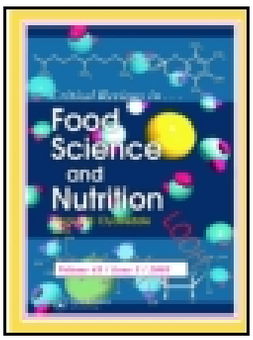

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REVIEW

A new look at early exposure to the flavors of the available vegetables as foundational mechanism of vegetable consumption habits and recipes of vegetables-based dishes

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ABSTRACT

The flavor of the maternal diet is transferred to women's amniotic fluid and breast milk, so that the amniotic fluid and breast milk become natural transmitters of flavor-related information developing babies are exposed to at early stages of development. We aimed to review the available evidence regarding the impact of early exposure to flavor on child vegetable intake, and to discuss for the first time possible effects of availability or unavailability of particular vegetables because of geographic reasons on these exposures, a variable that has been forgotten in the literature. We have focused on studies that have examined the association of prenatal and early postnatal -at breastfeeding- exposures to vegetable-related flavors with vegetable consumption in children. We have identified that this particular kind of exposures may lead to increases in children's acceptance, liking of and preference for the vegetables. Especially novel has been to identify that these effects might be modulated not only by the particular flavor of the vegetable -bitter *vs.* sweet- and the time of exposure -prenatal *vs.* breastfeeding- but also by vegetable availability because of geographic reasons of the place of residence of the mother, a variable that should be taken into account in future research. This would give rise to a new research line aimed at solving the mentioned gap. Finally, a theoretical model of cyclical processes that might explain the origin and perpetuation of transmission of particular patterns of vegetable consumption and vegetables-composed dishes over time in a given population is also included here as another new contribution.

KEYWORDS

Amniotic fluid; breastfeeding; children; intergenerational transmission of vegetable-related information; prenatal exposure; vegetable consumption

Introduction

Children usually eat what they like, and they naturally tend to like and reject the sweet and bitter tastes, respectively. They commonly reject vegetables, especially cruciferous (green) vegetables, such as artichoke and arugula due to the bitter taste of these foods. This is especially truth for children that are highly genetically predisposed to taste the bitter taste of an edible, also called tasters in comparison to children who are not so sensitive to that taste or non-tasters. This is problematic because eating a diet rich in vegetables is essential for children to prevent health-related diseases during childhood and adulthood, such as childhood obesity (Epstein et al. 2001; Anderson and Butcher 2006; Leahy et al. 2008; Aranceta-Batrina and Pérez-Rodrigo 2016) and cancer (Van Duyn and Pivonka 2000), respectively. It is well known that children's early experiences with vegetable-related flavors are critical for positive changes in their patterns of vegetable acceptance and consumption to occur. In addition, we also know that this is due to the fact that tasting vegetable-related flavors at early stages of development –at the prenatal, breastfeeding and weaning phases of development as well as early childhood, that is, two to six years of age- makes children to learn to like vegetables. This learning as well as other kinds of learning takes place thanks to the neural and behavioral plasticity that is typically displayed at those developmental stages. The food patterns that have been acquired or learned early in life usually last in adulthood.

The essential mechanism behind such kind of learning is the early repeated exposure to flavors of the vegetables that are typically consumed in the living environment or usual place of residence in which children grow up. There are basically two kinds of repeated exposure: «[repeated]*mere* exposure, that is, when exposure to a neutral [vegetable-related] flavor does not follow any consequence, and [repeated] *associative conditioning*, when exposure to the neutral [vegetable-related] flavor is followed by a given consequence, either positive, such as nutritive (caloric) ingestion or hedonic pleasure, or negative, such as nausea or emesis, due to repeated pairings of the neutral [vegetable-related] flavor with a high caloric substance, [such as honey or olive oil] or an already preferred flavor [such as the sweetness of a certain sauce], or an aversive substance [a disliked dressing], respectively» (Rohlfs Domínguez 2018, 2230). An increased familiarity with the stimulus, in this case,

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the flavor of this vegetable, and consequently, an increased liking of that stimulus, that is, the vegetable-related flavor underlies the effectiveness of repeated exposure (Zajonc 1968; Hill 1978; Bornstein 1989; Wadhera, Capaldi, and Wilkie 2015). As a consequence, an increased consumption of that particular or similar vegetable usually occurs. All types of flavors, including vegetable-related flavors, may be found either in substances that are naturally generated by women, such as the amniotic fluid or breast milk, since the flavor of maternal diet is transferred to these substances, or in industrialized products, such as milk formulas, foods and drinks. At the contrary, insufficient or lack of repeated exposure to vegetables at early stages of development may lead to either an ineffective learning or even a lack of learning to accept vegetables.

