Published in final edited form as:
Dev Psychobiol. 2002 December ; 41(4): 388–395. doi:10.1002/dev.10067.

Sweet and Sour Preferences During Childhood: Role of Early Experiences

Djin Gie Liem and **Julie A. Mennella**
Monell Chemical Senses Center 3500 Market Street Philadelphia, PA 19104–3308

Abstract

We investigated the effects of early experience on sweet and sour preferences in children. Eighty-three children were divided into four groups based on the type of formula fed during infancy and age. By using a forced-choice, sip-and-swallow procedure, we determined the level of sweetness and sourness preferred in juice. Children who were fed protein hydrolysate formulas, which have a distinctive sour and bitter taste and unpleasant odor, preferred higher levels of citric acid in juice when compared to older children who were fed similar formulas. No such difference was observed between the groups for sweet preference. However, the level of sweetness preferred in juice was related to the sugar content of the child's favorite cereal and whether the mother routinely added sugar to their foods. These data illustrate the wide variety of experiential factors that can influence flavor preferences during childhood.

Keywords

taste; early experience; hydrolysate formula; maternal behaviors; preferences

INTRODUCTION

In the biography on the life of his children, Charles Darwin (1877) astutely noted that children are living in different sensory worlds than adults. One century after these keen observations were made, the scientific investigation of taste preferences during human ontogeny began. This body of research has focused primarily, but not exclusively, on sweet tastes and has repeatedly demonstrated, as Darwin noted, the strong acceptance of sweet-tasting sugars during infancy and childhood (Desor, Green, & Maller, 1975a; Enns & Itallie, 1979; Maller & Desor, 1973; Nisbett & Gurwitz, 1970; Peiper, 1961/1963; Steiner, 1977), with preference levels decreasing to resemble that of the adult during late adolescence (Desor & Beauchamp, 1987).

The heightened preference for sweet taste during early development is universal and evident in children around the world (e.g., Brazil: Tomita, Nadanovsky, Vieira, & Lopes, 1999; France: Bellisle, Dartois, Kleinknecht, & Broyer, 1990; Iraq: Jamel, Sheiman, Watt, & Cowell, 1997; Israel: Steiner, 1977; Mexico: Vazquez, Pearson, & Beauchamp, 1982; Netherlands: De Graaf & Zandstra, 1999; North America: Beauchamp & Cowart, 1987; Desor et al., 1975a). However, individual variations do exists (Beauchamp & Moran, 1984; Enns &Itallie, 1979; Nilsson & Holm, 1983). Genetic variation (Bartoshuk, 2000; Drewnowski, Henderson, & Shore, 1997; Looy & Weingarten, 1992), as well as early experience (Beauchamp & Moran, 1982, 1984), play a role in establishing such individual differences. For example, children who were fed

Correspondesce to: J. A. Mennella mennella@monell.org.

sweetened water during the first several months of life exhibited a greater preference for sweetened water at two years of age when compared to those who had little of no experience with sweetened water (Beauchamp & Moran, 1984). Through dietary experiences, children develop a sense of what foods should or should not taste sweet (Cowart & Beauchamp, 1986; Sullivan & Birch, 1990).

In comparison to sweet taste, much less is known about the ontogeny of sour taste preferences. Unlike the innate preference for sweet tastes (Desor, Maller, & Turner, 1977), newborns reject the sour taste of citric acid as evidenced by facial grimacing (Steiner, 1977) and reduced intake (Desor, Maller, & Andrews, 1975b). That experiences during infancy impact upon sour preferences during childhood is suggested by our recent study (Mennella & Beauchamp, 2002). In that study, we exploited the substantial flavor variation inherent in commercially available infant formulas—traditional milk-based formulas and those based on hydrolyzed proteins. Although each formula brand has its own characteristic flavor profile, milk-based formulas often are described as being slightly sweet and having “sour and cereal-type” aromas whereas protein hydrolysate formulas (e.g., Nutramigen, Alimentum) have an extremely unpalatable, offensive taste and “off” odor due primarily to its sourness and bitterness, perhaps because many amino acids taste sour or bitter (Cook & Sarett, 1982). When compared to children who had been fed milk-based formulas during their infancy, 4- to 5-year-old children who were fed protein hydrolysate formulas during the first year of life were significantly more likely to prefer sour-flavored (.04 *M* citric acid) apple juices and less likely to make negative facial responses during the taste tests. We suggest that the inherent variation in these two classes of formula provides a particularly apt model system to study the role of preweaning flavor experiences on later preference behaviors because these formulas differ profoundly in flavor and because exposure is frequent and repeated (Beauchamp & Mennella, 1998; Mennella & Beauchamp, 1996).

The present study was built upon these previous findings and was designed to determine whether early experience with hydrolysate formulas influences preferences for a wider range of sour-flavored (0–0.070 *M* citric acid) apple juices in 4- to 5-year-old as well as older aged (6- to 7-year-old) children. Preference for a range of sweetened apple juices also was assessed for two reasons. First, the addition of citric acid to apple juice not only enhances its sour taste but also suppress its sweetness (Schifferstein & Frijters, 1990). Therefore, heightened sour preferences may be secondary to diminished sweet preferences. Second, there have been reports in the literature that infants who are feeding, or have been fed, protein hydrolysate formulas have a reduced preference for sweet foods (MacDonald et al., 1994; Still et al., 1996.) As a first step in evaluating the role of maternal factors on children's flavor preferences, we also queried children and mothers individually about their habits and preferences.

