CATÓLICA
ESCOLA SUPERIOR DE BIOTECNOLOGIA
PORTO

MOTHERS' DIET INFLUENCE ON FOOD ACCEPTANCE DURING WEANING: A SYSTEMATIC REVIEW

by

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January 2018

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Thesis presented to *Escola Superior de Biotecnologia* of the *Universidade Católica Portuguesa* to fulfill the requirements of Master of Science degree in Biotechnology and Innovation

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Place: *Escola Superior de Biotecnologia* of the *Universidade Católica Portuguesa*

Supervision: Elisabete Pinto (PhD)

January 2018

To my loving daughter
To the love of my life
To my parents and sister

ABSTRACT

First year of life infants start defining their food preferences and eating behaviors, which will track into adulthood influencing dietary habits later in life. Eating behaviors evolve and change from an exclusive milk diet through a complementary feeding until familiar diet. Weaning starts between 4 and 6 months and it's the period when caregivers start introducing solid foods. There are several and complex factors influencing initial responses to the introduction of new foods. As some flavors may pass through amniotic liquid and breast milk it was hypothesized that mothers' diet could affect food acceptance during weaning, through flavor learning. Mothers may also influence some children through modelling. And so, mothers' eating habits may influence food acceptance during weaning. However, there are still few studies focusing in role of mothers' diet as a predictor of food acceptance during weaning and so further researches are needed to better understand the role of mothers' diet.

KEYWORDS

Mothers' diet; infants; food acceptance; weaning; complementary feeding

RESUMO

As preferências, assim como os comportamentos, alimentares das crianças começam a ser definidos desde o primeiro ano de vida. E estes, por sua vez, irão influenciar os hábitos alimentares no futuro e, consequentemente, a sua saúde. Durante este primeiro ano de vida, naturalmente, os comportamentos alimentares evoluem drasticamente, uma vez que a criança passa de uma alimentação à base exclusiva de leite durante os primeiros 4 a 6 meses, passando pela fase da diversificação alimentar, em que são introduzidos novos alimentos até pass aar estar integrada na alimentação da família. São vários os factores, intrínsecos e extrínsecos que podem influenciar a aceitação de novos alimentos durante a diversificação alimentar. No que diz respeito à mãe, esta poderá influenciar a aceitação dos novos alimentos através da exposição a sabores desde o útero ou através da modelação. Embora pareça haver de facto um papel importante da alimentação da mãe, são ainda necessários mais estudos que procurem perceber de que forma é que esta influencia a aceitação de novos alimentos na diversificação alimentar.

PALAVRAS-CHAVE

Alimentação da mãe; crianças; aceitação de novos alimentos; diversificação alimentar

CONTENTS

1. INTRODUCTION

Dietary habits and nutritional status are two major contributors to non-communicable diseases, the leading cause of death and disability worldwide (1). In fact, diet and nutritional status are crucial for the reduction or increase of the risk of disease at long term (2) and we know today that it begins *in utero*, since environment before and after birth will influence offspring future health (3).

First years of life are crucial for establishment of dietary habits and future health (4-8). Also it's during first year of life that infants start learning what to eat, when and how much and start defining their food preferences and eating behaviors that will track into adulthood, influencing dietary habits later in life (4-8).

Eating behaviors dramatically evolve during infancy, changing from an exclusively "liquid diet" (from breast milk or formula) through a mix diet (liquid with complementary food) and ultimately to "family diet" (9). Weaning or complementary feeding should start between the 4^{th} and 6^{th} month of life and guarantee the right timing is essential for both nutritional and developmental reasons (9): "liquid diet" turns insufficient for infants' nutritional requirements (9) and so it's essential to introduce new and nutrient-rich foods to meet them. Second, the introduction of solid food may affect foods' preference and acceptance later (10, 11) and infants' initial response to new foods during this period may play in childhood food neophobia (12).

Children' food choices are primarily influenced by food preferences (13) – they prefer to eat what they like. And first year of life seems to be a sensitive period for food preferences acquisition (14, 15).

Evidence it's clear showing children's preferences for sugar-rich and salty foods and an aversion for vegetables (16, 17) and, nowadays, dietary habits reflect a promotion of these preferences and aversions – in Portugal, after first year of life only 47% reach the 5-a-day recommendation for fruits and vegetables (18).

Understanding mechanisms underlying liking and preferences for healthy foods since weaning it's crucial so that we may promote healthy eating behaviors as soon as possible.

There are complex factors influencing the development of food preferences and food acceptance (19) and, consequently, early eating behaviors. Food liking and preferences are based on genetic predisposition modulated by environmental experiences (20).

1.1. Innate Flavor Preferences and Genetic Predisposition

Evidence shows that we are born with an innate flavor preference for sweet flavors (21-24) and an aversion for bitter and sour tastes (22, 24, 25). Also, preference for salty flavor seems to be neutral (22) when infants are born and it will develop postnatally (26).

