United States Department of Agriculture

Influence of Maternal Diet on Flavor Transfer to Amniotic Fluid and Breast Milk and Children's Responses: A Systematic Review

The Pregnancy and Birth to 24 Months Project

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Nutrition Evidence Systematic Review
Center for Nutrition Policy and Promotion
Food and Nutrition Service
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This systematic review was conducted by the Nutrition Evidence Systematic Review (NESR) team at the Center for Nutrition Policy and Promotion, Food and Nutrition Service, USDA. This systematic review was completed for the Pregnancy and Birth to 24 Months Project (P/B-24 Project). All systematic reviews from the P/B-24 Project are available on the NESR website: https://nesr.usda.gov.

Conclusion statements drawn as part of these systematic reviews describe the state of science related to the specific question examined. Conclusion statements do not draw implications, and should not be interpreted as dietary guidance.

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- **P/B-24 Project overview:** Stoody EE, Spahn JM, Casavale KO. The Pregnancy and Birth to 24 Months Project: a series of systematic reviews on diet and health. *Am J Clin Nutr*. 2019;109(7):685S–97S. doi: 10.1093/ajcn/nqy372.
- **P/B-24 systematic review methodology:** Obbagy JE, Spahn JS, Psota TL, Spill MK, Dreibelbis C, Gungor DE, Nadaud PN, Raghavan R, Callahan EH, English LK, Kingshipp BJ, Lapergola CC, Shapiro MJ, Stoody EE. Systematic review methodology used in the Pregnancy and Birth to 24 Months Project. Am J Clin Nutr 2019;109(7):698S–704S. doi: 10.1093/ajcn/nqy226.
- **Related systematic reviews from the P/B-24 Project:**

- Spill MK, Johns K, Callahan EH, Shapiro MJ, Wong YP, Benjamin-Neelon SE, et al. Repeated exposure to food and food acceptability in infants and toddlers: a systematic review. Am J Clin Nutr. 2019;109(7):978S–89S. doi: 10.1093/ajcn/nqy308.
- Spill MK, Callahan EH, Shapiro MJ, Spahn JM, Wong YP, Benjamin-Neelon SE, et al. Caregiver feeding practices and child weight outcomes: a systematic review. Am J Clin Nutr. 2019;109(7):990S–1002S. doi: 10.1093/ajcn/nqy276.

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INTRODUCTION

This document describes two systematic reviews conducted to answer the following questions:

- What is the relationship between maternal diet during pregnancy on flavor transfer to amniotic fluid, child's behavioral response, and dietary intake (0-24 months, 24+ months)?
- What is the relationship between maternal diet during lactation on flavor transfer to breast milk, child's behavioral response, and dietary intake (0-24 months, 24+ months)?

These systematic reviews were conducted as part of the Pregnancy and Birth to 24 Months (P/B-24) Project by USDA's Nutrition Evidence Systematic Review (NESR).

The purpose of the P/B-24 Project was to conduct a series of systematic reviews on diet and health for women who are pregnant and for infants and toddlers from birth to 24 months of age. This project was a joint initiative led by USDA and HHS, and USDA's NESR carried out all of the systematic reviews. A Federal Expert Group (FEG), a broadly representative group of Federal researchers and program leaders, also provided input throughout the P/B-24 Project. More information about the P/B-24 Project has been published[ii] and is available on the NESR website: https://nesr.usda.gov/project-specific-overview-pb-24-0.

NESR, formerly known as the Nutrition Evidence Library (NEL), specializes in conducting food- and nutrition-related systematic reviews using a rigorous, protocol-driven methodology. To conduct each P/B-24 systematic review, NESR's staff worked with a Technical Expert Collaborative (TEC), which is a group of 7–8 leading subject matter experts.

NESR's systematic review methodology involves developing and prioritizing systematic review questions, searching for and selecting studies, extracting and assessing the risk of bias of data from each included study, synthesizing the evidence, developing a conclusion statement, grading the evidence underlying the conclusion statement, and recommending future research. A detailed description of the methodology used in conducting systematic reviews for the P/B-24 Project has been published[iii] and is available on the NESR website: https://nesr.usda.gov/pb-24-project-methodology-0. In addition, starting on page 91, this document includes details about the methodology as it was applied to the systematic reviews described herein. An analytic framework that illustrates the overall scope of the question, including the population, the interventions and/or exposures, comparators, and

[ii] Stoody EE, Spahn JM, Cassavale KO. The Pregnancy and Birth to 24 Months Project: a series of systematic reviews on diet and health. Am J Clin Nutr. 2019;109(7):685S-697S. doi:10.1093/ajcn/nqy372

[iii] Obbagy JE, Spahn JS, Psota TL, Spill MK, Dreibelbis C, Gungor DE, Nadaud PN, Raghavan R, Callahan EH, English LK, Kingshipp BJ, Lapergola CC, Shapiro MJ, Stoody EE. Systematic review methodology used in the Pregnancy and Birth to 24 Months Project. Am J Clin Nutr. 2019;109(7):698S–704S. doi: 10.1093/ajcn/nqy226

outcomes of interest, is found on page 99. In addition, the literature search plan, that was used to identify studies included in this systematic review is found on page 99.

List of abbreviations

Abbreviation	Full name
BF	Breastfed or breastfeeding
FEG	Federal Expert Group
HHS	Department of Health and Human Services
NEL	Nutrition Evidence Library
NESR	Nutrition Evidence Systematic Review
NIH	National Institutes of Health
P/B-24	Pregnancy and Birth to 24 Months Project
PICO	Population, Intervention or independent variable, Comparison, Outcome
RCT	Randomized controlled trial
TEC	Technical Expert Collaborative
US	United States of America
USDA	United States Department of Agriculture

Flavor is a combination of tastes and odors

Understanding the findings from this body of research requires an understanding of the terms ‘flavor’ and ‘volatiles’. The flavor of a food (which is often misinterpreted as the ‘taste of food’) is a complex combination of tastes (sweet, sour, salty, bitter, umami), textures, and volatile odors which travel to the olfactory receptors when foods or liquids are in the mouth via the retronasal pathway[1]. These odor volatiles can also be detected when inhaling through the nose, commonly referred to as orthonasal olfaction.

Odor volatiles contribute the most to the overall characteristics of the flavor of a food or beverage. While we refer to a particular flavor using a single term (e.g., garlic), it is important to note that every flavor is the consequence of a large number of chemical compounds in its volatile fraction (hence the term flavor volatiles); and, many foods and beverages which are distinct in their ‘taste’, share volatiles. For example, caraway and spearmint contain a common volatile, carvone, and anise and fennel contain a common volatile, anethole.

Measuring sensory responses to a flavor, from a child or adult, can be assessed when eating, through the retronasal perception of flavor volatiles, or when smelling, through the orthonasal perception of volatiles, or both. For the systematic reviews related to amniotic fluid and the review related to breast milk flavor, because they are bodily fluids, sensory panelists did not taste either, but evaluated whether its odor changed based on maternal ingestion. In one case, mothers blindly tasted their own milk samples to evaluate which milk samples tasted different based on time since flavor ingestion.

A complex question: flavor transmittance, detection, and infant response

To address the systematic review questions related to maternal diet during pregnancy and lactation, amniotic fluid and breast milk flavor, and child’s behavioral response to the flavor and child’s dietary intake, there are three levels of experimental evidence that were explored.

First, studies aimed to determine whether volatiles contained in the foods and beverages of the maternal diet transfer to and flavor amniotic fluid or breast milk. This was determined using chemical or adult sensory analyses of amniotic fluid or breast milk samples after maternal ingestion of a particular food or flavor. To determine whether there is a time-dependent nature to the transmittance of flavor, in some studies milk samples were collected before and at fixed intervals after maternal ingestion of a food or beverage containing those flavor volatiles. As part of the experimental design and rigor, in many studies mothers were put on bland diets that avoid a particular flavor prior to the study to ensure that the volatiles were absent in the baseline sample. Both analytic and sensory tests can indicate if volatiles of a flavor are present in amniotic fluid or breast milk; however, sensory analysis also demonstrates that the flavor is at a concentration level which is detectable by the human olfactory and taste systems.

Second, studies aimed to determine whether experiences with flavors in amniotic fluid or breast milk bias the child’s subsequent responses to the particular flavor. Often a

control odor/flavor was included to assess normal olfactory functioning or relative acceptance. The acceptance behaviors were appetitive in nature (or alternatively non-appetitive/aversive) and were measured during smelling when the volatiles are perceived orthonasally (e.g., head orientation toward, mouthing facial expressions of liking) or during feeding when the volatiles are perceived retronasally (e.g., facial expressions, length of feeding, amount consumed, and mother's perception of infant enjoyment during feeding). Comparisons with response to a control odor or food or control group often yield differential/relative responses. A differential response (or differences when compared to a control group) when the child is re-exposed to flavors ingested by the mother during pregnancy indicates that the human fetus was able to detect and store chemosensory information about the flavors of maternal diet in the prenatal environment. Similarly, a differential response by the infant or child when re-exposed to flavors ingested by the mother during lactation indicates that the child was able to detect and store chemosensory information about the flavor of the maternal diet during breastfeeding. Manipulating the timing of the maternal diet (and hence the timing of the flavor exposure during development) was done in some studies to determine whether the recency of flavor experience relative to testing matters, and/or whether there is a time period when the flavor experience occurs, independent of recency, that may have a stronger influence on acceptance.

Third, studies aimed to determine whether experiences with the flavors of the maternal diet in amniotic fluid or breastmilk impact the patterning and quality of the child's diet years later. This question poses serious methodological challenges because it is impossible to isolate the impact of flavor experiences only from maternal diet during pregnancy or only from maternal diet during lactation. Mothers' diet during pregnancy is related to her diet postnatally, and thus the infants can be exposed to flavors in both amniotic fluid and breastmilk. Also, a child's diet is typically a reflection of the mother's diet because she feeds her child what she eats; therefore, maternal report of child's dietary intake is not a good proxy for the child's food preferences.

In summary, these systematic reviews include studies that examine the relationship between maternal diet during pregnancy and lactation, amniotic fluid and breast milk flavor, and child's behavioral response to the flavor and child's dietary intake based on the following assessment methods:

Chemical analysis (analytic measures)

- To determine if volatiles from flavors ingested by a woman transfer to her amniotic fluid or breast milk
- Assessments quantify the concentration of flavor volatiles in amniotic fluid or breast milk
- Does not indicate if concentration level is detectable by human sensory system
- Commonly used method: gas chromatography-mass spectrometry (GC-MS)
- Commonly used approach: mothers maintain a bland diet devoid of the volatiles several days before the test session to ensure that baseline milk sample is devoid of the flavor volatiles under study and then milk samples are collected immediately before and at fixed intervals after ingestion

Adult sensory analysis

- To determine if volatiles from flavors ingested by a woman transfer to her amniotic fluid or breast milk at a concentration level that is detectable by the human sensory system; if detected by adults, it is likely that volatiles can be detected by the infant/fetus sensory system
- Tested using established psychophysical methods by having an adult sensory panel blindly evaluate the odor of amniotic fluid or human milk samples (orthonasal olfaction); to assess odor in breast milk samples, samples are collected from each mother before and at fixed intervals (0.5-8 hours) after ingestion of the flavor to determine whether and, if so, when a sensory change in the milk is detectable. In one study mothers tasted samples of their own milk collected at fixed intervals after ingestion (retronasal olfaction) and results were compared with that obtained from adult sensory panel[2]
- Commonly used approach: mothers maintain a bland diet devoid of the volatiles several days before the test session to ensure that baseline milk sample is devoid of the flavor volatiles under study and then milk samples are collected immediately before and at fixed intervals after ingestion

Infant behavioral response to odor volatiles/flavor

- The research aims to determine whether infants or children, whose mothers ingested a food or beverage containing distinct flavors during pregnancy or lactation, detected the flavor in amniotic fluid or breast milk, respectively, as evidenced by more appetitive responses during exposure to the flavor when compared to infants or children whose mothers did not ingest the flavor during pregnancy or lactation
- A variety of appetitive and aversive responses were measured during the child's re-exposure to the flavor of the maternal diet during smelling (orthonasal olfaction) or eating
- Depending on the context in which the infants are tested, outcome measures include: food intake, duration of feeding, head orientation, facial & body responses; food acceptability refers to differences in feeding response, specifically: food intake, duration of feeding, facial response, maternal perception of infant liking

Child overall dietary intake

- To determine if the maternal diet shapes infant/child's subsequent diet as a result of flavor experience in utero and/or via breast milk.

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[1] Rozin P. "Taste-smell confusions" and the duality of the olfactory sense. Percept Psychophys 1982;31(4):397-401.
[2] Mennella JA, Beauchamp GK. Experience with a flavor in mother's milk modifies the infant's acceptance of flavored cereal. Dev Psychobiol 1999;35(3):197-203.

PLAIN LANGUAGE SUMMARY

What is the question?

- The question is: what is the relationship between maternal diet during pregnancy on flavor transfer to amniotic fluid, children's behavioral response, and dietary intake?

What is the answer to the question?

- Limited but consistent evidence indicates that flavors contained in the foods and beverages in the maternal diet during pregnancy can transfer to and flavor amniotic fluid, and fetal exposure to these flavors increases acceptance of the exposed flavor during infancy and potentially childhood. Flavor transfer to amniotic fluid occurred after pregnant mothers ingested alcohol, anise, carrot, or garlic. These findings may not be generalizable to all foods and beverages in the maternal diet during pregnancy.
- A conclusion cannot be drawn to describe the relationship between maternal diet during pregnancy and children's dietary intake. Based upon current evidence, it is not feasible to isolate the influence of maternal diet during pregnancy on subsequent infant and child dietary intake.

Why was this question asked?

- This important public health question was identified and prioritized as part of the U.S. Department of Agriculture and Department of Health and Human Services Pregnancy and Birth to 24 Months Project.

How was this question answered?

- A team of staff from the Nutrition Evidence Systematic Review conducted a systematic review in collaboration with a group of experts called a Technical Expert Collaborative.

What is the population of interest?

- Generally healthy pregnant women and their healthy infants and toddlers who were ages 0-24 months. The child's food acceptability and dietary intake was examined through the lifespan.

What evidence was found?

- This review includes 11 studies published since 1995
- These studies compared maternal diet during pregnancy and: 1) changes in the flavor (odor) of amniotic fluid, 2) how experiences with flavors in amniotic fluid impact the infant's or child's behavioral responses during subsequent exposure to the flavor (or odor), and/or 3) dietary intake during childhood.
- The flavor of a food is a complex combination of tastes (sweet, sour, salty, bitter, umami), textures, and volatile odors, which travel to the olfactory

receptors when foods or liquids are in the mouth and when odor volatiles are inhaled through the nose.

- Flavors contained in foods or beverages in the maternal diet during pregnancy studied include: alcohol, anise, carrot, and garlic.
- One study showed that when mothers ate garlic during pregnancy there was a change in amniotic fluid odor, as detected by a sensory panel of adults.
- Six studies focused on the relationship between maternal ingestion of particular flavors during pregnancy and their child's behavioral response to the flavor, during smelling or eating.
    - Four studies showed that maternal intake of garlic, anise or alcohol flavors during pregnancy resulted in greater acceptance or more arousal by the infants when re-exposed to the odor, three hours to 10 days after birth compared to infants whose mothers did not ingest the flavor during pregnancy.
    - One study demonstrated that after weaning, infants whose mothers drank carrot juice during pregnancy exhibited greater acceptance of carrot-flavored cereal relative to plain cereal when compared to infants whose mothers avoided carrot juice or carrots during pregnancy.
    - One study focused on the relationship between maternal ingestion of garlic during pregnancy and the child's acceptance of garlic when they were 8- to 9-years-old. Children of mothers who consumed garlic during the last 4 weeks of pregnancy ate more garlic-flavored potatoes when compared to children of mothers who did not consume garlic during the last 4 weeks of pregnancy.
- For garlic, the convergence of findings from 3 separate studies revealed: 1) garlic ingestion by pregnant mothers in the second trimester alters the odor of amniotic fluid; 2) newborns respond differently to the odor of garlic, if their mothers ate garlic during the last month of pregnancy; and 3) experiences with garlic flavor during the last month of pregnancy resulted in greater child acceptance of garlic-flavored foods by the child 8-9 years later.
- Four studies found an association between maternal diet during pregnancy and diet quality or dietary patterns of children 9 months to 4 years of age. While this is important research, these studies cannot directly address the impact of maternal diet strictly during pregnancy on their children's dietary intake due to serious methodological limitations. These limitations include: similarities between maternal prenatal and postpartum diet, maternal influences on what foods are offered to children, and maternal and child dietary measures based on maternal report without direct measurements of children's acceptance of foods or flavors.

How up-to-date is this review?

- This review includes literature from 01/1980 to 06/2017.

TECHNICAL ABSTRACT

Background

- This systematic review was conducted as part of the U.S. Department of Agriculture and Department of Health and Human Services Pregnancy and Birth to 24 Months Project.
- The goal of this systematic review was to examine the following question: what is the relationship between maternal diet during pregnancy on flavor transfer to amniotic fluid, children's behavioral response, and dietary intake?
- The flavor of a food is a complex combination of tastes (sweet, sour, salty, bitter, umami), textures, and volatile odors, which travel to the olfactory receptors when foods or liquids are in the mouth and when odor volatiles are inhaled through the nose.

Conclusion Statement and Grades

- Limited but consistent evidence indicates that flavors contained in the foods and beverages in the maternal diet during pregnancy can transfer to and flavor amniotic fluid, and fetal exposure to these flavors increases acceptance of the exposed flavor during infancy and potentially childhood. Flavor transfer to amniotic fluid occurred after pregnant mothers ingested alcohol, anise, carrot, or garlic. These findings may not be generalizable to all foods and beverages in the maternal diet during pregnancy. **Grade**: Limited
- A conclusion cannot be drawn to describe the relationship between maternal diet during pregnancy and children's dietary intake. Based upon current evidence, it is not feasible to isolate the influence of maternal diet during pregnancy on subsequent infant and child dietary intake. **Grade**: Grade Not Assignable

Methods

- The systematic review was conducted by a team of staff from the Nutrition Evidence Systematic Review in collaboration with a Technical Expert Collaborative.
- Literature searches were conducted using 10 databases to identify studies that evaluated the relationship among maternal diet during pregnancy, amniotic fluid flavor; and children's food acceptability and overall dietary intake. A manual search was conducted to identify articles that may not have been included in the electronic databases searched. Articles were screened by two authors independently for inclusion based on pre-determined criteria.
- Data from each included article were extracted, risks of bias were assessed, and both were checked for accuracy. The body of evidence was qualitatively synthesized, a conclusion statement was developed, and the strength of the evidence (grade) was assessed using pre-established criteria including evaluation of the internal validity/risk of bias, adequacy, consistency, impact, and generalizability of available evidence.

Summary of Evidence

- This systematic review includes 11 studies
- The studies used multiple approaches to examine the relationship between

maternal ingestion of alcohol, anise, carrot, and garlic during pregnancy and: 1) changes in the flavor (odor) of amniotic fluid, 2) how experiences with flavors in amniotic fluid impact the infant's or child's behavioral responses during subsequent exposure to the flavor (or odor), and/or 3) dietary intake during childhood.

- One study demonstrated maternal ingestion of garlic during pregnancy resulted in a change in amniotic fluid odor, as detected by a sensory panel of adults.
- Six studies focused on the relationship between maternal ingestion of particular flavors during pregnancy and their child's behavioral response to the flavor, during smelling or eating.
    - Four studies indicated that maternal intake of garlic, anise or alcohol flavors during pregnancy resulted in greater acceptance or more arousal by the infants when re-exposed to the respective odor from three hours to 10 days after birth compared to infants whose mothers did not ingest the respective flavor during pregnancy.
    - One study demonstrated that after weaning, infants whose mothers consumed carrot juice during pregnancy exhibited greater acceptance of carrot-flavored cereal relative to plain cereal compared to infants whose mothers avoided carrot juice or carrots during pregnancy.
    - One study found that 8- to 9-year-old children of mothers who consumed garlic during the last 4 weeks of pregnancy ate more garlic-flavored potatoes when compared to children of mothers who were randomly assigned to not consume garlic during the last 4 weeks of pregnancy.
- For at least one commonly consumed flavor (garlic), the convergence of findings from 3 separate studies revealed: 1) garlic ingestion by pregnant mothers in the second trimester alters the sensory properties of amniotic fluid; 2) newborns respond differently to the odor of garlic, if their mothers ate garlic during the last month of pregnancy; and 3) experiences with garlic flavor during the last month of pregnancy resulted in greater child acceptance of a garlic-flavored food by the child 8-9 years later.
- Four longitudinal cohort studies found an association between maternal diet during pregnancy and diet quality or dietary patterns of children 9 months to 4 years of age. While this is important research, these studies cannot directly address the impact of maternal diet strictly during pregnancy on their children's dietary intake due to serious methodological limitations. These limitations include: similarities between maternal prenatal and postpartum diet, maternal influences on what foods are offered to children, and maternal and child dietary measures based on maternal report without direct measurements of children's acceptance of foods or flavors.

FULL REVIEW

Systematic review question

What is the relationship among maternal diet during pregnancy, amniotic fluid flavor and child food acceptability and dietary intake?

Conclusion statement

Limited but consistent evidence indicates that flavors contained in the foods and beverages in the maternal diet during pregnancy can transfer to and flavor amniotic fluid, and fetal exposure to these flavors increases acceptance of the exposed flavor during infancy and potentially childhood. Flavor transfer to amniotic fluid occurred after pregnant mothers ingested alcohol, anise, carrot, or garlic. These findings may not be generalizable to all foods and beverages in the maternal diet during pregnancy.

A conclusion cannot be drawn to describe the relationship between maternal diet during pregnancy and children's dietary intake. Based upon current evidence, it is not feasible to isolate the influence of maternal diet during pregnancy on subsequent infant and child dietary intake. **Grade not assignable**

Grade

Limited: Relationship between maternal diet during pregnancy and a) amniotic fluid flavor and/or b) child's behavioral response to flavor

Grade not assignable: Relationship between maternal diet during pregnancy and child's dietary intake

Summary

- Eleven studies examined the relationship between maternal diet during pregnancy and: 1) changes in the flavor (odor) of amniotic fluid, 2) how experiences with flavors in amniotic fluid impact the infant's or child's behavioral responses during subsequent exposure to the flavor (or odor), and/or 3) dietary intake during childhood.
- Flavors contained in foods or beverages in the maternal diet during pregnancy studied include: alcohol, anise, carrot, and garlic.
- One randomized controlled trial (RCT) demonstrated maternal ingestion of garlic during pregnancy resulted in a change in amniotic fluid odor, as detected by a sensory panel of adults.
- Six studies focused on the relationship between maternal ingestion of particular flavors during pregnancy and their child's behavioral response to the flavor, during smelling or eating. Five of these studies focused on infants and one focused on older children:
    - Four studies (one non-randomized control trial and three cohort studies) indicated that maternal intake of garlic, anise or alcohol flavors during pregnancy resulted in greater acceptance (e.g. increase in appetitive behaviors such as head orientation towards odor, more mouthing or sucking, facial responses of liking) or more arousal (e.g. increase in body movements) by the infants when re-exposed to the respective odor from

three hours to 10 days after birth compared to infants whose mothers did not ingest the respective flavor during pregnancy.
    - One RCT demonstrated that after weaning, infants whose mothers consumed carrot juice during pregnancy exhibited greater acceptance of carrot-flavored cereal relative to plain cereal as evidenced by fewer negative facial expressions and greater maternal perception of enjoyment when compared to infants whose mothers avoided carrot juice or carrots during pregnancy.
    - One study focused on the relationship between maternal ingestion of a particular flavor during pregnancy and the acceptance of the flavor during childhood: One RCT found that 8- to 9-year-old children of mothers who consumed garlic during the last four weeks of pregnancy ate more garlic-flavored potatoes when compared to children of mothers who were randomly assigned to not consume garlic during the last 4 weeks of pregnancy. There were no differences in maternal use of garlic or dietary intake of garlic during the preceding two weeks between the two groups of children.
- For at least one commonly consumed flavor (garlic), the convergence of findings from 3 separate studies revealed: 1) garlic ingestion by pregnant mothers in the second trimester alters the sensory properties of amniotic fluid; 2) newborns respond differently to the odor of garlic if their mothers ate garlic during the last month of pregnancy; and 3) experiences with garlic flavor during the last month of pregnancy resulted in greater child acceptance of garlic-flavored foods by the child 8-9 years later.
- Four longitudinal cohort studies found an association between maternal diet during pregnancy and diet quality or dietary patterns of children 9 months to 4 years of age. While this is important research, these studies cannot directly address the impact of maternal diet strictly during pregnancy on their children's dietary intake due to serious methodological limitations. These limitations include: similarities between maternal prenatal and postpartum diet, maternal influences on what foods are offered to children, and maternal and child dietary measures based on maternal report without direct measurements of children's acceptance of foods or flavors.

Description of the evidence

The 11 included studies were published in peer-reviewed journals from January 1980 to June 21, 2017. The search included articles from countries with a high or very high Human Developmental Index (United Nations Development Program, 2014) to be generalizable to the U.S. population. Studies included generally healthy women and those at risk for chronic disease who were pregnant at the time of the dietary intervention or exposure. The outcomes were measured in generally healthy infants, toddlers, and children. Studies were not included if they exclusively enrolled infants with gestational age at birth of less than 37 weeks or infants who were small for gestational age (<2500g).

This systematic review includes 11 studies (3 RCTs, 1 Non-randomized controlled trial, 7 longitudinal cohort studies) that examined maternal diet during pregnancy (specific to

alcohol, anise, carrot, and garlic flavors), changes in the flavor of amniotic fluid and how experiences with these flavors in amniotic fluid impact the infant's and child's responses when re-exposed to the flavor (or odor), as well as the child's dietary intake, measured as diet quality or dietary patterns. **Table 1** lists the type of method or methods used in each included study.

Table 1. Type of study outcomes used to assess the relationship between maternal diet during pregnancy on flavor transfer to amniotic fluid, children's behavioral responses to flavor, and dietary intake.

Maternal diet during pregnancy	Reference	Sensory analysis of AF	Children's behavioral response to flavor	Children's dietary intake
Flavor ingested by mothers during intervention or study[1]				
Alcohol	Faas et al., 2000	-------	X	-------
	Faas et al., 2015	-------	X	-------
Garlic	Mennella et al., 1995	X	------	-------
	Hepper et al., 1995	-------	X	-------
	Hepper et al., 2013	-------	X	-------
Carrot	Mennella et al., 2001	-------	X	-------
Anise	Schaal et al., 2000	-------	X	-------
Maternal overall dietary assessment[2]				
Dietary Quality and Variety	Jones et al., 2015	-------	-------	X[3]
	Ashman et al., 2016	-------	-------	X3
Dietary Patterns	Okubo et al., 2014	-------	-------	X[4]
	Lioret et al., 2015	-------	-------	X4

[1] Predominant flavor of the maternal dietary intervention or study, see Tables 2 and 3 for more details
[2] Maternal dietary assessment, see Table 4 for more details
[3] Children's overall dietary intake measured as dietary quality and variety
[4] Children's overall dietary intake measured as dietary patterns

Study details: (See tables 2, 3, and 4)

- **Study designs**:
  - Three randomized controlled trials (RCTs): Hepper, 2013; Mennella, 1995; Mennella, 2001b;
  - One non-randomized controlled trials (NRCT): Schaal, 2000;
  - Seven longitudinal cohort studies: Faas, 2000; Faas, 2015; Hepper, 1995; Ashman, 2016; Jones, 2015; Lioret, 2015; Okubo, 2014.
- **Independent variable**: Maternal diet during pregnancy. This was reflected as an experimental manipulation (mothers ate or avoided particular flavors, foods or juices) during pregnancy or as a comparison between different maternal dietary patterns or diet quality during pregnancy
- **Outcome measures**:
  - Chemical analysis:
    - 0 studies
  - Adult sensory analysis:
    - 1 study: Mennella, 1995
  - Infant behavioral response:
    - 6 studies: Hepper, 1995; Faas, 2000; Faas, 2015; Schaal, 2000; Mennella 2001b; Hepper, 2013;
  - Child overall dietary intake:
    - 4 studies: Jones, 2015; Ashman, 2016; Lioret, 2015; Okubo, 2014
- **Country**:
  - Controlled trials (randomized and non-randomized):
    - United States: Mennella, 1995; Mennella, 2001b;
    - Northern Ireland: Hepper, 2013;
    - France: Schaal, 2000
  - Cohort studies:
    - Argentina: Faas, 2000; Faas, 2015;
    - Japan: Obuko, 2014;
    - Australia: Ashman, 2016; Lioret, 2015;
    - Northern Ireland: Hepper, 1995; and,
    - England and France: Jones, 2014.
- **Sample size**: There were no inclusion criteria related to sample size, and sample size varied substantially based on study design, the number of groups and purpose.
  - One RCT used a sensory panel to evaluate whether the odor of amniotic fluid changed based on maternal ingestion of garlic or placebo; 13 panelists evaluated the AF samples collected from 10 mothers (Mennella, 1995)
  - Studies evaluating maternal diet during pregnancy on postnatal infant response to either the odor or flavor (3 trials and 3 cohorts) ranged in size from 20 to 44 mother-infant dyads (Controlled trials: Hepper, 2013; Mennella 2001b; Schaal, 2000; Cohort studies: Faas, 2000; Faas, 2015; Hepper, 1995)
  - The four longitudinal cohort studies evaluating the relationship between maternal diet and infant overall dietary intake varied greatly:
    - 52 mother-infant dyads (Ashman, 2016);

        - 421 mother-infant dyads (Lioret, 2015);
        - 758 mother-infant dyads (Okubo, 2014);
        - 9649 mother-infant dyads (from 2 cohorts) (Jones, 2014)
- Sample characteristics:
    - **Maternal age**: At the start of the studies, mean maternal age ranged from 23 to 35 years.
    - **Parity**: Six studies reported parity; Ashman, 2016 reported 50% of subjects were nulliparous; Hepper, 2013 reported mothers had a mean of 0.78 children; Faas, 2000 indicated a mean parity of approximately 2.4; and Mennella, 2001b, Obuko, 2014, and Lioret, 2015 reported 35%, 50% and 100% women were primiparous, respectively.
    - **Infant sex**: In the seven studies that reported infant or child sex, the number of boys and girls was well balanced. Percent females ranged from 39 to 61% (Schaal, 2000, Faas, 2015, Jones, 2014, Lioret, 2015, Okubo, 2014, Hepper, 2013, Mennella, 2001b).
    - **Race and ethnicity**: race and ethnicity were rarely reported; Mennella, 1995 described the study population as 70% white and 30% black. Mennella, 2001b described the race or ethnicity of mothers: 85% white, 9% black, 4 % Hispanic and 2% Asian. The Okubo, 2014 study population was 100% Japanese. While the Lioret, 2015 study took place in Australia, the only information potentially related to race/ethnicity provided was that 21 percent of subjects were born outside of Australia.
    - **Socioeconomic status (SES)**: Only five studies reported SES information; Variation in indicators used makes characterization difficult; however, each of these five studies indicated that many women were well-educated. Obuko, 2014 reported that 29% of Japanese mothers had greater than 15 years of education, 31% had a household annual income greater than 6 million yen (approximately $55,000 US dollars), 88% had a nuclear family structure, and 71% of mothers were unemployed, while 18% were employed full-time. Jones, 2014 reported that 40 to 58% of mothers had a high level of education, Lioret, 2015 reported that 59.4% of mothers had a university degree or higher, and Ashman, 2016 reported 75% of mothers were high school graduates. Hepper, 2013 reported 39% of mothers were employed full-time, 24% were employed part-time, and 36% were unemployed. Among those who were employed, 42% worked in skilled labor and 30% in professional and managerial level jobs.
    - **Maternal weight characteristics**: Only three studies described maternal weight status; Lioret, 2015 reported mean maternal pre-pregnancy BMI was 24.4 (SD=5.1). Ashman, 2016 reported 53% and 45% of women had a BMI in the normal and overweight/obesity range, respectively. Okubo, 2014 reported 73% of women had a BMI in the normal range, while 23% and 3% had a BMI in the underweight or overweight category, respectively.
    - **Smoking status**: Only two studies reported smoking status; Okubo, 2014 reported that 16% of mothers were current smokers and Ashman, 2016 reported 7.7% of women smoked at some point during pregnancy.
    - **Fetal age at time of maternal diet manipulation (controlled trials):**

        - 33.2 ±0.3 (mean±SD) weeks gestation and continued for 3 weeks (Mennella 2001b)
        - 35 weeks gestation and continued for 4 weeks (Hepper, 2013)
        - Second trimester, prior to a routine amniocentesis (Mennella, 1995).
        - Third trimester, last 15 days prior to expected delivery (Schaal, 2000)
    - **Timing of maternal ingestion during pregnancy/dietary assessment period (cohort studies):**
        - During last month of pregnancy (Hepper, 1995)
        - During pregnancy (measured retrospectively) (Faas, 2000)
        - During pregnancy (measured retrospectively) (Faas, 2015)
        - Diet collected during late pregnancy (Jones, 2015)
        - Diet collected at 19 and 36 wks gestation; data was averaged and used in analysis (Ashman, 2016)
        - Collected between 5-39 wks gestation for intake of previous month (Okubo, 2014)
        - Collected 3 months postpartum, retrospectively assessing diet during pregnancy (Lioret, 2015)
    - **Infant age at time of outcome assessment**: Infant age ranged from three hours to two years at the time of assessment and one study assessed food acceptance at 8-9 years.