SUBJECTS AND METHODS

Subjects

Mothers of 4- to 7-year-old children were recruited from advertisements in local newspapers. Four groups of children (N = 83; 42 girls, 41 boys) were formed based on their age (age groups: 4–5 years vs. 6–7 years) and early formula history (formula groups: milk formula vs. hydrolysate formula). There were no significant differences among the groups in the number of months that these children were fed formula during infancy, $F(1, 79) = 2.19$, $p = .14$. However, as expected, children in the hydrolysate group fed a milk- or soy-based formula during their first months (1.9 ± .4) of life and then, usually following their pediatrician's recommendation, were switched to hydrolysate until, on average, 11.8 (± .9) months of age. The vast majority of children in the hydrolysate group (83%) began this type of formula during the first 3 months of life. None of the children who were fed milk-based formulas were ever fed hydrolysate formulas.

All children were reported by their mothers to be healthy at the time of testing. Thirteen children were excluded because they could not understand the task. The procedures used in this study were approved by the Office of Regulatory Affairs at the University of Pennsylvania, and informed consent was obtained from each mother prior to testing.

Procedures

Children and their mothers were tested at the Monell Center on 2 days separated by 3.0 ± 0.5 days. Testing took place in a closed room specifically designed for sensory testing with a high air-turnover ventilation system. Each child sat at a small table designed for children. The mother, who was unaware of the hypothesis being tested, completed questionnaires about her child's feeding habits and preferences (discussed later) and sat approximately 2 ft behind the child, out of the child's view (see Mennella & Garcia, 2000). Mothers were asked to refrain from talking during the testing session, and replays of videotapes verified that they indeed did not talk during testing.

After the child acclimated to the room and personnel, we assessed the child's preference for sourness (0–0.070 *M* citric acid) during one test session and their preference for sweetness (.16–.93 *M* sucrose) during another. To this end, six solutions with different concentrations of citric acid (0, .007, .012, .022, .039, and .070 *M*) were made by dissolving citric acid (Sigma Chemical) in apple juice and six solutions which differed in sugar concentrations were made by either diluting the stock .34 *M* solution of apple juice (Mott's Inc., Stamford, CT) with water (.16 and .22 *M*) or by adding sucrose to the stock solution (.47, .66, and .93 *M*).

An age-appropriate, gamelike task that was fun for children and minimized the impact of language development were used to examine flavor preferences. Using a forced-choice procedure, each child was presented with all possible pairs of solutions (six solutions yield 15 possible pairs), one pair at a time, on each testing day. Ten ml of each stimuli were presented in identically colored opaque tumbler cups, containing a slit through which the child could sip its contents without seeing the color of the solution presented. The child was asked to taste each solution of the pair and to point to which of the pair he or she liked better. The order of presentation of the solutions was randomized within and between each pair. A 10-sec interval separated each pair of solutions, and a 5-min interval separated the tasting of the first eight pairs from the last seven pairs. During these intervals, children were offered a sip cup containing water and a small unsalted cracker to cleanse their palate.

Mothers completed a 10-item scale that measured their food neophobia, an 8-item scale that measured general neophobia (Pliner & Hobden, 1992), and a 25-item scale that measured temperament and food neophobia in their children (Pliner & Loewen, 1997). All but four of the mothers completed the temperament scales. They also were asked to indicate how often they added sugar to their child's diet and whether they perceived their child as a picky eater. Without communicating to the child, each mother was asked to write down their child's favorite cereals and candies. It should be noted that mothers completed this task before their child answered similar questions: “What is your favorite cereal (or candy) in the whole world?” and “Which cereal (or candy) do you ask your mom to buy the most?” All but four of the children were able to answer these questions. Mother–child agreement was 65% for the child's most favorite cereal and 54% for their favorite candy. The sugar content (g/100 g) of these cereals then was determined.

Statistical Analyses

Separate ANOVAs were conducted to determine whether there were significant differences between the groups on the age, body mass index (BMI: mass (kg)/height $(m)^2$, and temperament scores of the children as well as the age and variety seeking (with regards to foods), and food

and general neophobia scores of the mother. Least significant difference analyses were performed to investigate significant effects. Pearson chi-squares were performed to determine whether there were group differences in ethnicity, proportion of girls to boys, and the mothers' habit of adding sugar to their children's diet (e.g., those who never vs. those who frequently added sugar to their child's diet).