Detection and preference for sweet taste is shown even at birth, as it was shown by Rosenstein and Oster that preterm newborn's shown facial relaxation and sucking when presented to sucrose (22, 24), and on the opposite sour and bitter tastes elicited aversive expressions such as eye squinch, nose wrinkle and arm flails (22, 24) or ingested less quantity of citric acid solution when compared to sucrose solution (25).

On an evolutionary perspective innate preferences and aversions result from natural selection associated to basic biological reflex (27, 28). Animals, particularly humans, are born with the ability of choosing flavors that represent energy and sugar-rich foods essentials to their survival on restriction and starvation periods (28) and rejecting bitter-sour flavors is another mechanism of natural survival as this flavor is associated to poisons and toxins (29). And so, there is a genetic predisposition that may explain some individual preferences and liking (30). Research already identified specific genes related to different perceptions of taste, specific to sweet (T1R2+T1R3) (31), bitter (T2Rs) (32) and umami (T1R1+T1R3 (31) and mGluR1 and mGluR4 (33, 34)) receptors and different polymorphisms (35), influencing individual preferences, such as decreased sweet flavor perception (36), differences on umami sensitivity (37) and different degrees of bitter taste sensitivity depending on well-known polymorphism TAS2R38 (38, 39) and others (40, 41). Children with a higher degree of sensitivity to bitter taste, from 6-n-propylthouracil (PROP) compound, tend to dislike and consume less vegetables and other bitter-taste foods (42, 43), although not all studies have shown these results (39). Children with bitter taste sensitivity also seem to prefer sweets and beverages (20).

Innate preferences and aversions are in line with preferences and aversions of majority of children during childhood, rejecting vegetables (typical bitter-flavor-foods) and preferring sweet-foods. Actually, it was demonstrated that infants with about 7 months already show

dislike for some vegetables (44) and infants with 6/7 – 11 months are already pointed as being "picky eaters" by their caregivers (45, 46), which may be an important factor for new foods acceptance. An infant or a child is identified being picky eater when he/ she ingests a limited variety of food and frequently refuses familiar and/or unfamiliar (new) foods and food neophobia is defined as the reluctance or avoidance to eat new foods (47). Both are pointed as being part of a normal phase of development for some children when it doesn't prejudice normal growth and development of infants and children (46, 47), although it may affect food acceptance. During weaning, infants' preferences may influence acceptance of new foods, as it was suggested by Schwartz and colleagues that demonstrated a relationship between liking specific flavored liquids and foods with the same flavor pattern in infants between 5 and 7 months old (48).

However, innate preferences may not dictate future preferences, since they may be modulated and modified by early-life experiences and environmental context [49, 50]. Food preferences are malleable in a way that it's possible that a dislike for a food to be reduced or reversed [49].

1.2. "Flavor learning process"

Infants start a "*flavor learning process"* still before they are born. Taste (result from gustatory system) and smell (result from olfactory system, specially odors perceived retronasally) are together the basis of flavor perception (49) and it starts developing still *in utero*.

1.2.1. Flavor Perception during gestation

Human gustatory system, responsible for taste perception, start developing during the first pregnancy trimester. Since 8th week it's possible to observe first gustatory cells (taste buds) (50, 51) and between 14th and 15th week of gestation these taste buds are smaller but similar in format to adult ones and there are already nerve signals suggesting an initial taste perception (51). At the same time, during the second trimester fetus start being able to swallow and have nonnutritive suckling movements and during the 3rd trimester both abilities are perfectly coordinated (52). Olfactory systems is a more complex system as it is able to detect multiple odorants. Odor receptors start appearing during 8th week of gestation, as it happens with taste

cells, but they will become functional approximately on 28th week (53). Between 16th and 36th weeks, fetus will also inhale amniotic fluid (54).

Gustatory system will perceive one basic taste (sweet, sour, bitter, salty or umami) and olfactory system will perceive complex odorants and these two systems working together will perceive specific flavors (49) as we know them, for instance "strawberry flavor" or "chocolate flavor". Once both systems became mature and fetus starts swalling and inhale amniotic fluid this will be the first chemosensory experience and so the beginning of *"flavor learning process"* (49).

During pregnancy, some taste and odor molecules from foods and drinks ingested by mothers are absorbed to blood stream and consequently to fetus blood stream through placenta. On a physiological cycle fetus urinates into the amniotic fluid (55), and so taste and odors molecules are transferred to amniotic fluid. These molecules will confer flavor to amniotic fluid as it was shown with garlic (56), carrot (57) anise (58). And so, fetus will be surrounded by amniotic fluid flavored by mothers' diet during pregnancy, having his/her first flavor experience before birth. It seems that infants' flavor learning process may rely on mother's diet sooner as prenatally, and it may influence the acceptance of solid foods at beginning of weaning (59). The evidence that dietary intake during pregnancy can modulate later healthy food acceptance by offspring could encourage pregnant women to improve their diet (60).