Experimental Manipulation of Maternal Diet

In what follows, we list the beverages, encapsulated flavors, or foods ingested by the mothers.

- Alcohol: self-reported alcohol consumption, ≥1x per week during pregnancy measured retrospectively (Faas, 2000); self-reported alcohol consumption, ≥4x per month during pregnancy, measured retrospectively (Faas, 2015)
- Garlic: encapsulated garlic extract, 1.5 g, 1 time (Mennella, 1995); meals containing fresh garlic, >4 meals/week during last month of pregnancy (Hepper, 1995); meals containing fresh garlic, 3-4 meals/week for 4 weeks starting at 35 weeks gestation (~14 meals, 12-16) (Hepper, 2013)
- Carrot juice: 300 mL/day for 4 days/week for 3 consecutive weeks during last trimester of pregnancy (Mennella, 2001b)
- Anise: foods containing anethole, ~121.1 mg/d (SD=28.7) over the 5.6 d (SD=3.5) preceding delivery (Schaal, 2000)

Adult sensory analysis

One RCT evaluated the direct transfer of garlic volatiles from the maternal diet to AF (Mennella, 1995).

- In Mennella, 1995, five women ingested a capsule of garlic oil and five women ingested a placebo containing lactose approximately 45 minutes prior to a routine amniocentesis. Samples of AF were obtained and pairs of AF (one from a woman who ingested the garlic capsule and one from a woman that ingested the placebo) were compared by a panel of 13 adults who were blind to the hypothesis and group assignment of the pregnant mothers who donated the AF samples. Each pair was presented six times, in random order to each of the 13

panelists individually and each panelist indicated which of the pair smelled stronger or more like garlic. Panelists rated four of five pairs of samples of AF from women who had consumed a garlic capsule as smelling stronger of garlic than the AF from women who had consumed a placebo indicating that garlic ingestion by pregnant women alters the odor of AF.

Table 2. Summary of the evidence-base of the effect of maternal diet during pregnancy on flavor transfer to amniotic fluid: chemical and sensory analysis[1]

Reference; **Country;** **Study design;** **Participants**	**Intervention and analysis methods**	**Outcomes**	
		Chemical analysis	Adult sensory analysis
Flavor: Garlic			
Mennella et al., 1995; **US;** **RCT (within-subject);** **10 women; 13 adult sensory panelists**	During 2nd trimester of pregnancy mothers were randomized to 2 groups: Garlic Group: Pregnant women consumed 1.5 g garlic capsule (n=5 women); Placebo Group: Pregnant women consumed placebo capsules containing lactose (n=5 women); Capsules were ingested ~45min [mean: 48.0 (9.6) min] prior to a scheduled amniocentesis where AF samples were obtained.	NA	For 4 of 5 pairs of samples, 13 sensory panelists rated AF from women who had consumed garlic supplements as smelling stronger than the AF of women who had consumed a placebo. Pair 1: P=0.004; Pair 2: NS (women reported consuming garlic in the 24-h prior to amniocentesis); Pair 3: P=0.002; Pair 4: P=0.004; Pair 5: P=0.02.

[1] USA, United States of America; NA, not applicable; NS, not significant (p>0.05); RCT, Randomized controlled trial; AF, amniotic fluid;

Children's behavioral responses to odor or flavor

Six studies examined children's response to a flavor that had been ingested by the mother during pregnancy compared to a control stimuli or control group of infants whose mothers did not ingest (or ingested less) of that flavor; 5 were on infants and one on older children. When testing infant response, four of these studies used an odor stimulus (Schaal, 2000; Faas, 2000 and 2015; Hepper, 1995) and two used a food (Mennella, 2001b; Hepper, 2013).

- In a cohort study by Hepper, 1995, mothers were assigned to one of two groups based on their liking or disliking of garlic. During the last month of pregnancy, mothers in the garlic group consumed a minimum of 4 meals per week containing fresh garlic, while mothers in the non-garlic group never ate meals containing garlic. Between 15 and 28 hours after birth, newborns were presented with two cotton swabs, one on each side of their cot. One swab had garlic paste and the other was unadulterated (neutral stimulus). The order of presentation, left or right side of the cot, was balanced. For 3 minutes, the baby's head orientation to the odor was recorded. Preference for garlic was calculated based on a percentage of the time spent facing the garlic stimulus compared to the total time spent facing both the garlic and the neutral stimulus. Newborns whose mothers consumed garlic during the last month of pregnancy spent a greater percentage of time facing the garlic odor (60% ± 5.7) compared to newborns whose mothers did not eat garlic during pregnancy (35.6% ± 7.2, $p=0.016$).

- In a non-randomized control trial by Schaal, 2000, mothers were recruited based on their intake of anise-flavored foods and beverages and assigned to either an anise-consuming group or non-anise-consuming group. In the 15 days prior their due date, mothers in the anise-consuming group were given anise-flavored foods and beverages to consume ad libitum and completed diet records indicating the amount of anise-flavored food and beverages consumed. Mothers in the non-anise-consuming group did not consume anise flavors during this time. Anise-consuming mothers did not consume any anise between delivery and postnatal testing. Infant's response to anise odor was evaluated within 8 hours from delivery (prior to their first postnatal ingestive experience) and when they were 4 days old. On each day, two tests were conducted. In the first test, infant reactions to two successive odor stimuli (anise and neutral) were recorded. The odor was presented on a cotton swab for 10 seconds, one at a time with at least 60 seconds separating the presentations. In the second test, odors were presented simultaneously, one on either side of infants' head and the time that the infant oriented its head toward each smell was recorded. Differential reactions to anise odor were observed between newborns whose mothers consumed anise during pregnancy and those whose mothers did not. On the day of birth (within the first 8 hours of life), infants of mothers who did not consume anise had significantly greater frequency and duration of negative facial responses and fewer mouthing actions when presented with an anise odor compared to infants whose mothers consumed anise during pregnancy ($p<0.01$, $p=0.003$, $p<0.01$, respectively). Infants whose mothers consumed

anise during pregnancy had a longer duration of mouthing actions and longer relative duration of head orientation when presented with anise odor compared to a neutral odor ($p=0.004$, $p<0.01$, respectively). Infants were more likely to orient their heads towards a neutral odor (versus an anise odor) if their mothers did not consume anise during pregnancy ($p<0.05$); meanwhile infants were more likely to orient their heads towards an anise odor (versus neutral odor) if their mothers consumed anise during pregnancy ($p<0.05$). Four days following birth, there was no difference between groups in negative facial actions, mouthing, or duration of these responses to anise odor. However, infants of mothers who consumed anise during pregnancy oriented their heads toward the anise odor longer than the control odor ($p<0.005$). Among infants whose mothers did not consume anise, there was no difference in head orientation between the two stimulants (<0.003).

- In Faas, 2000 and Faas, 2015, each cohort study had two groups of women formed based on maternal consumption of alcohol during pregnancy: frequent drinkers and infrequent drinkers. In Faas, 2000, healthy newborn infants between 24 and 48 hours old were presented with a series of 11 odor stimulants, either primarily ethanol (the dishabituating odor was lemon) or primarily lemon (the dishabituating odor was ethanol). The first and last odors were presented 5 times in a row and the middle (dishabituating) odor was presented once. Each stimuli was presented for 15 seconds with a 45 second break before the next. Overall body activity and head and facial movements were measured. In Faas 2015, the same procedure was employed but infant mean age was 10 days old and facial expressions were clustered into 'appetitive' (mouthing/suckling, tongue protrusion and smiling) and 'aversive' (gaping, eye blinking and brow wrinkling). (Note: none of these babies had been diagnosed with a genetic or congenital disease among other congenital pathologies, Fetal Alcohol Syndrome or Fetal Alcohol Spectrum Disorders, and all were deemed by doctors to be in optimal health.) Babies responded differently depending on if their mothers were frequent or infrequent alcohol consumers. In Faas, 2000, there was a difference in head and facial movements between the two groups of infants. Babies born to frequent drinkers had significantly more head and facial movements in response to ethanol when it was presented in the first and seventh position (i.e. after presented with the control, dishabituating odor lemon). There were no differences in responses between the two groups when lemon was the primary stimulant, providing evidence that response was specific to ethanol. Faas, 2015 reported that newborns whose mothers were frequent alcohol drinkers during pregnancy, when compared to newborns of infrequent drinkers, exhibited significantly higher frequencies of appetitive facial responses, specifically tongue protrusion, when primarily stimulated with alcohol odor (19.4 ± 2.2 vs. 11.20 ± 1.6, $p<0.03$). No significant difference was found between groups for overall general activity, duration of appetitive facial reaction, and duration and frequency of aversive facial expressions. Faas, 2015 also found maternal ethanol consumption was positively and significantly correlated with the frequencies of appetitive facial reactions, specifically tongue protrusion, to the primarily alcohol sequence ($r=0.52$, $p<0.05$). There was no correlation between maternal alcohol

consumption with aversive facial reactions or with any reaction when lemon was the primarily stimulant, providing evidence the response was specific to ethanol and olfactory acuity was similar for the control odor lemon.

- In an RCT by Mennella, 2001b, pregnant women were randomized to one of three groups. In one group, women consumed 300mL of carrot juice 4 days per week for 3 consecutive weeks during the last trimester of pregnancy and consumed water (while avoiding carrots) during the first 2 months of lactation. In a second group, women drank water (and avoided carrots) during the last trimester of pregnancy and drank carrot juice during the first two months of lactation. The control group drank water during both pregnancy and lactation and avoided carrots throughout the study period. On two separate days of testing, approximately four days apart (order counterbalanced), recently weaned infants (mean of 5.7 months of age) were fed cereal prepared with water or with carrot juice. Proportional differences of total cereal intake (carrot/(carrot+plain), frequency of negative facial expressions, length of feedings, and mothers' ratings of their infants' enjoyment of the food were assessed to evaluate differences between the groups in the infants' acceptance of carrot flavor. The groups of infants responded differently to carrot-flavored versus plain cereal. Infants whose mothers drank carrot juice during pregnancy showed fewer negative facial expressions when consuming carrot-flavored cereal compared to plain cereal (4.0 ± 0.8 vs 5.4 ± 0.8, $p<0.05$) and their mothers rated their enjoyment of carrot-flavored cereal greater than plain cereal (7.5 ± 0.5 vs 5.3 ± 0.6, $p<0.05$) when compared to the control group; however, there were no significant differences between the groups in the proportional amount of carrot flavored cereal ingested relative to plain cereal or in the proportional length of time spent feeding carrot flavored cereal relative to plain cereal.

- An RCT by Hepper, 2013 examined the effect of maternal consumption of garlic during pregnancy on child's consumption of a garlic flavored food 8-9 years later. Mothers were selected if they did not dislike garlic, have a strong preference for garlic, cook with or eat garlic more than once per week. Mothers were randomized into one of two groups; the garlic group consumed 3 to 4 meals per week containing fresh garlic (~14 meals) from 35 weeks gestation for 4 weeks and the mothers in the non-garlic group did not eat any meals with garlic during this time. When their children were 8 to 9 years old, the children participated in two test meals at their home, one month apart, at the typical mealtime**.** Based on a detailed two-week food diary and an interview with mothers regarding their cooking with garlic, purchasing garlic-flavored food or ready meals, there was no significant difference in the foods eaten by the children or postnatal garlic experience between the two groups from the time of maternal garlic intake during pregnancy to testing. Each child was presented with a meal containing a beef burger, beans and two, four oz servings of potato gratin (one with and one without garlic). Parents told children to taste each gratin and then eat as much as they wished. Plates were weighed before and after the test. Acceptability of garlic flavor was determined by proportionally comparing the amount of garlic-flavored potatoes consumed to the total amount

of potatoes consumed (garlic and non-garlic-flavored potatoes). They found that children whose mothers consumed garlic during pregnancy consumed a greater percentage of garlic potatoes than children whose mothers did not consume garlic during pregnancy (20.3% vs. 12.7%, $p<0.001$). Caution is advised when interpreting these findings because this is the only study that measured the impact of maternal diet during pregnancy on a child's subsequent preferences several years (8-9 years) later.

Table 3. Summary of the evidence-base on the effect of maternal diet during pregnancy on the flavor of amniotic fluid: children's behavioral response[1]

Reference; **Country;** **Study design;** **Participants;** **Child age at testing**	**Maternal intervention and child testing and assessment methods**	**Effect of maternal diet intervention on children's behavioral response to flavor**
Flavor: Alcohol		
Faas et al., 2000; **Argentina;** **Cohort Study;** **44 mother-infant dyads;** **24- 48 h (mean=35.97 ± 7.51)**	Women divided into 2 groups based on self-report of overall alcohol intake; Type of maternal drinker during pregnancy (measured retrospectively) (n): Frequent drinkers (n=17 women): ≥1x per wk; Infrequent drinkers (n=33 women): <4x per mo; Infants were quasi-randomly assigned by maternal drinking. Infants were presented with ETOH or lemon.odors on swabs placed 2.5 cm from infant's nostrils for 60 s; Olfactory condition during testing (sequence odor tests): Lemon primary odor, ethanol dishabituating odor (Lem–EtOH–Lem), lemon tested during trials 1–5 and 7–11, alcohol during trial 6; Alcohol primary odor, lemon dishabituating odor (EtOH–Lem–EtOH), trials 1–5 and 7–11 tested alcohol, trial 6 lemon.	Overall motor activity: There was no difference in duration of either sequence of alcohol or lemon odors between babies of frequent or infrequent drinkers: NS. Overall head and facial movements: There were significant differences between babies of frequent and infrequent drinkers when ethanol was the primary stimulant. Babies born to frequent drinkers had significantly more head and facial movements in response to ethanol when it was presented in the first and seventh position compared to babies born to infrequent drinkers: NR; There were no differences between babies of frequent or infrequent drinkers when a non-ethanol stimulus, lemon, was the primary stimulant: NS.

Reference; Country; Study design; Participants; Child age at testing	Maternal intervention and child testing and assessment methods	Effect of maternal diet intervention on children's behavioral response to flavor
Faas et al., 2015; **Argentina;** **Cohort Study;** **43 mother-infants dyads;** **7-14 d (mean 9.9 ± 1.6)**	Women divided into 2 groups based on self-report of overall alcohol intake; Type of maternal drinker during pregnancy (measured retrospectively) (n): Frequent drinkers (n=16 women): ≥ 4x per mo; Infrequent drinkers (n=27 women): <4x per mo; Infants were quasi-randomly assigned by maternal drinking. Infants were presented with ETOH or lemon odors on swabs placed 2.5 cm from infant's nostrils for 60 s; Olfactory condition during testing (sequence odor tests): Lemon primary odor, ethanol dishabituating odor sequence (Lem–EtOH–Lem), lemon tested during trials 1–5 and 7–11, alcohol during trial 6; Alcohol primary odor, lemon dishabituating odor (EtOH–Lem–EtOH), trials 1–5 and 7–11 tested alcohol, trial 6 lemon.	Duration of aversive responses: babies born to frequent drinkers exhibited significantly longer episodes of gaping during trial 9 compared to trial 2 ($p<0.05$); babies of frequent drinkers had longer durations of eye blinking during trials 10-11 compared with age counterparts in trials 5 and 9 of infrequent drinkers ($p<0.05$). Frequency of aversive responses: NS. Duration of appetitive responses: NS. Frequency of appetitive responses: Babies born to frequent drinkers had higher frequencies of appetitive responses compared to babies of infrequent drinkers when mainly stimulated with EtOH (19.4 ± 2.2 vs 11.2 ± 1.6, $p<0.025$); With lemon as the primary stimulant, NS. Monthly levels of absolute maternal alcohol consumption positively and significantly correlated with the frequencies of appetitive facial reactions to alcohol ($p<0.05$), but not when lemon was the primary stimulant. No significant correlations were observed when considering duration.
Flavor: Garlic		

Reference; Country; Study design; Participants; Child age at testing	Maternal intervention and child testing and assessment methods	Effect of maternal diet intervention on children's behavioral response to flavor
Hepper et al., 1995; **Northern Ireland;** **Cohort Study;** **20 mother-infant dyads;** **15- 28 h**	Dyads assigned to groups based upon mother's self-reported liking or disliking garlic: Garlic Group (n=10): During the last mo of pregnancy, ate ≥4 meals per wk with garlic. Non-garlic Group (n=10): During the last mo of pregnancy, did not eat any garlic. 2-choice odor preference test.	Newborns, whose mothers reported they ate garlic during last mo of pregnancy, spent a greater percentage of time orienting to the garlic odor (60% ± 5.7) when compared to newborns whose mothers did not eat garlic during pregnancy (vs 35.6% ± 7.2, p=0.016).

Reference; Country; Study design; Participants; Child age at testing	Maternal intervention and child testing and assessment methods	Effect of maternal diet intervention on children's behavioral response to flavor
Hepper et al., 2013; **Northern Ireland;** **RCT (within and between subjects);** **33 mother-infant dyads;** **8-9 y**	Mothers randomized at 24-27 wk gestation: <u>Garlic Group (n=16):</u> At 35 wk gestation, consumed 3-4 meals per wk with garlic for 4 wk (~14 meals, ranged 12-16 meals); <u>Non-garlic Group (control) (n=17):</u> At 35 wk gestation, did not eat any meals with garlic for 4 wk; At 8 y, all mothers reported that they did not cook with garlic, nor purchase garlic flavored food; validated via detailed 2 wk food diaries. Child (8-9 y) presented with a meal at home containing beef burger, beans and 2, 4 ounce servings of potato gratin (with and without garlic).	There was no significant difference in the foods eaten by the children in each group during the period from prenatal exposure to testing. % Garlic Flavored Potato Eaten: Significant effect of trial: A higher percentage of garlic flavored potato was eaten on trial 1 (18.4%) than trial 2 (14.6%), p=0.014; Significant effect of group: Children whose mothers ate garlic during pregnancy ate a greater amount of garlic potato (20.3%) than children whose mothers did not eat garlic during pregnancy (12.7%), p<0.001; Trial by group effect: Children whose mothers ate garlic during pregnancy consumed significantly more garlic potato in trial 1 (p<0.001) and trial 2 (p=0.038) than children whose mothers did not eat garlic during pregnancy, p=0.026; Children whose mothers ate garlic during pregnancy ate a higher percentage of garlic flavored potato in the trial 1 than trial 2 (24% vs 16%) whereas children whose mothers did not eat garlic, did not. Total Amount of Potato Consumed: Children whose mothers ate garlic during pregnancy, ate more total gratin than children whose mothers ate garlic during pregnancy in trial 2 (p=0.041) but not in trial 1. There was a significant correlation between % garlic eaten (p=0 .042) and total amount of potato eaten (p=0.004), in trials 1 and 2.
Flavor: Carrot		

Reference; Country; Study design; Participants; Child age at testing	Maternal intervention and child testing and assessment methods	Effect of maternal diet intervention on children's behavioral response to flavor
Mennella et al., 2001; **US;** **RCT (within- and between-subjects);** **29 mother-infant dyads *[total from control and pregnancy group only];*** **~5.7 mo**	Pregnant women randomized to 1 of 3 groups: Group 1 (lactation): mothers ingested water (avoided carrots) 4 d/wk during the last trimester of pregnancy and 300 mL of carrot juice 4 d/wk for 3 consecutive w during first 2 mo of lactation; Group 2 (control): mothers ingested water during both last trimester of pregnancy and first 2 mo of lactation and avoided carrots throughout; Group 3 (pregnancy): mothers ingested carrot juice during last trimester of pregnancy and water (avoided carrots) during first 2 mo of lactation; Mothers fed infants cereal prepared with carrot juice on 1 d or with water on another d; testing order counter balanced.	Total cereal intake: There was no difference in proportional intake of carrot-flavored cereal between the pregnancy group and the control group: NS. Length of feedings: There was no difference in length of feed of carrot-flavored cereal between the pregnancy group and the control group: NS. Frequency of negative facial expressions: There was a significant interaction between group and flavor ($p=0.05$); Infants whose mothers drank carrot juice during pregnancy exhibited less negative facial responses when fed cereal with carrot compared to plain cereal (4.0 ± 0.8 vs 5.4 ± 0.8, $p<0.05$); No significant difference between carrot-flavored and plain cereal for infants from control group. Mothers' ratings of their infants' enjoyment of the food: There was a significant interaction between group and flavor ($p=0.04$); Infants whose mothers drank carrot juice during pregnancy were perceived as enjoying the carrot-flavored cereal over the plain cereal (7.5 ± 0.5 vs 5.3 ± 0.6, $p<0.05$); For control group, no significant difference in rating of enjoyment between carrot-flavored and plain cereal.
Flavor: Anise		

Reference; Country; Study design; Participants; Child age at testing	Maternal intervention and child testing and assessment methods	Effect of maternal diet intervention on children's behavioral response to flavor
Schaal et al., 2000; France; NRCT (within- and between-subjects); ~24 mother-infant dyads; Within 8 h (mean age 2.9 ± 1.9 h, range 0.5-8 h) and in a follow-up test conducted on d 4 (mean age 87.3 ± 10.7 h, range 68-110 h)	Mothers recruited during pregnancy and allocated based on self-reported intake of anise flavored foods or drinks. Anise-consuming pregnant mothers (AC): (n=12 dyads) consumed ~121.1 mg/d (SD=28.7) of anethole, the pure anise flavor, over the 5.6 d (SD=3.5) preceding delivery. Anise-non-consuming pregnant mothers (nAC): (n=12 dyads) consumed no foods in which anise was the dominant flavor over the same time period. Oro-facial test: Neonate presented with 2 successive anethole or control odor for 10 s; Head orientation test: 2 gauze pads with either anethole dilution or pure paraffin oil presented to each side of the infant's face.	D 1 [AC (n=11) vs nAC (n=12)]: Negative facial responses: Frequency of negative facial responses to anise odor between groups: AC 18.2% < nAC 83.3%, p<0.01; Frequency of negative facial responses to anise odor relative to control odor: AC: NS; nAC: 83.3% vs 25.0%, p=NR; Duration of negative facial responses to anise odor relative to control odor: AC: NS; nAC: p<0.003; p-interaction=0.003; Mouthing actions: Frequency of mouthing actions: AC 90.9% > nAC 33.3%, p<0.01; Duration of mouthing actions to anise relative to control: AC > nAC, p<0.02; AC, p=0.004, nAC, NS; Mouthing actions to control: AC: NS; nAC: NS; Head orientation: Relative duration of head orientation to anise odor vs control odor: AC: p<0.01; nAC: NS; More AC infants oriented for longer to anise relative to control; nAC showed reverse pattern; p<0.05. D 4 [AC (n=10) vs nAC (n=10)]: Frequency and duration of infants displaying negative facial actions and mouthing in response to anise odor between infants from AC vs nAC mothers: NS; Relative duration of head orientation to anise relative to control odor: AC: p<0.005; nAC: NS; Number of newborns orienting head towards anise relative to control odor: AC: anise>control; nAC: anise<control; p<0.003; Responsiveness of both breast- and bottle-fed infants to anise odor on d 4 did not affect the behavioral outcomes including duration of negative facial response, duration of mouthing and relative duration of head orientation, respectively, p>0.05 in all cases.

[1]US, United States, NRCT, non-randomized controlled trial; SD, standard deviation; NR, not reported NS, not significant (p>0.05); AC, anise-consuming pregnant mothers; nAC, anise-non-consuming pregnant mothers;

Child overall dietary intake

Four longitudinal cohort studies examined the relationship between maternal diet during pregnancy and infant or child subsequent dietary intake; two of these measured diet quality (Ashman, 2016; Jones, 2015) and two reported dietary patterns (Okubo, 2014; Lioret, 2015). None of these studies measured intake of foods or beverages containing particular flavors.

- Jones, 2015 defined diet quality in terms of a Healthy Plate Variety Score (HPVS) for mothers and their children enrolled in the ALSPAC and EDEN cohorts. The HPVS is an index that assesses dietary variety against five food groups (starchy foods, fruit, vegetable, meat and dairy). Data used to calculate the HPVS was collected from mothers who completed a validated food frequency questionnaire (FFQ) during late pregnancy and FFQs for children reported by parents when children were 2 and 3 years old (ALSPAC and EDEN cohorts) and at 4 years of age (ALSPAC only). Maternal HPVS scores measured during pregnancy were positively associated with higher child HPVS scores at all ages in the ALSPAC (age 2: β=0.22, age 3: β=0.32, age 4: β=0.31, all $p<0.05$) and EDEN (age 2: β=0.25, age 3: β=0.25, both $p<0.05$) cohorts were positively associated with higher child HPVS scores at all ages.

- Ashman, 2016 explored whether intake of a wider variety of fruits and vegetables and overall higher diet quality during pregnancy was correlated with acceptance of a greater variety of these foods and better diet quality in children. Authors defined diet quality, fruit variety, and vegetable variety using the Australian Recommended Food Score for mothers, and the Australian Child and Adolescent Recommended Food Score for children. Prenatal maternal dietary data were collected at 19 and 36 weeks gestation using a validated 74-item Dietary Questionnaire for Epidemiology Studies FFQ and child and maternal postnatal dietary intake information was collected from mothers when children were 2 and 3 years of age using a validated 19-item Australian Child and Adolescent Eating Survey FFQ. Analysis revealed that maternal diet during pregnancy and child's diet at 2 and 3 years were correlated for overall diet quality ($r=0.66$, $p< 0.001$); fruit variety ($r=0.46$, $p< 0.001$) and vegetable variety ($r=0.52$, $p< 0.001$). Only a small subset of the total cohort (52 of 180 recruited) were included in this analysis (only seven mother-child dyads completed FFQs at all time points). Further, mediation analysis showed the effect of maternal diet during pregnancy on child's diet, specifically for fruits, is mediated significantly through the maternal post-natal diet.

- Okubo, 2014 examined the relationship between dietary patterns among Japanese infants with maternal socioeconomic, diet, and lifestyle characteristics. Authors defined dietary patterns in Japanese pregnant women and infants 16 to 24 months of age using diet history questionnaires completed by mothers at 5 to 39 weeks gestation and 18 months post-partum. Cluster analysis was used to identify three maternal diet clusters and two infant diet clusters. Three maternal diet clusters were identified: "meat and eggs", "wheat products" and "rice, fish and vegetables", and two infant dietary patterns: "fruits,

vegetables and high-protein foods” and “confectionaries and sweetened beverages”. After adjustment for all other predictors, maternal dietary patterns were independently associated with dietary patterns of infants. Infants in the “confectionaries and sweetened beverages” pattern had a higher proportion of mothers in the “wheat products” pattern and a lower proportion in the “rice, fish and vegetables” pattern ($p<0.001$). Infants in the “fruits, vegetables and high-protein foods” pattern had a higher proportion of mothers in the “rice, fish and vegetables” pattern and a lower proportion in the ”wheat products” pattern ($p<0.001$).

- Lioret, 2015 examined whether the relationship between maternal education and infants' diet is mediated by mothers' diet. Authors retrospectively collected maternal dietary information from pregnancy through three months postpartum using a validated FFQ. Four maternal dietary patterns, accounting for 24% of variation, were identified through principal component analysis (PCA): “fruits and vegetables”, “high-energy snack and processed foods”, “high-fat foods”, and “cereals and sweet foods”. When children were nine months old, trained nutritionists assessed infant’s diet through telephone administered multi-pass 24-hour recalls with parents on two or three non-consecutive days. PCA was used to identify three child dietary patterns in 9-month olds accounting for 25% of variation: “balanced weaning diet”, “formula”, and “high-energy snack and processed foods”; and four dietary patterns in mothers: “fruits and vegetables”, “high-energy snack and processed foods”, “high-fat foods”, and “cereals and sweet foods”. After accounting for education level, mothers’ with higher adherence to a "fruits and vegetables" pattern predicted higher children scores in the "balanced weaning diet" pattern (0.16, 95% CI [0.07, 0.24], $p<0.05$) and lower scores in the "formula pattern" (-0.12, 95% CI [-0.20, -0.05], $p<0.05$). There were no other significant relationships between maternal diet and infant diet patterns.