To determine whether early experience was related to sour preferences, we determined the number of times (of 10) each child preferred the two most sour juices (.04 and .07 *M* citric acid) as "tasting better." Please recall that our previous findings revealed that children who were fed hydrolysates were more likely to prefer sour apple juice (.04 *M*). Similarly, we also determined the number of times (of 15) that each child preferred the apple juices with added sugar (.47, .66, and .93 *M* sucrose). To determine whether there were significant differences in sweet and sour preferences between the groups, separate ANOVAs were conducted with age group (4–5 vs. 6–7 years) and formula history (milk vs. hydrolysate) as the between-subject variables. Finally, to determine whether preference for sweetness in juices was related to preference for sweetness in cereal, a multiple regression was performed between the average sugar concentration of the child's most favorite cereals and the number of times children preferred the apple juices with the added sugar. All summary statistics are expressed as means ± SEM.

RESULTS

Subject Characteristics

Salient characteristics of the four groups of children and their mothers are listed in Table 1. For those children who were 4 to 5 years of age, there was no significant difference between the formula groups (milk vs. hydrolysate) in their age: $F(1, 37) = 1.26$, $p = 0.27$, BMI (kg/m^2): $F(1, 37) = 0.51$, $p = 0.48$, the proportion of girls to boys: $\chi^2(1) = 0.02$, $p = 0.88$, or the age of the mothers: $F(1, 37) = 1.13$, $p = 0.30$. Likewise, there were no significant differences between the formula groups for those who were 6 to 7 years of age on any of these measures, children's age: $F(1, 41) = 0.07$, $p = 0.80$, BMI: $F(1, 41) = 0.18$, $p = 0.68$, sex ratio: $\chi^2(1) = 0.10$, $p = 0.76$, or mothers' age: $F(1, 42) = 3.77$, $p = 0.06$. However, the two formula groups did differ in their ethnicity, $\chi^2(2) = 6.53$, $p < 0.04$. That is, significantly more subjects in the hydrolysate group were Caucasian and less were African American (77% Caucasian, 17% African-American, 6% Other) when compared to those who were fed milk formulas (44% Caucasian, 52% African-American, 4% Other). However, there was no main effect of ethnicity on any of the outcome variables examined (*ps* > .05).

With regards to child temperament measures, there were no significant interactions between age or formula-history groups on the children's negative reactions to foods, $F(1, 76) = 1.98$, $p = .16$, or emotionality, $F(1, 79) = 1.02$, $p = .32$, nor was there a significant difference in the percentage of mothers who reported that their child was a picky eater (Fisher's exact $p = .36$). However, there was a significant interaction between age and formula-history groups on children's shyness, $F(1, 78) = 4.62$, $p < .05$, sociability, $F(1, 78) = 11.42$, $p < .01$, and activity levels, $F(1, 79) = 4.70$, $p < .05$. Post hoc analyses revealed that 4- to 5-year-old children who were fed hydrolysate formulas were perceived by their mothers as being less social ($p < .05$) and less active ($p < .05$), and tended to be perceived as more shy ($p = .05$) when compared to 6- to 7-year-old children who were fed similar formulas. In contrast, younger aged children who were fed milk-based formulas were perceived by their mothers as being more social ($p < 0.05$) when compared to older aged children who were fed similar formulas. Further analyses of the children's temperament revealed no significant main effect of child's temperament on any of the outcome variables examined (*ps* > .05).

For mothers' eating habits, there was no significant interaction between age and formula-history groups on the mothers' variety-seeking behavior to foods: $F(1, 78) = .02$, $p = .90$, food neophobia: $F(1, 76) = .03$, $p = .90$, or general neophobia: $F(1, 76) = 1.90$, $p = .17$, as determined by questionnaires nor were there differences between the groups in the mothers' habit of adding sugar (Fisher's exact $p > .05$) to their children's foods.

Effect of Early Experience and Age on Sour Preferences

As seen in Figure 1, there was a significant interaction between age group (4–5 vs. 6–7 years) and formula group (milk vs. hydrolysate) in the children's preference for the extreme sour juices, $F(1, 79) = 4.91$, $p < .05$. That is, children who were 4 to 5 years of age and fed hydrolysate formulas during their infancy preferred these sour juices significantly more than did older children who were fed similar formulas, $F(1, 33) = 5.81$, $p < .05$. No such age-related difference was observed in children who were fed milk-based formulas during infancy, $F(1, 46) = .54$, $p = .50$.

Effect of Early Experience and Age on Sweet Preferences

Unlike that observed for sour preference, there was no significant interaction between age group and formula group in their preference for sweetened juices, $F(1, 79) = .10$, $p = .76$ (Figure 2). That is, children of both age groups and early feeding history were significantly more likely to prefer the juices with added sugar ($ps < .001$). Moreover, there was no significant interaction between the groups in the sugar content of the children's favorite cereals, $F(1, 75) = .63$, $p = .43$, which was, on average, 30.6 + 1.5 g/100 g.