1.2.2. Flavor Perception during milk feeding

Infants' flavor experience continues after birth through milk, independently if infant is breastfed or formula-fed. And mothers' diet seems to play a role on breast milk flavor since it is possible to detect specific flavors such as garlic (61), vanilla (62) and yet tobacco smoke (63) or alcohol (64). Flavor compounds are transmitted differentially from mother's diet to milk (65) so from one mother to another there is no equal milk and breast milk flavor is perceived by infants and it will influence its intake (62, 66). Breastfeeding seems to facilitate acceptance of new flavors (67) and solid foods during weaning (59, 68, 69) when compared with formula-fed infants.

Mennella and colleagues (59) showed that exposure postnatally to carrot juice, through mother's diet influenced the acceptance of carrot-flavored cereals at the beginning of weaning, but preferences of infants formula-fed (exposed to a more stable flavor experience) also seem to be influenced by the type of formula given on a long term basis (70).

Although the role of breastfeeding on the acceptance of new foods may be beyond specific flavor compounds presented or absented on mother's milk (67), it was shown that the type of formula and its typical flavor also influence infants' response to taste compounds in cereal before solid foods introduction (71): infants fed with extensively hydrolyzed protein formulas (ePHFs) develop preferences for savory, sour and bitter tastes as they ate more infant cereals with those flavors and at faster rates when compared with cow-milk-formulas (CMFs) or breastfed infants (71).

Again and besides any preference, new foods acceptance may be modified through experience-learning by repeated exposure (44, 68, 72, 73) and variety offered early in weaning (68, 69, 72). Both are important factors that affect the acceptance of new foods.

1.3. Repeated and Variety Exposure

Evidence shows that several times of trying (repeated exposure) with the same food, in different context, will result in food acceptance during weaning (68, 72, 74, 75), even if infants didn't like it initially (44), and until 12 months old (76). Increasing in food acceptance (higher intakes of that food) may not immediately translate in increasing in liking. Infants may maintain some negative expressions while they eat that food and so exposure should be beyond food acceptance for shifting food liking (77).

At same time, exposure to variety of flavors promotes better acceptance of different types of foods (72, 78, 79). However exposure to variety of flavors seems to be more important on the infants beginning weaning later at 6 months (79), when compared with weaning at 4 months.

Offering a variety of foods and repeated exposures rely mostly on mothers and on their resilience. In case of mothers perceived an infants' rejection or dislike for more than 3 – 5 times, there's a probability that she will decide not offer any more that specific food to their child (45), not reaching the number of times that infants need to be exposed to that specific food (44, 68) and inhibiting a possible future acceptance.

1.4. Sensorial Perception of Foods

Flavor perception seems to be the foundation for food preferences and, consequently, food acceptance (80). However foods may implicate other senses rather than taste and smell leading to different sensorial responses when in contact with specific food; for instance picky

eaters are usually more sensitive to touching and tend to not like the sensation of foods in mouth (81). Different sensations perception, and let infants touch, smell and feel foods may increase their willing to try new ones (82), in children between 1 and 3 years old. Texture is also very important on infants development and it seems that a delay on introduction of lumpy foods, outside a "window of opportunity" will implicate a worse acceptance of lumpy foods later (83, 84).

1.5. Mothers' role on weaning

Besides the role of mothers' diet on flavor exposure, infants depend on a daily basis on them: infants are always dependent on what mothers, or other caregiver, give them to eat, how much, how many times and on what way. So, infants will learn based on cultural and family practices and attitudes towards foods and eating habits and mothers also play a role here.

It was shown positive associations between parents and children fruit and vegetable consumption (85) and maternal intake of fruit, vegetables and meat, fish and eggs and children's intake of the same foods at 3 years (86), that might be explained for parental modeling, food availability or early exposure. Also it was found similarities between the types of foods fed to infants during weaning and foods eaten more by mothers during pregnancy in Mexico (87). More recently maternal diet was shown to be a predictor of toddler's diet quality and variety of fruit and vegetables intakes ate age 2 and 3 years, but only on a period early after birth and not during pregnancy (88).

Children's rejection of novel foods at 6 months seems not to be related with maternal neophobia, however high levels of maternal neophobia may override infants' initial tendencies of food rejection during weaning – highly neophobic mothers reported high levels of neophobia in their children, even when they have low levels of rejection at 6 months. However at 12 months rejection of new foods tends to be more stable and does not depends on parents (12). Modelling seems to be one more pathway where mothers may influence food acceptance. It was related to lower levels of food fussiness and higher levels of food liking and children's eating behaviors among children aged between 2 and 6 years old (89).