An indispensable requirement for this mechanism to be triggered is that there is vegetable availability for human consumption, but what is commonly understood in the scientific literature under the concept of vegetable availability? Is there universal equality regarding vegetable availability? What can be responsible for lack of vegetable availability? According to prior research (i.e. Asfaw 2008; Miller et al. 2016), vegetable availability refers to individuals having vegetables in their home, and lack of vegetable availability is usually attributed to a non-affordability of vegetables and people's poverty. Consequently, a low vegetable consumption is associated with low affordability and poverty, especially in low-income countries, such as in some African countries, where vegetable prices are more expensive than higher income countries (Asfaw 2008; Miller et al. 2016). Additionally, geographic factors, in particular, climatic and political conditions, along with poverty affecting a given geographic region might be also contributing to explain that lack of vegetable availability. Regarding climatic conditions, we are mainly referring to the existence of liquid water. Regarding political conditions, we are referring to the political decisions regarding the use of a country's farmland.

This review aims, in light of recently published studies and author's deep reflection, a two-fold analysis: on the one hand, it aims to discuss effects of repeated exposure to vegetables during early stages of development, in particular, during prenatal gestation and breastfeeding, on vegetable acceptance, and liking of and preference for vegetables in children, and to discuss how the geographic place of residence of the mother may impact vegetable availability, and thus the development of both particular vegetable consumption patterns and particular recipes of vegetable-based dishes, on the other hand. These two objectives are closely linked for two reasons: vegetable availability is a *sine qua non* requirement for the action and effects of repeated exposure to vegetables to be deployed, and a better understanding of these effects necessarily raises concerns about the reasons for vegetable (un) availability. Finally, implications of this two-fold analysis for future research, including three new related working hypotheses are included here.

This review is exclusively focused on studies that include vegetables as targeted stimuli and have used natural mere exposure -when this mechanism is triggered through substances that are naturally generated by the mother, such as the amniotic fluid and breast milk- as mechanism to establish infants' and children's acceptance of and preference for vegetables. This is, to the best of our knowledge, the first review that deals with these objectives jointly.

Effects of prenatal repeated exposure to vegetable-related flavors on children's consumption of and preferences for vegetables

During prenatal development, fetuses or future babies remain surrounded by amniotic fluid within the boundaries of the placenta that forms in the uterus of the mother, from the moment of the implantation of the embryo in the uterine wall, an event that occurs approximately a week after the fertilization has taken place. This amniotic fluid is provided with the flavors derived from the maternal diet during pregnancy, for example, the taste of garlic (Mennella, Johnson and Beauchamp 1995). Usually, a pregnant woman, like any other person, feeds on products that can be accessed, and therefore are available for human consumption in her place of residence or environment. The taste and odor molecules -flavor composition- of the ingredients of foods and drinks that are typically found in the mother's environment and are ingested by her, are retained during digestion (Guichard and Salles 2016) and transferred to the mother's bloodstream and, hence, to that of the fetus through the umbilical cord that is attached to the placenta (Smith and Lau 2016), thus reaching all the cells of the fetus and its urine. Indeed, the molecular composition of the urine of the fetus reflects that of the substances transported to its bloodstream (Brace and Moore 1991; Brunzel 2018). This means that the composition of the baby's urine turns out to be coated with the taste and smell molecules -flavors- that have been previously transferred to its bloodstream. Moreover, since prenatal babies regularly urinate in the amniotic fluid (Touboul et al. 2008), the fetal urine carries the taste and odor molecules from the mother's diet to the amniotic fluid (Mennella and Beauchamp 1998). Once here and since fetuses regularly breath and take amniotic fluid into and out of the lungs, these molecules stimulate the taste and smell receptors of the fetus (see Rohlfs Domínguez 2018 for a review) in such a way that the developing baby begins to detect certain flavors, such as sweetness during the prenatal phase of development (Trazer et al. 1985, Maone et al. 1990).