Because there were no significant differences of age or formula-history groups on the mothers' habit of adding sugar to their child's foods, children were divided into two groups: those whose mothers reported that they never added sugar to their foods (n = 29) versus those whose mother did so on a routine basis (n = 51) to further investigate whether maternal behaviors are related to children's preferences. Table 2 reveals that children whose mothers reported adding sugar to their foods on a routine basis were significantly more likely to prefer apple juices with added sugar, $F(1, 78) = 4.68$, $p < .05$, and reported that they preferred a cereal with a significantly higher sugar content, $F(1, 74) = 6.02$, $p < .05$, when compared to children whose parents reported that they never added sugar to their children's foods. The mothers who added sugar also were more likely to be African Americans, $\chi^2(2) = 17.06$, $p < .0001$, and were older in age, $F(1, 78) = 11.03$, $p < .001$, when compared to mothers who never added sugar to their child's diet.

DISCUSSION

This study expands upon our previous findings and demonstrates that the type of formula fed during infancy influences sour, but not sweet, preferences several years after the last exposure to the formula. However, these effects were only observed when children were 4 to 5 years of age. In other words, children who were fed protein hydrolysate formulas, which have distinctive sour and bitter tastes and unpleasant odors, preferred higher levels of citric acid in juice when compared to 6- to 7-year-old children who were fed hydrolysate formulas. Because there was no significant difference in sweet preference between the groups, the preference for the more sour juices (which also were less sweet) in the younger children does not appear to be due to a reduced sweet preference.

Why were the effects of early experience not seen in the older children? It is unlikely that the enhanced sour preference in the younger children was due to a poorer ability to perform the sensory tests. The pair-wise comparison test has been frequently used to determine preference and discriminatory ability in young children (Birch & Marlin, 1982; Kimmel, Sigman-Grant,

& Guinard, 1994; Leon, Couronne, Marcuz, & Koster, 1999). Moreover, there were no age-related differences in the level of sweetness preferred, which was determined by procedures identical to those used for determining sour preferences.

We hypothesize that the observed shift in sour preference in those children who were fed hydrolysate during infancy was due to the older children's more expanded experience with foods and flavors (Nicklas, 1995) which, in turn, leads to learning the appropriate level and context of sour taste in different foods. On the other hand, we hypothesize that the heightened preference for sour tastes would persist with continued exposure to hydrolysate formula. Consistent with this hypothesis is the report that adolescent patients with phenylketonuria who were fed a type of protein hydrolysate formula (which is specifically treated with charcoal to remove most of the phenylalanine) throughout childhood and adolescence reported that one of their most preferred flavors, which was often added to the formulas, was lemon (Hogan, Gates, MacDonald, & Clark, 1986).

Because we did not randomly assign children to groups (parents decided which formulas they would feed their infants.), this was not a strict experimental study. Nonetheless, we attempted to match the groups as closely as possible to maximize the probability that any group differences were due only to differences in early formula-feeding experiences. Because there were no significant differences among the groups in the mothers' variety-seeking scores or food-neophobia scores, the differences observed in the children's behavioral responses to the sour flavor were unlikely to bedue to the mothers' eating habits or attitudes toward foods.

There were significant age-related differences with temperament. Four- to five-year-old children who were fed hydrolysate formulas were perceived by their mothers as being less social and less active when compared to 6- to 7-year-old children who were fed similar formulas. Despite the paucity of research on sour taste preference, a recent study on sweet taste preference suggested that young adults who scored high on arousability and pleasure gave higher intensity ratings to a sweet solution under mild stress conditions when compared to those who scored low on these temperament scores (Dess & Edelheit, 1998). However, despite the significant age-related differences in temperament observed in the present study, no significant main effect of child temperament was observed for any of the outcome variables.

Are mothers of young children who were on hydrolysate more likely to perceive their children differently? Of interest here is the finding that mothers who switched their children's formula during infancy because of feeding problems were more likely to perceive their 3.5-year-old children as more vulnerable several years after last exposure to the formula, despite no observed difference in the children's personalities or incidence of asthma or eczema (Forsyth & Canny, 1991). Recall that every mother in the hydrolysate group switched her child's formula during infancy. Forsyth and Canny (1991) suggested that the mere experience of changing formula during early infancy has long-term effects on mother–infant interaction and perceptions. Nevertheless, controlled experimental studies in which these formulas are introduced at differing ages and in which later preferences and temperament are determined by examining the child directly and not by maternal reports are needed for confirmation. Such studies are ongoing in our laboratories.

The findings from the present study also indicate that, at least for cereals, it is possible to relate sweet preference as measured in a laboratory setting to preferences for sweets in everyday foods such as cereals, as reported by the child. That experience influences sweet preferences is suggested by the finding that children whose mothers routinely added sugar to their diet preferred higher levels of sugar in apple juice and cereals when compared to children whose mothers reported never adding sugar. Such findings are consistent with previous research demonstrating that experience with sweetened water during infancy resulted in higher

preferences for sweetened water at 2 years of age (Beauchamp & Moran, 1982, 1984) and that preference for sweet taste, as assessed by psychophysical methods, is related to carbohydrate intake in healthy adults (Mattes & Mela, 1986).