Although there are studies focusing on mothers' and their role on food acceptance during childhood, there are fewer that focus on weaning period. New foods acceptance during weaning research to date does not focus on direct or indirect mothers' diet impact, even though she may be a major channel of flavor learning process and model.

Systematic review will present information trying to understand the role of mothers' diet on foods acceptance during weaning.

2. OBJECTIVE

The aim of this systematic review was to understand the influence of mothers' diet on infants' new foods acceptance during weaning.

3. METHODS

In October 2017 electronic searches were undertaken in two databases: PubMed/ MEDLINE and CINAHL using the following MeSH terms: ("maternal diet" OR "mother's diet" OR "women diet") AND ("weaning" OR "complementary feeding")
without any restriction on publication date.
Inclusion criteria limited articles to those in humans, assessing mothers' eating habits and the weaning period of infants. Only manuscripts in English, Portuguese or Spanish were able to be included. Ultimately, hand searches were made to the reference lists of all pertinent reviews and studies to found other relevant publications.
They were considered to be eligible published reports, including prospective observational, case-control and cross-sectional studies, case reports or randomized controlled trials assessing the influence of mothers' diet on infants' acceptance of new foods during weaning. Primary outcomes measurements included at least one parameter to evaluate new food acceptance, such as total food intake in grams or calories, duration of feeding, feeding rates (grams per minute), frequency of distaste facial expressions and mothers' perception. Secondary outcomes included mothers' eating habits. Other studies design such as reviews, editorials or commentaries were excluded. Participants included were healthy mother-infant pairs without any condition interfering on weaning.
After literature research, the main researcher and her supervisor (RM, EP) reviewed and independently selected papers based on title and abstract for a comprehensive full-text screening. Authors agreed on final list of articles and assessed them to analyze and determine which met all eligibility criteria previous mentioned. **Figure 3.1** shows the flowchart of research conduction which was based on Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement (90) guidelines as it is recommended (91). One researcher (RM) extracted data from included studies and the second one (EP) checked the extracted data. Different points of view were discussed and it was reached an agreement.