A series of studies has examined the relationship between prenatal exposure to the flavors of the maternal diet and certain variables related to child acceptance and liking of and preferences for vegetables (Table 1).

In view of that what is indicated in Table 1, it may be deduced that tasting the sapid amniotic fluid acts as a first opportunity to learn naturally to accept the vegetables-related flavors. In particular, the positive effects of prenatal exposure to vegetables on children's diet are clearly displayed in some phases of postnatal development, such as the perinatal phase (Schaal, Marlier, and Soussignan 1998), first postnatal months (Mennella et al. 2005) and late childhood (Hepper et al. 2013). However, in the case of early childhood,

Table 1. Compendium of results of studies that have examined the impact of *in utero* exposure to the flavors of vegetables ingested by the mother on the taste for and consumption of vegetables in childhood, where D = day, E = exposure (age at which the exposure took place), EE = effects of the exposure (age at which the effects of the previous exposure were measured), EG = exposed group, GW = gestational weeks, M = month, NEG = non-exposed group and Y = year.

Reference	Ingested vegetable/herb	A (E)	A (EE)	Measured Variable/s	Results
Schaal, Marlier and Soussigan (1998).	Anise *versus* no anise consumption.	37-42 GW.	Immediately after birth.	Hedonic reaction (oro-facial activity) to the presentation of anise odor	The EG showed positive facial responses. The NEG showed negative or neutral facial responses.
Mennella, Jagnow, and Beauchamp (2001).	Carrot juice during the lactation period and water during pregnancy *versus* carrot juice during pregnancy and water during lactation *versus* water during both pregnancy and lactation.	Last prenatal trimester and first two PM.	Weaning (5.7 ± 0.2 PM).	Acceptance of CFC *versus* plain cereal.	The EGs consumed more CFC, and showed less negative facial expressions tan the NEG.
Mennella et al. (2005).	Various unspecified fruits and vegetables.	Unspecified	6 PD – 9 PM.	Acceptance of various fruits and vegetables (unspecified) at weaning.	The type of fruits and vegetables that were accepted by the infants correlated with the type of fruits and vegetables that were ingested by the mother.
Hepper et al. (2013).	Meals that were seasoned with fresh garlic *versus* no garlic consumption	Four final GW	8-9 Y.	Consumption of potatoes that were seasoned with fresh garlic.	The EG consumed more potato with fresh garlic than the NEG.
Nicklaus et al. (2014)	Vegetable variety (unspecified)	Pregnancy (unspecified GW)	2 Y	Children's acceptance of vegetables	No effect of was found
Ashman et al. (2016)	Variety of unspecified fruits and vegetables.	19-36 GW	2-3 Y.	Acceptance of the unspecified variety of vegetables.	Children's acceptance of fruits and vegetables correlated with maternal diet during pregnancy. This effect was modulated by the maternal diet during childhood.

and especially at the age of 2 years, the evidence is absent, which could be due to the type of vegetable -bitter vs. non-bitter vegetable- that was ingested by the mother during pregnancy. This hypothesis should be examined in future research work (see Rohlfs Domínguez 2018 for a review).

The importance of the association of prenatal exposure to the flavors of the vegetables that are consumed by mothers during pregnancy with postnatal development of preferences for and consumption of vegetables lies on the adaptive nature of this association (Nicklaus 2016), which should make it easier for prenatal developing babies to learn to prefer and to eat the vegetables that will be available in their environment, once they are born, to the detriment of those that will not be available, thus increasing babies' chances of nutritional survival during early postnatal life (Rohlfs Domíngez 2018), a period of maximum vulnerability.