Table 4. Summary of the evidence-base on the relationship between maternal dietary intake during pregnancy and children's dietary intake[1]

Reference; **Study design;** **Country;** **Participants;** **Child age at assessment**	**Maternal and child overall dietary intake assessment methods**	**Relationship between maternal dietary intake and child dietary intake**
Jones et al., 2015; **Longitudinal Cohort Study** **ALSPAC: British Avon Longitudinal Study of Parents and Children cohort;** **England;** **8,308 mother-infant dyads;** **2, 3, and 4 y;** **EDEN: French Etude des Déterminants pre et postnatals de la santé et du développement de L'Enfant cohort;** **France;** **1,341 mother-infant dyads;** **2 and 3 y**	Mothers' diets during late pregnancy assessed by self-reported validated FFQ's; FFQ data used to calculate Healthy Plate Variety Score (HPVS): index that assessed maternal dietary variety against 5 food groups (starchy foods, fruit, vegetable, meat and fish, dairy). Final HPVS is sum of 5 food groups scores (potential of 5); Parents completed child's FFQ; ALSPAC (31-33 items) and EDEN (19-20 items derived from mother's validated FFQ); FFQ used to calculate child HPVS; Maternal post-natal diet not controlled for in analysis.	Maternal HPVS scores measured during pregnancy were positively associated with higher child HPVS scores at all ages in the ALSPAC (age 2: β=0.22, age 3: β=0.32, age 4: β=0.31, all $p<0.05$) and EDEN (age 2: β=0.25, age 3: β=0.25, both $p<0.05$) cohorts.

Reference; Study design; Country; Participants; Child age at assessment	Maternal and child overall dietary intake assessment methods	Relationship between maternal dietary intake and child dietary intake
Ashman et al., 2016; **Australia;** **Longitudinal Cohort Study;** **Women and Their Children's Health (WATCH) study;** **52 mother-infants dyads;** **2 and 3 y**	Mothers completed a validated FFQ at 19 and 36 wk gestation; an average of scores was used in analysis. Australian Recommended Food Score used to calculate maternal diet quality scores for total diet quality, vegetable variety and fruit variety; Mothers completed validated toddler FFQ. The Australian Child and Adolescent Recommended Food Score used to calculate diet quality and variety scores; Child diet quality scores were calculated for total diet quality, vegetable variety and fruit variety.	Maternal pregnancy diet and child diet at 2-3 y were correlated: Diet quality: (r=0.66, p< 0.001); Fruit variety: (r=0.46, p< 0.001); Vegetable variety (r=0.52, p< 0.001); Maternal post-natal diet (2-3 y) and child diet at 2-3 y were correlated: Diet quality: (r=0.65, p< 0.001); Fruit variety: (r=0.59, p< 0.001); Vegetable variety: (r=0.61, p< 0.001); Mediation Analysis: Diet quality- Effect of maternal pregnancy diet on the total quality of the child diet: Direct effect: NS; Indirect effect: NS; Total effect: 0.64 (95%CI: 0.28, 0.99); Fruit variety- Maternal pregnancy diet had an indirect effect on child fruit variety mediated through maternal post-natal diet: Direct effect: NS; Indirect effect: 0.32 (95%CI: 0.01, 0.64); Total effect: 0.46 (95%CI: 0.10, 0.83); Vegetable variety- Maternal pregnancy diet had a total effect on child diet: Direct effect: NS; Indirect effect: NS; Total effect: 0.39 (95%CI: 0.04, 0.74).

Reference; Study design; Country; Participants; Child age at assessment	Maternal and child overall dietary intake assessment methods	Relationship between maternal dietary intake and child dietary intake
Okubo et al., 2014; **Japan;** **Longitudinal cohort study;** **The Osaka Maternal and Child Health Study;** **758 mother-infant dyads16-24 mos**	Mothers reported dietary intake during previous mo using self-administered diet history questionnaire; Dietary patterns of mothers were collected at baseline during 5-39 wk gestation and grouped into 3 clusters using k-means cluster analysis; Dietary patterns of infants based on maternal report of frequency of infants weekly consumption (portion sizes not specified) of 15 food groups during the previous mo were grouped into 2 clusters using k-means cluster analysis.	Infants whose mothers had a “rice, fish and vegetables” dietary pattern (OR: 0.56, 95% CI: 0.36, 0.87) were less likely to belong to the “confectionaries and sweetened beverages” pattern than the “fruits, vegetables and high-protein foods” pattern. Infants whose mothers had an educational level more than 13 y (OR: 0.65, 95% CI: 0.44, 0.95) and the “rice, fish and vegetables” dietary pattern (OR: 0.56, 95% CI: 0.36, 0.87) were less likely to belong to the “confectionaries and sweetened beverages” pattern compared to the “fruits, vegetables and high-protein foods” pattern. Infants whose mothers had a higher number of infant’s older siblings (OR: 1.79, 95% CI: 1.24, 2.58) and the “wheat product” dietary pattern (OR: 1.51, 95% CI: 1.04, 2.21) were more likely to belong to the “confectionaries and sweetened beverages” than the “fruits, vegetables and high-protein foods” pattern. Infants whose mothers had a “wheat product dietary” pattern (OR: 1.51, 95% CI: 1.04, 2.21) were more likely to belong to “confectionaries and sweetened beverages” pattern than “fruits, vegetables and high-protein foods pattern”. Infants in the ”fruits, vegetables and high-protein foods” pattern had a higher proportion of mothers in the ”rice, fish and vegetables” pattern and a lower proportion in the ”wheat products” pattern, with a relatively high intake of bread, confectionaries and soft drinks ($p<0.001$). Infants in the “confectionaries and sweetened beverages” pattern had a higher proportion of mothers in the “wheat products” pattern and a lower proportion in the ”rice, fish and vegetables” pattern ($p<0.001$).

Reference; Study design; Country; Participants; Child age at assessment	Maternal and child overall dietary intake assessment methods	Relationship between maternal dietary intake and child dietary intake
Lioret et al., 2015; **Australia;** **Longitudinal cohort study;** **421 mother-infant dyads;** **~9 mos**	Mothers completed a validated 98 item Melbourne FFQ when infants were 3 mo (retrospectively assessed over the past 12 mo); 4 dietary patterns (accounting for 24% of variation) were identified through principal component analysis; Infant nutrition assessed through multi-pass 24 h recalls on 2 or 3 non-consecutive ds; Nutrient intakes were evaluated using 2007 AUSNUT Database; 3 dietary patterns identified through principal component analysis.	After accounting for education level, higher adherence of mothers to a ”fruits and vegetables” pattern predicted higher scores for their children in a ”balanced weaning diet” pattern (0.16,95% CI: 0.07, 0.24, p<0.05), predicted lower scores in ”formula pattern” (-0.12, 95% CI: -0.20, -0.05, p<0.05), and was not associated with the children's ”high energy snack and processed foods” pattern. Mothers' ”high energy snack and processed foods” pattern predicted higher scores for children in the “formula” pattern (0.09, 95% CI: 0, 0.19, p<0.05), but there was no association with the children's ”balanced weaning diet” or ”high energy snack and processed foods” patterns. There was no association between a mothers' adherence to a “high-fat foods” pattern with children's dietary patterns.

[1] NS, not significant (p>0.05); NR, not reported;

Limitations

The NEL Bias Assessment Tool was used to evaluate the internal validity of each included study.

Limitations of the evidence examining flavor transfer via sensory panel or infant response: (7 studies: 3 RCTs, 1NRCT, 3 cohorts)

- Mennella 1995 (RCT) – Sensory analysis
    - Mothers assigned to ingest either placebo or garlic capsule; there was no indication of randomization.
    - Pairs of samples randomized when presented to sensory panelists; cannot determine how randomization sequence was generated.
- Mennella 2001b (RCT) – Infant response
    - Pregnant women randomly assigned to 1 of 3 groups; cannot determine how randomization sequence was generated.
    - Mothers not blinded to conditions (consumed carrot juice or water; fed infants carrot-flavored cereal and plain cereal; reported perceived liking of carrot-flavored cereal and plain cereal), but were unaware of the hypothesis of the study.
- Hepper 2013 (RCT) – Child response
    - Mothers randomly assigned to 1 of 2 groups; Cannot determine how randomization sequence was generated.
    - Mothers not blinded to conditions; Mothers prepared and served the test foods to their children during outcome assessment; Taste and smell of test foods differed; likely but unclear that children were unaware of hypothesis.
- Schaal 2000 (NRCT) – Infant response
    - Non-randomized; participants recruited based on habitual intake of anise-flavored foods and drinks.
    - The following potential confounders were not assessed: SES, race/ethnicity, pre-pregnancy BMI, or smoking status.
- Hepper 1995 (Cohort) – Infant response
    - Not-randomized; women were assigned to a group based on garlic liking or disliking.
    - Unclear if the outcome assessors were blinded.
    - Investigators did not control for potential confounders including: maternal diet outside of study foods, tobacco and drug use, race/ethnicity, SES, household composition, or parity.
- Faas 2000 (Cohort) – Infant response
    - Non-random assignment to groups based on maternal alcohol consumption.

    - Outcome assessor was aware of stimulant but used coding and computer-based program for assessment.
    - The following potential confounders were not assessed: SES, household composition, race/ethnicity, tobacco, and drug use.
- Faas 2015 (Cohort) – Infant response
    - Non-random assignment to groups based on maternal alcohol consumption.
    - The following potential confounders were not assessed: SES, household composition, race/ethnicity, tobacco, and drug use.

There were several limitations within the 4 cohort studies assessing the relationship between maternal diet during pregnancy only and overall dietary intake of the child: (4 studies)

- A women's diet is relatively consistent before, during, and after pregnancy; therefore, is it difficult to isolate the impact of a women's diet during pregnancy alone on child dietary intake.
- Self-reported data can include bias, or involve greater measurement error than other forms of data collection.
- Mothers reported both maternal and child dietary intake which is likely to inflate the association between the two reports.
- Dietary intake measures in very young children are a reflection of what they are fed rather than a valid measure of their food acceptability.
- No direct measure of infant/child food acceptability
- Potential confounders highlighted in the Analytic Framework were not consistently accounted for across studies.

Evidence synthesis

To address the systematic review question about the relationship between maternal diet during pregnancy, amniotic fluid flavor, and infant response, 11 studies were reviewed. One study used a sensory panel to detect the presence of a flavor in amniotic fluid after maternal ingestion; six studies measured infant response to flavors that had been ingested by their mother during pregnancy; and four studies analyzed the relationship between maternal diet during pregnancy and the subsequent diet of the child. All studies reported an indication that maternal diet during pregnancy impacted either the flavor of amniotic fluid, infant response, or child’s diet.

Although the number of studies and the number of flavors investigated are limited, evidence was consistent in showing that the flavor volatiles (alcohol, anise (anethole), carrot, and garlic), consumed by the mother in these studies, transfer from the maternal diet to amniotic fluid and have an impact on infant and child response during subsequent presentation to the odor or flavor. One study that assessed flavor transfer from maternal ingestion to amniotic fluid found that garlic odors were detectable in amniotic fluid 45 minutes after maternal ingestion of garlic tablets via an adult sensory panel. Four studies found a differential response to an odor stimulant (garlic, ethanol, or anise) by infants within the first two weeks of life whose mothers consumed beverages or foods containing the odor volatiles during pregnancy using a range of body and facial response measures, including head orientation, facial responses, and

mouthing actions (Hepper, 1995; Faas, 2000 and 2015; Schaal, 2000, respectively). In infants at the time of weaning, Mennella (2001b) found that infants responded differently to carrot-flavored versus unflavored cereal if their mother's had consumed carrot juice prenatally when compared to infants whose mothers did not consume carrot juice prenatally. Hepper (2013) showed that maternal diet during pregnancy may have a lasting effect into childhood. Eight- and nine-year old children of mothers who consumed garlic during pregnancy ate more garlic-flavored potatoes at a test meal than children whose mothers did not consume garlic during pregnancy.

Additionally, for one commonly consumed flavor (garlic), the convergence of findings from three separate studies revealed: 1) garlic ingestion by pregnant mothers alters the sensory properties of amniotic fluid; 2) newborns respond differently to the odor of garlic if their mothers ate garlic during late pregnancy; and 3) prenatal experiences with garlic resulted in greater child acceptance of garlic flavored foods eight to nine years after mothers diet during pregnancy was the experimentally manipulated.

This research provides evidence that some flavors from the maternal diet during pregnancy transfer to and flavor amniotic fluid; and, the flavors within amniotic fluid are detected by the fetus and recognized after birth as evidenced by differential behavior response. To date, the flavors tested, which are complex and contain many volatiles, include alcohol, anise, carrot, and garlic, and the extent to which other flavors are transferred is unknown. More research is needed to determine the extent of transfer of other volatiles from the maternal diet to amniotic fluid.

A conclusion could not be drawn to address the relationship between maternal diet during pregnancy alone and child's dietary intake. While four longitudinal studies showed an association between maternal diet during pregnancy and child's diet quality (Ashman, 2016; Jones, 2015) or dietary patterns (Lioret, 2015; Okubo, 2014), these studies need to be interpreted with caution. A woman's diet is relatively consistent before, during, and after pregnancy; therefore, is it difficult to isolate the impact of a women's diet during pregnancy alone on child dietary intake. Dietary intake in very young children is primarily a measure of what they are fed, not a measure of food acceptability and therefore there was no direct measure of food acceptability. Other limitations included maternal report of both maternal and child's diet without any direct assessment of child acceptance, heterogeneity of diet assessment methods, and that key potential confounders were not accounted for consistently across studies.

Assessment of the body of evidence

- **Internal validity** (determined with NEL Bias Assessment Tool): Internal validity was strong for the controlled trials, and weaker for cohort studies due to incomplete assessment of confounders and maternal report of both exposure and outcome data.
- **Adequacy:** There were 11 studies in total, 4 controlled trials and 7 cohort studies, from 8 distinct research groups. Sample sizes varied based on the study design. Controlled trials included 20 to 44 mothers or dyads, while cohort studies ranged from 52 to 8,308 mother-infant dyads. Power calculations were generally not reported.
- **Consistency:** All studies showed a significant impact of maternal diet during pregnancy on an infant/child's response to an odor or flavor as well as on child's dietary intake or dietary patterns. However, consistency is limited due to

heterogeneity of exposure flavors and outcome measures.

- **Impact:** This evidence highlights the importance of maternal diet on infant's response to flavors; however, the body of evidence is limited to a small number of flavors, and it is unknown what component(s) of those flavor compounds are transferred and detected by the fetus.
- **Generalizability:** This evidence should be expanded to more diverse populations; however, the physiological mechanism of flavor transfer from maternal diet through amniotic fluid and infant response should be generalizable to all demographics. Little is known about how different flavor components (volatiles) transfer from maternal diet to the amniotic fluid and are detected by the infant (e.g., molecular weight and size, polarity, etc.). This research focused on four specific flavors and, therefore, should not be generalized to all flavors.

Included articles

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WHAT IS THE RELATIONSHIP BETWEEN MATERNAL DIET DURING LACTATION ON FLAVOR TRANSFER TO BREAST MILK, CHILDREN'S BEHAVIORAL RESPONSE, AND DIETARY INTAKE?

PLAIN LANGUAGE SUMMARY

What is the question

- The question is: what is the relationship between maternal diet during lactation on flavor transfer to breast milk, child's behavioral response, and dietary intake?

What is the answer to the question?

- Moderate evidence indicates that flavor volatiles originating from the maternal diet during lactation transmit to and flavor breast milk in a time-dependent manner as determined by chemical and sensory measures. Evidence indicates flavor transfer to human breast milk occurs after lactating mothers ingest alcohol, anise, caraway, carrots, eucalyptus, garlic, and mint flavors.
- Moderate evidence also indicates that infants can detect diet-transmitted flavors in mother's milk as evidenced by differential response to flavors they have previously been exposed to through their mother's milk when compared with infants who did not have previous exposure. Differential infant behavioral response was found: 1) within hours of a single maternal ingestion of flavor (alcohol, garlic, vanilla); 2) within days after their lactating mothers ingested a flavor (garlic, carrot juice) repeatedly (daily for 3 or 7 days); and 3) several months after their lactating mothers ingested the flavor (variety of vegetable juices including carrot) during 1 to 4 months postpartum.
- No conclusion can be drawn to describe the relationship between maternal diet during lactation and toddler dietary intake, since there was no research identified to answer this question.

Why was this question asked?

- This important public health question was identified and prioritized as part of the U.S. Department of Agriculture and Department of Health and Human Services Pregnancy and Birth to 24 Months Project.

How was this question answered?

- A team of Nutrition Evidence Systematic Review staff conducted a systematic review in collaboration with a group of experts called a Technical Expert Collaborative.

What is the population of interest?

- Generally healthy lactating women and their healthy infants and toddlers who were ages 0-24 months. The child's food acceptability and dietary intake was examined through the lifespan.

What evidence was found?

- This systematic review included 15 controlled trials which examined the relationship between maternal diet during lactation, breast milk flavor, and/or

infant response to a flavor.

- The flavor of a food is a complex combination of tastes (sweet, sour, salty, bitter, umami), textures, and volatile odors which travel to the olfactory receptors when foods or liquids are in the mouth and when odor volatiles are inhaled through the nose.
- The foods, beverages, or supplements ingested by lactating mothers investigated in this review include: alcohol; garlic extract; raw garlic; carrot juice; vegetable juices including carrot, celery, beet, and mixed vegetable; fennel-anise-caraway tea; vanilla extract; fish oil supplements, d-carvone supplement; trans-anethole supplement (associated with anise, licorice, fennel flavors); and 1,8-cineole (associated with eucalyptus flavor).
- Ten studies analyzed breast milk samples, via chemical or sensory analysis methods, to determine whether there were time-dependent changes in the flavor of breast milk after when compared to before maternal flavor ingestion.
    - Eight of ten studies provide evidence that flavor volatiles found in alcohol, anise, caraway, carrots, eucalyptus, garlic, and mint originating from the maternal diet during lactation, transfer and flavor breast milk. Transmission of flavor from fish oil supplements, fennel-anise-caraway tea and 3-methylbutyl acetate was not demonstrated, which may have been due to limitations in experimental design.
        - Volatile levels or changes in the perceived odor of the breast milk were evident 30 minutes to 1 hour after alcohol ingestion and 2 to 3 hours after ingestion of raw garlic or encapsulated garlic extract, carrot juice or capsules containing caraway, mint and anise flavor and dissipated over the following 3 to 8 hours.
        - When both chemical and sensory analyses were conducted, there was concordance in the findings; when a change in the flavor volatile concentration was detected by chemical analysis, a change in the flavor of the breast milk was also detected by sensory evaluation analysis.
- Ten studies evaluated the infants' behavioral responses, which was assessed 1 of 3 ways: a) during breastfeeding, within hours of a single maternal ingestion of flavor; b) within days after their lactating mothers' ingested the flavor repeatedly for 3 or 7 days; or c) several months after their lactating mothers ingested the flavor for 1 to 3 months.
    - Evidence from 5 studies displayed that infants could detect a flavor change as evidenced by differential behavioral response 1 to 3 hours after mothers ingested the flavor.
    - Evidence from 2 of 3 studies on repeated maternal ingestion of flavor and infant response days after maternal ingestion of the flavor found that repeated ingestion of carrot juice or garlic by lactating mothers impacted their infant's acceptance of similarly flavored breast milk or cereal days later when compared to a non-exposed control group.
    - Two studies revealed that repeated ingestion of carrot and other vegetable juices by lactating mothers during the first 2 to 4 months of lactation modifies their infants' acceptance of carrot flavored cereal several months later.
- Evidence indicates that the timing may be more important than duration of

exposure.

How up-to-date is this review?

- This review includes literature from 01/1980 to 06/2017.

TECHNICAL ABSTRACT

Background

- This systematic review was conducted as part of the U.S. Department of Agriculture and Department of Health and Human Services Pregnancy and Birth to 24 Months Project.
- The goal of this systematic review was to examine the following question: what is the relationship between maternal diet during lactation on flavor transfer to breast milk, child's behavioral response, and dietary intake?
- The flavor of a food is a complex combination of tastes (sweet, sour, salty, bitter, umami), textures, and volatile odors which travel to the olfactory receptors when foods or liquids are in the mouth and when odor volatiles are inhaled through the nose.

Conclusion Statement and Grades

- Moderate evidence indicates that flavor volatiles originating from the maternal diet during lactation transmit to and flavor breast milk in a time-dependent manner as determined by chemical and sensory measures. Evidence indicates flavor transfer to human breast milk occurs after lactating mothers ingest alcohol, anise, caraway, carrots, eucalyptus, garlic, and mint flavors. **Grade**: Moderate
- Moderate evidence also indicates that infants can detect diet-transmitted flavors in mother's milk as evidenced by differential response to flavors they have previously been exposed to through their mother's milk when compared with infants who did not have previous exposure. Differential infant behavioral response was found: 1) within hours of a single maternal ingestion of flavor (alcohol, garlic, vanilla); 2) within days after their lactating mothers ingested a flavor (garlic, carrot juice) repeatedly (daily for 3 or 7 days); and 3) several months after their lactating mothers ingested the flavor (variety of vegetable juices including carrot) during 1 to 4 months postpartum. **Grade**: Moderate
- No conclusion can be drawn to describe the relationship between maternal diet during lactation and toddler dietary intake, since there was no research identified to answer this question. **Grade**: Grade Not Assignable

Methods

- The systematic review was conducted by a team of staff from the Nutrition Evidence Systematic Review in collaboration with a Technical Expert Collaborative.
- Literature searches were conducted using 10 databases to identify studies that evaluated the relationship among maternal diet during lactation, breast milk flavor; and children's food acceptability and overall dietary intake. A manual search was conducted to identify articles that may not have been included in the electronic databases searched. Articles were screened by two authors independently for inclusion based on pre-determined criteria.
- Data from each included article were extracted, risks of bias were assessed, and both were checked for accuracy. The body of evidence was qualitatively synthesized, a conclusion statement was developed, and the strength of the evidence (grade) was assessed using pre-established criteria including

evaluation of the internal validity/risk of bias, adequacy, consistency, impact, and generalizability of available evidence.

Summary of Evidence

- This systematic review included 15 controlled trials, which examined the relationship between maternal diet during lactation, breast milk flavor, and/or infant response to a flavor (odor or food stimulus).
- The foods, beverages, or supplements ingested by lactating mothers investigated in this review include: alcohol; garlic extract; raw garlic; carrot juice; vegetable juices including carrot, celery, beet, and mixed vegetable; fennel-anise-caraway tea; vanilla extract; fish oil supplements, d-carvone supplement; trans-anethole supplement (associated with anise, licorice, fennel flavors); and 1,8-cineole (associated with eucalyptus flavor).
- Ten studies analyzed breast milk samples, via chemical or sensory analysis methods, to determine whether there were time-dependent changes in the flavor of breast milk after when compared to before maternal flavor ingestion.
    - Eight of ten studies provide evidence that flavor volatiles found in alcohol, anise, caraway, carrots, eucalyptus, garlic, and mint originating from the maternal diet during lactation, transfer and flavor breast milk. Transmission of flavor from fish oil supplements, fennel-anise-caraway tea and 3-methylbutyl acetate was not demonstrated, which may have been due to limitations in experimental design.
        - Volatile levels or changes in the perceived odor of the breast milk were evident 30 minutes to 1 hour after alcohol ingestion and 2 to 3 hours after ingestion of raw garlic or encapsulated garlic extract, carrot juice or capsules containing caraway, mint and anise flavor and dissipated over the following 3 to 8 hours.
        - When both chemical and sensory analyses were conducted, there was concordance in the findings; when a change in the flavor volatile concentration was detected by chemical analysis, a change in the flavor of the breast milk was also detected by sensory evaluation analysis.
- Ten studies evaluated the infants' behavioral responses, which was assessed 1 of 3 ways: a) during breastfeeding, within hours of a single maternal ingestion of flavor; b) within days after their lactating mothers' ingested the flavor repeatedly for 3 or 7 days; or c) several months after their lactating mothers ingested the flavor for 1 to 3 months.
    - Evidence from 5 studies displayed that infants could detect a flavor change as evidenced by differential behavioral response 1 to 3 hours after mothers ingested the flavor.
    - Evidence from 2 of 3 studies on repeated maternal ingestion of flavor and infant response days after maternal ingestion of the flavor found that repeated ingestion of carrot juice or garlic by lactating mothers impacted their infant's acceptance of similarly flavored breast milk or cereal days later when compared to a non-exposed control group.
    - Two studies revealed that repeated ingestion of carrot and other vegetable juices by lactating mothers during the first 2 to 4 months of lactation modifies their infants' acceptance of carrot flavored cereal

several months later.

- Evidence indicates that the timing may be more important than duration of exposure.

FULL REVIEW

Systematic review question

What is the relationship among maternal diet in breastfeeding women, breast milk flavor and food acceptability and dietary intake?

Conclusion statement

Moderate evidence indicates that flavor volatiles originating from the maternal diet during lactation transmit to and flavor breast milk in a time-dependent manner as determined by chemical and/or sensory measures. Evidence indicates flavor transfer to breast milk occurs after mothers ingest alcohol, anise, caraway, carrots, eucalyptus, garlic, or mint flavors.

Moderate evidence indicates that infants can detect diet-transmitted flavors in mother's milk as demonstrated by differential response to flavors they have previously been exposed to through their mother's milk when compared with infants who did not have previous exposure. Differential infant behavioral response was found: a) within hours of a single maternal ingestion of flavor (alcohol, garlic, vanilla); b) within days after their lactating mothers ingested a flavor (garlic, carrot juice) multiple times (daily for 3 or 7 days); and c) several months after their lactating mothers ingested the flavor for 1 to 4 months postpartum (carrot juice alone or with a variety of vegetable juices).

No conclusion can be drawn to describe the relationship between maternal overall diet (e.g., food group intake, dietary pattern, or diet quality) during lactation and toddler dietary intake, since there was no research identified to answer this question. **Grade not assignable**

Grade

Moderate: Relationship between maternal diet during lactation and breast milk flavor

Moderate: Relationship between maternal diet during lactation and child's behavioral response to flavor

Grade not assignable: Relationship between maternal overall diet during lactation and toddler dietary intake

Summary

- This systematic review included 15 controlled trials which examined the relationship between maternal diet during lactation, breast milk flavor, and/or infant response to a flavor (odor or food stimulus).
- The foods, beverages, or supplements ingested by lactating mothers investigated in this review include: alcohol; garlic extract; raw garlic; carrot juice; vegetable juices including carrot, celery, beet, and mixed vegetable; fennel-anise-caraway tea; vanilla extract; fish oil supplements, d-carvone supplement; trans-anethole supplement (associated with anise, licorice, fennel flavors); and 1,8-cineole (associated with eucalyptus flavor).
- Ten studies analyzed breast milk samples, via chemical or sensory analysis methods, to determine whether there were time-dependent changes in the flavor of breast milk after when compared to before maternal flavor ingestion.

- Eight of ten studies provide evidence that a wide range of flavor volatiles found in alcohol, anise, caraway, carrots, eucalyptus, garlic, and mint originating from the maternal diet during lactation, transfer and flavor breast milk. Transmission of flavor from fish oil supplements, fennel-anise-caraway tea and 3-methylbutyl acetate was not demonstrated, but may have been due to limitation in experimental design.
    - Evidence indicates flavor transmission occurs in a time dependent manner. Volatile levels or changes in the perceived odor of the breast milk were evident 30 minutes to 1 hour after alcohol ingestion and 2 to 3 hours after ingestion of raw garlic or encapsulated garlic extract, carrot juice or capsules containing caraway, mint and anise flavor and dissipated over the following 3 to 8 hours.
    - When both chemical and sensory analyses were conducted, there was concordance in the findings; when a change in the flavor volatile concentration was detected by chemical analysis, a change in the flavor of the breast milk was also detected by sensory evaluation analysis.

- Ten studies evaluated the infants' behavioral responses, which was assessed 1 of 3 ways: a) during breastfeeding, within hours of a single maternal ingestion of flavor; b) within days after their lactating mothers' ingested the flavor repeatedly for 3 or 7 days; or c) several months after their lactating mothers ingested the flavor for 1 to 3 months.
    - Evidence on lactating mothers one-time ingestion of flavor on their infants' immediate (within hours) breastfeeding behavioral response indicates that infants could detect the flavor change as evidenced by differential behavioral response 1 to 3 hours after mothers ingested the flavor. This time frame parallels the time-dependent changes identified in the chemical and sensory properties of the milk following maternal ingestion.
        - Differential behavioral responses detected included sucking more frequently (alcohol and garlic), increased time attached to the mother's nipple (garlic and vanilla) and increased intake of flavored milk (vanilla).
    - Evidence from 2 of 3 studies on repeated maternal ingestion of flavor and infant response days after maternal ingestion of the flavor found that repeated ingestion of carrot juice (300mL/day for 1 week) or garlic (1.5 g/d for 3 days) by lactating mothers impacted their infant's acceptance of similarly flavored breast milk or cereal days later when compared to a non-exposed control group.
        - Infants were more accepting of the test flavor (garlic) when they did not have recent experience with the flavor (control group) compared to infants whose mothers had ingested the flavor for several days prior to testing.
        - One study, did not find repeated maternal ingestion of d-carvone in hummus impacted their infants' acceptance of caraway-flavored potato puree; however no sensory testing was done to assess whether the amount of volatile transmitted to breastmilk was

detectable by the human sensory system.
    - Two RCTs exploring the effect of maternal ingestion of a flavor during the first few months of lactation on infants' acceptance of the flavor when tested several months later revealed that repeated ingestion of carrot and other vegetable juices by lactating mothers during the first 2 to 4 months of lactation modifies their infants' acceptance of carrot flavored cereal several months later.
- Evidence indicates that the timing may be more important than duration of exposure.

Description of the evidence

The 15 included papers were published in peer-reviewed journals from January 1980 to June 2017. The search included articles from countries with a high or very high Human Developmental Index (United Nations Development Program, 2014) to be generalizable to the U.S. population. Studies included generally healthy women who were breastfeeding at the time of the intervention or exposure assessment and their generally healthy infants. Outcomes were measured in both mothers (breastmilk analysis) and infants. Studies were not included if they exclusively enrolled infants with gestational age at birth of less than 37 weeks or infants who were small for gestational age (<2500g).