To be sure, mothers have an important influence on their children's diet (Fisher & Birch, 1999), such as the types of foods eaten (Klesges, Stein, Eck, Isbell, & Klesges, 1991) and frequency of exposure to sweet foods (Ritchey & Olson, 1983). However, these data underscore the importance of obtaining such information from the child directly because parents are not always reliable sources of this type of information. For example, mothers may be more accurate in identifying their child's favorite cereal when compared to candy because parents do most of the cereal purchasing. In conclusion, the findings of the present study illustrate the wide variety of experiential factors that can influence flavor preferences during childhood and highlight the importance of assessing children's preferences directly. The goal of our research program is to identify the early experiences that influence why we like the foods we do.

Acknowledgments

We acknowledge the expert technical assistance of Brian Pollack, Saadia Khan, Mayla Henderson, and Lamoy Morgan. This work was supported by Grant HD37119 from the National Institute of Child Health and Human Development. The research reported in this article was completed as part of the first author's dissertation in the Department of Human Nutrition and Epidemiology, Wageningen University, The Netherlands.

REFERENCES

Bartoshuk LM. Comparing sensory experiences across individuals: Recent psychophysical advances illuminate genetic variation in taste perception. Chemical Senses 2000;25:447–460. [PubMed: 10944509]

Beauchamp, GK.; Cowart, BJ. Development of sweet taste.. In: Dobbing, J., editor. Sweetness. Springer-Verlag; Berlin: 1987. p. 127-138.

Beauchamp, GK.; Mennella, JA. Annales Nestlé, Nestlé Nutrition Workshop Series. Vol. 56. Nestec; Raven Press; Vevey, Switzerland: New York: 1998. Sensitive periods in the development of human flavor perception and preference; p. 19-31.

Beauchamp GK, Moran M. Dietary experience and sweet taste preference in human infants. Appetite 1982;3:139–152. [PubMed: 7137993]

Beauchamp GK, Moran M. Acceptance of sweet and salty tastes in 2-year-old children. Appetite 1984;5:291–305. [PubMed: 6529258]

Bellisle F, Dartois A-M, Kleinknecht C, Broyer M. Perception of and preference for sweet taste in uremic children. Journal of the American Dietetic Association 1990;90:951–954. [PubMed: 2365936]

Birch LL, Marlin DW. I don't like it; I never tried it; Effects of exposure on two-year-old children's food preferences. Appetite 1982;3:353–360. [PubMed: 7168567]

Cook, DA.; Sarett, HP. Design of infant formulas for meeting normal and special need.. In: Lifshitz, F., editor. Pediatric nutrition: Infant feeding, deficiencies, disease. Marcel Dekker; New York: 1982. p. 71-85.

Cowart, BJ.; Beauchamp, GK. Factors affecting acceptance of salt by human infants and children.. In: Kare, MR.; Brand, JG., editors. Interaction of the chemical senses with nutrition. Academic Press; New York: 1986. p. 25-44.

Darwin CH. A biographical study of a young child. Kosmos 1877;1:367–376.

De Graat C, Zandstra EH. Sweetness intensity and pleasantness in children, adolescents, and adults. Physiology & Behavior 1999;67:513–520. [PubMed: 10549887]

Desor JA, Beauchamp GK. Longitudinal changes in sweet preferences in humans. Physiology & Behavior 1987;39:639–641. [PubMed: 3588712]

Desor JA, Green LS, Maller O. Preference for sweet and salty in 9- to 15-year-old and adult humans. Science 1975a;190:686–687. [PubMed: 1188365]

Desor JA, Maller O, Andrews K. Ingestive responses of human newborns to salty, sour, and bitter stimuli. Journal of Comparative and Physiological Psychology 1975b;89:966–970. [PubMed: 1184802]

Desor, JA.; Maller, O.; Turner, RE. Preference for sweet in humans: Infants, children, and adults.. In: Weiffenbach, JM., editor. Taste and development: The genesis of sweet preference. U.S. Government Printing Office; Washington, DC: 1977.

Dess NK, Edelheit D. The bitter with the sweet: The taste/stress/temperament nexus. Biological Psychology 1998;48:103–119. [PubMed: 9700013]

Drewnowski AD, Henderson SA, Shore AB. Genetic sensitivity to 6-n-propylthiouracil (PROP) and hedonic responses to bitter and sweet tastes. Chemical Senses 1997;22:27–37. [PubMed: 9056083]

Enns MP, Itallie TB. Contribution of age, sex, and degree of fatness on preferences and magnitude estimations for sucrose in humans. Physiology & Behavior 1979;22:999–1003. [PubMed: 504405]

Fisher JO, Birch LL. Restricting access to palatable foods affects children's behavioral response, food selection, and intake. American Journal of Clinical Nutrition 1999;69:1264–1272. [PubMed: 10357749]

Forsyth BWC, Canny PF. Perceptions of vulnerability 3.5 years after problems of feeding and crying behavior in early infancy. Pediatrics 1991;88:757–763. [PubMed: 1896279]

Hogan SE, Gates RD, MacDonald GW, Clark JTR. Experience with adolescents with phenylketonuria returned to phenylalanine-restricted diets. Journal of the American Dietetic Association 1986;86:1203–1207. [PubMed: 3745744]

Jamel HA, Sheiham A, Watt RG, Cowell CR. Sweet preference, consumption of sweet tea, and dental caries: Studies in urban rural Iraqi population. International Dental Journal 1997;47:213–217. [PubMed: 9532462]

Kimmel SA, Sigman-Grant M, Guinard JX. Sensory testing with young children. Food Technology 1994:92–99.