Effects of repeated exposure to vegetable-related flavored breastmilk on children's preferences for and consumption of vegetables

The second opportunity to learn to accept vegetables appears once the baby is born. From birth, the baby continues to learn information about the flavors of the vegetables of the maternal diet, since breast milk, in addition to the amniotic fluid, also contains molecules of the tastes and smells of the flavors of the foods and drinks, including vegetables that are eaten by the mother. This is known thanks to a series of studies that have detected the presence of different substances, such as garlic, alcohol, mint, vanilla and orange juice in the breast milk of mothers who had previously ingested such substances (Mennella 1995; Mennella and Beauchamp 1991a, 1991b, 1996, 1999). This means that during lactation the baby is also subjected to repeated exposure to the tastes and smells of the flavors of the foods and drinks that are accessible to the mother, and she decides to consume. This type of repeated exposure may also induce changes in the acceptance and, therefore, in the liking for different foods, including vegetables (Table 2).

Table 2 shows that only a few studies have addressed the cause effect relationship between exposure to flavors of vegetables during lactation and the subsequent vegetable consumption during weaning. The first mentioned study (Mennella and Beauchamp 1999) did not find this causal relationship, which the authors of this study attribute to sensory-specific satiation (SSS). SSS is «the progressive decline during a meal in liking the flavor and appearance of a specific food» (Rohlfs Domínguez et al. 2013, p. 109) as a result of repeated exposure to that food (Rolls, Rowe, and Rolls 1982). The second study of the table (Mennella, Jagnow, and Beauchamp 2001), however, did find it, and demonstrates

Table 2. Synthesis of studies that have examined the impact of exposure, during breastfeeding, to the taste of the vegetables that were ingested by the mother on liking for and consumption of vegetables in infants, where: BFC = broccoli-flavored cereal, CFC = carrot-flavored cereal, CCJ = cereal with carrot juice, CW = cereal with water, E = exposure (age at which the exposure took place), EE = effects of the exposure (age at which the effects of the previous exposure were measured), EG = exposed group, M = month, NEG = non-exposed group, PD = postnatal day, PM = postnatal month.

Reference	Ingested vegetable	Age (E)	Age (EE)	Measured variable/s	Results
Mennella and Beauchamp (1999).	Carrot juice during the lactation period *versus* water during lactation period.	Carrot juice: 174.4 ± 9.7 PD. Water: 171.6 ± 6.2 PD.	Weaning (10-12 days older than at the time of exposure).	Acceptance of CFC *versus* plain cereal.	In comparison to the NEG, the EG consumed less CFC than plain cereal and for less time.
Mennella, Jangow, and Beauchamp (2001)	Carrot juice during the lactation period and water during pregnancy *versus* carrot juice during pregnancy and water during lactation *versus* water during both pregnancy and lactation.	Last prenatal trimester and first two PM.	Weaning (5.7 ± 0.2 PM).	Acceptance of CFC *versus* plain cereal.	The EGs consumed more CFC, and showed less negative facial expressions tan the NEG.
Mennella, Daniels, and Reiter (2017).	Variety of vegetable juices: carrot, beetroot, celery, roots and vegetables, for 1 M *versus* for 3 M, *versus* no vegetable consumption.	0.5 PM, *versus* at 1.5 PM, *versus* at 2.5 PM	After weaning (7.9 PM).	Acceptance of simple cereal, *versus* CFC, *versus* BFC.	The group that was exposed for 1 M and for which the exposure started at 0.5 PM showed a higher rate of consumption of CFC than if the exposure had lasted 3 M; the exposure had started at a posterior PM and the NEG. No effect was found regarding consumption of the BFC.

that being exposed to a given vegetable, such as carrot, a sweet vegetable, during lactation may produce an increase in the subsequent acceptance of foods that contain this flavor. Finally, the third study (Mennella, Daniels, and Reiter 2017), shows that a relatively brief -a month- but early -half a month of age- repeated exposure to a variety of sweet vegetables, such as beet and carrot and bitter vegetables, such as celery and roots during lactation increases the subsequent acceptance of a sweet vegetable -carrot- that had been already experienced in breast milk. However, this brief but early exposure has no effect on acceptance of new and bitter vegetables, such as broccoli.