Included studies examined whether flavor volatiles in the diet of breastfeeding women were transmitted to breast milk in a time-dependent manner as evidenced by: a) chemical analysis; b) sensory analysis; and/or c) changes in the infants' behavioral responses to breast milk or a food containing the flavor ingested by their lactating mothers. **Table 5** lists the type of method or methods used in each included study.

Table 5. Type of study outcomes found to assess the relationship between maternal diet during lactation on flavor transfer to breast milk and the breastfed children's behavioral responses.

Flavor ingested by mothers[1]	Reference	Chemical analysis of breast milk	Sensory analysis of breast milk	Children's behavioral response to flavor[2]
Alcohol	Mennella et al., 1991	X	X	X[3]
	Mennella et al., 1993	X	X	X
	Mennella et al., 2001	-------	-------	X[3]
Garlic	Mennella et al., 1991	-------	X	X[3]
	Mennella et al., 1993	-------	-------	X[4]
	Scheffler et al., 2016	X	X	-------
Carrot	Mennella et al., 1999	-------	X	X[4]
	Mennella et al., 2001	-------	-------	X[5]
Variety of vegetables	Mennella et al., 2017	-------	-------	X[5]
Caraway	Hausner et al., 2010	X	-------	X[4]
Vanilla	Mennella et al., 1996	-------	-------	X[3]
Eucalyptus	Kirsch et al., 2012	X	X	-------
Anise,	Hausner et al., 2008	X	-------	-------
Caraway,		X	-------	-------
Mint,		X	-------	-------
Fruit		X	-------	-------
Fish oil	Sandgruber et al., 2011	X	X	-------
Fennel-anise-caraway tea	Denzer et al., 2015	X	X	-------

[1] Predominant flavor of the maternal dietary intervention, see Tables 6 and 7 for more details
[2] Children's behavioral response to flavor in breast milk or solid food
[3] Children's behavioral responses measured during breastfeeding immediately after (3-4 hours) maternal ingestion of flavor
[4] Children's behavioral responses measured within days (1-5 days) after mothers repeated ingestion of the flavor (for 3 or 7 days) when compared to control group;
[5] Children's behavioral responses measured approximately 4-6 months after mothers' repeated ingestion of the flavor for 1-3 months when compared to control group

Chemical and sensory analyses were conducted on breast milk samples collected before (baseline) and at intervals up to 8 hours after maternal ingestion of flavor. Infants' behavioral responses were measured: a) during the breast feedings that occurred 0.5 to 16 hours after maternal ingestion of a flavor on one occasion and/or a placebo on another; b) 1-5 days following repeated maternal ingestion of the flavor of an exposure period of (3-10 days) or following no maternal ingestion (control group); or c) 4-6 months following repeated maternal ingestion of the flavor that lasted 1-3 months or following no ingestion (control group).

Study details: (see Tables 6 and 7)

- Study designs: all studies were controlled trials (Note: Mennella, 1999 reported on two studies):
    - 6 randomized controlled trials (RCT): Mennella, 1993b; Mennella, 1999 (Study 2); Mennella, 2001b; Hausner, 2010; Sandgruber, 2011; Mennella, 2017
    - 5 controlled crossover studies: Mennella, 1991a; Mennella, 1991b; Mennella, 1993a; Mennella, 1996; Mennella, 2001a
    - 5 controlled trials (CT) (single group, within-subject design): Mennella, 1999 (Study 1); Hausner, 2008; Kirsch, 2012; Denzer, 2015; Scheffler, 2016
- Sample size: There were no inclusion criteria related to sample size and sample size varied.
    - Chemical analysis: Within the 8 studies that used chemical analysis, the number of women who provided breast milk samples to be evaluated ranged from 5 (Denzer, 2015; within-subject controlled trial) to 40 (Hausner, 2010; within- and between-subject RCT).
    - Sensory analysis: Within the 8 studies that used sensory analysis, breast milk samples were collected from a range of 1 (Denzer, 2015; within-subject controlled trial) to 23 (Sandgruber, 2011; between-subject RCT) mothers. Sensory panels ranged in size from 6 (Mennella, 1991a; Mennella, 1993) to 13 adults (Denzner, 2015); in one study, 5 lactating women evaluated (tasted) their own breast milk samples.
    - Infant behavioral response: Within the 10 studies that evaluated infant behavioral response, the number of participating mother-infant dyads ranged from 8 (Mennella, 1991b; crossover RCT) to 75 (Mennella, 2017; within- & between-subject RCT).
- Country: 9 of 15 papers reported on studies conducted in the United States.
    - United States: Mennella, 1991a; Mennella, 1991b; Mennella, 1993a; Mennella, 1996; Mennella, 1999 (both studies); Mennella, 2001a; Mennella, 2001b; Mennella, 1993b; Mennella, 2017
    - Denmark: Hausner, 2008; Hausner, 2010
    - Germany: Sandgruber, 2011; Kirsch, 2012; Denzer, 2015; Scheffler, 2016
- Sample characteristics:
    - Maternal age: At the start of the studies, mean maternal age ranged from 27 to 34 years.
    - Parity: Twelve studies reported parity. Within these studies, women ranged from 8% to 80% primiparous prior to the pregnancy of the infant

included in the study.

- Race and ethnicity of mothers: The majority of studies did not report race and ethnicity. Mennella, 1996 described 8 of the participants as black, 3 as white, and 1 as Hispanic. Mennella, 1999 (study 1) described the race or ethnicity of mothers: 60% white, 20% black, and 20% Hispanic, whereas Mennella, 1999 (study 2) reported: 61% white, 21% black, 6% Hispanic, 3% Asian, and 9% other. Mennella, 2001a described 10 of the participants as white, and 2 as black. Mennella, 2001b described the race or ethnicity of mothers: 85% white, 9% black, 4% Hispanic, and 2% Asian. Mennella, 2017 described the race or ethnicity of mothers: 55% white, 27% black, 3% Asian, and 16% more than one race reported.
- Socioeconomic status (SES): Only 2 studies reported SES. Mennella, 2017 reported that 66% of participants had a college education, 11% had an income of <$10,000 per year, 36% had an income of $10,000-49,000 per year, and 53% had an income of $50,000 per year. Hausner, 2010 reported that study groups did not differ in social class or educational level, but did not report details.
- Maternal weight characteristics: Only 4 studies described maternal weight status. Mennella, 1993a and Hausner, 2008 reported mean maternal pre-pregnancy weight of 64.1 ± 2.8 kg and 65.2 ± 7.4 kg, respectively. Hausner, 2010 reported mean maternal pre-pregnancy BMI as 22.8 ± 0.8 kg/m2 and Sandgruber, 2011 reported a range of maternal BMI at the time of conception of 23-32 kg/m2.
- Smoking status: Only 5 studies reported smoking status and all 5 reported that mothers were healthy, non-smokers (Hausner, 2008; Mennella, 1993b; Mennella, 1996; Mennella, 1999 (study 1); Mennella, 2001a).
- Infant sex: Nine of 10 studies that assessed infants' behavioral responses reported infant sex, which ranged from 39 (Mennella, 2001b) to 75% (Mennella, 1993a) female (Mennella, 1991a; Mennella, 1993a; Mennella, 1993b; Mennella, 1996; Mennella, 1999 (study 2); Mennella, 2001a; Mennella, 2001b; Hausner, 2010; Mennella, 2017).
- Infant age at outcome assessment: Of the 10 studies that tested infant response, infant ages ranged from as young as 25 days in Mennella, 1991a (which had an age range of 25 – 216 days) to as old as 8 months old in Mennella, 2017 (which had an age range of 6 – 8 months).

Experimental Manipulation of Maternal Diet

In general, when conducting chemical or sensory analytics on breast milk samples or when studying infant behavioral responses during breastfeeding following a single maternal ingestion of flavor, lactating mothers were asked to avoid eating certain foods, beverages, or supplements or avoid using cosmetics containing the experimental flavor for several days to a week prior to testing. This was done to ensure that the baseline milk sample was devoid of the flavor and that infants did not have recent exposure to the flavor under study. During testing, what lactating mothers ingested and in what form (encapsulated, beverage, food) was chosen to ensure that mothers ingested the same amount within a fixed period of time so that time-

dependent changes in her breast milk (chemical and sensory analysis) or in the behaviors of her infant during feeding could be determined. In the majority of studies, the collection of breast milk samples and evaluation of infant behavioral response included a control day of testing that controlled for time of day (since breast milk intake varies with time of day) and time at which mothers' ingested a placebo.

In general, for studies that manipulated maternal diet over a number of days or months, mothers were asked to ingest the flavor 0.5-2 hours prior to breastfeeding during the intervention period to ensure infants breastfed during the time the flavor was transmitted to breast milk. After the period of maternal diet manipulation, testing occurred. In general, infants breastfed or fed at their regular pace during testing. The time of day that testing occurred was controlled since lactation performance and infant intake varies with time of day. A control food and/or control group of mothers who ingested the placebo/water during the intervention period were also included to determine specificity of responses.

In what follows, we list the beverages, encapsulated flavors, or foods ingested by the mother.

- Alcohol: in orange juice, 0.3 g ethanol/kg body weight (Mennella, 1991a); in beer, 0.3g ethanol/kg body weight (Mennella, 1993a; Mennella 2001a)
- Garlic: encapsulated garlic extract, 1.5 g, 1 time (Mennella, 1991b); 1.5 g/d for 3 days (Mennella, 1993b), or raw garlic, 3 g , one time (Scheffler, 2016)
- Carrot juice: 500 mL 1 time (Mennella, 1999 [study 1]); 300 mL/day for 1 week (Mennella, 1999 [study 2]); 300 mL/day for 4 days/week for 3 consecutive weeks (Mennella, 2001b)
- Mixed Vegetable juices including carrot, celery, beet, and mixed vegetable: 118 mL/d, 24 times/month for 1 or 3 months (Mennella, 2017)
- Fennel-anise-caraway tea: 950 mL one time; Key flavor volatiles measured in tea samples ingested by mothers were: Trans-anethole (volatile found in foods including anise, licorice, fennel): 858 ± 1973 μg/L; carvone (volatile found in caraway): 238 ± 308 μg/L; limonene (associated with citrus flavor): 8.36 ± 4.83 μg/L); and 1,8-cineole (volatile found in eucalyptus):1.24 ± 0.53 μg/L) (Denzer, 2015)
- Vanilla: extract, 10 mL (Mennella, 1996)
- Fish oil supplements: 3000 mg tuna fish oil/day during pregnancy (starting at 14-16 weeks gestation) through the first 4 months of lactation (Sandgruber, 2011)
- Caraway: encapsulated d-carvone (flavor volatile found in foods/spices including caraway, spearmint, some citrus fruit), 100 mg (Hausner, 2008); d-carvone, 30 mg, in hummus every third day for 28 days (Hausner, 2010)
- Mint: encapsulated l-menthol (flavor volatile found in mint), 100 mg (Hausner, 2008)
- Fruit: encapsulated 3-methylbutyl acetate (flavor volatile found in fruits such as banana, pear), 100 mg (Hausner, 2008)
- Anise: encapsulated trans-anethole, 100 mg (Hausner, 2008)
- Eucalyptus: encapsulated 1,8-cineole (100 mg) (Kirsch, 2012)

Outcomes: Studies on the transmission of flavor from the maternal diet to breast

milk: Chemical and sensory analysis (Table 6)

Ten studies analyzed breast milk samples, via chemical or sensory analysis methods, to determine whether there were time-dependent changes in the flavor of breast milk after when compared to before maternal ingestion (or when compared to the same time of day during the control session) (Mennella, 1991a; Mennella, 1993a; Mennella, 1991b; Scheffler, 2016; Mennella, 1999; Kirsch, 2012; Hausner, 2008; Hausner, 2010; Denzer, 2015; Sandgruber, 2011. Seven of these studies were designed to assess the pattern of flavor change over time (Mennella, 1991a; Mennella, 1993a; Mennella, 1991b; Mennella, 1999; Scheffler, 2016; Hausner, 2008; Denzer, 2015).

- Eight studies used chemical analysis, either conducted by nicotinamide adenine dinucleotide-alcohol dehydrogenase enzymatic assay for determination of alcohol (Mennella, 1991a; Mennella, 1993a) or by gas chromatography−mass spectrometry for determination of odor volatiles (Hausner, 2008; Hausner, 2010; Sandgruber, 2011; Kirsch, 2012; Denzer, 2015; Scheffler, 2016).
- Eight studies used adult sensory analysis (Mennella, 1991a; Mennella, 1991b; Mennella, 1993a; Sandgruber, 2011; Mennella, 1999 (study 1); Kirsch, 2012; Denzer, 2015; Scheffler, 2016).
- Six studies used both chemical and sensory analysis methods (Mennella, 1991a; Mennella, 1993a; Denzer, 2012; Kirsch, 2012; Scheffler, 2016; Sandgruber, 2016).

Table 6. Summary of the evidence-base of the effect of maternal diet during lactation on flavor transfer to breast milk: chemical and sensory analysis[1]

Reference; Country; Study design; Participants	Intervention and analysis methods	Outcomes	
		Chemical analysis	Adult sensory analysis
Flavor: Alcohol			
Mennella et al., 1991; US; Crossover study; 12 lactating women; 17 adult sensory panelists (6-8 panelists were presented with samples)	Mothers drank 0.3 g ethanol/kg BW, in orange juice (15% vol/vol) on one d and orange juice alone (control) on another d; order counterbalanced; Milk collected before and 0.5, 1, 2, 3 h post ingestion; Chemical analysis: nicotinamide adenine dinucleotide-alcohol dehydrogenase enzymatic assay; Sensory panel: Panelists were randomly presented with all possible pairs of breast milk samples from each mother twice; asked which of the pair smelled "more like alcohol" or "stronger".	Ethanol content in breast milk peaked 30 mins to 1 h after alcohol consumption when compared to baseline and then decreased thereafter. No ethanol was detected when mothers ingested orange juice alone. Changes in the ethanol content of milk paralleled changes in the odor of the milk on the d mothers ingested alcohol in orange juice ($p<0.0001$).	Changes in the odor of the milk detected 30 mins to 1 h after alcohol ingestion and then decreased thereafter ($p<0.0001$). Breast milk odor changes peaked 30 mins to 1 h after alcohol consumption then decreased ($p<0.001$); no perceived odor change after consumption of orange juice without ethanol.

Reference; Country; Study design; Participants	Intervention and analysis methods	Outcomes	
		Chemical analysis	Adult sensory analysis
Mennella et al., 1993; US; Crossover study; 11 lactating women; 17 adult sensory panelists (6-8 panelists were presented with samples)	Mothers drank 0.3 g alcohol/kg BW, alcoholic beer (4.5% vol/vol) on one d and non-alcoholic beer (<0.05% vol/vol alcohol) (control) on another d; order counterbalanced; Milk collected before and 1, 2, 3 and 4 h post ingestion; Chemical analysis: nicotinamide adenine dinucleotide-alcohol dehydrogenase enzymatic assay; Sensory panel: Panelists were randomly presented with all possible pairs of breast milk samples from each mother twice; asked which of the pair smelled "more like alcohol" or "stronger".	Alcoholic beer: ethanol content changed as a function of time after beer consumption ($p<0.001$). Nonalcoholic beer: no ethanol was detected, NS. Changes in the ethanol content of milk paralleled sensory changes in milk on the d mothers consumed alcoholic beer.	Alcoholic beer: significant change in perceived odor of breast milk during h after consumption of alcoholic beer for all women ($p<0.01$); odor intensity peaked at 1 h after beer consumption then decreased. Nonalcoholic beer: small but significant change in odor of milk samples following consumption of nonalcoholic beer in 5 of 11 women ($p<0.05$).

Reference; Country; Study design; Participants	Intervention and analysis methods	Outcomes	
		Chemical analysis	Adult sensory analysis
Mennella et al., 1991; US; Crossover study; 8 lactating women; 11 adult sensory panelists	Mothers ingested a 1.5 g garlic extract capsule on one d and placebo capsules (control) on another; milk collected before and 0, 1, 2 and 3 h post ingestion; Sensory panel: Panelists were randomly presented with all possible pairs of breast milk samples from each mother twice; asked to indicate which of the pair smelled "stronger" on "more like garlic."	NA	There was no noticable difference in the 5 milk samples taken from a woman on the d she ingested the placebo. There was a significant difference in perceived odor of the milk samples taken after when compared to before garlic ingestion. Odor change was first detected in breast milk collected 2 h after mothers ingested garlic, and in 3 of 8 samples at 3 h post-ingestion. The percentage of intervention samples that were chosen over control samples in the paired forced-choice procedure at each time point was (mean ± SE): -1 h (30.7 ± 3.1%), 0 h (35.2 ± 3.5%), 1 h (48.0 ± 4.4%), 2 h (78.6 ± 3.6%), 3 h (57.3 ± 6.9%).

Reference; Country; Study design; Participants	Intervention and analysis methods	Outcomes	
		Chemical analysis	Adult sensory analysis
Scheffler et al., 2016; Germany; CT (within-subject); 6 lactating women, sensory panelists n: NR	All mothers ingested 3 g raw garlic; Milk collected before and at two intervals (2-3 and 4-5 h) post ingestion. Chemical analysis: GC-MS Sensory panel: Trained panel of adults smelled and rated the intensity of previously determined breast milk aroma characteristics and added 'garlic-like' and 'cabbage-like', rated from 0 (no perception) to 3 (strong perception).	Time-intensity: High interindividual differences in metabolism/excretion rates of garlic metabolites; 2/6 increased over test period (~5 h) while 4/6 peaked (~2-3 h) then decreased.	Garlic and cabbage-like odors were not perceived in any milk samples prior to garlic ingestion, but 3 to 5 h after ingestion breast mik was pereived to have "slight to average" odor intensities (0.5-2.0 on a scale from 0 [no perception] to 3 [strong perception].
Flavor: Carrot			
Mennella et al., 1999; US; Study 1: CT (within-subject); Study 1 = 5 lactating women, 11 adult sensory panelists	All mothers ingested 500 mL carrot juice; Milk collected before and 1, 2, and 3 h post ingestion. Sensory panel: evaluated milk samples collected from 4 of 5 mothers; panelists were randomly presented with all possible pairs of breast milk samples from each mother twice; asked to indicate which of the pair smelled "more like carrots" or "stronger". Maternal detection of flavor: mothers were randomly presented with pairs of their breast milk samples and asked to indicate which of the pair tasted "more like carrots" or "stronger. Repeated 2-3 times for each pair.	NA	Detection of change in the odor of breast milk collected after, when compared to before, consumption of carrot juice. Odor change peaked 2 h after ingestion of carrot juice. Mothers perceived the breast milk collected 3 h after ingestion of carrot juice as more like carrot when compared to baseline sample collected before ingestion (percent chosen = 85.7%, $p<0.001$); no difference between baseline and samples at 1 h or 2 h after carrot juice ingestion.
Flavor: Eucalyptus			

Reference; Country; Study design; Participants	Intervention and analysis methods	Outcomes	
		Chemical analysis	Adult sensory analysis
Kirsch et al., 2012; Germany; CT (within-subject); 12 lactating women, 8 adult sensory panelists	Ingestion of 100 mg 1,8-cineole (eucalyptus) capsule; Milk collected only after mothers perceived eucalyptic-like odor on their breath; some women repeated the experiment and some expressed more than one sample after capsule intake (21 samples). Chemical analysis: GC-MS. Sensory panel: evaluated 21 samples obtained from 12 women; panelists rated intensity of aroma of each sample on a scale from 0 (no perception) to 3 (strong perception); subsequent reduced panel of 3-5 judges rated samples as "smelling like eucalyptus" or "not smelling like eucalyptus".	High amounts of 1,8-cineole were detected in the 14 eucalyptus-smelling samples and only trace amounts were detected in the 7 non-eucalyptus-smelling samples; Quantification of 1,8-cineole levels showed large variation. Those samples with the eucalyptus odor had concentrations ranging from 70 - 2090 µg/kg milk, most ranged from 100-500 µg/kg. Samples without the eucalyptus smell ranged from ~1-20 µg/kg.	14 of 21 samples had distinct eucalyptus smell; 7 samples did not.
Other Flavors: Fennel, Caraway, Mint, Fruit			

Reference; Country; Study design; Participants	Intervention and analysis methods	Outcomes	
		Chemical analysis	Adult sensory analysis
Hausner et al., 2008; **Denmark;** **CT (within-subject);** **18 lactating women**	Mothers ingested 4 capsules, 100 mg capsules of each: d-carvone (spearmint, caraway), l-menthol (mint), 3-methylbutyl acetate (banana, pear), trans-anethole (caraway, anise, fennel) on 3 separate test ds (each separated by at least 3 ds). Milk collected at home before and 2, 4, 6, 8 h post ingestion on each test d. Chemical analysis: GC-MS.	d-carvone: milk concentrations peaked ~2 h post ingestion and returned to baseline by 8 h post-ingestion; Concentration (Conc) (micro-g/L) at 0, 2, 4, 6, 8 h: 1.33 < 7.17 = 5.61 = 4.30 > 2.66 ($p<0.05$); trans-anethole: milk concentrations peaked ~2 h post ingestion and returned to baseline by 8 h post-ingestion; Conc (micro-g/L) at 0, 2, 4, 6, 8 h: 2.00<9.90=9.20=7.26>4.25 ($p<0.05$); l-menthol: volatile first detected 2 h and did not decrease by 8 h post-ingestions; Conc (micro-g/L) at 0, 2, 4, 6, 8 h: 2.11 < 4.85 = 5.87 = 5.82 = 4.14 ($p<0.05$); 3-methylbutyl acetate: not detected in any milk sample; Conc (micro-g/L) at 0, 2, 4, 6, 8 h: not detected. There was large intra-individual variation in flavor content of each compound among the 3 test ds. Between-person variation of flavor content in milk samples exceeded intra-individual variations.	NA

Reference; Country; Study design; Participants	Intervention and analysis methods	Outcomes	
		Chemical analysis	Adult sensory analysis
Hausner et al., 2010; Denmark; RCT (within- and between-subjects); 40 lactating women (20 intervention group, 20 control group)	Mothers ingested either 30 mg d-carvone/75 g hummus or 75 g plain hummus every 3rd d for 28 ds; milk collected 2 h post ingestion on ds 1 and 28. Chemical analysis: GC-MS	Detection of d-carvone in milk samples: d-carvone was detected in milk samples from 18 of 20 women in the experimental group (in 2 women it was detected in only 1 of 2 milk samples); detection rate was 83% (concentrations not significantly different after the first and tenth exposure); Mean (SEM) d-carvone concentration in breast milk of women who ate caraway hummus: 3.2 ug/L (1.0), range 0-13.2 ug/L; no d-carvone detected in milk samples from women who ate plain hummus.	NA

Reference; Country; Study design; Participants	Intervention and analysis methods	Outcomes	
		Chemical analysis	Adult sensory analysis
Denzer et al., 2015; Germany; CT (within-subject); Analytic analysis: 5 lactating women; Sensory analysis: 1 lactating woman, 13 adult sensory panelists	Analytic analysis: Mothers ingested 950 mL of fennel-anise-caraway tea on 3 test ds each separated by at least 6 ds; milk collected at on a control d (prior to ingestion), and at 0.5, 1, and 2 h post ingestion. Mean concentration of predominant flavor components in 1 L of tea: Limonene (associated with citrus flavor): 8.36 ± 4.83 µg/L); 1,8-cineole:1.24 ± 0.53 µg/L carvone (238 ± 308 µg/L); Trans-anethole: 858 ± 1973 µg/L There was a significant difference in concentrations across tea samples. Chemical analysis: GC-MS Sensory analysis: 1 mother ingested 950 mL of fennel-anise-caraway tea; Milk collected before and 30, 105, 155, and 225 mins post ingestion. Panelists rated the odor of milk samples using a scale of 0 (no perception) to 3 (strong perception) with 0.5 increments.	There were no differences in concentration of flavor volatiles collected before when compared to after tea consumption ($p>0.05$); large inter- and intra-individual variation in the tea ingested was demonstrated.	No difference in the sensory attributes of the 5 samples of milk collected from one women before and after tea ingestion.
Flavor: Fish Oil			

Reference; Country; Study design; Participants	Intervention and analysis methods	Outcomes	
		Chemical analysis	Adult sensory analysis
Sandgruber et al., 2011; Germany; RCT (between-subjects); 23 lactation women; 8 adult sensory panelists	Intervention Group: mothers ingested 3 PUFA preparation (1000 mg of tuna fish oil with; 0.3% vitamin E; 0.3% sunflower oil) capsules per d beginning at 14-16 wk gestation through 4 mos postpartum. Control group: refrained from any fish oil supplementation during pregnancy and lactation. Milk sampling occurred on an empty stomach after an overnight fast in the morning h on 2 occasions: when women were 4-6 and 16-18 wk postpartum. Chemical analysis: GC-MS Sensory panel: Panelists were randomly presented 9 control and 7 intervention group samples; asked todescribe and rate intensities from 0 (no perception) to 3 (strong perception).	No significant difference in mean concentration values of target marker substances between groups; high inter-individual variability between samples was reported for both groups.	Aroma profile analysis: NS between groups.

[1] USA, United States of America; BW, body weight; GC-MS, gas chromatography−mass spectrometry; NS, not significant (p>0.05); NA, not applicable; NR, not reported; SE, standard error;

Outcomes: Studies on the infants' behavioral responses to flavor in breast milk or solid food (Table 7)

Ten studies evaluated the infants' behavioral responses, which was assessed 1 of 3 ways: a) during breastfeeding, within hours of a single maternal ingestion of flavor; b) within days after their lactating mothers' ingested the flavor repeatedly for 3 or 7 days; or c) several months after their lactating mothers ingested the flavor for 1 to 3 months. Behaviors during breastfeeding or feeding solid foods were videotaped for later coding by trained observers frequently blinded to the condition or group assignment. Mothers who ingested the flavor and who evaluated their infants' behaviors and enjoyment of the food were blind to the hypotheses being tested.

- Five controlled crossover studies examined infants' behaviors while breastfeeding during the hours immediately following a single ingestion of the flavor by their mothers to determine whether infants could detect the flavor in breast milk. Infants' behavioral responses to the flavor were compared to a control day wherein mothers ingested a placebo (breast milk therefore should not contain the flavor) (Mennella, 1991a; Mennella, 1991b; Mennella, 1993a; Mennella, 1996; Mennella, 2001a).
    - Flavors ingested by lactating mothers included: alcohol in orange juice or beer (Mennella, 1991a; Mennella, 1993a; Mennella, 2001a), encapsulated garlic extract (Mennella, 1991b), and vanilla extract (Mennella, 1996). [Three of these studies confirmed the transmission of the flavor (alcohol and garlic) from the maternal diet to breast milk using sensory analysis (Mennella, 1991b) or both chemical and sensory analysis (Mennella, 1991a; Mennella, 1993a). One study based the time period of observation on previously published findings (Mennella, 2001a).
    - A variety of behavioral (appetitive) responses were measured during breastfeeding that occurred within 3-4 hours after maternal ingestion. Breast feedings were videotaped and trained observers blind to condition determined the meal or feeding duration, time attached to the nipple, number of sucks. Infants were weighed before and after feedings to determine breast milk intake. Mothers rated their infants' behaviors and nursing experience.
    - One study extended the time period to measure infant behavioral response to 16 hours, well beyond the expected flavor transmission period. This extension was to study infant self-regulation of intake, not response to flavor (Mennella, 2001a).
- Three RCTs examined how repeated ingestion of a flavor 3 to 10 times by lactating mothers influenced their infants' acceptance of similarly flavored breast milk (garlic) or foods (carrot, caraway) 1 to 5 days after the last maternal ingestion when compared to a non-exposed control group (Mennella, 1993b; Mennella 1999; Hausner 2010). Across these 3 studies, a variety of behavioral responses were measured to determine whether experience with flavor in breast milk modified the infants' subsequent response during the immediate days following exposure to the flavor when compared to the control group. Behavioral (appetitive) responses that were measured included breast milk or cereal intake, caloric intake, and mothers' rating of their infant's enjoyment of

the food. Feedings were videotaped and trained observers determined meal or feeding duration, number of accepted spoons, number of refused spoons and number of feedings.

  - Mennella, 1993b examined the effect of the recency of maternal ingestion of 1.5 g encapsulated garlic to the infants' behavioral assessment during breastfeeding. Following a 4 day washout period, all mothers ingested a placebo and infant behavior responses during breastfeeding were evaluated over 4 hours. Mothers were randomized to 1 of 3 groups that differed in the type and timing of flavor ingestion over the next 6 days. One group (control) did not ingest garlic until the test day (a placebo was ingested during the last 3 days of the intervention period), a second group ingested garlic capsules each day for first 3 days of intervention period and the third group ingested garlic each day during the last 3 days of the intervention period. The following day infant behavioral testing was conducted during breastfeeding, 4 hours following maternal ingestion of a garlic capsule.
  - Mennella, 1999 evaluated the effects of repeated ingestion of 300 mL per day of carrot juice or water (control group) for 1 week on infants' acceptance of carrot flavored and plain cereal 1 to 3 days after the last day of maternal ingestion, when compared to before the intervention period.
  - Hausner, 2010 evaluated the effect of repeated ingestion of caraway flavor in a 2-part study. In study 1, lactating mothers consumed (10 times over a 28 day period) caraway-flavored (30 mg d-carvone) or plain hummus (control group) and infant acceptance of the flavor in a potato puree was tested. In study 2, which immediately followed the first, both groups of infants consumed d-carvone flavored potato puree at home for 10 meals on alternate days and infant acceptance of the flavor in a potato puree was tested. Infant testing occurred within approximately 3.6 and 5.4 days after the last day of the intervention period within study 1 and study 2, respectively. After each study, infants participated in two separate test days. They were fed 200 g of caraway-flavored potato puree on 1test day and 200 g plain potato puree on the other day (order was counter-balanced).

- Two RCTs examined how repeated ingestion of a flavor by lactating mothers during the first months of an infant's life impact infants' acceptance of similarly flavored food several months after maternal flavor ingestion (Mennella, 2001b; Mennella, 2017). Behavioral responses were measured to determine whether infants' prior exposure to the flavor in breast milk modified their acceptance of similarly flavored food, as evidenced by more appetitive responses by the exposed group(s) when compared to control food and control group. A variety of behavioral (appetitive) responses were measured. Feedings were videotaped and trained observers blind to conditions and hypotheses determined the durations and rate of feeding, number of spoons accepted or refused and infant facial expressions. Food bowls were weighed before and after feedings to determine intake. Mothers rated their infants' enjoyment of the foods immediately after each feed.
  - Mennella, 2001b evaluated whether repeated maternal ingestion (4

days/week for 3 consecutive weeks) of carrot juice (or water for the control group) during the first 2 months postpartum affected their infants' acceptance of a carrot-flavored and plain cereal 4 months later (when infants were ~6 months old) when compared to the control group who avoided carrots throughout pregnancy and lactation.