Klesges RC, Stein RJ, Eck LH, Isbell TR, Klesges LM. Parental influence on food selection in young children and its relationship to childhood obesity. American Journal of Clinical Nutrition 1991;53:859–864. [PubMed: 2008864]

Leon F, Couronne T, Marcuz MC, Koster EP. Measuring food liking in children: A comparison of nonverbal methods. Food Quality and Preference 1999;10:93–100.

Looy H, Weingarten HP. Facial expressions and genetic sensitivity to 6-n-propylthiouracil predict hedonic response to sweet. Physiology & Behavior 1992;52:75–82. [PubMed: 1529017]

MacDonald A, Rylance GW, Asplin DA, Hall K, Harris G, Booth IW. Feeding problems in young PKU children. Acta Paediatrica Supplement 1994;407:73–74. [PubMed: 7766964]

Maller, O.; Desor, JA. Effect of taste on ingestion by human newborns.. In: Bosma, JF., editor. Fourth Symposium on Oral Sensation and Perception: Development of the fetus and infant. U.S. Government Printing Office; Washington, DC: 1973. p. 279-291.DHEW Publication No. NIH 73–546

Mattes RD, Mela DJ. Relationships between and among selected measures of sweet-taste preference and dietary intake. Chemical Senses 1986;4:523–539.

Mennella JA, Beauchamp GK. Developmental changes in the infants' acceptance of protein-hydrolysate formula and its relation to mothers' eating habits. Journal of Developmental and Behavioral Pediatrics 1996;17:386–391. [PubMed: 8960567]

Mennella JA, Beauchamp GK. Flavor experiences during formula feeding are related to preferences during childhood. Early Human Development 2002;68:71–82. [PubMed: 12113993]

Mennella JA, Garcia PL. Children's hedonic response to the smell of alcohol: Effects of parental drinking habits. Alcoholism—Clinical and Experimental Research 2000;24:1167–1171.

Nicklas TA. Dietary studies of children and young adults (1973–1988): The Bogalusa heart study. American Journal of Medical Sciences 1995;310:S101–S108.

Nilsson B, Holm A-K. Taste threshold, taste preference, and dental caries in 15-year-olds. Journal of Dental Research 1983;62:1069–1072. [PubMed: 6578237]

Nisbett RE, Gurwitz SB. Weight, sex, and the eating behavior of human newborns. Journal of Comparative and Physiological Psychology 1970;73:245–253. [PubMed: 5493265]

Peiper, A. Consultants Bureau; New York: 1963. Cerebral function in infancy and childhood. B. Nagler & H. Nagler(Original work published 1961)

Pliner P, Hobden K. Development of a scale to measure the trait of food neophobia in humans. Appetite 1992;19:105–120. [PubMed: 1489209]

Pliner P, Loewen ER. Temperament and food neophobia in children and their mothers. Appetite 1997;28:239–254. [PubMed: 9218097]

Ritchey N, Olson C. Relationship between family variables and children's preference for and consumption of sweet foods. Ecology of Food and Nutrition 1983:257–266.

Schifferstein HNJ, Frijters JER. Sensory integration in citric acid/sucrose mixtures. Chemical Senses 1990;15:87–109.

Steiner, JE. Facial expressions of the neonate infant indication the hedonics of food-related chemical stimuli.. In: Weiffenbach, JM., editor. Taste and development: The genesis of sweet preference. U.S. Government Printing Office; Washington, DC: 1977. p. 173-188.

Still S, Little SA, Pollard C, Bevin S, Hourihane JO'B, Harris G, Warner JO, Dean TP. Comparison of taste preference development between breastfed infants and infants receiving standard, soy, or hydrolysate formulas. Journal of Clinical Immunology 1996;A232:240.

Sullivan SA, Birch LL. Pass the sugar, pass the salt: Experience dictates preference. Developmental Psychobiology 1990;26:546–551.

Tomita NE, Nadanovsky P, Vieira AL, Lopes ES. Taste preferences for sweet and caries prevalence in preschool children. Revista de Saúde Pública 1999;33:542–546.

Vazquez M, Pearson PB, Beauchamp GK. Flavor preferences in malnourished Mexican infants. Physiology & Behavior 1982;28:513–519. [PubMed: 6804997]