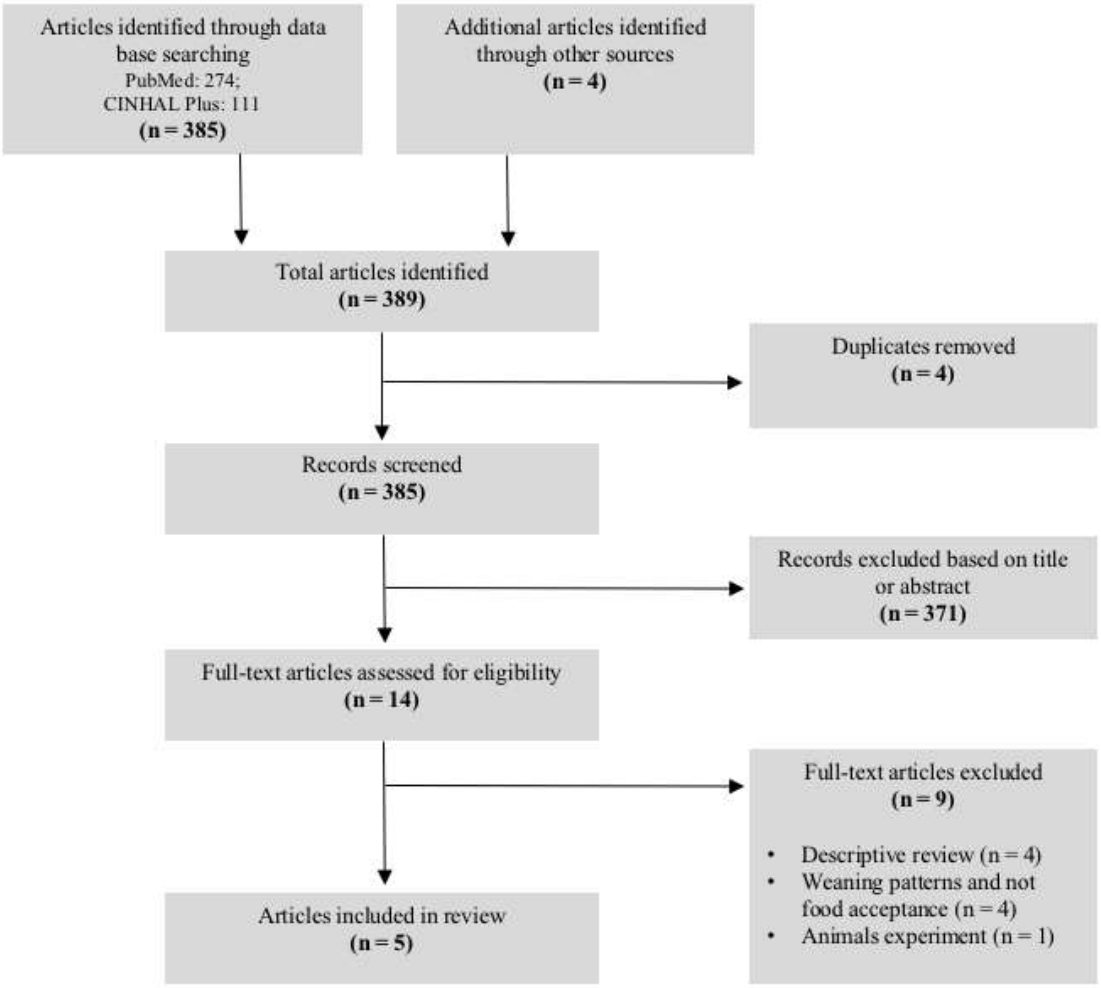

FIGURE 3.1 *PRISMA flowchart for studies' selection*

4. RESULTS

The electronic search dated until October 2017 with MeSH terms mentioned above retrieved 385 papers (274 PubMed/ MEDLINE and 111 CINAHL), plus 4 added after hand search screening. After first title and abstract readings 375 articles were excluded: 4 for being duplicated and 371 for being out of scope the review. A total of 14 full-text articles were reviewed and after that 5 articles met eligibility criteria as it is presented in **Figure 3.1**. Included articles are presented in **Table 4.1**, where details about study design, intervention period, test procedures and primary findings are summarized. All but one studies are from the same research group, the Monnell Chemical Senses Center in United States of America (57, 59, 77, 92). The last study is from Hausner H. (67) from University of Copenhagen, Faculty of Life Sciences.

Four of five studies are experimental testing acceptance of specific foods or flavored ones during weaning, after mothers' intake of some specific food (57, 59, 67, 92). One study was observational and focus on mothers' fruit and vegetables eating habits and infants' acceptance of fruit and vegetables on weaning (77).

Typical intervention periods fixed in postnatal phase, including both breast and formula-feeding (67, 77) or exclusively breastfeeding mothers (57, 59, 92). Only one study tested the impact of mother's diet during pregnancy (59).

Primary outcomes included facial responses during feeding, mothers' perceptions of infants' enjoyment, food intake, meal duration or rate of feeding, accepted and rejected spoons. Mothers' perception and total food intake were both the outcomes always evaluated as it is presented in **Table 4.2**. Total food intake is an important outcome for food acceptance as it is related on how much a food is wanted (93).

Overall, the five studies provided few insights into the influence of mother's diet on food acceptance during weaning, specially in the role of mother's diet during pregnancy, since there was only one study, from 2001, that provide some theory. Also, they were all experimental studies and only one actually evaluated the role of mother's diet in real-life context and none evaluated the possibility of "modeling" role of mothers.

TABLE 4.1 *Summary of included studies evaluating the influence of mother's diet on food acceptance during weaning*

REFERENCE	STUDY DESIGN	INTERVENTION PERIOD	EXPOSED FOOD AND DURATION	TESTED FOOD	RESULTS
Mennella, J.A. (2017)	Experimental study	Postnatal (lactation)	Carrot, beet, celery and vegetable juices 1 or 3 month	Carrot-flavoured, broccoli-flavoured and plain cereals	Infants exposed liked more carrot-flavoured cereal than not exposed ones. Timing of exposure influenced carrot-flavoured cereal acceptance. No effect of mothers drinking vegetable juice on infants' acceptance of new flavoured cereal
Hausner, H. (2010)	Experimental study	Postnatal (weaning)	Caraway-flavoured hummus and plain hummus 10 non-sequent days	Caraway-flavoured potato purée and plain potato purée	Similar acceptance of flavoured and plain purées between exposed and non-exposed infants Formula-fed infants with lower acceptance of flavoured purée
Forestell, C.A. (2007)	Observational study	Postnatal (weaning)	n.a.	Green beans, peaches	Peaches better acceptance and liking was related to amount of fruit ingested by breastfeeding mothers. No significant relation between infants' green beans acceptance or liking and mothers' consumption of green beans.
Mennella, J.A.; (2001)	Experimental study	Prenatal (pregnancy) and postnatal (lactation)	Carrot juice, 4x3 wk	Carrot-flavoured and plain cereals	Infants exposed exhibited less negative facial responses, were perceived enjoying and tended to ingest carrot-flavoured cereal more. No relationship between mothers' variety seeking score, carrots liking or frequency of consumption and cereal acceptance by infants.
Mennella, J.A. Beauchamp, G.K. (1999)	Experimental study	Postnatal (lactation and weaning)	Carrot juice, 1 wk	Carrot-flavoured and plain cereals	Infants exposed ingested less carrot-flavoured cereal and during less time than plain cereal. Infants not exposed ingested similar amounts of both cereals. No relationship between mothers' eating habits or attitudes and infants' cereal acceptance.