- Mennella, 2017 evaluated the effects of the timing (when during lactation) and duration (for how long during lactation) of maternal ingestion of a variety vegetable juices (carrot, beet, celery, and mixed vegetable juices) on their infants' acceptance of carrot-flavored (exposed flavor), broccoli-flavored (novel flavor) and plain cereal 4.5 to 6.5 months after the maternal intervention period (depending on the group). Across five groups, mothers drank 118 mL/d of the vegetable juices 24 days/month for 1 month beginning at 0.5, 1.5, or 2.5 months postpartum, for 3 months beginning at 0.5 months postpartum or did not ingest vegetable juices at all for the entire 3 months (control group).

Table 7. Summary of the evidence-base on the effect of maternal diet during lactation on flavor transfer to breast milk: children's behavioral response[1]

Reference; Country	Study design	Participants	Maternal intervention and child testing methods	Child age at testing[2]	Effect of maternal diet intervention on children's behavioral response to flavor
Flavor: Alcohol					
Mennella et al., 1991; US	Crossover study	12 lactating mother-infant dyads	Lactating mothers drank 0.3 g ethanol/kg BW in orange juice (15% vol/vol) on one test d; equal volume of orange juice alone on another (control) d; test order counter balanced. Infant's breastfed as per usual 3 h following maternal ingestion. Intake assessed by weighing infants before and after a breast feed (test weighing) and infant behaviors monitored by videotape.	25 – 216 d/ during breastfeeding	Infants consumed less breast milk during the 3 h after maternal EtOH consumption than orange juice alone (120 ± 9.5 mL, 156.4 ± 8.2 mL, respectively, $p<0.001$). Frequency of sucks: infants sucked more frequently during first min of breastfeeds that occurred after maternal EtOH consumption, compared to first min after orange juice alone ($p<0.002$). No significant difference in number of feedings; time attached to nipple and number of sucks.
Mennella et al., 1993; US	Crossover study	11 lactating mother-infants dyads	Lactating mothers drank 0.3 g alcohol/kg BW alcoholic beer (4.5% vol/vol) on one d and non-alcoholic beer (<0.05% vol/vol alcohol) on another (control) d; test order counter balanced. Infants breast-fed as per usual 4 h following maternal ingestion. Intake assessed by test weighing and infant behaviors monitored by videotape.	150 d (median)/ during breastfeeding	Infants consumed less milk after maternal alcoholic beer consumption when compared to non-alcoholic beer consumption (mean ± SE) (149.5 ± 13.1 mL, 193.1 ± 18.4 mL, $p=0.03$). No significant difference in feeding duration (number of feeds and time attached to the nipple at each feed) and maternal perception of enjoyment.

Reference; Country	Study design	Participants	Maternal intervention and child testing methods	Child age at testing[2]	Effect of maternal diet intervention on children's behavioral response to flavor
Mennella et al., 2001; **US**	Crossover study	12 lactating mother-infant dyads	Lactating mothers drank 0.3 g ethanol/kg BW in orange juice (15% vol/vol) on one d; control: orange juice alone on another d; test order counter balanced. Infants breast fed as per usual 4 h following maternal ingestion in lab; Intake assessed by test weighing and infant behaviors monitored by videotape. For the next 16 h infant milk intake was assessed via test weighting at home by mothers to study infant self regulation of breast milk intake.	1.8 – 5.0 mo/ during breastfeeding	Breast milk intake: 0-4 h after ingestion, infants consumed less milk after maternal alcohol consumption when compared to after orange juice alone (147.4 ± 17.7 mL, vs. 200.6 ± 24.4 mL, respectively, p=0.04); (149.1 ± 17.4 mL, 117.8 ± 16.9 mL, respectively, p=0.05); 8-12 h after ingestion, infants consumed more milk after maternal alcohol consumption than after orange juice alone (149.1 ± 17.4 mL, 117.8 ± 16.9 mL, respectively, p=0.05); No significant difference 12-16 h and 0-16 h after alcohol ingestion compared to after orange juice alone. Number of feeds: 8-12 h after ingestion, infants had a greater number of feeds after maternal alcohol consumption compared to after orange juice alone (2.1 ± 0.3, 1.5 ± 0.2, respectively, p=0.04), indicating that infants compensated for the decreasesd milk intake that occurred 0-4 h post maternal alcohol consumption. No significant difference in number of feedings: 0-4 h, 4-8 h, 12-16 h, and 0-16 h after alcohol ingestion compared to after orange juice alone. No significant difference in mothers' perception of infant behavior during the feedings following ingestion of alcohol compared to orange juice alone.
Flavor: Garlic					

Reference; Country	Study design	Participants	Maternal intervention and child testing methods	Child age at testing[2]	Effect of maternal diet intervention on children's behavioral response to flavor
Mennella et al., 1991; **US**	Crossover study	8 lactating mother-infant dyads	Lactating mothers ingested a 1.5g garlic extract capsule on one d and a placebo capsule (control) on another d; test order counter balanced. Infant's breast-fed as per usual 3 h following maternal ingestion. Intake assessed by test weighing and infant behaviors monitored by videotape.	90 – 121 d/ during breastfeeding	Time attached to nipple: infants spent more time attached to the nipple during the 4 h after mothers ingested garlic compared to after mothers ingested placebo, (32.8 ± 6.6 mins vs 27.4 ± 5.2 min, respectively, p<0.02). Interaction between treatment (garlic vs placebo) and time (before or after the odors first appeared in milk), p<0.005. There was no difference in time suckling during feeds that occured within 1.5 h from capsule ingestion (placebo vs garlic, NS), indicating the infants were at similar baseline levels in the 2 d of testing. However, in the breast feeds that occurred 1.5 to 3 h after garlic capsule ingestion, when the sensory panelists detected that the milk smelled stronger and more like garlic, there was a difference between treatment: infants spent more time attached to nipple 1.5-3 h after maternal garlic ingestion when compared to 1.5-3 h after maternal placebo ingestion (garlic vs placebo: 18.8 ± 3.6 min vs 12.4 ± 2.6 min, p< 0.005). Number of sucks: Infants sucked more frequently during the feeds that occurred 1.5-3 h post-maternal garlic ingestion when compared to maternal placebo ingestion(garlic vs placebo: 946 ± 208.9 vs 637.6 ± 164.5, p= 0.007). No significant difference between treatment (maternal garlic or placebo ingestion) in amount of milk consumed; and number of feeds.

Reference; Country	Study design	Participants	Maternal intervention and child testing methods	Child age at testing[2]	Effect of maternal diet intervention on children's behavioral response to flavor
Mennella et al., 1993; US	RCT (within- and between-subject)	30 lactating mother-infant dyads	Dyads randomized to 1 of 3 groups. D 1-3: all groups ate bland diet devoid of sulfur volatiles (e.g., garlic, onion); D 4, (test session 1): all mothers ingested placebo, and over the next 4 h infants breast fed on demand as customary; breast milk intake was assessed; infant behavior monitored; D 5-10: groups differed in type and timing of capsule ingestion: Group 1, mothers ingested placebo on d 5-10 (control); Group 2 ingested garlic capsules (1.5 g garlic extract) on d 5-7; Group 3 ingested garlic capsules on d 8-10; D 11 (test session 2): all mothers ingested garlic capsule; and over the next 4 h infants breast fed on demand as customary. Breast milk intake was assessed via test weighing; infant behavior monitored by videotape.	124.3 ± 13.6 d (mean)/ during breastfeeding 1 d after, when compared to before maternal intervention	Feeding duration: Between subjects: Infants whose mothers ingested garlic on d 5-7 (group 2) or d 8-10 (group 3) spent less time breastfeeding during the test session in which their mothers consumed garlic than did infants whose mothers maintained a bland diet and ingested the placebo capsule during d 8-10 (group 1)(Group 1: 47.9 ± 5.8 min, Group 2: 24.6 ± 3.7 min, Group 3: 27.8 ± 5.8 min; both $p<0.05$). Within subjects: Infants whose mothers ingested the placebo (group 1) spent more time attached to the breast during the test session on d 11 where mothers consumed garlic compared to the test session on d 4 where their mothers consumed the placebo(47.9 ± 5.8 min vs 37.6 ± 4.4 min, $p=0.009$; Groups 2 and 3, NS). No significant difference in number of feedings per session; and milk intake.
Flavor: Carrot and/or Vegetable Juices (carrot, beet, celery, and mixed vegetable)					

Reference; Country	Study design	Participants	Maternal intervention and child testing methods	Child age at testing[2]	Effect of maternal diet intervention on children's behavioral response to flavor
Mennella et al., 1999; **US**	Study 2: RCT (between- and within-subject)	38 lactating mother-infant dyads	Dyads randomized to one of two groups; all infants tested on 2 separate ds before the 1-wk intervention period. Mothers fed infants cereal prepared with water on one d and cereal prepared with carrot juice on another d; test order counter balanced. Intake was assessed by test weighing; infant behavior monitored. After preexposure testing, dyads differed in what mothers ingestion during the 1-wk intervention period. Group 1: Lactating mothers ingested 300 mL carrot juice every d for 1 wk; Group 2: Mothers ingested water every d for 1 wk (control); Within 3 ds after the last d of the 1-wk intervention: mothers fed infants cereal prepared with water on one d and cereal prepared with carrot juice on another d; test order counter balanced. Intake was assessed by test weighing; infant behavior monitored by videotape.	173.0 ± 8.0 d/ during feeding 1-3 d after when compare to before maternal intervention	Intake: Infants whose mothers ingested carrot juice consumed less carrot-flavored cereal compared to plain cereal, (cereal weight in g) p=0.004, calories ingested p=0.05; Infants whose mothers did not ingest carrot juice consumed similar amounts of plain and carrot flavored cereal after, when compared to before the maternal intervention period. Feeding time: Infants whose mothers ingested carrot juice spent relatively less time eating carrot-flavored cereal compared to plain cereal (p=0.004); There was no significant difference in infants in the control group. No significant difference in maternal perception on infants enjoyment between groups.

Reference; Country	Study design	Participants	Maternal intervention and child testing methods	Child age at testing[2]	Effect of maternal diet intervention on children's behavioral response to flavor
Mennella et al., 2001; **US**	RCT (within- and between-subjects)	31 mother-infant dyads *[total from water/carrot group and water/water group only]*	Pregnant women randomized to 1 of 3 groups: Group 1(water/carrot): mothers ingested water (avoided carrots) 4 ds per wk during the last trimester of pregnancy and 300 mL of carrot juice 4 ds per wk for 3 consecutive wk during first 2 mos of lactation; Group 2 (control: water/water): mothers ingested water during both last trimester of pregnancy and first two mos of lactation and avoided carrots throughout; Group 3 (carrot/water): mothers ingested carrot juice during last trimester of pregnancy and water (avoided carrots) during first 2 mos of lactation. All infants exclusively breastfed during the intervention period. When infants were 5.7 mos (~ 4 mos after maternal intervention of group 1 and 2 and ~ 6 mos for group 3) and had been eating solids for about 4 wk, mothers fed infants cereal prepared with carrot juice on 1 d or with water on another d; testing order counter balanced. Intake was assessed by test weighing; infant behavior monitored by videotape.	5.7 ± 0.2 mos (mean)/ during feeding mos after maternal intervention period	Facial expressions of distaste: Infants whose mothers drank carrot juice during lactation had less negative facial expressions when eating carrot-flavored cereal compared to plain cereal (3.4 ± 0.6 vs 4.7 ± 0.8, p=0.03) as compared to an unexposed control group. (A similar finding was reported in part 1 among infants whose mothers ingested carrot juice during pregnancy). No significant difference in length of feed and maternal perception of enjoyment of carrot-flavored vs plain cereal.

Mennella et al., 2017; **US**	RCT (within- and between-subjects)	75 lactating mother-infant dyads	Dyads were randomized to 1 of 5 groups. Group 1M0.5: lactating mothers ingested 118 mL/d carrot, beet, celery, and mixed vegetable juices from 0.5-1.5 mos postpartum (24 total exposures); Group 1M1.5: mothers ingested 118 mL/d carrot, beet, celery, and mixed vegetable juices from 1.5-2.5 mos postpartum (24 total exposures); Group 1M2.5: mothers ingested 118 mL/d carrot, beet, celery, and mixed vegetable juices from 2.5-3.5 mos postpartum (24 total exposures); Group 3M0.5: mothers ingested 118 mL/d carrot, beet, celery, and mixed vegetable juices from 0.5-3.5 mos postpartum (24 total exposures/mo); Control Group: mothers ingested equal amounts of water and did not consume vegetable juices (24 total exposures/mos). When infants were ~8 mos and had been eating solid foods for about few wk, they were tested on 3 separate ds. At the time of infant vegetable acceptance testing, the time since the maternal intervention period was 6.5 (Group 1M0.5), 5.5 (Group 1M1.5), or 4.5 (Groups 1M2.5 and 3M0.5) mos. Mothers fed infants cereal prepared with	6-8 mos/ during feeding 4.5-6.5 mos after maternal intervention	Timing (1 mo of maternal ingestion starting at age 0.5 mos, 1.5 mos, and 2.5 mos compared to control): Carrot-flavored cereal intake and rate of feeding: infants who consumed vegetable juices from 0.5-1.5 mos (1M0.5 group) consumed more carrot flavored cereal compared to infants whose mothers did not consume vegetable juices (78.2 ± 14.8 g and 41.0 ± 7.6 g, p=0.03) and at a faster rate (7.2 ± 1.1 and 3.9 ± 0.6 g/min, p=0.01); no signficant difference in facial expressions; and maternal rating of infant enjoyment between groups. There were no significant differences in intake, rate of feeding, facial expressions and maternal rating of enjoyment between the groups whose mothers drank the juices for one mo starting 1.5 or 2.5 mos postpartum and the control group. Duration (1M0.5 vs 3M0.5): Timing was more important than duration. Intake and rate of feeding: Infants whose mothers drank the juices for 1 mo (1M0.5) ate more carrot-flavored cereal at a greater rate than did infants in the control group, but were no different from those with 3 mos of exposure (3M0.5) (p<0.02). No significant difference in 1M0.5 and 3M0.5 groups in intake, rate of feeding facial expressions, and maternal rating of infant enjoyment. Maternal ingestion of the vegetables juices did not affect the relative acceptance of the novel broccoli-flavored food when compared to the control group.

Reference; Country	Study design	Participants	Maternal intervention and child testing methods	Child age at testing[2]	Effect of maternal diet intervention on children's behavioral response to flavor
			water (control) on one d, cereal prepared with broccoli juice (novel vegetable flavor) and cereal prepared with carrot juice (exposed vegetable flavor) on another d; test order counter balanced. Intake was assessed by test weighing; infant behavior was monitored by videotape, and infants' enjoyment after eating was rated by mothers on a scale of 1 (extreme dislike) to 9 (extreme like).		
Flavor: Caraway (d-carvone)					

Reference; Country	Study design	Participants	Maternal intervention and child testing methods	Child age at testing[2]	Effect of maternal diet intervention on children's behavioral response to flavor
Hausner et al., 2010; Denmark	RCT (within- and between-subjects)	40 lactating mother-infant dyads*[total from BF-E group and BF-Non group only]*	Part 1: Group 1 (BF-E): Mothers ingested 30 mg d-carvone/75 g hummus every 3rd d for 28 d; infant acceptance of the flavor in a potato puree was tested. Group 2 (BF-Non): Mothers ingested 75 g plain hummus every 3rd d for 28 d; infant acceptance of the flavor in a potato puree was tested. Group 3 (FF): Formula-feeding mothers ingested 30 mg d-carvone/75 g hummus every 3rd d for 28 d; infant acceptance of the flavor in a potato puree was tested. Part 2: which immediately followed, both groups of infants consumed d-carvone flavored potato puree at home for 10 meals on alternate ds and infant acceptance of the flavor in a potato puree was tested. Part 1 and 2: In both parts of the study, infant testing occurred within 5.4 d after the last d of the intervention period. Infants fed 200 g of caraway-flavored potato puree on 1 d and 200 g plain potato puree on another d; test order counter balanced.	7.0 ± 0.1 mos (mean); ~5 d after maternal intervention period	Part 1: No significant difference between or within groups in intake, number of accepted spoons, number of refused spoons, meal duration, and maternal perception of liking. Part 2: No within or between group differences in intake, meal duration, number of accepted spoons and mothers' perception of liking. Within groups: Number of refused spoons: Infants of mothers who consumed plain hummus refused fewer spoons when fed caraway-flavored vs plain puree (8.6 ± 1.1 and 14.2 ± 2.1, $p<0.05$).

Reference; Country	Study design	Participants	Maternal intervention and child testing methods	Child age at testing[2]	Effect of maternal diet intervention on children's behavioral response to flavor
Flavor: Vanilla					
Mennella et al., 1996; **US**	Crossover study	12 lactating mother-infant dyads	Mothers ingested 10 mL vanilla extract on one d and a diluent (control) on another d. Infant's breast fed as per usual 3 h following maternal ingestion; Intake assessed by weighing and infant behaviors monitored by videotape.	35 – 138 d/ during breastfeeding	Milk intake: Infants consumed more milk during 3 h after their mothers consumed vanilla compared to the diluent (vanilla vs. control: 205.0 ± 15.6 vs 178.2 ± 17.1 mL, $p<0.02$). Feeding duration (time attached to nipple): The infants spent significantly more time attached to their mother's nipple during the 3 h that followed their mother's ingestion of the vanilla compared to the diluent (vanilla vs. control: 39.0 ± 3.3 vs. 32.9 ± 4.1 mins, $p<0.05$). No significant difference in number of feedings per session, mothers perception of infant feeding behavior or lactational performance.

[1] US, United States; BW, body weight; 1M0.5, group that ingested juices for 1 mo starting at 0.5 mo; 1M1.5, group that ingested juices for 1 mo starting at 1.5 mo; 1M2.5, group that ingested juices for 1 mo starting at 2.5 mo; 3M0.5, group that ingested juices for 3 mo starting at 0.5 mo; BF-E, group of mothers who ingested flavor while breastfeeding; BF-non, group of mothers who did not ingest flavor while breastfeeding; FF, group of mothers who ingested flavor while formula feeding their children and not breastfeeding; NS, not significant ($p>0.05$); SE, standard error;
[2] Child age at testing including the range and context of the testing

Limitations

The NEL Bias Assessment Tool was used to evaluate the internal validity of each included study.

Evidence on transmission of flavor from the maternal diet to breast milk from chemical and sensory detection methods

- Denzer, 2015: Low and highly variable volatile content in the fennel-anise-caraway tea ingested by lactating mothers likely limited the ability to detect volatiles via chemical analytic methods. Sensory analyses of milk samples was conducted on samples collected from only 1 woman, eliminating the ability to reach a valid conclusion. Experimental rigor was lacking; mothers prepared the tea and collected the breast milk samples at home and little information was provided on storage of samples prior to analysis.
- Kirsch, 2012: Timing of breast milk collection was based on a mother's subjective judgement of when her breath smelled of eucalyptus; therefore timing of testing was not uniform and may be a source of detection bias.
- Sandgruber, 2011: Timing of the collection of breast milk, after an overnight fast rather than soon after fish oil supplement ingestion, may explain negative findings in both chemical and sensory analysis, since flavor volatiles from the maternal diet are transmitted to breast milk in a time-dependent manner and dissipate hours after ingestion.

Evidence on the infants' behavioral responses to flavor change in their mother's milk

- Evidence on the effect of maternal ingestion of alcohol on lactation performance (2010 DGAC Report), confounds studies evaluating infant response to maternal ingestion of alcohol during breastfeeding. For this reason, behavioral response results in these studies (Mennella, 1991a; Mennella, 1993a; Mennella, 2001a) must be interpreted in light of subsequent research findings. The decreased milk intake at the breast following maternal alcohol ingestion is not due to infants rejecting its flavor but rather alcohol had direct effects on lactation performance of mothers. Nevertheless, it was later verified that breastfed infants could detect the flavor of alcohol in breast milk as evidenced from differences in their suckling response (2010 DGAC Report; Mennella, 1997 https://www.ncbi.nlm.nih.gov/pubmed/9194908).

Evidence synthesis

Evidence on the transmission of flavor from the maternal diet to breast milk: Chemical and sensory analysis

Eight studies provide evidence that a wide range of flavor volatiles found in caraway (d-carvone), anise (trans-anethole), mint (l-menthol), eucalyptus (1,8-cineole), garlic, carrots, and alcohol originating from the maternal diet during lactation, transfer and flavor breast milk as determined by chemical and sensory analyses (Mennella, 1991a; Mennella, 1991b; Mennella, 1993a; Mennella, 1999; Hausner, 2008; Hausner, 2010; Kirsch, 2012; Scheffler, 2016). The flavors ingested ranged from sulfur-containing volatiles found in garlic to sweet-smelling volatiles in fruits and those found in spices,

foods and beverages eaten by various cultures. Seven of these studies (Hausner, 2008; Kirsch, 2012; Mennella, 1991a; Mennella, 1991b; Mennella, 1993a; Mennella, 1999; Scheffler, 2016) provide evidence of the time-dependent manner of this transfer. Volatile levels or changes in the perceived odor of the breast milk were evident 30 minutes to 1 hour after alcohol ingestion (Mennella, 1991a; Mennella, 1993a); 2-3 hours after ingestion of raw garlic or encapsulated garlic extract (Mennella, 1991b; Scheffler, 2016), carrot juice (Mennella, 1999) or capsules containing caraway (d-carvone), anise (trans-anethole), (Hausner, 2008); such changes in levels of volatiles in or sensory characteristics of breast milk then dissipated over a few hours. While mint volatiles were first detected 2 hours after maternal ingestion of l-menthol containing capsules, volatiles could still be detected 8 hours later. Kirsh, 2012 demonstrated that changes in the chemical and sensory properties of milk following eucalyptus ingestion paralleled changes in the eucalyptus odor on mothers' breath.

When both chemical and sensory analyses were conducted (Mennella, 1991a; Mennella, 1993a; Scheffler, 2016; Kirsch, 2012), there was concordance in the findings; when a change in the flavor volatile concentration was detected by chemical analysis, a change in the flavor of the breast milk was also detected by sensory evaluation analysis. Additionally, when both sensory and infant behavioral responses were conducted, there was agreement in the findings; when a change in the flavor of breast milk was detected by sensory evaluation, infant breastfeeding behaviors also differed during the 2-3 hours following maternal ingestion of flavor (Mennella, 1991a; Mennella, 1993a, Mennella, 1991b).

Transmission of flavor from fish oil supplements (Sangruber, 2011), fennel-anise-caraway tea (Denzer, 2015) and 3-methylbutyl acetate (Hausner, 2008) was not demonstrated. The negative findings could be due to any of several reasons, including an insufficient intake of the volatile (concentration), timing of breast milk collection, or selective transmission.

Two crossover studies, examined the time-dependent transmission of alcohol ingested by mothers during lactation (Mennella, 1991a; Mennella, 1993a). Testing occurred on 2 separate days separated by 1 week. Mothers either drank 0.3 g ethanol/kg body weight in orange juice (15% vol/vol) on 1 day (Mennella, 1991a) or 0.3 g alcohol/kg body weight alcoholic beer (4.5% vol/vol) on 1 day and a similar non-alcoholic control beverage on another day (Mennella, 1993a). Milk was collected before and at specific time intervals 0.5 to 3 hours (Mennella, 1991a) or 1-4 hours (Mennella, 1993a) following ingestion. Nicotinamide adenine dinucleotide-alcohol dehydrogenase enzymatic assay was used to measure the alcohol content of breast milk and adult sensory panels evaluated the odor of milk samples. Alcohol was detected by chemical and sensory analysis in milk samples from the experimental groups, but not the control groups. The alcohol content and odor intensity of alcohol in breast milk samples changed as a function of time after alcohol consumption, peaking approximately 1 hour after ingestion and subsequently decreased.

Mennella, 1991b used a similar crossover design to examine the time-dependent transmission of garlic using a sensory panel after maternal ingestion of garlic extract. Eight mothers maintained a diet devoid of sulfur volatiles for several days before testing then ingested 1.5 g encapsulated garlic extract on 1 day and placebo capsules (control) on another (separated by 1 week). Milk was collected before and 0, 1, 2, and 3 hours post ingestion. Evaluation by a sensory panel revealed that there was a time-

dependent change in the odor of the milk. Garlic odor was evident 2 hours post garlic ingestion then decreased to baseline values at 3 hours post ingestion. It was noted however that garlic was still evident in the milk collected from 3 of the 8 women 3 hours post ingestion. There was no garlic odor in milk samples prior to garlic ingestion or 1 hour after ingestion.

Scheffler, 2016 conducted a controlled trial to evaluate the time dependency of flavor transmission following a single ingestion of raw garlic. Six lactating women ingested 3 g of raw garlic and milk was collected before and at 2-3 hours and 4-5 hours post ingestion. Analysis with GC-MS found a metabolite with a garlic-like aroma (allyl methyl sulfide) in breast milk from 4 women and the concentration peaked approximately 2 to 3 hours after garlic ingestion and then decreased, while allyl methyl sulfide concentrations in the other 2 women increased over approximately 5 hours. (Other metabolites, allyl methyl sulfoxide and allyl methyl sulfone, were identified, but did not have a detectable odor). A sensory panel reported garlic and cabbage-like odors were not present in breast milk prior to garlic ingestion, but after ingestion, breast milk samples were perceived to have “slight to average” garlic and cabbage like odor intensity. High inter-individual differences in metabolism and excretion rates of garlic volatiles were observed.

Mennella, 1999 (study 12), a within-subject controlled study, evaluated sensory changes to breast milk before compared to after maternal carrot juice consumption, assessed by a sensory panel and by mothers taste testing their own milk samples. Five lactating mothers ingested 500 mL carrot juice on the test day. Milk samples were collected before and 1, 2, and 3 hours post ingestion. A sensory panel evaluated the odor of milk samples from 4 of 5 mothers (1 mother was excluded because the baseline sample had a strong minty odor) and mothers blindly evaluated the taste of a baseline and post-ingestion sample of their own breast milk. Consumption of carrot juice altered the odor and taste of breast milk. The sensory change in the odor of the milk peaked 2 hours after ingestion, and mother’s perceived significant difference in the taste of the breast milk collected 3 hours after ingestion.

Hausner, 2008 used gas chromatography−mass spectrometry (GC-MS) to evaluate the time-dependent transfer of favor volatiles to breast milk following maternal ingestion of capsules containing 4 flavor volatiles, each representing a different food class: 3-methylbutyl acetate (volatile found in fruits), d-carvone (volatile found in caraway), l-menthol (mint volatile) and trans-anethole (volatile found in anise). Eighteen lactating mothers avoided foods containing the flavors 3 days prior to testing. Mothers ingested flavor capsules and breast milk was collected before and 2, 4, 6, and 8 hours post ingestion on each of 3 test days. D-carvone and trans-anethole milk concentrations peaked 2 hours post ingestion (7.17 ug/L and 9.90 ug/L, respectively) and returned to baseline 8 hours after ingestion (2.66 ug/L and 4.25 ug/L) . l-menthol was first detected 2 hours after ingestion when compared to baseline (4.85 ug/L) and remained at this level for the next 8 hours (4.14 ug/L). 3-methylbutyl acetate was not detected in any milk samples during the 8 hours after ingestion. This finding may indicate that volatiles are selectively transmitted in low quantities. There was large intra-individual variation in flavor content of each compound in breast milk samples. Between-person variation of flavor content in milk samples exceeded intra-individual variations. Mother's weight-adjusted dose (mg/kg/day) did not affect the flavor concentration-time profiles of the milk.

Hausner 2010 examined transmission of caraway (d-carvone) in a RCT, where 40 women ingested either 30 mg d-carvone in hummus or plain hummus every third day for 28 days. Breast milk was collected 2 hours post ingestion after the first and tenth ingestion of hummus. Gas chromatography was used to evaluate the percentage of breast milk samples from the exposed and unexposed groups that contained d-carvone. d-carvone was detected in milk samples from 18 of the 20 women who had ingested d-carvone and was not detected in any milk samples from women who did not consume d-carvone. There was no significant difference in d-carvone concentration following the first and the tenth ingestion of d-carvone, indicating d-carvone flavor is not stored in breast milk.

Kirsch, 2012 evaluated 1,8-cineole (eucalyptus flavor volatile) transmission in 12 lactating women. A preliminary experiment was conducted to inform the timing of milk collection during the study. Time dependency of 1,8-cineole was conducted using milk samples from 1 woman, who on 3 separate days provided a series of samples expressed before and after consuming a 1,8-cineole capsule and plus an additional sample provided 1 morning the day following a serial collection. At regular intervals during this period, the 1,8-cineole content of the mother's breath gas was measured. Two of the serial milk collections and the morning after sample were evaluated by a sensory panel using a scale of 0 (no perception) to 3 (strong perception). Chemical analysis of milk samples was performed to verify sensory panel findings. Results indicated that breastmilk 1,8-cineole content more or less coincided with its presence in exhaled breath of the mother.

In the second part of the study, 12 lactating women ingested 100 mg 1,8-cineole in a capsule and milk was collected only after mothers perceived eucalyptic-like odor on their own breath. Twenty-one samples were collected in total because some women repeated the experiment and some women expressed more than 1 sample after ingesting a capsule. Based on chemical and sensory evaluation, high amounts of 1,8-cineole were detected in the 14 eucalyptus-smelling samples (70 to an approximately 2090 ug/kg) and only trace amounts were detected in the 7 non-eucalyptus-smelling samples (<20 ug/kg). Quantification of 1,8-cineole levels (ug/kg) revealed large inter- and intra-individual differences; however timing of breast milk collection was not uniform and mother's judgement of the eucalyptus odor of their breath is subjective.