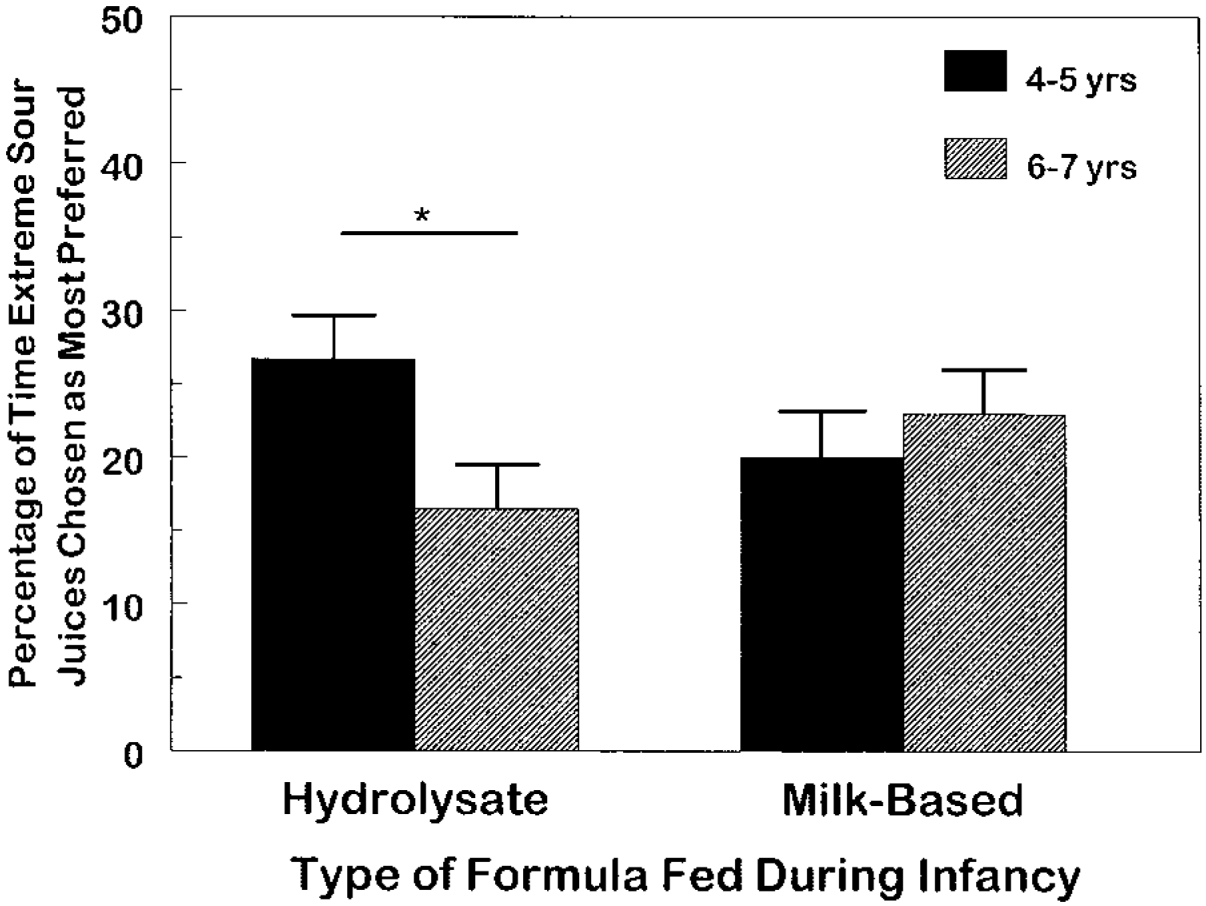

FIGURE 1.

The percentage of time that 4- to 5-year-old children (solid bars) and 6- to 7-year-old children (hatched bars) preferred the two most sour juices (.04 and .07 *M* citric acid) as "tasting better." The groups differed in the type of formula (i.e., milk, hydrolysate) that the children were fed during infancy. There was a significant interaction between age group (4–5 vs. 6–7 years) and formula group (milk vs. hydrolysate) in the children's preference for the extreme sour juices. *Children who were 4 to 5 years of age and fed hydrolysate formulas during their infancy preferred these sour juices significantly more than did older children who were fed similar formulas ($p < .05$).