TABLE 4.2 *Summary of primary outcomes on new foods' acceptance*

PRIMARY OUTCOMES	MENNELLA, J.A. (2017)	HAUSNER, H. (2010)	FORESTELL, C.A. (2007)	MENNELLA, J.A. (2001)	MENNELLA, J.A. (1999)
Frequency facial responses during first min feeding	X	-	X	X	-
Mothers' perception of infants' liking	X	X	X	X	X
Total food intake (g and/or kcal)	X	X	X	X	X
Meal duration (min)	-	X	X	X	X
Rate of feeding (g/min)	X	-	X	-	-

4.1. Prenatal influence of mother's diet on food acceptance during weaning

Classical experimental study of Mennella and colleagues in 2001 (59) is the only included study that provides evidence about the role of mother's diet during pregnancy on food acceptance on weaning. Forty-six pregnant mothers were recruited and divided in 3 groups and they had to consume 300 mL of carrot juice or water for four days per week for 3 weeks and then during first 2 months postnatally. One group drank first, prenatally, carrot juice and then water; other group drank, prenatally, water and the carrot juice and the third group was the control group, drinking water all the time. All 46 women were refrained of eating carrots or drinking other drinks carrot-flavored during all test period. After the beginning of weaning infants were tested by giving them, on two different days, plain cereal and carrot-flavored cereal and they were evaluated by frequency of facial responses during feeding, mother's perception on infants' liking, total food intake and meal duration.

Authors were able to show that infants exposed to carrot- flavored prenatally exhibited less negative facial responses when compared to plain cereal (5.4±0.8 vs 4.0±0.8, $p<0.05$) and mother's perception of infants liking cereals were higher (7.5±0.5 vs 5.3±0.6, $p<0.05$). Exposed infants have shown a trend to eat more carrot-flavored cereal (80.5±18.2 vs 55.2±18.2), even though it was not statistical significant.

Also, there was no significant differences between mothers' variety seeking (intrinsic desire for variety), how much they liked carrots or in frequency they ate carrot, so authors were able

to demonstrate that results were because of intervention and not because of eating habits or attitudes toward foods. Findings suggested that prenatal exposure, as early postnatal exposure as presented later, may predispose infants to favorably respond to familiar flavors, facilitating transition between exclusive liquid diet to familiar diet.

4.2. Postnatal influence of mother's diet on food acceptance during weaning

In 1999, Mennella and Beauchamp had suggested, for the first time with an experimental study, a role of mother's milk flavor on new foods acceptance during weaning in the short term (57). Thirty-eight breastfeeding mothers and beginning weaning with cereal (prepared with water) were recruited and randomly assigned to one of two groups: in one group women drank water and in the other group women drank carrot juice, during one week. Each infant was observed on four occasions, two before exposure and two after exposure to carrot flavor through mothers' milk (also assessed in present study), eating plain or carrot-flavored cereals. Authors have determined the total cereal and caloric intakes and duration of meal, for all test sessions. Exposure to carrot-flavored milk affected the amount of cereal and calories ingested. The timing of test session also affected the amount of cereal consumed, both groups consumed more cereals after exposure: infants exposed to carrot-flavor through mother's milk consumed significantly less carrot-flavored cereal (Flavor x Timing of Sessions x Group Effect, $F(1, 36\ df) = 6.92$, $p = 0.012$), when compared with plain cereal and infants not exposed consumed similar amounts of cereals. Also, exposure to flavor affected duration of meal – exposed infants spent less time consuming flavored-cereal. Authors could find any difference between both groups in the frequency mothers ate carrots, variety seeking or food neophobia. And so, it was suggested that infants' acceptance was due to flavor exposure and not because mothers' eating habits or attitudes toward foods.

Later in 2001, Mennella and colleagues hypothesized about prenatal and early postnatal experiences influence responses to flavor in solid foods during weaning (59). Through an experimental design, already described above, authors shown that exposed infants to carrot flavor exhibited less negative facial responses, also postnatally (paired t [16 df] = 2.41; p = 0.03) and there was a trend, with no statistical significance, to mothers perceived infants' liking more the carrot-flavored (paired t [13 df] = -0.79; p = 0.44). Even though it was demonstrated a significant effect of flavor on the amount of cereal intake and duration of meal, there was not a significant effect of exposed infants. Again, similarly to what was

mentioned before, there were no significant differences between groups respecting to mothers' variety seeking, how much they liked carrots or frequency of carrots intake.

In 2007, Forestell bring more insights about the influence of mother's diet on food acceptance, with a twelve-day experimental study on 45 mothers, with infants between 4 to 8 months starting weaning with cereal for few weeks (77). Authors had two major aims with this research which were to understand the early determinants of fruit and vegetables, such as role of diet mothers, the repeated exposure and familiarity. In the present review it only be described methods and results specific to the role of mothers' diet, since the others are out of scope of this review.