Hausner et al. (2015) and Mennella, Reiter, and Daniels (2016) affirm that repeated exposure to food-related flavors during breastfeeding seems to be a bridge between experiences with the food-related flavors that were experienced *in uterus* and experiences with the flavors of future novel solid foods. Since the targeted flavor that was used in the studies that are showed in Table 2 was the same flavor in both experimental conditions, that is, when diluted in human milk and when presented in solid food, and therefore, it was not a novel flavor, we suppose that the term novel is referring to the solid condition of the food. In a similar way, we might argue that repeated exposure to vegetable-related flavors during breastfeeding seems to be a bridge between experiences with the vegetable-related flavors that are diluted in the amniotic fluid and experiences with the flavors of future solid and thus novel vegetables.

On the other hand, and with the exception of the research work by Mennella, Jagnow, and Beauchamp (2001), the studies that are shown in Table 2 did not assess nor control the type of vegetables -bitter *vs.* non-bitter- that were consumed, if any, by the mothers during pregnancy. Therefore, it is unknown, whether this vegetable consumption affected the resulted effects that were found by those studies. In consequence, the questions that arise now are: 1) Is it determinant that the vegetables that are ingested by the mother during both phases, that is, pregnancy and breast feeding, and the ones that are ingested by the infant at weaning are the same/similar vegetables in order to "build" that bridge? 2) What would happen if the vegetables that are ingested by the mother during breastfeeding are not the same as those ingested during pregnancy? 3) Would the "construction of the bridge" be "interrupted"? If this is the case 4) to what extent? What particular effects would have this interruption? Given the fact that fresh-cut vegetables show different features -flavor (taste + odor), texture, color, mass, etc.- (Barrett, Beauleu, and Shewfelt 2010), a possible answer to those particular questions might be that the prenatal stage of development and the lactation period might be different sensitive periods of development of preferences for different types of vegetables, depending on the particular flavor of the vegetable type -bitter *vs.* non-bitter-.

We may define «sensitive periods [of sensory development] as restricted periods of time (i.e. specific ages) in

development during which there is a biological display of an extreme neural sensitivity to the storage of experience-driven sensory information […]. The main effects of repeated exposure to particular stimuli during a sensitive period are the lasting or even everlasting changes in the individual's behavior and in its underlying sensory function» (Rohlfs Domínguez 2011, p. 909). Sensitive periods are usually located at prenatal and perinatal phases of development and infancy and early childhood. There are some evidences that point out to the existence of sensitive periods in the gustatory and olfactory domains (see Rohlfs Domínguez 2018, 2233–2234 for a review). In summary, these evidences show, for example, that early exposure -during early childhood, that is, during the age of 2 to 3 years- to foods, including vegetables, induce a long-lasting acceptance of and preferences for those foods and, particularly, for vegetables. The term "long-lasting" refers to the fact that such effects are observed in late childhood, adolescence and young.

We recommend trying to answer those questions and testing that particular hypothesis (Hypothesis 1) through future research effort. Doing this would require varying the vegetable type that is consumed -bitter *vs.* non-bitter- by the mothers; varying the timing of mothers' vegetable consumption -during pregnancy *vs.* breastfeeding- as well as testing its effect on children's vegetable intake at weaning by means of a longitudinal experimental paradigm.

On how the geographic place of residence of the mother may determine the availability of particular vegetables that are consumed during pregnancy and breastfeeding and, therefore, generate particular patterns of child (non) vegetable consumption

The place of residence of the mother may determine vegetable availability because of the geographic factors, in particular, climatic and political conditions that are associated with that place of residence.

