $p = 0.03$).

4. Discussion

Consistent with previous findings [5,22,23], babies can clearly discriminate different types of vegetables and prefer some more than others. In the present study, infants, as a group, preferred the pureed carrots to pureed broccoli/cauliflower. However, the type of formula infants were feeding influenced their acceptance of the latter vegetables. That is, the broccoli/cauliflower mixture was rejected more in infants who were feeding a hydrolysate formula that shared a similar flavor note when compared to those fed milk-based formulas. Mothers were apparently aware of this difference.

Such findings are consistent with our prior research which demonstrated a sensory specific satiety following repeated exposure to a particular flavor in mothers' milk [7,24] or formula [24]. We hypothesize that when infants are experiencing a flavor in milk or formula, the preference that develops is specific to that context (e.g., milk). Only after time has elapsed, does the preference generalize to other contexts such as solid foods [9]. Thus, we hypothesize that over the longer term, those feeding hydrolysate formulas would exhibit enhanced acceptance of broccoli, cauliflower, or other sulfur-containing vegetables. In support of this hypothesis, recent experimental studies indicate that 4- to 5-year-old children, who were fed hydrolysate formulas during infancy, exhibited more positive responses to sensory attributes associated with these formulas (sour taste, aroma) and were significantly more likely to prefer broccoli several years after their last exposure to the formula, when compared with same-aged children without such experience [14].

Mother—child dynamics surrounding early feeding can have long-lasting effects on mothers' perception of their children's temperament. For example, problems of early infancy are often managed by changing the infants' formula from a milk formula to soy or protein hydrolysate [25], as was the case for several of the hydrolysate infants in the present study. These early feeding dynamics have been shown to have a long-term impact on mother—infant interaction [21]. Mothers whose infants experienced a formula change during infancy from a milk-based to a hydrolysate formula perceived their children as being more vulnerable several years later. The present findings revealed that these perceptions are evident even earlier, when infants are younger than one year of age. Because a recent experimental study which randomized infants to be fed different types of formulas during the first 7 months of life revealed no effect on the type of formula on various measures of infant temperament [26], the present finding that mothers of hydrolysate-fed infants rated their infants as more active and hesitant does not appear to be due to the formula, per se.

Concerns about the introduction to solid foods (beikost) represent one of the primary matters discussed by mothers with their child's pediatrician [23,27]. Although more basic research is needed to determine how preferences for foods such as vegetables develop, we know that 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 8 to 9 days [5,28] or by providing them with bridges of familiarity such that they experience the same flavor in the two feeding situations [6]. As shown herein, although infants may consume less of a vegetable that shares similar flavor notes to their formula while they are formula feeding, over time, preferences may develop for such foods [9]. Of interest is the finding that hydrolysate infants were significantly more likely to be feeding protein sources of nutrients such as chicken. Whether early experience with protein hydrolysate formulas enhances the infants' acceptance of foods high in protein is currently under investigation. An appreciation of the complexity of early feeding and a greater understanding of the mechanisms underlying the development of food preferences will aid in our development of evidence-based strategies and programs to facilitate fruit and vegetable acceptance by children.

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Figure 1.

The amount of pureed carrots and broccoli/cauliflower (grams) consumed by infants who were currently feeding either a milk-based (hatched bars) or a hydrolysate (solid bars) formula.

Table 1

Subject characteristics

	Formula group	
	Milk-based formula	Hydrolysate formula
Infants' age in months	8.5±0.2	8.9±0.3
Ethnicity of infants		
African American	44.0%	37.5%
Asian	4.0%	0%
Caucasian	38.0%	50.0%
Hispanic	0%	4.2%
Other	14.0%	8.3%
Sex of infants (girls:boys)	27:23	10:14
Infants' body mass index (kg/m ²)	18.2±0.4	17.8±0.5
Infants' weight (kg)	9.0±0.2	9.0±0.2
Infants' length (cm)	70.5±0.7	71.2±1.2
Infant temperament measures		
Activity	4.18±0.08	4.49±0.16*
Rhythmicity	2.74±0.12	2.84±0.12
Approach	2.69±0.12	3.06±0.18
Adaptability	2.47±0.11	2.83±0.15
Intensity	3.62±0.08	3.71±0.10
Mood	3.10±0.11	3.43±0.21
Persistence	3.15±0.11	2.92±0.18
Distractibility	2.61±0.09	2.81±0.12
Threshold	3.78±0.10	4.00±0.16
Infants' prior exposure to carrot		
Percent with experience	96.0%	95.8%
Age of introduction (months)	5.3±0.2	5.1±0.3
Frequency during past week	2.3±0.3	1.6±0.3
Infants' prior exposure to broccoli-cauliflower		
Percent with experience	48.0%	54.2%
Age of introduction (months)	6.2±0.4	6.2±0.3
Frequency during past week	1.4±0.6	1.6±0.4
Mothers' age in years	28.5±0.9	30.6±1.1
Mothers' parity % primiparous	30.0%	45.8%
Mother's years of schooling	14.1±0.3	14.1±0.4
Mothers' food neophobia score (range: 10-70)	37.4±1.7	35.0±2.4
Mothers' general neophobia score (range: 8-56)	24.1±1.4	24.9±1.6
# Mother-infant pairs	50	24

* Signifies $p < 0.05$ when compared to milk-based formula group.

Table 2
Effects of current formula on infants' vegetable acceptance

	Formula group	
	Milk-based formula	Hydrolysate formula
<i>Infant feeding measures</i>		
Intake (g)		
Carrot	127.4±13.2	116.1±13.8
Broccoli-cauliflower	101.0±12.1	64.8±9.6 [*]
Proportional response: broccaul/broccaul+carrot	0.44±0.03	0.34±0.03 [*]
Intake (calories)		
Carrot	39.5±4.1	36.0±4.3
Broccoli-cauliflower	53.5±6.4	34.4±5.1 [*]
Proportional response: broccaul/broccaul+carrot	0.55±0.03	0.46±0.04 [*]
Length of feeding (min)		
Carrot	14.9±1.1	12.7±1.3
Broccoli-cauliflower	15.9±2.0	9.7±1.1 [*]
Proportional response: broccaul/broccaul+carrot	0.48±0.02	0.43±0.03
<i>Maternal perception measures</i>		
Did baby enjoy food? (% yes)		
Carrot	93.9%	95.8%
Broccoli-cauliflower	72.0%	45.8% [*]
Infant ratings of enjoyment (1-9; 1=did not enjoy)		
Carrot	7.5±0.3	7.2±0.4
Broccoli-cauliflower	6.9±0.7	6.5±0.8
Proportional response: broccaul/broccaul+carrot	0.44±0.02	0.38±0.03
Number of mother-infant Pairs	50	24

One group of infants was currently feeding a milk-based formula whereas the other was feeding a hydrolysate formula.

^{*} Signifies $p < 0.05$ when compared to milk-based formula group.