On twelve-day experimental study, mothers participated in 4 test sessions (2 before and 2 after) and an 8-day home-exposure period. Two days before home-exposure period mothers and infants went to laboratory to evaluate infants' acceptance of green beans on one day and peaches on the other. After each feeding session mothers have rated infants' liking each food (green beans and peaches) and it was determined total food intake (grams and calories), duration of meal (minutes), rate of feeding (grams per minute), and frequency of negative facial responses during feeding. Authors suggested that facial displays were related to food acceptance (infants who displayed more negative facial responses ate at slower rates both foods). Breastfed infants consumed significantly more peaches, for longer periods and at a faster rate. These infants also displayed less negative facial responses during feeding. At the same time, it was shown that breastfeeding mothers significantly have eaten more fruits during previous week, when compared with formula-feeding mothers. On the other hand, formula-feeding mothers consumed more green beans after infants were born, but they were not found any differences between initial intake or type of facial responses. Ultimately, Forestell and Mennella have shown that flavor experience should be familiar so that new food acceptance could be facilitated.

Hausner and colleagues, in 2010, also have shown that breastfeeding facilitated acceptance of new foods during weaning (67). However, on contrary to what was expected, they were not able to attribute to mothers' diet the key role of acceptance. Authors recruited fifty-eight mothers with an eating history of not ingesting spices, since pregnancy or postnatally. Women were assigned for three groups, breastfeeding or formula-feeding mothers and between breastfeeding mothers, women were randomly assigned to consume caraway flavored hummus or plain hummus, during 28 days every 3 days (consumption in a total of 10 days). Formula-feeding mothers also had to eat caraway flavored hummus as breastfeeding mothers assigned to one of the two groups. After this home-exposure period, infants had a session test

on 2 different days where they had to eat caraway-flavored potato purée or plain potato purée. It was not demonstrated any effect of milk exposure to flavored pureed: breastfed infants, independently if they were exposed to caraway or not, ate more flavored purée and refused fewer spoons when compared to formula-fed infants. On the other hand, formula-fed had lower acceptance of caraway-flavor purée. Exposure to caraway did not show to display acceptance in learning, since it was registered similar acceptance of caraway and plain purées between breastfed infants. Authors hypothesized that this could be because of the low concentration of add caraway flavor to hummus and/or purée that could not be enough to be identified.

Recently, Mennella and colleagues in a trial study with seventy-five breastfeeding mothers who were recruited and completed all trial. Mothers had to drink 4 types of vegetable juices (carrot, beet, celery and vegetables) between first 4 months postnatally, during one or three months. Women were divided in 5 groups: the first 3 groups differed on when mothers should drink vegetable juices (0.5 to 1.5 month, 1.5 to 2.5 month or 2.5 to 3.5 month), other group should drink juices during all 3 months and the last was the control group. All mothers were instructed to refrain ingestion of vegetables juices or solid foods with those flavors. At the beginning of weaning infants were tested for plain cereal acceptance, carrot-flavored cereal and broccoli-flavored cereal on three different days. At test session, it was measured total intake (grams) and rate of feeding (grams per minutes) and mothers' perception of infants' liking after each test. Infants preferred carrot-flavored cereal, according to amount of ingestion (53.1 ± 5.6 vs 42.0 ± 4.8 vs 32.8 ± 4.9) comparing to plain and broccoli-flavored cereal, respectively. Mothers' perception of infants' liking was in line with this (6.1 ± 0.3 vs 4.6 ± 0.3 vs 4.1 ± 0.3). Timing seemed to influence infants' acceptance of carrot-flavored cereal, but not acceptance of plain or broccoli-flavored cereals: when infants were exposed earlier at 2 weeks, they ate carrot-flavored cereal at a fast rate and higher amounts. Exposed infants, regardless the timing, tended to display less negative facial responses to their first spoonful of carrot-favored cereal.

5. DISCUSSION

The aim of this review was to understand whether mothers' diet during pregnancy and/or postnatally may influence infants' food acceptance during weaning. To our knowledge this is, to date, the first review focusing exclusively on role of mothers' diet on food acceptance during weaning.

The first finding is that although the majority of specialists recognized a possible influence of mothers' diet during pregnancy and postnatally there is still very few studies focusing on which way could mothers' diet influence food acceptance during weaning.

It was demonstrated that amniotic fluid flavor (taste and odor) is influenced by specific compounds that may be present in mothers' diet, since it was already proven that flavors pass through it (56-58). Theoretically, this early exposure to different flavors could modulate food's acceptance during weaning.