Regarding climatic conditions, mainly existence of sufficient liquid water for irrigation, they play a fundamental role when it comes to importing or growing a particular type of vegetables. These climatic conditions will depend, in turn, on the geographic location of the crops (Gardas, Raut, and Narkhede 2018; Bouzembrak and Marvin 2019; Kyriacou et al. 2019; Parajuli, Thoma, and Matlock 2019; Maseko et al. 2019; Zudaire et al. 2019). This applies either to when the vegetables are grown outdoors or in greenhouses, since, in the latter case, what is done is to recreate the natural climatic conditions so that a particular vegetable can be harvested inside the greenhouse. Taking the region of South Africa as an example, «South Africa is a dry country with some areas experiencing shortages of drinking water and crop production mostly practiced under water deficit» (Maseko et al. 2019, 78), and the so called "hidden hunger" or nutrition insecurity -scarcity of nutrients, such as iron, iodine and magnesium, among others- that is affecting South Africa has been attributed to this water deficit (Maseko et al. 2019). Other geographic areas that are being affected by issues regarding water supply are the rural areas of China (Fan et al. 2019). It is worth indicating here that green vegetables, such as broccoli, spinach and chard are rich in these nutrients, and they require appropriate irrigation levels to be suitable for human consumption.

Regarding political conditions of a given geographic region, mainly political decisions regarding the use of a country's farmland, we have to point out that they may determine to what extent the cultivable land is dedicated to livestock and cultivation of feed for cattle rather than the cultivation of vegetables for human consumption. In this sense, it is worth mentioning the deforestation that, due to those two land uses, is taking place in Latin America (Roebeling and Hendrix 2010; Gollnow and Lakes 2014; Gasparri and De Waroux 2015). An *in cresecnedo* increase in the demand for meat consumption is probably the cause or one of the causes of such deforestation. In fact, consumption of meat, in general, and pork, in particular, is growing in China (Zhang, Wang, and Martin 2018), and China is the most populous of the world. Therefore, to feed it with meat it is necessary that a large amount of land be devoted to livestock and the cultivation of food for livestock, thus probably reducing the land for growing vegetables for human consumption, which might have an impact on child vegetable consumption.

In addition, other geographic factors, such as facility support -i.e. existence of means of transportation or lack of it-, limited or no limited market opportunities and lack or no lack of expertise in the field of agriculture may determine the type of vegetables grown, as in the case of rural areas of China (Fan et al. 2019), for instance. Moreover, the ability to manage food loss after harvest and to make investments to manage it is an additional geographic factor that is affecting food access (vegetable access) in some regions of the planet, in particular, in developing countries, such as Kenya (Gogo et al. 2017).

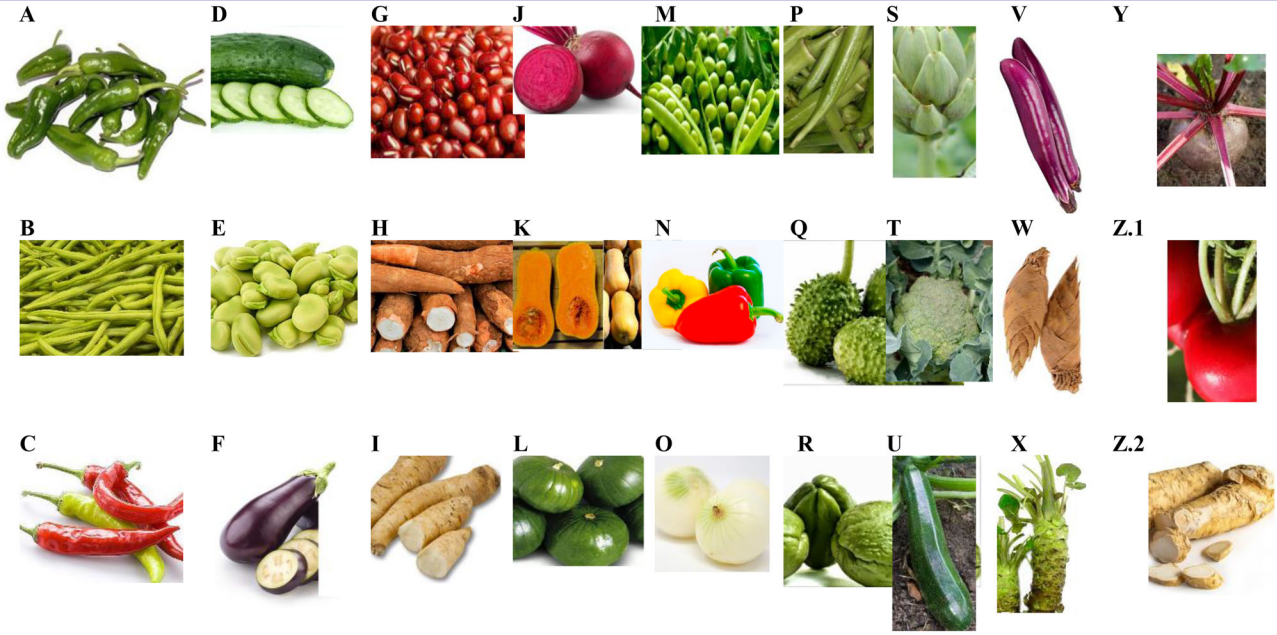
There is at least one report (Mason-D'Croz et al. 2019) that shows that insufficient production of vegetables reduces vegetables availability, thus preventing people's -therefore children's- consumption of recommended amounts of vegetables in several countries, especially in Sub-Saharan Africa.