Denzer, 2015 evaluated a commercial fennel-anise-caraway "nursing tea" popular in Germany. Five women participated in an experiment that had 3, 6 day blocks. The first 4 days were washout days and a control breast milk sample was collected from the mothers on day 4. On day 5, mothers prepared fennel-anise-caraway tea and drank 950 mL of it within 30 minutes. In each block, women provided a sample at a different time point after tea ingestion: 30 min (block 1), 1 hour (block 2), and 2 hours (block 3). However because mothers could decide at what block they provided a milk sample, not all women participated in every block and some women repeated blocks. Flavor volatile concentrations in the tea were low (approximately 1−1000 µg) compared with other included studies and the odorant profile was complex. GC-MS conducted on milk samples from 5 women found no difference in concentration of any tea flavor compounds between before and after tea consumption at any time point. A sensory panel found no difference in the sensory attributes of milk samples collected from 1 woman over time after tea ingestion. Large variation in flavor volatile concentrations was observed across tea samples and in breast milk samples collected before and

after tea consumption. It is worth noting that several factors suggest that the study lacked sufficient experimental rigor to test the hypothesis: 1) the tea was prepared by the mother; 2) concentration of flavor volatiles may have been insufficient in the tea to detect flavor transmission (e.g., tea contained 238 ± 308 µg/L carvone, 858 ± 1973 µg/L and trans-anethole compared to 30 mg100mg d-carvone and 100 mg trans-anethole concentrations tested by Hausner, 2008); 3) some of the baseline breast milk samples had higher levels of the flavor volatile that those collected post ingestion; 4) volatile content of the tea ingested varied widely among mothers

Sandgruber, 2011 used a RCT to evaluate flavor transfer from fish oil supplements. The intervention group ingested 3 capsules (1000 mg each) per day beginning at 14-16 weeks gestation through 4 months postpartum, while the control group refrained from any fish oil supplementation. Milk sampling occurred on an empty stomach in morning hours at 4-6 and 16-18 weeks postpartum. No significant differences were detected in flavor volatile concentrations and in breast milk odor between groups. Because milk collection was conducted in the morning on an empty stomach, it is assumed that fish oil supplements were not ingested during the hours before milk collection. This null finding for fish oil is consistent with time-dependent results from other flavors reviewed herein, indicating flavor volatiles are not stored in breast milk, but dissipate within hours of maternal ingestion.

Evidence on the infants' immediate (within hours) behavioral responses to breastfeeding after their lactating mothers one-time ingestion of flavor

Five cross-over controlled studies examined infants' behaviors while breastfeeding and found that infants' behaviors at the breast were different during 1-3 hours after their mothers' ingested a flavor when compared to the same time of day in a control test session (Mennella, 1991a; Mennella, 1991b; Mennella, 1993a; Mennella, 1996; Mennella, 2001a). Flavors and respective controls (placebos) ingested by lactating mothers included: alcohol in orange juice or orange juice alone (Mennella, 1991a; Mennella, 2001a); alcoholic beer or nonalcoholic beer (Mennella, 1993a), encapsulated garlic extract or placebo capsules (Mennella, 1991b), and vanilla extract or placebo diluent (Mennella, 1996).

For each of the 3 flavors (alcohol, garlic, vanilla), it was found that infants could detect the flavor change as evidenced by differential behavioral response during the immediate (1-3 hours) after mothers ingested the flavor; this time frame parallels the time-dependent changes identified in the chemical and sensory properties of the milk following maternal ingestion. In the case of alcohol, as noted earlier, subsequent research findings revealed that the infants were not rejecting their mothers' milk following maternal alcohol ingestion. While this body of evidence identifies that breastfed infants detected the flavor of alcohol in the breast milk, as evidenced from suckling responses, diminished milk intake was due to alcohols effect on the mother's lactation performance (2010 DGAC Report; Mennella, 1997; https://www.ncbi.nlm.nih.gov/pubmed/9194908).

Two crossover studies found after alcohol ingestion, infants ingested less breast milk during the next 3 hours (120 ± 9.5 mL, 156.4 ± 8.2 mL, respectively, $p<0.001$) (Mennella, 1991a), or 4 hours (149.5 ± 13.1 mL v. 193.1 ± 18.4 mL, $p=0.03$) (Mennella, 1993a). Mennella, 1991a found infants sucked more frequently after maternal ingestion of an alcoholic beverage when compared to control beverage ($p<0.002$). A

third crossover study, Mennella, 2001a, replicated the decreased intake at the breast during the 4 hours after maternal alcohol consumption compared with a placebo (147.4±17.7mL, 200.6±24.4mL, respectively, p=0.04) and provided evidence of compensation by the infants 8 to 12 hours later when infants compared to the control condition breastfed more often (2.1 ± 0.3, 1.5 ± 0.2, respectively, p=0.04), and ingested more breast milk (149.1 ± 17.4 mL, 117.8 ± 16.9 mL, respectively, p=0.05).

Mennella 1991b found breastfed infants spent more time attached to their mother's nipple (garlic vs placebo: 18.8 ±3.6 vs 12.4 ±2.6 min, p< 0.005) and sucked more frequently (garlic vs placebo: 946 ±208.9vs 637.6 ±164.5, p= 0.007) during the 1.5-3 hours after their mothers ingested garlic when compared to when they ingested placebo. The time of the changes in the infants' behavior during breastfeeding coincided with the time when the sensory panel detected that the breast milk collected from their mothers smelled stronger or more like garlic (p<0.005). There was no difference between groups found with regards to the number of feedings or the amount of milk that was consumed.

In a sample of 12 breastfed infants, Mennella, 1996 found that during the 3 hours after their mothers ingested vanilla, infants ingested more breast milk (vanilla vs placebo: 205.0 ± 15.6 vs 178.2 ± 17.1 mL, p<0.02) and spent longer time attached to the breast (vanilla vs placebo: 39.0 ± 3.3 vs. 32.9 ± 4.1 minutes, p<0.05) when compared to the control session when their mothers ingested a placebo. Breastfed infants were tested on 2 days separated by 1 week. After following a bland diet devoid of vanilla flavors for several days, half the mothers consumed vanilla extract (10 mL) on the first test day and placebo on the second test day; the order was reversed for the other half of mothers. There was no difference between groups with regards to the number of feedings or mother's perception of infant's feeding behaviors or lactation performance.

Evidence on the infants' behavioral responses within days of repeated maternal ingestion of flavor

Three RCTs manipulated whether and for how long mothers repeatedly ingest a flavor and then looked at their infants' response to the flavor in the days following maternal ingestion (Mennella, 1993b; Mennella, 1999; Hausner, 2010). Two of the 3 studies found that repeated ingestion of flavor (carrot juice 1/day for 1 week) or garlic (3 times over 10 days) by lactating mothers impacted their infant's acceptance of similarly flavored breast milk (Mennella 1993b) or carrot-flavored cereal (Mennella 1999) days later when compared to a non-exposed control group. Infants were more accepting of the test flavor (garlic) when they did not have recent experience with the flavor (control group) compared to infants whose mothers had ingested the flavor for several days prior to testing. One study, Hausner, 2010, did not find repeated maternal ingestion of d-carvone in hummus impacted their infants' acceptance of caraway-flavored potato puree.

In Mennella, 1993b, 30 mother-infant dyads (mean infant age at testing ~4 months) participated in an 11-day experimental period. After eating a bland diet for 3 days all infants were tested for their acceptance of plain cereal on day 4. Dyads were randomized into 1 of 3 groups which differed in what mother ingested (placebo or 1.5 g garlic extract capsules) and when they ingested the capsules during a 5-day period (placebo capsules on days 8-10; garlic capsules on days 5-7; garlic capsules 8-10). Infants' acceptance of garlic-flavored cereal was tested on day 11. Confirming prior

results mentioned above, the infants whose mothers diets were devoid of garlic during the experimental period spent more time breastfeeding during the test session that infants whose mothers ingested garlic on study days 5-7 ($p<0.05$) or on days 8-10 (47.9 ± 5.8 minutes, 24.6 ± 3.7 minutes, 27.8 ± 5.8 minutes, $p<0.05$ respectively).

In Mennella, 1999 (study 2), 38 lactating mothers (mean infant age at testing ~5.5 months) were randomized to drink either 300 mL of carrot juice per day or an equal volume of water over a 1-week period. Immediately before and after the 1-week period (4 days of testing), the infants, (all of whom had been fed cereal for an average of 21.3 days) were tested for their acceptance of cereal prepared with carrot juice on 1 day and cereal prepared with water on another. Within- and between-subject differences were analyzed. Infants whose mothers ingested carrot juice consumed less carrot-flavored cereal compared to plain cereal (cereal intake, g: $p=0.004$; calories ingested: $p=0.05$) and spent less time eating carrot-flavored cereal compared to plain cereal ($p=0.004$). Infants whose mothers did not ingest carrot juice consumed similar amounts of plain and carrot flavored cereal after the maternal ingestion period.

These studies provide further evidence that infants can detect garlic (Mennella, 1993b) or carrot (Mennella,1999) flavors in breast milk and that the infants response varies depending on recency of exposure; that is whether the flavor had not been experienced by the infants in breast milk during the recent past or whether the infant had repeated, recent experience with the flavor. Results from these studies, in which mothers eat bland diets devoid of a given flavor for a week, generally resulted in greater acceptance (as evidenced by more sucking, longer time spent breastfeeding, or greater intake) to the flavor by the infant during breastfeeding. Infants suck more when they are aroused and so detection of a flavor not experienced in the past week may arouse the infants' interest, resulting in a change in nursing behavior. However, if mothers had been ingesting the flavor for several days prior to testing and their infants were repeatedly exposed to the flavor in breast milk, the flavor may be less interesting or arousing to the infant. This may represent an early form of sensory specific satiety such that acceptability of a food decreases after recent consumption.

Chemical analysis on breast milk samples demonstrated the transmission of caraway (d-carvone) flavors to breast milk (Hausner, 2008; Hausner, 2010). Hausner, 2010 further explored breastfed infants' reaction to carawy-flavored foods after their mothers consumed caraway-flavored hummus. In part-one of this study, 40 mother-infant dyads (mean infant age at testing ~7 months) were randomized to ingest either 30 mg d-carvone per 75 g hummus or 75 g plain hummus every third day for 28 days (10 exposures). Infants were tested for their initial acceptance of caraway after the ingestion period. In part-two of the study, which immediately followed, both groups of infants consumed d-carvone-flavored potato puree at home for 10 meals (one meal every other day for 19 days) followed by testing of infant acceptance of the caraway-flavored puree. Infant testing occurred on average 3.6 and 5.4 days after the last day of the intervention period for parts 1 and 2 of the study, respectively. During acceptibility testing, infants were fed 200 g of caraway-flavored potato puree on one day and 200 g plain potato puree on another day and the test order was counter balanced. Intake was assessed by weighing the food and infant behaviors were monitored by videotape. Upon initial exposure to caraway-flavored food, there was no difference in infants reaction to plain and caraway-flavored purees within or between groups. After 10 exposures of the caraway-flavored puree, the only difference was that

infants whose mothers did not consume caraway-flavored hummus refused fewer spoons of caraway-flavored puree than plain puree (8.6±1.1 and 14.2±2.1, respectively, $p<0.05$), while there was no difference in number of refused spoons between caraway-flavored and plain puree within the group of infants whose mothers consumed caraway-flavored hummus. While it has been established that caraway (d-carvone) transfers to breast milk as detected using chemical analysis, it remains unknown whether maternal ingestion of 30 mg of caraway in hummus is enough to produce a detectable flavor in breast milk since no sensory testing was conducted.

Evidence on the infants' behavioral responses to a flavor several months post weaning after their mother's had ingested the flavor during the first few months of lactation.

Two RCTs reveal that repeated ingestion of carrot and other vegetable juices by lactating mother during the first 2-4 months of lactation modifies their infants acceptance of carrot flavored cereal several months later (Mennella, 2001b; Mennella, 2017). Mennella, 2001b found that infants repeated exposure to carrot in mothers' milk during the first 2 months of lactation resulted in relatively greater acceptance of carrot-flavored cereal 4 months later (versus plain cereal), compared to infants without any prior exposure. Subsequent work revealed that the timing of exposure was more important than duration of exposure (Mennella, 2017). Maternal ingestion of vegetable juices for 1 month, beginning when the infant was 2 weeks of age, had a greater impact on the infant's acceptance of carrot-flavored cereal after weaning, compared to infants who had one month exposure starting at 1.5 or 2.5 months of age. Also, Infants whose mothers drank the juices for 1 month starting 2 weeks post-partum ate more carrot-flavored cereal and at a faster rate than did infants whose mothers did not drink vegetable juices. Timing of exposure was more important than duration of exposure. There were no differences in acceptability of carrot-flavored cereal between infants whose mothers began drinking vegetable juices at 2 weeks postpartum for either one month or 3 months. Also, flavor learning was specific to the exposed flavor (carrot) and did not generalize to a novel flavor of broccoli in foods.

In Mennella, 2001b, 31 mother-infant dyads were randomized to ingest 300 mL carrot juice or water 4 days per week for 3 consecutive weeks during the first 2 months of lactation. (A third group not described here, ingested carrot juice during pregnancy). Infants were approximately 5.7 months at testing and weaned ~ 4 months after the intervention phase. Testing occurred approximately 4 weeks after introduction of solids. All women breastfed their children during the intervention phase and all but 7 of the women were still breastfeeding at the time of testing. Infants were fed cereal flavored with water on 1 day and with carrot juice on another test day in counterbalanced order. Infants who had been exposed to carrot flavor via maternal ingestion of carrot juice during lactation displayed less negative facial expressions when eating carrot-flavored cereal compared to plain cereal (3.4 ± 0.6 vs 4.7 ± 0.8, $p=0.03$). Infants in the control group did not demonstrate a difference. There were no differences in the proportional amount consumed, length of feeding, or maternal perception of infant enjoyment between groups.

Building on this finding, the next RCT, Mennella, 2017, focused on the first 3.5 months of lactation and the intervention entailed mothers ingesting a variety of vegetable juices, 1 of which was carrot (i.e., carrot, beet, celery, mixed vegetables). The study was designed to determine the effects of both the timing of maternal ingestion (when

mothers drank a variety of vegetable juices, beginning at 0.5, 1.5, 2.5 months) and duration of maternal ingestion (how often she drank a variety of vegetables juices; 0, 1 or 3 months) on the infants' acceptance of carrot-flavored food (exposed flavor) and broccoli-flavored (novel flavor) food 4.5 to 6.5 months later (depending on the group). The timing of vegetable juice consumption impacted the acceptance of food containing 1 of the exposed flavors, carrot. One month of maternal ingestion of vegetable juice beginning when the infants were 2 weeks postpartum had the greatest effect on relative carrot flavor acceptance several months later when compared to the control group, as measured by intake (78.2 ± 14.8 g and 41.0 ± 7.6 g, p=0.03), and a faster rate of feeding (7.2 ± 1.1 and 3.9 ± 0.6 g/min, p=0.01). Infants whose mothers drank the juices for 1 month starting at 0.5 months lactation ate more carrot-flavored cereal than did infants in the control group, but were no different from those with 3 months of exposure who started the intervention at 0.5 month lactation. There were no significant differences in intake, rate of feeding, facial expressions and maternal rating of enjoyment between the groups whose mothers drank the juices for 1 month starting 1.5 or 2.5 months postpartum and the control group or between infants whose mothers consumed juices for 1 versus 3 months starting 2 weeks postpartum. Maternal ingestion of the vegetables juices did not affect the relative acceptance of the novel broccoli-flavored food when compared to the control group.

Assessment of the body of evidence

- **Internal validity** (determined with NEL Bias Assessment Tool): All studies were controlled trials and have strong internal validity; detection bias identified in studies testing alcohol, fennel-anise-caraway tea, and fish oil supplements; performance bias may exist in the study examining fennel-anise-caraway tea, since mothers prepared their own tea.
- **Adequacy**: There were 15 papers in this body of evidence, twelve flavors were tested, and each flavor was tested in one to three studies. Adequacy was judged to be moderate.
- **Consistency**: Results were consistent within flavors, across outcome types, and across research groups. Negative findings from three studies are likely due to methodological details (e.g., timing of sample collection). Consistency was assessed as moderate.
- **Impact**: Impact is limited because evidence focused on particular flavors in isolation rather than the full maternal diet and long-term effects were not assessed.
- **Generalizability**: Evidence is specific to flavors tested and therefore may not be generalize to other flavors within the maternal diet; therefore generalizability of the body of evidence was considered to be limited.

Included articles

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OBSERVATIONS ACROSS SYSTEMATIC REVIEWS

Results from these systematic reviews are in accordance with one another and combined provide evidence that flavors from the maternal diet are present in amniotic fluid and breast milk, and are detected by the fetus or infant. Studies across both reviews showed that 4 flavors—alcohol, anise, carrot, and garlic—transferred and were later recognized by infants. The results are supported by a combination of analytic methods (chemical, sensory, and infant behavioral analyses). One study was designed to examine maternal consumption during both maternal time-periods and found that at 6 mo of age carrot flavor was detected by infants after maternal ingestion of carrot juice during pregnancy or during lactation. Evidence investigating garlic in both reviews demonstrated a continuation of findings over these early life stages. Garlic flavors transferred to amniotic fluid and breast milk and infants and children responded differently to the odor and taste of garlic, if their mothers ate garlic during the last month of pregnancy or ate garlic while breastfeeding. Further, experiences with garlic flavor during the last month of pregnancy resulted in greater acceptance of garlic-flavored foods by the child 8–9 y later. The convergence of this evidence highlights the importance of the maternal diet during pregnancy and lactation on infants' responses to flavors and the potential to influence subsequent dietary intake and quality.

RESEARCH RECOMMENDATIONS

In order to better understand the impact of what mother's eat during pregnancy and lactation on the infant or child's acceptance of flavors and their overall dietary intake, further research addressing these topics should:

- More research is needed to determine whether flavors from other foods and beverages transmit to and flavor amniotic fluid, the amount needed to be consumed by the mother to elicit a flavor change, and how often the fetus needs to be exposed to the flavor to modify subsequent sensory responses.
- Further examine the timing and duration of exposure to flavors in amniotic fluid and/or breastmilk on subsequent acceptance of a particular food or foods during infancy. Specifically, when does the exposure to a particular flavor need to occur (timing) for the infant to develop a preference for that flavor? What is the minimum amount of exposure (duration, repetition) required for infants to develop a preference for that flavor? Does the child need repeated exposures to the food after weaning to maintain the preference, especially since the flavor is first experienced in a liquid (amniotic fluid and/or breast milk) and the flavor experienced in a solid food is more complex in texture and other sensory properties.
- Conduct research to explore how early flavor experience interacts with variation in taste and flavor genetics in how accepting the child is of flavors and foods after weaning. Specifically, do some children require a different type or prolonged exposure to learn to like the taste of healthy foods (e.g. vegetables) based, for example, on variation in their sensitivity to bitter tastes?
- Evaluate how long the flavor memory that is formed prenatally in amniotic fluid or during breastfeeding lasts and whether such flavor experiences impact food acceptance of the infant at weaning and the rate of acceptance of the foods/flavors following repeated exposure, particularly if the infant is formula fed and there is a lack of continuity in flavor experienced postnatally with that experienced prenatally.
- Conduct randomized controlled trials with longitudinal follow-up at multiple time points from infancy through childhood and into adulthood to assess changes in food and flavor acceptability and dietary intake that include direct measurements of acceptance and liking by the child.
- Evaluate whether there is an optimal time to intervene to improve the diet of both mothers and their children.
- Improve data collection methods, specifically for dietary assessment of mother and child, and food and flavor response measures in the birth to 24 month population. Dietary intake measures of children should not solely rely on maternal report. Investigations into what children eat and what they like to eat should include direct measurements of children.
- Assess the impact of duration of breastfeeding, formula feeding, and a combination of the two on acceptance of foods and flavors during and after weaning to include evaluation of picky eating, willingness to try new foods, and the variety of the child's diet.
- Evaluate the relationship between maternal eating behaviors (e.g. pickiness, low variety) and what she feeds on her child, and her child's eating behaviors,

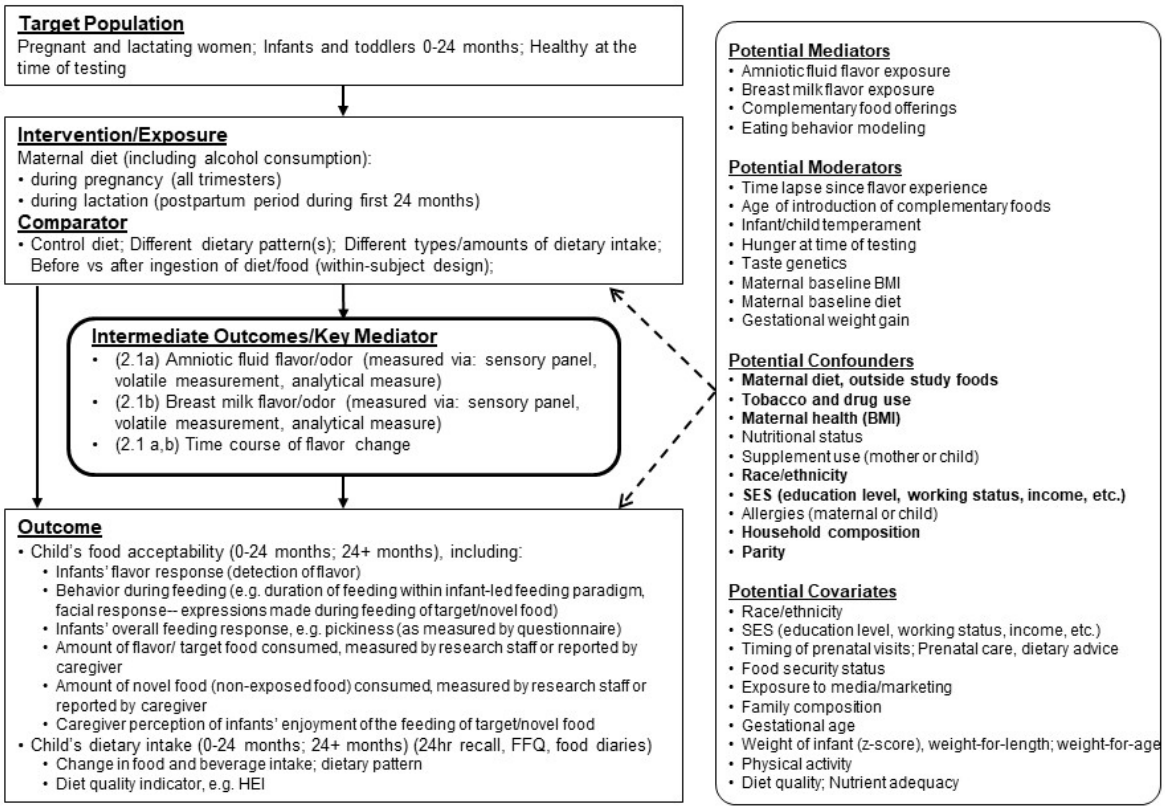
specifically, food/flavor acceptability, picky eating, willingness to try new foods, and amount of variety in their diet.

ANALYTIC FRAMEWORK

The analytic framework (Figure 1) illustrates the overall scope of the systematic review, including the population, the interventions and/or exposures, comparators, and outcomes of interest. It also includes definitions of key terms and identifies key confounders considered in the systematic review. This is the analytic framework for the systematic reviews conducted to examine the relationships between (a) maternal diet during pregnancy on flavor transfer to amniotic fluid, child's behavioral response, and dietary intake (0-24 months, 24+ months), and (b) maternal diet during lactation on flavor transfer to breast milk, child's behavioral response, and dietary intake (0-24 months, 24+ months).

Figure 1: Analytic framework

Q 2.1 Analytic Framework:(a) What is the relationship between **maternal diet during pregnancy** on flavor transfer to amniotic fluid, child's behavioral response, and dietary intake (0-24 months, 24+ months)? (b) What is the relationship between **maternal diet during lactation** on flavor transfer to breast milk, child's behavioral response, and dietary intake (0-24 months, 24+ months)?



SEARCH PLAN AND RESULTS

Inclusion and exclusion criteria

The inclusion and exclusion criteria are a set of characteristics to determine which studies will be included or excluded in the systematic review. This table provides the

inclusion and exclusion criteria for the systematic review question(s):

- What is the relationship between maternal diet during pregnancy on flavor transfer to amniotic fluid, child's behavioral response, and dietary intake (0-24 months, 24+ months)?
- What is the relationship between maternal diet during lactation on flavor transfer to breast milk, child's behavioral response, and dietary intake (0-24 months, 24+ months)?

Table 8. Inclusion and exclusion criteria

Category	Inclusion Criteria	Exclusion Criteria
Study Design	• Randomized controlled trials • Within-subject design • Non-randomized controlled trials • Prospective cohort studies • Retrospective cohort studies	• Case-control studies • Pre/post studies with a control • Cross-sectional studies • Uncontrolled studies • Pre/post studies without a control • Narrative reviews • Systematic reviews • Meta-analyses
Intervention/ Exposure	• Maternal diet during pregnancy or post-partum period • Amniotic fluid flavor (related to maternal diet exposure) • Breast milk flavor (related to maternal diet exposure)	N/A
Comparator	• Control diet; dietary patterns • Different types/amounts of dietary intake • Before vs after ingestion of food/diet	N/A
Date Range	• January 1980 – June 2017	N/A
Risk of Bias	• All studies regardless of NEL BAT risk of bias rating	N/A

Category	Inclusion Criteria	Exclusion Criteria
Language	• Studies published in English	• Studies published in languages other than English
Study Setting/Country	• High, Very high	N/A
Study Duration	• No criterion is needed for study duration	N/A
Publication Status	• Studies published in peer-reviewed journals	• Grey literature, including unpublished data, manuscripts, reports, abstracts, conference proceedings
Study Subjects	• Human subjects • Males • Females • Pregnant women • Lactating women • Non-lactating postpartum women	• Hospitalized patients, not including birth and immediate post-partum hospitalization of healthy mothers and babies
Age of Study Subjects	• Mothers Include: o Adolescents (13-18 years) o Adults (19 and older) • Children Include (for outcomes): o Infants and Toddlers (0-24 months) o Children and adults (24+ months)	• Older adults (65 to 79 years) • Older adults (80+ years)
Size of Study Groups	N/A	N/A

Category	Inclusion Criteria	Exclusion Criteria
Health Status of Study Subjects (Infants/ Toddlers, Birth to 24 months)	• Studies done in generally healthy samples • Studies done in samples where infants were born full-term (≥37 and 0/7 weeks gestational age)	• Studies that exclusively enroll infant subjects with a disease or with the health outcome of interest (intermediate or endpoint health outcomes) • Studies of exclusively pre-term babies (gestational age <37 and 0/7 weeks), exclusively babies that have low birth weight (2500g), and/or exclusively babies that are small for gestational age • Studies done in subjects hospitalized for illness or injury (i.e., this does not include birth and immediate post-partum hospitalization of healthy babies) or malnourished subjects

Health Status of Study Subjects (Mothers, when applicable)	• Studies done in generally healthy samples • Studies done in samples with elevated chronic disease risk or that enroll some subjects with a disease or with the health outcome of interest (intermediate or endpoint health outcomes) o Anemia[1]: hemoglobin (Hg), hematocrit (Hct), or Hb/Hct <5th percentile for age/gender-specific cutoffs o Prediabetes[2]: ▪ A1C: 5.7-6.4% ▪ Fasting plasma glucose (FPG): 100-125 mg/dL ▪ Oral glucose tolerance test (OGTT): 140-199 mg/dL o Prehypertension[3]: ▪ Systolic blood pressure (SBP): 120-139 mmHg ▪ Diastolic blood pressure (DBP): 80-89 mmHg o LDL-Cholesterol[4]: above optimal (≥100 mg/dL) o Total Cholesterol[4]: above desirable (≥200 mg/dL) o Low HDL Cholesterol[4]: <40 mg/dL o Triglycerides[4]: above normal (≥150 mg/dL) • Samples with diagnosed disease states and conditions common during pregnancy in the US (e.g., obesity, diabetes, gestational diabetes, anemia,	• Studies that exclusively recruited subjects that have celiac disease and depression • Studies done in subjects hospitalized for illness or injury (i.e., this does not include birth and immediate post-partum hospitalization of healthy mothers) or malnourished subjects • Studies of subjects with infectious diseases (e.g. HIV/AIDS)

Category	Inclusion Criteria	Exclusion Criteria
	allergies, pre-eclampsia), and taking associated medications	
Source of Foods, Beverages, or Nutrients **(IV or DV)**	• Whole food sources • Fortified foods/beverages • Enriched foods/beverages • Flavors (essential oils, beverages, spices, seasonings, etc.) • Mother's own milk (MOM) [specify delivery mode; e.g. at the breast, expressed fresh, or frozen milk] • Infant formulas (e.g., milk-based, soy, partially-hydrolyzed, extensive-hydrolyzed, amino acid-based) • Baby foods (purees, cereals, etc)	• Vitamin and mineral supplements (e.g., iron drops) • Donor or banked milk • Medical foods/supplements (e.g. Pedialyte)
Breast milk flavor/Amniotic fluid flavor **(DV)**	• As measured via: o Analytic measures o Sensory panel o Flavor response (see 'food response', below)	N/A

Category	Inclusion Criteria	Exclusion Criteria
Food Response/ Acceptance (DV)	• Infants' flavor response (detection of flavor) • Behavior during feeding (e.g. duration of feeding within infant-led feeding paradigm, facial response-- expressions made during feeding of target/novel food) • Infants' overall feeding response, e.g. pickiness (as measured by questionnaire) • Amount of flavor/ target food consumed, measured by research staff or reported by caregiver • Amount of novel food (non-exposed food) consumed, measured by research staff or reported by caregiver • Caregiver perception of infants' enjoyment of the feeding of target/novel food	N/A
Dietary Intake (DV)	• Change in food intake[5] • Diet quality indicator, e.g. HEI[5]	N/A

[1] CDC, 1998
[2] NIDDK, 2014
[3] NHLBI, 2004
[4] NHLBI, 2001
[5] Measured via 24hr recall, FFQ, food diaries

Search terms and electronic databases used

PubMed:

Date(s) Searched: 5/11/16; 6/21/2017

Search date range: 1980-6/2017

Search Terms:

(Maternal OR Mother*[tiab] OR mothers[mesh] OR pregnan*[tiab] OR "Pregnant Women"[Mesh] OR "Pregnancy"[Mesh] OR "Lactation"[Mesh] OR lactat*[tiab] OR natal[tiab] OR postnatal[tiab] OR "Perinatal Care"[Mesh] OR Perinatal[tiab] OR prenatal OR periconception OR gestation*[tiab] OR gravid*[tiab] OR peripartum[tiab])