We were expecting to find several studies trying to understand the role of mothers' diet during pregnancy on food acceptance in weaning. But it was found only one study, from Mennella in 2001 (59) describing a better acceptance of new foods of infants' whose mothers drank carrot juice during last trimester of pregnancy, showing some trend to eat more carrot-flavored cereals, with significantly less negative facial expressions and with higher mothers' rating on infants' liking. Although authors could show some positive effects of mothers' diet on food acceptance in early weaning, more studies in this field are needed as it may be a promisor field. In an intra-cultural study in Mexico, based on interviews, was suggested that mothers' diet during pregnancy were similar to the types of foods offered to infants during weaning and this finding indicates that mothers' diet during pregnancy may be the basis of infants' weaning patterns (87). However we cannot understand if these foods are accepted and/or liked or if they are presented only for being part of cultural environmental.

The majority of studies focused on postnatal period and on the role of mothers' diet through breastfeeding as being a way of flavor transmission (57, 61, 63-65). As it happened in pregnancy, Mennella and colleagues have shown that when women ate carrot juice during breastfeeding, infants also exhibited less negative facial responses when exposed to carrot-flavored cereal when compared to plain cereal (59). These findings suggest that both prenatal and postnatal flavor experiences influence initial response to new foods during weaning.

However on a contradictory perspective, Ashman and colleagues were not able to demonstrate a direct effect between mothers' diet quality during pregnancy and diet quality of the

offspring at 2 -3 years old, but only mothers' diet early postnatal showed to be a predictor of diet quality particularly in fruits and vegetables variety (88).

Mennella have shown trends of infants' exposed to carrot-flavor liking more carrot-flavored cereal when compared to not-exposed infants and a possible sensitive period early in life (92), when hedonic response may be enhanced. On an opposite way, when exposure to flavor and introduction of food occurs in a short-term, breastfeeding seemed to be inhibited the acceptance of flavored-cereal when compared with plain cereal (57).

These findings suggested that mothers' diet during pregnancy may be a representation of mothers' diet postnatal. And that, probably, postnatal period is a more sensitive period for mothers' influence their infants' food acceptance.

Hausner (67) noticed no differences on acceptance of flavored purée between two groups of breastfed infants (one exposed to caraway flavor through mother's diet and one not exposed). Both breastfed groups had a better acceptance of flavored purée when compared with formula-fed infants, even though formula-fed mothers had eaten caraway flavored hummus during exposure period. Accordingly, breastfeeding seemed to facilitate food acceptance during weaning regardless mothers' diet.

Although all experimental studies seem to point out to a direction where mother's eating habits did not have an impact on food acceptance during weaning, infants with a better acceptance and liking of peaches were those whose mothers' had a great fruit ingestion during the week prior the test period, however the same was not observed on vegetables (77). Authors hypothesized that, lack of effect on vegetables may be due to low frequency of consumption leading to low levels of exposure. These results are supported by Ashamn study on the role of mothers' diet postnatally on food quality of infants (88)

Experience with breastfeeding alone may not be sufficient to enhance initial acceptance of new foods, the more familiar the flavor experience, the better the likelihood of acceptance (77).

It seems that, besides genetic predisposition (20) environmental has a much more important role on modulating food preferences and acceptance. And regardless of flavor perception in utero mothers will have a much more important role after birth. As mothers influence children via their own preferences and may limit offered foods (11) it's crucial to promote healthy eating habits in women and families so that infants had contact with healthy foods since the beginning early in life. However mothers tend to give up after 3 to 5 times after they perceived infant's rejection or dislike (45) and this decision will enable infants of being exposure the minimum 8 – 10 times (44, 68) for food acceptance.

Familiarization with foods by repeated exposure and variety it's essential for promote food acceptance (44, 69, 73, 75, 79).

Nevertheless, it's clear that mothers' diet plays a key role on food acceptance during weaning and it's essential to better understand on what way, so that mothers could receive guidance about the influence of their own eating behaviors on their infants' eating behaviors, the importance of repeated exposure and focusing on intakes and not only in facial expressions.

Ideally it should be conducted a well-designed longitudinal study evaluating mothers eating habits during pregnancy and first year after birth and infants' food acceptance and preferences on introduction of new foods. With this study it would be possible to understand more frequent foods eaten by mothers and if those foods correspond or not to better acceptance during weaning. It should not be limited to fruit and vegetables, but include all food groups for guarantee a healthy diet.

Major limitation of present review is the small number of studies included, and majority of studies are from the same study group providing insights about mothers' diet and food acceptance during weaning on the same perspective. Another limitation is that, although seeming a promising study field, the majority of included studies had more than 10 years. Nevertheless, this is a very specific theme limiting a lot the field of study.

6. CONCLUSION

In line with these findings, mothers' eating habits may have some influence on food acceptance during weaning. However, mothers' diet may be more than a simple way of "flavor exposure" during weaning. Mothers are vehicles of food contact for infants and they are able to provide all the basis needed for food acceptance and food preference.

We cannot take any strong conclusion about mother's diet influence on food acceptance during weaning. Additional randomized controlled interventions, focusing on maternal dietary intakes / habits during pregnancy and postnatally and infants' food acceptance during weaning are needed for better understanding of these relationship.

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