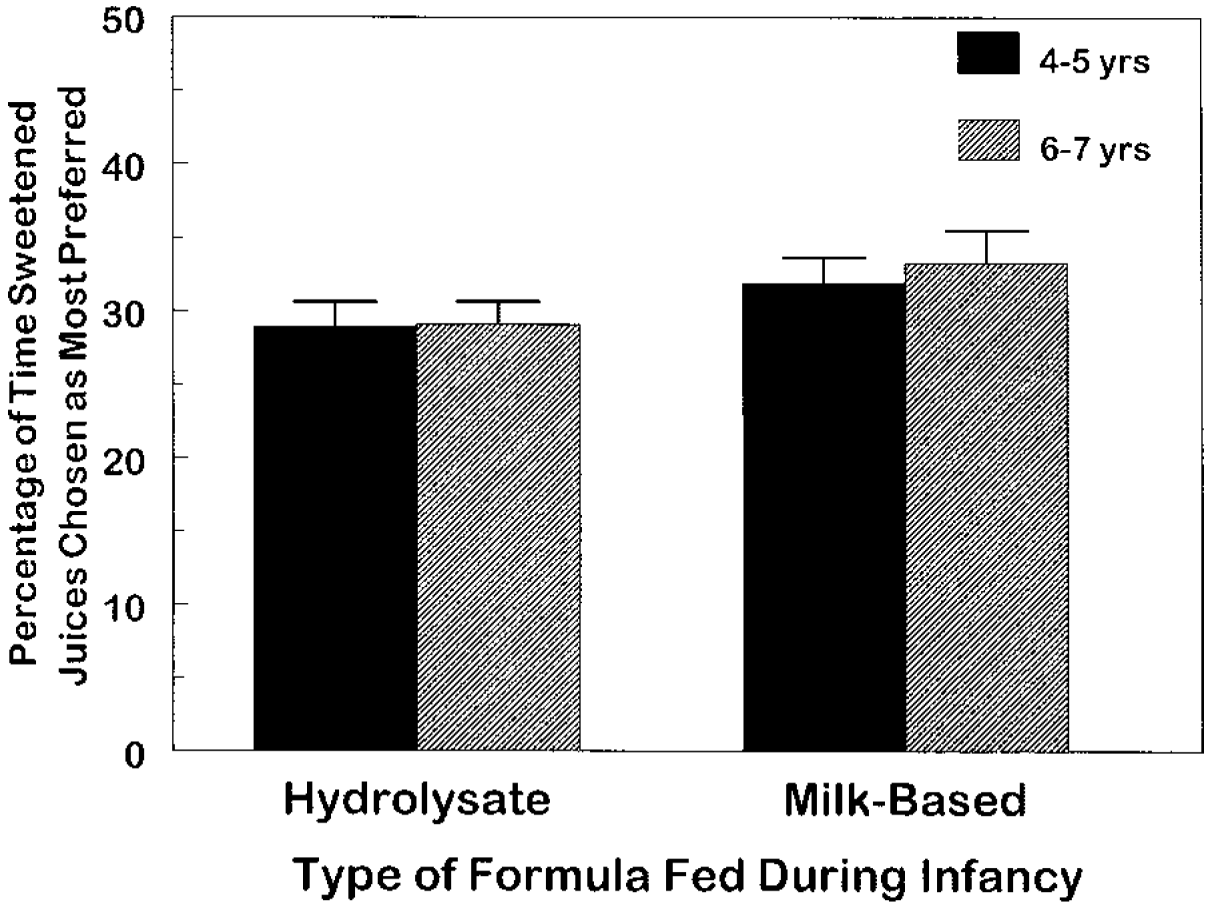

FIGURE 2.

The percentage of time that 4- to 5-year-old children (solid bars) and 6- to 7-year-old children (hatched bars) preferred the apple juices with added sugar (.47, .66, and .93 *M* sucrose) as "tasting better." The groups differed in the type of formula (i.e., milk, hydrolysate) that the children were fed during infancy. There was no significant interaction between age group and formula group in the children's preference for sweetened juices.

Table 1

Subject Characteristics and Type of Formula Children Were Fed During Infancy

Characteristics	Group I		Group 2	
	Milk-Based Formula		Hydrolysate Formula	
Age range (yr)	4–5	6–7	4–5	6–7
Age (yr)	5.5±0.1	6.8±0.1	5.4±0.1	6.9±0.1
Sex F/M	11/10	14/13	9/9	8/9
Body Mass Index (kg/m^2)	16.6±0.6	16.1±0.6	16.7±0.5	17.2±0.5
Child temperament measures[a]				
Shyness[b]	2.3±0.2	2.5±0.2[c]	2.6±0.2	1.9±0.2
Emotionality	2.9±0.2	2.7±0.2	2.9±0.2	3.1±0.2
Sociability[b]	3.8±0.1	3.4±0.1[c]	3.3±0.2	3.8±0.2[d]
Negative reactions to food	3.2±0.2	3.1±0.2	3.0±0.2	3.5±0.2
Activity[b]	4.2±0.2	4.0±0.1[c]	3.5±0.2	4.0±0.1
Percentage of mothers reporting That Their child is picky eater	47.6	51.9	44.4	64.7
No. Mother–child pairs	21	27	18	17

[a] Measures ranged from 1–5; 1 = not at all characteristic of the child; 5 = very characteristic of the child. All summary statistics are expressed as mean ± *SEM*.

[b] Significant age (4–5, 6–7 years) by formula (milk, hydrolysate) group interaction; $p < 0.05$.

[c] Significantly different from 4–5 hydrolysate group.

[d] Significantly different from 4–5 milk group.

Table 2

Mother's Habit of Adding Sugar to Child's Food: Subject Characteristics and Preference

	Does Mother Add Sugar to Child's Food?	
	Frequently	**Never**
Children's age (yr)	6.2±0.1	6.2±0.2
Ethnicity (%)[a]		
African American	47%	3.5%
Caucasian	47%	93%
Other	6%	3.5%
Mother's age (yr)	34.1±0.8	38.3±1.0[b]
Children's Body Mass Index (kg/m^2)	16.3±0.4	17.0±0.4
No. times (of 15) that child preferred apple juices with added sugar	9.6±0.32	8.4±0.47[a]
Sugar content of favorite cereals (g/100g)	32.9±1.7	25.2±2.8[a]
No. mother–child pairs	51	29

[a] $p < 0.05$

[b] $p < 0.001$.