AND

diet[mh:noexp] OR diet[ti] OR diets[ti] OR food preferences[mh] OR feeding behavior[mh] OR food*[tiab] OR "Food"[mh:noexp] OR "Eating"[mh] OR caloric intake* OR fruit*[tiab] OR vegetable*[tiab] OR dietary intake*[tiab] OR food intake*[tiab] OR food habits[mh] OR dietary habit*[tiab] OR diet habit*[tiab] OR eating habit*[tiab] OR nutrient intake*[tiab] OR food choice*[tiab] OR "diet quality"[tiab] OR dietary choice*[tiab] OR dietary change*[tiab] OR diet records[mh] OR dietary pattern*[tiab] OR eating pattern*[tiab] OR food pattern*[tiab] OR eating habit*[tiab] OR dietary habit*[tiab] OR food habit*[tiab] OR dietary profile*[tiab] OR food profile*[tiab] OR eating profile*[tiab] OR dietary guideline*[tiab] OR dietary recommendation*[tiab] OR food intake*[tiab] OR dietary intake*[tiab] OR eating style*[tiab] OR dietary score*[tiab] OR adequacy index*[tiab] OR kidmed[tiab] OR Food Score*[tiab] OR Diet Score*[tiab] OR MedDietScore[tiab] OR "healthy eating index"[tiab] OR ((index*[ti] OR score*[ti] OR indexes[ti] OR scoring[ti] OR indices[ti]) AND (dietary[ti] OR nutrient*[ti] OR eating[tiab] OR food[ti] OR food[mh] OR diet[ti] OR diet[mh]) AND (pattern* OR habit* OR profile*))

OR

(beverage*[tiab] OR beverages[mh] OR cereal*[tiab] OR "Edible Grain"[Mesh] OR bread*[tiab] OR bread[mh] OR whole grain*[tiab] OR juice*[tiab] OR milk[tiab] OR "Milk"[Mesh] OR dairy[tiab] OR "Dairy Products"[Mesh] OR meat[tiab] OR cheese[tiab] OR yogurt[tiab] OR yoghurt*[tiab] OR fruit*[tiab] OR "Fruit"[Mesh] OR honey[mh] OR vegetable*[tiab] OR "Vegetables"[Mesh] OR egg*[tiab] OR "Eggs"[Mesh:noexp] OR “egg white”[mh] OR egg yolk[mh] OR nut[ti] OR nuts[ti] OR peas[tiab] OR beans[tiab] OR legume*[tiab] OR snack*[tiab] OR candy[mh] OR condiments[mh] OR condiment*[tiab] OR "Fast Foods"[Mesh] OR meat[mh] OR molasses[mh] OR nuts[mh] OR "Raw Foods"[Mesh] OR seeds[mh])

FA search:

taste OR flavor* OR flavour* OR accepta* OR preference* OR enjoy* OR choice* OR habit* OR discriminat* OR aversion* OR avert* OR ("Facial Expression"[Mesh] OR ((facial[tiab] OR face[tiab]) AND (expression* OR response* OR react*))) OR (reject*

OR dislike* OR disliking OR neophobi*) OR odor* OR smell*

AND

(food OR dietary OR diet OR eating OR beverage* OR food*[tiab] OR "Food and Beverages"[Mesh] OR beverage*[tiab] OR cereal*[tiab] OR Cereal* OR bread*[tiab] OR whole grain*[tiab] OR juice*[tiab] OR milk[tiab] OR "Milk"[Mesh] OR dairy[tiab] OR "Dairy Products"[Mesh] OR meat[tiab] OR cheese[tiab] OR yogurt[tiab] OR yoghurt*[tiab] OR fruit*[tiab] OR "Fruit"[Mesh] OR vegetable*[tiab] OR "Vegetables"[Mesh] OR egg*[tiab] OR "Eggs"[Mesh] OR nut[tiab] OR nuts[tiab] OR peas[tiab] OR beans[tiab] OR legume*[tiab] OR rice OR soup OR snack*[tiab] OR meals OR meal)

OR "Taste"[Mesh] OR gustat*[tiab] OR taste sense*[tiab] OR "Taste Threshold"[Mesh] OR "Taste Perception"[Mesh] OR flavor* OR flavor* OR distaste OR hedoni* OR palatab* OR unpalatab*

AND

infant* OR baby OR babies OR toddler* OR newborn*[tiab] OR "Child, Preschool"[Mesh] OR preschool*[tiab] OR pre-school*[tiab] OR “early childhood”[tiab] OR early year*[tiab] OR pre-k[tiab] OR pre-primary[tiab] OR under five*[ti] OR young child*[ti] OR “head start”[tiab] OR prekindergarten[tiab] OR pre-kindergarten[tiab] OR weanling* OR “first two years” OR “first 2 years”

(includes age filter: Filters: Infant: birth-23 months)

("Study Characteristics" [Publication Type] OR “clinical trial”[ptyp] OR random*[tiab] OR "Epidemiologic Studies"[Mesh] OR "Support of Research"[ptyp] OR cohort[tiab] OR observational[tiab] OR retrospective[tiab] OR longitudinal[tiab] OR controlled trial*[tiab] OR trial[tiab] OR trials[tiab] OR epidemiolog*) NOT (editorial[ptyp] OR comment[ptyp] OR news[ptyp] OR letter[ptyp] OR review[ptyp] OR systematic[sb])

For prior to 2009; just NOT (editorial[ptyp] OR comment[ptyp] OR news[ptyp] OR letter[ptyp] OR review[ptyp] OR systematic[sb]) (don’t do: doesn’t exclude that many more.)

Embase:

Date(s) Searched: 5/16/16; 6/22/2017

Search Terms:

('maternal nutrition'/exp OR mother/exp OR 'pregnancy'/exp OR 'pregnant woman'/exp

OR 'lactation'/exp OR 'prenatal period'/exp OR 'perinatal period'/exp)

AND (('dietary intake'/de OR 'feeding behavior'/exp OR 'eating habit'/de OR 'food preference'/de OR 'food intake'/exp OR 'fruit'/exp OR 'vegetable'/exp OR 'food'/exp OR 'portion size'/de OR 'caloric intake'/exp OR 'alcohol consumption'/exp OR 'fluid intake'/exp OR 'diet restriction'/exp OR 'fluid intake'/exp) NOT ('postprandial state'/exp OR 'enteric feeding'/exp OR 'parenteral nutrition'/exp))

OR ((food/exp NOT ('animal food'/exp OR 'dietary fiber'/exp OR 'fat'/exp OR 'food color'/exp OR 'food contamination'/exp OR 'food drug interaction'/exp OR 'functional food'/exp OR 'genetically modified food'/exp)) OR 'baby food'/exp OR 'cereal'/exp OR 'dairy product'/exp OR 'egg'/exp OR 'fruit'/exp OR 'meat'/exp OR 'sea food'/exp OR 'milk'/exp OR fish/exp OR 'poultry'/exp OR 'beverage'/exp OR 'vegetable'/exp OR nut/exp OR pea/exp OR meal/exp)

OR

(Maternal OR mother* OR pregnan* OR lactat* OR natal OR postnatal OR Perinatal OR prenatal OR periconception OR gestation* OR gravid* OR peripartum) NEAR/3

(Diet OR diets OR dietary OR ‘whole grain’ OR ‘whole grains’ OR dairy OR egg OR eggs OR meat OR poultry OR seafood OR ‘sea food' OR fruit* OR milk OR fish* OR poultry OR beverage* OR vegetable OR vegetable* OR pea OR peas OR nut OR nuts OR cereal OR bread* OR yog*urt* OR cheese* OR juice* OR rice OR soup OR snack* OR meal* OR beans OR legume*)

(‘amnion fluid'/exp OR ((amnio* OR allantoi* OR amnii) NEAR/1 (liquid OR fluid*)))

OR

('breast milk'/exp OR 'human milk':ab,ti OR 'breast milk':ti,ab OR breast-milk:ti,ab OR breastmilk:ti,ab OR ((mother* OR maternal OR human) NEAR/1 milk):ti,ab)

AND

(taste OR flavor* OR flavour* OR accepta* OR preference* OR enjoy* OR choice* OR habit* OR discriminat* OR aversion* OR avert* OR distaste OR hedonic OR palatab* OR unpalatab* OR "Facial Expression"/exp OR ((facial OR face OR physiogno*) AND (expression* OR response* OR react*)) OR smile* OR smiling OR reject* OR dislike* OR disliking OR neophobi* OR odor* OR smell* OR odour* OR aroma* OR gustat* OR 'smelling and taste'/exp)

OR ((nutrient* NEAR/3 dense*) OR (nutrient* NEAR/3 rich*)) AND (food* OR beverage*):ti,ab ?

AND

(infant*:ti,ab OR infant/exp) OR (baby OR babies OR toddler* OR newborn* OR nurser*):ti,ab OR 'newborn'/exp OR 'newborn care'/exp OR preschool*:ti,ab OR “early years”:ti,ab OR pre-school:ti,ab OR 'preschool child'/exp OR 'infancy'/exp OR “early childhood”:ti,ab OR pre-k:ti,ab OR 'nursery'/exp OR 'nursery school'/exp OR prekindergarten:ti,ab OR pre-kindergarten:ti,ab OR weanling:ti,ab (postnatal, perinatal?)

OR ([newborn]/lim OR [infant]/lim OR [child]/lim OR [preschool]/lim) not needed (got same # as just doing the infant search.)

AND ([in process]/lim OR [article]/lim OR [article in press]/lim)

NOT [medline]/lim

'clinical article'/exp OR ‘clinical trial':ti,ab OR 'controlled study':ti,ab OR ‘clinical study':ti,ab OR 'randomized controlled’:ti,ab OR 'clinical study':ti,ab OR 'cohort analysis'/exp OR cohort:ti,ab OR 'types of study'/exp OR

(('article'/it OR 'article in press'/it) AND ('case report'/de OR 'clinical article'/de OR 'clinical trial'/de OR 'cohort analysis'/de OR 'comparative study'/de OR 'controlled clinical trial'/de OR 'controlled study'/de OR 'human'/de OR 'human experiment'/de OR 'longitudinal study'/de OR 'major clinical study'/de OR 'normal human'/de OR 'observational study'/de OR 'prospective study'/de OR 'randomized controlled trial'/de OR 'retrospective study'/de))

Dietary intake/diet/foods

diet*:ti OR 'caloric intake':ab, ti OR 'dietary intake':ab, ti OR 'dietary quality':ab, ti OR 'eating pattern':ab, ti OR 'food pattern':ab,ti OR 'dietary habit':ab,ti OR 'food habit':ab,ti OR 'food intake':ab,ti OR 'food choice':ab, ti OR 'diet quality':ab, ti OR 'dietary profile':ab, ti OR 'food profile':ab, ti OR 'diet profile':ab, ti OR 'eating profile':ab, ti OR 'eating style':ab, ti OR 'dietary score':ab, ti OR kidmed:ab, ti OR 'food score':ab, ti OR 'diet score':ab, ti OR 'meddietscore':ab, ti OR 'dietary pattern score':ab, ti OR 'healthy eating index':ab, ti OR (index:ab, ti OR score:ab, ti OR scoring:ab, ti OR indices:ab, ti AND (dietary:ab, ti OR nutrient:ab, ti OR eating:ab, ti OR food:ab, ti OR diet:ab, ti) AND (pattern:ab, ti OR habit:ab, ti OR profile:ab, ti) OR

“food consumption” OR “food ingestion” OR “food uptake” OR “meal ingestion”

OR (('dietary intake'/de OR 'feeding behavior'/exp OR 'eating habit'/de OR 'food preference'/de OR 'food intake'/exp OR 'fruit'/exp OR 'vegetable'/exp OR 'food'/exp OR 'portion size'/de OR 'caloric intake'/exp OR 'alcohol consumption'/exp OR 'fluid intake'/exp OR 'diet restriction'/exp OR 'fluid intake'/exp)

NOT ('postprandial state'/exp OR 'enteric feeding'/exp OR 'parenteral nutrition'/exp))

OR ((food/exp NOT ('animal food'/exp OR 'dietary fiber'/exp OR 'fat'/exp OR 'food color'/exp OR 'food contamination'/exp OR 'food drug interaction'/exp OR 'functional food'/exp OR 'genetically modified food'/exp)) OR 'baby food'/exp OR 'cereal'/exp OR 'dairy product'/exp OR 'egg'/exp OR 'fruit'/exp OR 'meat'/exp OR 'sea food'/exp OR 'milk'/exp OR fish/exp OR 'poultry'/exp OR 'beverage'/exp OR 'vegetable'/exp OR nut/exp OR pea/exp OR meal/exp)

OR

('whole grain' OR 'whole grains' OR dairy OR egg OR eggs OR meat OR poultry OR seafood OR 'sea food' OR fruit* OR milk OR fish* OR poultry OR beverage* OR vegetable OR vegetable* OR pea OR peas OR nut OR nuts OR cereal OR bread* OR yog*urt* OR cheese* OR juice* OR rice OR soup OR snack* OR meal* OR beans OR legume*):ti,ab

Cochrane:

Date(s) Searched: 5/24/16; 6/23/2017

Search Terms:

((maternal OR mother* OR pregnan* OR lactat* OR natal OR postnatal OR perinatal OR prenatal OR periconception OR gestation* OR gravid* OR peripartum) AND (infant*:ti,ab OR (baby OR babies OR toddler* OR newborn* OR nurser*):ti,ab OR preschool*:ti,ab OR "early years":ti,ab OR pre-school:ti,ab OR "early childhood":ti,ab OR pre-k:ti,ab OR prekindergarten:ti,ab OR pre-kindergarten:ti,ab OR weanling:ti,ab)) NEAR/3 (diet:ti OR diets:ti OR dietary:ti OR 'whole grain' OR 'whole grains' OR dairy OR egg OR eggs OR meat OR poultry OR seafood OR 'sea food' OR fruit* OR milk OR fish* OR poultry OR beverage* OR vegetable OR vegetable* OR pea OR peas OR nut OR nuts OR cereal OR bread* OR yog*urt* OR cheese* OR juice* OR rice OR soup OR snack* OR meal* OR beans OR legume* OR 'caloric intake':ab,ti OR 'dietary intake':ab,ti OR 'dietary quality':ab,ti OR 'eating pattern':ab,ti OR'food pattern':ab,ti OR 'dietary habit':ab,ti OR 'food habit':ab,ti OR 'food intake':ab,ti OR 'food choice':ab,ti OR 'diet quality':ab,ti OR 'dietary profile':ab,ti OR 'food profile':ab,ti OR 'diet profile':ab,ti OR 'eating profile':ab,ti OR 'eating style':ab,ti OR 'dietary score':ab,ti OR kidmed:ab,ti OR 'food score':ab,ti OR' diet score':ab,ti OR 'meddietscore':ab,ti OR 'dietary pattern score':ab,ti OR 'healthy eating index':ab,ti OR ((index:ab,ti OR score:ab,ti OR scoring:ab,ti OR indices:ab,ti) AND (dietary:ab,ti ORnutrient:ab,ti OR eating:ab,ti OR food:ab,ti OR diet:ab,ti) AND (pattern:ab,ti OR habit:ab,ti OR profile:ab,ti)) OR "food

consumption” OR “food ingestion” OR “food uptake” OR “meal ingestion”) 20; imported; 12 unique

(maternal OR mother* OR pregnan* OR lactat* OR natal OR postnatal OR perinatal OR prenatal OR periconception OR gestation* OR gravid* OR peripartum OR infant*:ti,ab OR (baby OR babies OR toddler* OR newborn* OR nurser*):ti,ab OR preschool*:ti,ab OR “early years”:ti,ab OR pre-school:ti,ab OR “early childhood”:ti,ab OR pre-k:ti,ab OR prekindergarten:ti,ab OR pre-kindergarten:ti,ab OR weanling:ti,ab) NEAR/3 (diet:ti OR diets:ti OR dietary:ti OR 'whole grain' OR 'whole grains' OR dairy OR egg OR eggs OR meat OR poultry OR seafood OR 'sea food' OR fruit* OR milk OR fish* OR poultry OR beverage* OR vegetable OR vegetable* OR pea OR peas OR nut OR nuts OR cereal OR bread* OR yog*urt* OR cheese* OR juice* OR rice OR soup OR snack* OR meal* OR beans OR legume* OR 'caloric intake':ab,ti OR 'dietary intake':ab,ti OR 'dietary quality':ab,ti OR 'eating pattern':ab,ti OR'food pattern':ab,ti OR 'dietary habit':ab,ti OR 'food habit':ab,ti OR 'food intake':ab,ti OR 'food choice':ab,ti OR 'diet quality':ab,ti OR 'dietary profile':ab,ti OR 'food profile':ab,ti OR 'diet profile':ab,ti OR 'eating profile':ab,ti OR 'eating style':ab,ti OR 'dietary score':ab,ti OR kidmed:ab,ti OR 'food score':ab,ti OR' diet score':ab,ti OR 'meddietscore':ab,ti OR 'dietary pattern score':ab,ti OR ‘healthy eating index':ab,ti OR ((index:ab,ti OR score:ab,ti OR scoring:ab,ti OR indices:ab,ti) AND (dietary:ab,ti ORnutrient:ab,ti OR eating:ab,ti OR food:ab,ti OR diet:ab,ti) AND (pattern:ab,ti OR habit:ab,ti OR profile:ab,ti)) OR “food consumption” OR “food ingestion” OR “food uptake” OR “meal ingestion”)

((amnio* OR allantoi* OR amnii) NEAR/1 (liquid OR fluid*))

OR

('human milk':ab,ti OR 'breast milk':ti,ab OR breast-milk:ti,ab OR breastmilk:ti,ab OR ((mother* OR maternal OR human) NEAR/1 milk):ti,ab)

AND

(taste OR gustatory OR flavor* OR flavour* OR accepta* OR preference* OR enjoy* OR choice* OR habit* OR discrimination* OR aversion* OR avert* OR distaste OR hedonic OR palatab* OR unpalatab* OR ((facial OR face OR physiogno*) AND (expression* OR response* OR react*)) OR smile* OR smiling OR reject* OR dislike* OR disliking OR neophobi* OR odor* OR smell* OR aroma* OR odour* OR gustat*)

((food* OR beverage* OR diet* OR eating OR taste* OR tasty OR tastiness OR gustatory OR flavo*r* OR distaste*) NEAR/3 (accepta* OR prefer* OR choice* OR habit* OR discriminat* OR select* OR liking OR like* OR enjoy* OR avert* OR avers* OR facial OR face OR reject* OR dislik* OR neophobi* OR hedoni*))

((Face OR facial) NEAR/4 (react* OR respons* OR expressi*)):ti,ab need?

OR

((‘whole grain’ OR ‘whole grains’ OR dairy OR egg OR meat OR poultry OR seafood OR fruit* OR milk OR fish* OR poultry OR vegetables* OR pea OR nut OR cereal OR beverage* OR bread* OR seafood OR yog*urt* OR cheese* OR juice* OR beans OR legume* OR snack* OR meal*) NEAR/7 (accepta* OR prefer* OR choice* OR habit* OR discriminat* OR select* OR liking OR like* OR enjoy* OR avert* OR aversion* OR facial OR face OR reject* OR dislik* OR neophobi* OR hedoni* OR distaste* OR taste* OR tasty OR tastiness OR odor* OR smell odour* OR aroma*))

(Palatab* OR unpalatab*):ti,ab

AND

infant* OR baby OR babies OR toddler* OR newborn* OR nurser* OR preschool* OR pre-school OR “early childhood” OR “early years” OR pre-k OR prekindergarten OR pre-kindergarten OR weanling*

CINAHL (Plus)

Date(s) Searched: 6/7/16; 6/23/2017;

Search Terms:

((MH "Food Intake+") OR "dietary intake" OR (MH "Infant Feeding+") OR

((MH "Food and Beverages+") OR (MH "Food") OR (MH "Diet") OR (MH "Eating") OR (MH "Eating Behavior") OR (MH "Meals+") OR (MH "Taste") OR (MH "Taste Buds") OR (MH "Cereals") OR (MH "Dairy Products") OR (MH "Yogurt") OR (MH "Cheese") OR (MH "Milk") OR (MH "Eggs") OR (MH "Fruit") OR (MH "Fruit Juices") OR (MH "Meat") OR (MH "Seafood") OR (MH "Fish") OR (MH "Poultry") OR (MH "Vegetables") OR (MH "Nuts") OR (MH "Legumes") OR (MH "Bread") OR (MH "Facial Expression"))

(MH "Expectant Mothers") OR (MH "Adolescent Mothers") OR (MH "Mothers")

DI AND maternal and child Done; imported 46

AF/BM 96 results; imported 5

((MH "Milk, Human") AND (taste OR gustatory OR flavor* OR flavour* OR accepta*

OR preference* OR enjoy* OR choice* OR discrimination* OR aversion* OR avert* OR distaste OR hedonic OR palatab* OR unpalatab* OR reject* OR dislike* OR disliking OR neophobi* OR odor* OR smell* OR odour* OR aroma* OR gustat*)) OR (MH "Amniotic Fluid")

OR (MH "Food Preferences") OR (MH "Food Habits") dupes; 1 imported.

Limit to “all infant” OR

(MH "Infant") OR (MH "Infant, Newborn") OR (MH "Infant Behavior") OR (MH "Infant Feeding") OR (MH "Infant Feeding Schedules") OR (MH "Child, Preschool")

((Mother* OR maternal) AND (infant* OR baby OR babies OR toddler* OR newborn* OR nurser* OR preschool* OR pre-school OR “early childhood” OR “early years” OR pre-k OR prekindergarten OR pre-kindergarten OR weanling*)) n3 (food* OR beverage* OR diet* OR eating OR taste* OR gustatory OR flavo#r* OR‘whole grain’ OR ‘whole grains’ OR dairy OR egg OR eggs OR meat OR poultry OR seafood OR fruit* OR milk OR fish* OR poultry OR vegetables* OR pea OR peas OR nut OR nuts OR cereal OR beverage* OR bread* OR seafood OR yog#urt* OR cheese* OR juice* OR snack* OR meal OR meals)

OR (infant* OR baby OR babies OR toddler* OR newborn* OR nurser* OR preschool* OR pre-school OR “early childhood” OR “early years” OR pre-k OR prekindergarten OR pre-kindergarten OR weanling*) NEAR/3

FSTA/BIOSIS/CAB

Date(s) Searched: 6/2016

Search Terms:

((food* OR beverage* OR diet* OR eating OR taste* OR gustatory OR flavor* OR flavor*) NEAR/7 (accepta* OR prefer* OR choice* OR habit* OR discriminat* OR select* OR liking OR like* OR aversion* OR avert* OR face OR facial OR reject* OR dislik* OR neophobi* OR react* OR respons* OR expressi* OR hedoni* OR distaste* OR tasty OR tastiness))

Imported one from FSTA; none from BIOSIS/CAB; dupes/irrelevant/not able to limit to humans/non conference

("whole grain" OR "whole grains" OR dairy OR egg OR eggs OR meat OR poultry OR seafood OR fruit* OR milk OR fish* OR poultry OR vegetables* OR pea OR peas OR nut OR nuts OR cereal OR beverage* OR bread* OR seafood OR yogurt* OR yoghurt* OR cheese* OR juice* OR snack* OR meal OR meals) NEAR/7 (accepta* OR prefer* OR choice* OR habit* OR discriminat* OR select* OR liking OR like* OR enjoy* OR aversion* OR avert* OR face OR facial OR reject* OR dislik* OR neophobi* OR react* OR respons* OR expressi* OR distaste* OR taste* OR tasty OR tastiness)

infant* OR baby OR babies OR toddler* OR newborn* OR nurser* OR preschool* OR pre-school OR "early childhood" OR "early years" OR pre-k OR prekindergarten OR pre-kindergarten OR weanling*

Web of science

Date(s) Searched: 6/2016

Search Terms:

((food OR beverage OR diet OR eating OR taste OR gustatory OR flavor) w/3 (accepta* OR prefer* OR choice OR habit* OR discriminat* OR select* OR like* OR enjoy* OR avert* OR aversion OR face OR facial OR dislike OR reject OR neophobi* OR respons* OR react*))

OR

('whole grain' OR 'whole grains' OR dairy OR eggs OR meat OR poultry OR seafood OR fruit OR milk OR fish OR poultry OR vegetables OR peas OR nuts OR cereal OR beverage OR bread OR seafood OR yogurt OR cheese OR juice) w/3 (accepta* OR prefer* OR choice OR habit* OR discriminat* OR select* OR like OR enjoy* OR avert* OR aversion OR face OR facial OR dislike OR distaste OR reject OR neophobi* OR respons* OR react*)

AND

(infant* OR (baby OR babies OR toddler OR newborn OR nurser*) OR preschool* OR pre-school OR "early childhood" OR pre-k OR prekindergarten OR pre-kindergarten OR "early years" OR weanling)

APA PsycNET (PsycInfo/PsycArticles)

Date(s) Searched: 6/9/2016; 6/23/17

Search Terms:

({Food Intake} OR {Food Preferences} OR {Food Refusal} OR {Diets} OR {Food} OR {Beverages (Nonalcoholic)} OR {Appetite} OR {Taste Buds} OR {Eating Behavior} OR {Taste Perception} OR Palatab* OR unpalatab* OR food* OR beverage* OR diet* OR eating OR taste* OR gustatory OR flavor* OR flavour* OR 'whole grain' OR 'whole grains' OR dairy OR egg OR eggs OR meat OR poultry OR seafood OR fruit* OR milk OR fish* OR poultry OR vegetables* OR pea OR peas OR nut OR nuts OR cereal OR beverage* OR bread* OR seafood OR yogurt* OR cheese* OR juice* OR snack* OR meal OR meals)

AND ({Expectant Mothers} OR {Mothers} OR {Adolescent Mothers} OR {Pregnancy} OR {Human Females} OR maternal OR mother*) OR/AND (infant* OR baby OR babies OR toddler* OR newborn* OR nurser* OR preschool* OR pre-school OR "early childhood" OR "early years" OR pre-k OR prekindergarten OR pre-kindergarten OR weanling*)

(infant* OR baby OR babies OR toddler* OR newborn* OR nurser* OR preschool* OR pre-school OR "early childhood" OR "early years" OR pre-k OR prekindergarten OR pre-kindergarten OR weanling*) NEAR/3

(food* OR beverage* OR diet* OR eating OR taste* OR gustatory OR flavor* OR flavour* OR 'whole grain' OR 'whole grains' OR dairy OR egg OR eggs OR meat OR poultry OR seafood OR fruit* OR milk OR fish* OR poultry OR vegetables* OR pea OR peas OR nut OR nuts OR cereal OR beverage* OR bread* OR seafood OR yogurt* OR cheese* OR juice* OR snack* OR meal OR meals)

{Amniotic Fluid} OR ((Breast NEAR/3 milk) AND (taste OR gustatory OR flavor* OR flavour* OR accepta* OR preference* OR enjoy* OR choice* OR discrimination* OR aversion* OR avert* OR distaste OR hedonic OR palatab* OR unpalatab* OR reject* OR dislike* OR disliking OR neophobi* OR odor* OR smell* OR favor* OR gustat*))

PsycNET:

Date(s) Searched: 2/4/2016;

Search terms: see above for update:

(food* OR beverage* OR diet* OR eating OR taste* OR tasty OR tastiness OR gustatory OR flavo*) NEAR/3 (accepta* OR prefer* OR choice* OR habit* OR discriminat* OR select* OR liking OR like* OR enjoy* OR avert* OR avers* OR facial OR face OR reject* OR dislik* OR neophobi* OR hedoni*) 520

((‘whole grain’ OR ‘whole grains’ OR dairy OR egg* OR meat OR poultry OR seafood OR fruit* OR milk OR fish* OR vegetables* OR pea OR nut OR cereal OR beverage* OR bread* OR seafood OR yogurt* OR yoghurt* OR cheese* OR juice* OR beans OR legume* OR snack* OR meal*) NEAR/3 (accepta* OR prefer* OR choice* OR habit* OR discriminat* OR select* OR liking OR like* OR enjoy* OR avert* OR aversion* OR facial OR face OR reject* OR dislik* OR neophobic* OR hedoni* OR distaste* OR taste* OR tasty OR tastiness)) 9 none selected

ScienceDirect:

Date(s) searched: 6/2016

Search terms:

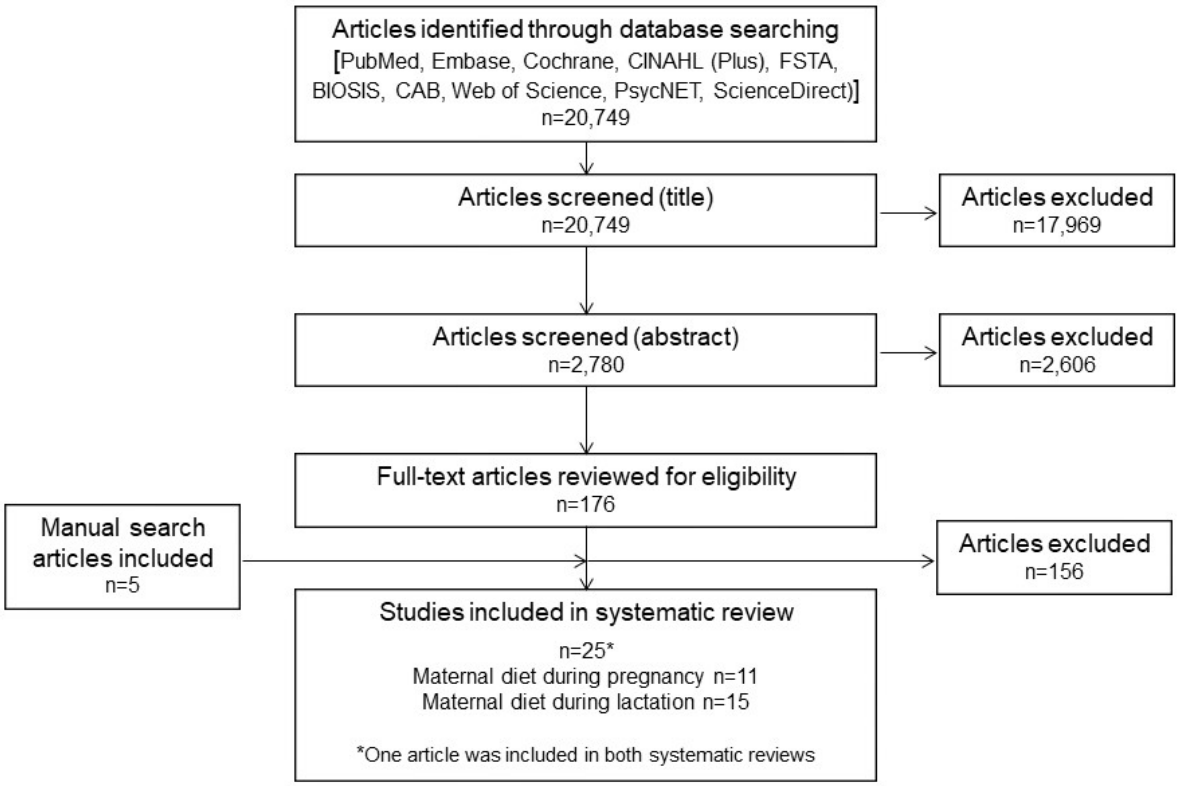
(docsubtype(FLA) and pub-date > 1979 and (food OR beverage OR diet OR eating OR taste OR gustatory OR flavor) w/3 (accepta* OR prefer* OR choice OR habit* OR discriminat* OR select* OR like OR enjoy* OR avert* OR aversion OR face OR facial OR dislike OR distaste OR reject OR neophobi* OR respons* OR react*) AND LIMIT-TO(cids, "271256","Food Quality and Preference")) AND (pub-date > 1979 and (infant* OR (baby OR babies OR toddler OR newborn OR nurser*) OR preschool* OR pre-school OR “early childhood” OR pre-k OR prekindergarten OR pre-kindergarten OR “early years” OR weanling) AND docsubtype(FLA))

((food OR beverage OR diet OR eating OR taste OR gustatory OR flavor) w/3 (accepta* OR prefer* OR choice OR habit* OR discriminat* OR select* OR like OR enjoy* OR avert* OR aversion OR face OR facial OR dislike OR distaste OR reject OR neophobi* OR respons* OR react*)) AND NOT (‘whole grain’ OR ‘whole grains’ OR dairy OR eggs OR meat OR poultry OR seafood OR fruit OR milk OR fish OR poultry OR vegetables OR peas OR nuts OR cereal OR beverage OR bread OR seafood OR yogurt OR cheese OR juice)

AND

(pub-date > 1979 and (infant* OR (baby OR babies OR toddler OR newborn OR nurser*) OR preschool* OR pre-school OR “early childhood” OR pre-k OR prekindergarten OR pre-kindergarten OR “early years” OR weanling) AND docsubtype(FLA) LIMIT-TO(cids, "271256","Food Quality and Preference")

Figure 2: Flow chart of literature search and screening results



This flow chart illustrates the literature search and screening results for articles examining the relationships between maternal diet during pregnancy on flavor transfer to amniotic fluid, child's behavioral response, and dietary intake (0-24 months, 24+ months), and maternal diet during lactation on flavor transfer to breast milk, child's behavioral response, and dietary intake (0-24 months, 24+ months). The results of the electronic database searches were screened independently by two NESR analysts in a step-wise manner by reviewing titles, abstracts, and full text articles to determine which articles met the criteria for inclusion. A manual search was done to ascertain articles not identified through the electronic database search. The systematic review on maternal diet during pregnancy included 11 articles, and the systematic review on maternal diet during lactation included 15 articles.

Excluded articles

The table below lists the excluded articles with at least one reason for exclusion, and may not reflect all possible reasons.

Table 9. Excluded articles

	Citation	Rationale
1	Aksoy Okan, M.,Gunduz, M.,Okur, M.,Akgun, C.,Esin, K.. Does maternal diet affect infantile colic?. J Matern Fetal Neonatal Med. 2015;1-3.	Dependent variable
2	Amir LH, Donath SM. Maternal diet and breastfeeding: a case for rethinking physiological explanations for breastfeeding determinants. Breastfeeding Review. 2013;21:52-52 1p.	Study design
3	Andersen, L. B.,Molgaard, C.,Michaelsen, K. F.,Carlsen, E. M.,Bro, R.,Pipper, C. B.. Indicators of dietary patterns in Danish infants at 9 months of age. Food Nutr Res. 2015;59:27665.	Study design, Independent variable
4	Antoniou, E. E.,Roefs, A.,Kremers, S. P. J.,Jansen, A.,Gubbels, J. S.,Sleddens, E. F. C.,Thijs, C.. Picky eating and child weight status development: a longitudinal study. Journal of Human Nutrition & Dietetics. 2016;29:298-307 10p.	Independent variable, Age
5	Apple RD. An Unexpected but Fruitful Combination. Nurs Hist Rev. 2016;24:76-80.	Study design
6	Ashman AM,Collins CE,Weatherall L,Brown LJ,Rollo ME,Clausen D,Blackwell CC,Pringle KG,Attia J,Smith R,Lumbers ER,Rae KM. A cohort of Indigenous Australian women and their children through pregnancy and beyond: the Gomeroi gaaynggal study. J Dev Orig Health Dis. 2016;1-12.	Study design, Dependent variable
7	Barroso CS,Roncancio A,Moramarco MW,Hinojosa MB,Davila YR,Mendias E,Reifsnider E. Food security, maternal feeding practices and child weight-for-length. Appl Nurs Res. 2016;29:31-6.	Study design
8	Beauchamp, G. K.,Mennella, J. A.. Early flavor learning and its impact on later feeding behavior. Journal of Pediatric Gastroenterology & Nutrition. 2009;48:S25-30 1p.	Study design

	Citation	Rationale
9	Betoko A,Charles MA,Hankard R,Forhan A,Bonet M,Saurel-Cubizolles MJ,Heude B,de Lauzon-Guillain B. Infant feeding patterns over the first year of life: influence of family characteristics. Eur J Clin Nutr. 2013;67:631-7.	Independent variable
10	Biering-Sorensen, F.,Hilden, J.,Biering-Sorensen, K.. Breast-feeding in Copenhagen, 1938-1977. Data on more than 365,000 infants. Dan Med Bull. 1980;27:42-8.	Study design
11	Bingham PM,Stevens-Tuttle D,Lavin E,Acree T. Odorants in breast milk. Arch Pediatr Adolesc Med. 2003;157:1031.	Study design
12	Blankenbaker, R. G.. WIC: a food program intended to improve nutritional status. J Indiana State Med Assoc. 1981;74:748.	Study design
13	Breastfeeding for the health of baby and mother. Nurs J India. 2011;102:179.	Study design
14	Carruth, B. R.,Skinner, J. D.,Moran, J. D., III,Coletta, F.. Preschoolers' food product choices at a simulated point of purchase and mothers' consumer practices. Journal of Nutrition Education. 2000;32:146-151 6p.	Independent variable, Age
15	Catalano, P. M.. Diabetic pregnancy: is it time to enjoy the fruits of our labors?. Diabetes Care. 1988;11:292-3.	Study design
16	Caton SJ,Ahern SM,Hetherington MM. Vegetables by stealth. An exploratory study investigating the introduction of vegetables in the weaning period. Appetite. 2011;57:816-25.	Study design, Age
17	Chapman DJ,Nommsen-Rivers L. Impact of maternal nutritional status on human milk quality and infant outcomes: an update on key nutrients. Adv Nutr. 2012;3:351-2.	Study design
18	Chatoor I,Egan J,Getson P,Menvielle E,O'Donnell R. Mother-infant interactions in infantile anorexia nervosa. J Am Acad Child Adolesc Psychiatry. 1988;27:535-40.	Independent variable, Health Status

	Citation	Rationale
19	Chen GW,Ding WH,Ku HY,Chao HR,Chen HY,Huang MC,Wang SL. Alkylphenols in human milk and their relations to dietary habits in central Taiwan. Food Chem Toxicol. 2010;48:1939-44.	Independent variable, Dependent variable
20	Chen, X. C.,Liu, D. S.,Fu, A. Z.,Yan, H. C.,Yin, T. A.,Jing, Y. S.,Xu, Q. M.. A longitudinal study on infant growth during the first sixth months of life, in relation to the nutrition of the lactating mothers and to the breastmilk output. Prog Food Nutr Sci. 1989;13:113-37.	Dependent variable
21	Chien YC,Huang YJ,Hsu CS,Chao JC,Liu JF. Maternal lactation characteristics after consumption of an alcoholic soup during the postpartum 'doing-the-month' ritual. Public Health Nutr. 2009;12:382-8.	Dependent variable
22	Collins, L. J.,Lacy, K. E.,Campbell, K. J.,McNaughton, S. A.. The Predictors of Diet Quality among Australian Children Aged 3.5 Years. J Acad Nutr Diet. 2016.	Independent variable
23	Conover B. Exposures during pregnancy and lactation. Nebr Med J. 1992;77:65-7.	Study design
24	Contreras, C. M.,Gutierrez-Garcia, A. G.,Mendoza-Lopez, R.,Rodriguez-Landa, J. F.,Bernal-Morales, B.,Diaz-Marte, C.. Amniotic fluid elicits appetitive responses in human newborns: fatty acids and appetitive responses. Dev Psychobiol. 2013;55:221-31.	Independent variable
25	Cooke L,Wardle J,Gibson EL. Relationship between parental report of food neophobia and everyday food consumption in 2-6-year-old children. Appetite. 2003;41:205-6.	Study design, Independent variable
26	Cooke, L.,Fildes, A.. The impact of flavour exposure in utero and during milk feeding on food acceptance at weaning and beyond. Appetite. 2011;57:808-811.	Study design
27	Corbett, M. A.,Burst, H. V.. Nutritional intervention in pregnancy. J Nurse Midwifery. 1983;28:23-9.	Study design, Dependent variable
28	de Barse, L. M.,Tharner, A.,Micali, N.,Jaddoe, V. V.,Hofman, A.,Verhulst, F. C.,Franco, O. H.,Tiemeier, H.,Jansen, P. W.. Does maternal history of eating disorders predict mothers' feeding practices and preschoolers' emotional eating?. Appetite. 2015;85:1-7.	Independent variable

	Citation	Rationale
29	Deming, Denise M.,Briefel, Ronette R.,Reidy, Kathleen C.. Infant Feeding Practices and Food Consumption Patterns of Children Participating in WIC. Journal of Nutrition Education & Behavior. 2014;S29-37 1p.	Study design
30	Dennison BA,Erb TA,Jenkins PL. Predictors of dietary milk fat intake by preschool children. Prev Med. 2001;33:536-42.	Independent variable, Age
31	Dieting okay for breastfeeding mothers. J Natl Med Assoc. 2000;92:A14.	Study design
32	Dobe, M.. Optimal infant feeding in rural areas--the missing agenda of communication needs. Indian J Public Health. 2002;46:145-50.	Country
33	Dondero, Molly,Van Hook, Jennifer. Generational status, neighborhood context, and mother-child resemblance in dietary quality in Mexican-origin families. Social Science & Medicine. 2016;150:212-220.	Age
34	Doucet, Sébastien,Soussignan, Robert,Sagot, Paul,Schaal, Benoist. The "smellscape" of mother's breast: Effects of odor making and selective unmasking on neonatal arousal, oral, and visual responses. Developmental Psychobiology. 2007;49:129-138.	Independent variable
35	Dunn C,Kolasa K,Dunn PC,Ogle MB. Dietary intake of pregnant adolescents in a rural southern community. J Am Diet Assoc. 1994;94:1040-1.	Independent variable, Dependent variable
36	Durao C,Severo M,Oliveira A,Moreira P,Guerra A,Barros H,Lopes C. Association of maternal characteristics and behaviours with 4-year-old children's dietary patterns. Matern Child Nutr. 2016.	Age
37	Dusdieker LB,Stumbo PJ,Kross BC,Dungy CI. Does increased nitrate ingestion elevate nitrate levels in human milk?. Archives of pediatrics & adolescent medicine. 1996;150:311-4.	Independent variable, Dependent variable
38	Emmett PM,Jones LR,Golding J. Pregnancy diet and associated outcomes in the Avon Longitudinal Study of Parents and Children. Nutrition Reviews. 2015;73:154-174 21p.	Study design, Dependent variable

	Citation	Rationale
39	Emmett, P. M.,Jones, L. R.,Northstone, K.. Dietary patterns in the Avon Longitudinal Study of Parents and Children. Nutr Rev. 2015;73 Suppl 3:207-30.	Study design, Independent variable
40	Emmett, P. M.. Dietary Patterns during Complementary Feeding and Later Outcomes. Nestle Nutr Inst Workshop Ser. 2016;85:145-54.	Independent variable
41	Emmett, Pauline M.,Jones, Louise R.. Diet, growth, and obesity development throughout childhood in the Avon Longitudinal Study of Parents and Children. Nutrition Reviews. 2015;73:175-206 32p.	Study design, Independent variable
42	Fangupo LJ,Heath AL,Williams SM,Somerville MR,Lawrence JA,Gray AR,Taylor BJ,Mills VC,Watson EO,Galland BC,Sayers RM,Hanna MB,Taylor RW. Impact of an early-life intervention on the nutrition behaviors of 2-y-old children: a randomized controlled trial. Am J Clin Nutr. 2015;102:704-12.	Independent variable
43	Fetal effects of maternal alcohol use. Jama. 1983;249:2517-21.	Study design
44	Fewtrell, M.. 2.4 Complementary foods. World Rev Nutr Diet. 2015;113:109-12.	Study design
45	Fisk CM,Crozier SR,Inskip HM,Godfrey KM,Cooper C,Robinson SM. Influences on the quality of young children's diets: the importance of maternal food choices. Br J Nutr. 2011;105:287-96.	Age
46	Flanders-Stepans, M. B.. Breast milk from mothers who smoke and drink smells!. J Perinat Educ. 1999;8:45-6.	Study design
47	Font, L.. "Incidental" maternal dietary intake and infant refusal to nurse. J Hum Lact. 1990;6:9.	Study design
48	Forbes, R.. Alcohol-related birth defects. Public Health. 1984;98:238-41.	Study design
49	Forestell CA,Mennella JA. Early determinants of fruit and vegetable acceptance. Pediatrics. 2007;120:1247-54.	Independent variable

	Citation	Rationale
50	Forestell CA. The Development of Flavor Perception and Acceptance: The Roles of Nature and Nurture. Nestle Nutr Inst Workshop Ser. 2016;85:135-43.	Study design
51	Forsum E,Lonnerdal B. Effect of protein intake on protein and nitrogen composition of breast milk. Am J Clin Nutr. 1980;33:1809-13.	Dependent variable
52	Gentry, J. A.,Luiselli, J. K.. Treating a child's selective eating through parent implemented feeding intervention in the home setting. Journal of Developmental & Physical Disabilities. 2008;20:63-70 8p.	Study design
53	Gerrard, J. W.. Allergies in breastfed babies to foods ingested by the mother. Clin Rev Allergy. 1984;2:143-9.	Study design
54	Gopalan S,Puri RK,Sachdev HP. Adequacy of vegetarian diets for optimal nutrition of mother and child. Indian Pediatr. 1993;30:1379-86.	Study design, Independent variable
55	Gregory JE,Paxton SJ,Brozovic AM. Maternal feeding practices predict fruit and vegetable consumption in young children. Results of a 12-month longitudinal study. Appetite. 2011;57:167-72.	Independent variable
56	Gross, R. S.,Mendelsohn, A. L.,Gross, M. B.,Scheinmann, R.,Messito, M. J.. Randomized Controlled Trial of a Primary Care-Based Child Obesity Prevention Intervention on Infant Feeding Practices. J Pediatr. 2016.	Independent variable, Dependent variable
57	Hackney, A. R.. Breast feeding. Am J Nurs. 1990;90:70.	Study design
58	Haftel L,Berkovich Z,Reifen R. Elevated milk beta-carotene and lycopene after carrot and tomato paste supplementation. Nutrition. 2015;31:443-5.	Dependent variable
59	Hetherington, M. M.,Schwartz, C.,Madrelle, J.,Croden, F.,Nekitsing, C.,Vereijken, C. M.,Weenen, H.. A step-by-step introduction to vegetables at the beginning of complementary feeding. The effects of early and repeated exposure. Appetite. 2015;84:280-90.	Independent variable

	Citation	Rationale
60	Hjern A,Kocturk-Runefors T,Jeppson O. Food habits and infant feeding in newly resettled refugee families from Chile and the Middle East. Scand J Prim Health Care. 1990;8:145-50.	Independent variable
61	Horan, M. K.,Donnelly, J. M.,McGowan, C. A.,Gibney, E. R.,McAuliffe, F. M.. The association between maternal nutrition and lifestyle during pregnancy and 2-year-old offspring adiposity: analysis from the ROLO study. Z Gesundh Wiss. 2016;24:427-436.	Dependent variable
62	Howard, A. J.,Mallan, K. M.,Byrne, R.,Magarey, A.,Daniels, L. A.. Toddlers' food preferences. The impact of novel food exposure, maternal preferences and food neophobia. Appetite. 2012;59:818-25.	Study design, Independent variable
63	Hudson P,Buckley R. Vegetarian diets. Are they good for pregnant women and their babies?. Pract Midwife. 2000;3:22-3.	Study design, Independent variable
64	Huffman, S. L.,Dewey, K. G.,Schofield, D.. Moving ahead with maternal, infant, and young child nutrition: need to integrate actions. Food Nutr Bull. 2010;31:S99.	Study design
65	Jacobson, H. N.. Roundtable. V. Diet therapy and the improvement of pregnancy outcomes. Birth. 1983;10:29-31.	Study design
66	Jelliffe, D. B.,Patrice-Jelliffe, E. F.. Maternal nutrition, breast-feeding, and contraception. Br Med J (Clin Res Ed). 1982;285:806-7.	Study design
67	Johnson, Samantha,Matthews, Ruth,Draper, Elizabeth S.,Field, David J.,Manktelow, Bradley N.,Marlow, Neil,Smith, Lucy K.,Boyle, Elaine M.. Eating difficulties in children born late and moderately preterm at 2 y of age: a prospective population-based cohort study. American Journal of Clinical Nutrition. 2016;103:406-414 9p.	Study design, Independent variable
68	Kilanowski JF. Patterns and correlates of nutrition among migrant farm-worker children. West J Nurs Res. 2012;34:396-416.	Age

	Citation	Rationale
69	Kirsch F,Buettner A. Characterisation of the metabolites of 1,8-cineole transferred into human milk: Concentrations and ratio of enantiomers. Metabolites. 2012;3:47-71.	Duplicate of Findings
70	Kirsch F,Buettner A. Characterisation of the metabolites of 1,8-cineole transferred into human milk: concentrations and ratio of enantiomers. Metabolites. 2013;3:47-71.	Duplicate of Findings
71	Kirsch F,Horst K,Röhrig W,Rychlik M,Buettner A. Tracing metabolite profiles in human milk: Studies on the odorant 1,8-cineole transferred into breast milk after oral intake. Metabolomics. 2013;9:483-496.	Duplicate of Findings
72	Klohe-Lehman DM,Freeland-Graves J,Clarke KK,Cai G,Voruganti VS,Milani TJ,Nuss HJ,Proffitt JM,Bohman TM. Low-income, overweight and obese mothers as agents of change to improve food choices, fat habits, and physical activity in their 1-to-3-year-old children. J Am Coll Nutr. 2007;26:196-208.	Age
73	Kocturk T. Infant feeding pattern in three districts of Istanbul. J Trop Pediatr. 1988;34:193-7.	Study design, Independent variable
74	Koletzko, B.. 1.5 Early nutrition and long-term health. World Rev Nutr Diet. 2015;113:72-7.	Study design
75	Kravitz, E.,Pollack, R. L.,Mueller, D. H.. Nutrition during pregnancy, infancy, childhood, and adolescence. J Pedod. 1983;7:182-95.	Study design
76	Kristiansen AL,Lande B,Sexton JA,Andersen LF. Dietary patterns among Norwegian 2-year-olds in 1999 and in 2007 and associations with child and parent characteristics. Br J Nutr. 2013;110:135-44.	Study design, Independent variable, Age
77	Lambert, E. J.,Hall, M. A.. Infant nutrition. Part 1: Preweaning (0-4 months). Br J Hosp Med. 1995;53:567-9.	Study design
78	Laster, L. E.,Lovelady, C. A.,West, D. G.,Wiltheiss, G. A.,Brouwer, R. J.,Stroo, M.,Ostbye, T.. Diet quality of overweight and obese mothers and their preschool children. J Acad Nutr Diet. 2013;113:1476-83.	Independent variable, Age

	Citation	Rationale
79	Lee SY, Hoerr SL, Schiffman RF. Screening for infants' and toddlers' dietary quality through maternal diet. MCN Am J Matern Child Nurs. 2005;30(1):60-6. PMID: 15622151.	Independent variable
80	Lee Y,Birch LL. Diet quality, nutrient intake, weight status, and feeding environments of girls meeting or exceeding the American Academy of Pediatrics recommendations for total dietary fat. Minerva Pediatr. 2002;54:179-86.	Study design, Age
81	Lee, Y.,Joo, N.. The awareness level and needs for education on reducing sugar consumption among mothers with preschool children. Nutr Res Pract. 2016;10:229-36.	Independent variable, Dependent variable, Age
82	Linderborg KM,Kalpio M,Makela J,Niinikoski H,Kallio HP,Lagstrom H. Tandem mass spectrometric analysis of human milk triacylglycerols from normal weight and overweight mothers on different diets. Food Chem. 2014;146:583-90.	Independent variable, Dependent variable
83	Loos HM,Doucet S,Soussignan R,Hartmann C,Durand K,Dittrich R,Sagot P,Buettner A,Schaal B. Responsiveness of human neonates to the odor of 5alpha-androst-16-en-3-one: a behavioral paradox?. Chem Senses. 2014;39:693-703.	Independent variable
84	Magarey, A.,Mauch, C.,Mallan, K.,Perry, R.,Elovaris, R.,Meedeniya, J.,Byrne, R.,Daniels, L.. Child dietary and eating behavior outcomes up to 3.5 years after an early feeding intervention: The NOURISH RCT. Obesity (Silver Spring). 2016;24:1537-45.	Independent variable
85	Marlier, L.,Schaal, B.,Soussignan, R.. Bottle-fed neonates prefer an odor experienced in utero to an odor experienced postnatally in the feeding context. Dev Psychobiol. 1998;33:133-45.	Independent variable
86	Marlier, L.,Schaal, B.,Soussignan, R.. Neonatal responsiveness to the odor of amniotic and lacteal fluids: a test of perinatal chemosensory continuity. Child Dev. 1998;69:611-23.	Independent variable
87	Marlier, L.,Schaal, B.,Soussignan, R.. Orientation responses to biological odours in the human newborn. Initial pattern and postnatal plasticity. C R Acad Sci III. 1997;320:999-1005.	Independent variable

	Citation	Rationale
88	Mason, M.. Women, infants, and children supplemental food program: its impact on infant nutrition. Nebr Med J. 1982;67:58-9.	Study design
89	McEachan RR,Santorelli G,Bryant M,Sahota P,Farrar D,Small N,Akhtar S,Sargent J,Barber SE,Taylor N,Richardson G,Farrin AJ,Bhopal RS,Bingham DD,Ahern SM,Wright J. The HAPPY (Healthy and Active Parenting Programmme for early Years) feasibility randomised control trial: acceptability and feasibility of an intervention to reduce infant obesity. BMC Public Health. 2016;16:211.	Study design, Dependent variable
90	McGowan, L.,Croker, H.,Wardle, J.,Cooke, L. J.. Environmental and individual determinants of core and non-core food and drink intake in preschool-aged children in the United Kingdom. Eur J Clin Nutr. 2012;66:322-8.	Age
91	Mennella JA,Garcia PL. Children's hedonic response to the smell of alcohol: effects of parental drinking habits. Alcohol Clin Exp Res. 2000;24:1167-71.	Independent variable, Age
92	Mennella, J. A.,Beauchamp, G. K.. Mothers' milk enhances the acceptance of cereal during weaning. Pediatr Res. 1997;41:188-92.	Study design, Independent variable
93	Mennella, J. A.,Forestell, C. A.,Morgan, L. K.,Beauchamp, G. K.. Early milk feeding influences taste acceptance and liking during infancy. Am J Clin Nutr. 2009;90:780s-788s.	Independent variable
94	Mennella, J. A.. Infants' suckling responses to the flavor of alcohol in mothers' milk. Alcohol Clin Exp Res. 1997;21:581-5.	Study design, Independent variable
95	Mesirow, M. S.,Cecil, C.,Maughan, B.,Barker, E. D.. Associations between Prenatal and Early Childhood Fish and Processed Food Intake, Conduct Problems, and Co-Occurring Difficulties. J Abnorm Child Psychol. 2017;45:1039-1049.	Dependent variable
96	Mizuno, K.,Ueda, A.. Antenatal olfactory learning influences infant feeding. Early Hum Dev. 2004;76:83-90.	Independent variable

	Citation	Rationale
97	Moding, K. J.,Stifter, C. A.. Stability of food neophobia from infancy through early childhood. Appetite. 2016;97:72-8.	Independent variable
98	Moses, R. G.,Luebke, M.,Petocz, P.,Brand-Miller, J. C.. Maternal diet and infant size 2 y after the completion of a study of a low-glycemic-index diet in pregnancy. American journal of clinical nutrition. 2007;86:1806.	Study design, Dependent variable
99	Mosley SA,Shahin AM,Williams J,McGuire MA,McGuire MK. Supplemental conjugated linoleic acid consumption does not influence milk macronutrient contents in all healthy lactating women. Lipids. 2007;42:723-9.	Dependent variable
100	Mothers influence the milk-drinking habits of their daughters. Mayo Clin Womens Healthsource. 2001;5:3.	Study design
101	Naja F,Nasreddine L,Al Thani AA,Yunis K,Clinton M,Nassar A,Farhat Jarrar S,Moghames P,Ghazeeri G,Rahman S,Al-Chetachi W,Sadoun E,Lubbad N,Bashwar Z,Bawadi H,Hwalla N. Study protocol: Mother and Infant Nutritional Assessment (MINA) cohort study in Qatar and Lebanon. BMC Pregnancy Childbirth. 2016;16:98.	Study design
102	Nguyen TT,Risbud RD,Chambers CD,Thomas JD. Dietary Nutrient Intake in School-Aged Children With Heavy Prenatal Alcohol Exposure. Alcohol Clin Exp Res. 2016;40:1075-82.	Dependent variable, Age
103	Nguyen, A. N.,de Barse, L. M.,Tiemeier, H.,Jaddoe, V. W.,Franco, O. H.,Jansen, P. W.,Voortman, T.. Maternal history of eating disorders: Diet quality during pregnancy and infant feeding. Appetite. 2017;109:108-114.	Independent variable, Dependent variable
104	Northstone K,Emmett P. The associations between feeding difficulties and behaviours and dietary patterns at 2 years of age: the ALSPAC cohort. Matern Child Nutr. 2013;9:533-42.	Independent variable
105	Nutrition for mother and child. Nurs J India. 1990;81:181-8.	Study design
106	Oski, F. A.. What we eat may determine who we can be. Nutrition. 1997;13:220-1.	Study design

	Citation	Rationale
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108	Ovaskainen ML,Nevalainen J,Uusitalo L,Tuokkola JJ,Arkkola T,Kronberg-Kippila C,Veijola R,Knip M,Virtanen SM. Some similarities in dietary clusters of pre-school children and their mothers. Br J Nutr. 2009;102:443-52.	Independent variable
109	Palmer DJ,Gold MS,Makrides M. Effect of maternal egg consumption on breast milk ovalbumin concentration. Clin Exp Allergy. 2008;38:1186-91.	Dependent variable
110	Papas, M. A.,Hurley, K. M.,Quigg, A. M.,Oberlander, S. E.,Black, M. M.. Low-income, African American adolescent mothers and their toddlers exhibit similar dietary variety patterns. J Nutr Educ Behav. 2009;41:87-94.	Study design, Dependent variable
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112	Pilgrim A,Barker M,Jackson A,Ntani G,Crozier S,Inskip H,Godfrey K,Cooper C,Robinson S. Does living in a food insecure household impact on the diets and body composition of young children? Findings from the Southampton Women's Survey. J Epidemiol Community Health. 2012;66:e6.	Independent variable, Dependent variable
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114	Pobocik RS,Heathcote GM,Spiers JB,Otto CT. Nutritional and anthropometric assessment of a sample of pregnant women and young children in Palau. Asia Pac J Clin Nutr. 2000;9:102-14.	Independent variable, Age
115	Prentice, A. M.,Cole, T. J.,Whitehead, R. G.. Food supplementation in pregnant women. Eur J Clin Nutr. 1988;42:87-91.	Study design

	Citation	Rationale
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122	Rosso, P.. Nutrition and maternal-fetal exchange. Am J Clin Nutr. 1981;34:744-55.	Study design, Dependent variable
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124	Ryan C,Dwyer J,Ziegler P,Yang E,Moore L,Song WO. What Do Infants Really Eat?. Nutr Today. 2002;37:50-56.	Study design
125	Salvatori, P.,Andrei, F.,Neri, E.,Chirico, I.,Trombini, E.. Pattern of mother-child feeding interactions in preterm and term dyads at 18 and 24 months. Front Psychol. 2015;6:1245.	Independent variable

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127	Scott, J. A.,Chih, T. Y.,Oddy, W. H.. Food variety at 2 years of age is related to duration of breastfeeding. Nutrients. 2012;4:1464-74.	Independent variable
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133	Streissguth AP,Martin DC,Martin JC,Barr HM. The Seattle longitudinal prospective study on alcohol and pregnancy. Neurobehav Toxicol Teratol. 1981;3:223-33.	Dependent variable
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139	Tull, M. W.,Brown, A. L.. Pediatric drug information: effects of caffeine on pregnancy and lactation. Pediatr Nurs. 1981;7:51-2.	Study design
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143	Wallace, J. P.,Inbar, G.,Ernsthausen, K.. Infant acceptance of postexercise breast milk. Pediatrics. 1992;89:1245-7.	Independent variable
144	Wallis, J.. Positive role of breastfeeding during the first six weeks. Midwives. 2012;15:31.	Study design
145	Walsh, A. D.,Cameron, A. J.,Crawford, D.,Hesketh, K. D.,Campbell, K. J.. Dietary associations of fathers and their children between the ages of 20 months and 5 years. Public Health Nutr. 2016;1-7.	Independent variable

	Citation	Rationale
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148	Whichelow, M. J.,Doddridge, M. C.. Lactation in diabetic women. Br Med J (Clin Res Ed). 1983;287:649-50.	Study design, Health Status
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153	Yuan, W. L.,Nicklaus, S.,Lioret, S.,Lange, C.,Forhan, A.,Heude, B.,Charles, M. A.,de Lauzon-Guillain, B.. Early factors related to carbohydrate and fat intake at 8 and 12 months: results from the EDEN mother-child cohort. Eur J Clin Nutr. 2017;71:219-226.	Dependent variable
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	Citation	Rationale
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156	Zhang, Gen-Hua,Chen, Meng-Ling,Liu, Si-Si,Zhan, Yue-Hua,Quan, Ying,Qin, Yu-Mei,Deng, Shao-Ping. Effects of mother's dietary exposure to acesulfame-K in pregnancy or lactation on the adult offspring's sweet preference. Chemical Senses. 2011;36:763-770.	Study design