Therefore, whether or not vegetables can be successfully grown in a particular geographic region, the choice of particular vegetables for outdoor or indoor cultivation, and thus vegetable access is influenced by the mentioned geographic factors, and thus differ among different regions of the planet. For this reason, we may affirm that there is a geographic diversity in relation to the availability and consumption of particular vegetables. This geographic vegetable diversity can be appreciated at the state level -within the same state- as well as at the interstate and even intercontinental levels.

At the state level, we can take, for example, two different belonging to the same state -for instance, Spain-. These autonomous communities would be the Basque Country -in Basque, Euskadi-, that is, a northern autonomous community and Andalusia, a southern autonomous community. The author knows well both of them. Thus, among the vegetables that are usually grown in the Basque Country, green

Table 3. Images of a sample of different harvested vegetables according to the geographical localization of the planet.

		Interstate level						
State level		Distant states to each other		Close states to each other		Intercontinental level		
Basque Country	Andalusian	Venezuela	Argentina	Colombia	Brazil	Australia	Japan	Russian
A	D	G	J	M	P	S	V	Y
B	E	H	K	N	Q	T	W	Z.1
C	F	I	L	O	R	U	X	Z.2



Comparisons are made at the state, interstate and intercontinental levels, respectively, where A = raw green pepper from Gernika (adapted from Dastatu, Basque Country Gourmet, DBCG. 2018), B = raw *vainas* or green beans (adapted from Euskal Irrati Telebista, EITB. 2019), C = raw *guindilla* or chili (adapted from Vasco 2019) , D = raw cucumber (adapted from Cuantas calorías 2019), E = raw beans (adapted from the Spanish Association of Frozen Vegetable Manufacturers, SAFVM. 2019), F = raw eggplant (adapted from Puleva 2019), G = raw beans or *frijoles* (adapted from MSC Invernaderos, MSCI. 2019a), H = raw yucca (adapted from MSCI. 2019b), I = raw creole celery (adapted from Dia Fit 2019), J = raw beet (adapted from the Healthy Eating Foundation, HEF. 2019), K = raw *zapallo* (adapted from the Gorvernment of Argentina 2019b) L = raw *zapallito* (adapted from the Association of Horticultural Producers of the Province of Córdoba, Argentina, AHPPC 2019), M = *arveja* o peas (adapted from Mercantile Exchange of Colombia, MEC. 2019), N = *pimentón* or chili pepper (adapted from Integral Nutrition and Esthetics Center Mokaná SAS, in Colombia, INACMSAS. 2014), O = raw big onion (adapted from Foundation of Businesswomen 2019), P = raw okra (adapted from World Crops 2019), Q = raw *maxixe* (adapted from Labor University of Toledo 2019), R = raw *xuxu* (adapted from Labor University of Toledo 2019), S = artichoke (adapted from Growing Interactive, Ltd 2019b), T = broccoli (adapted from Growing Interactive, Ltd 2019c), U = zuccini (adapted from Growing Interactive, Ltd 2019d), V = raw japanese aubergine (adapted from Martínez 2018), W = raw bambu shoots (adapted from Martínez 2018), X = raw *wasabi* (adapted from Martínez 2018), Y = raw beet (adapted from Growing Interactive and Ltd 2019e), Z.1 = raw radish (adapted from Growing Interactive and Ltd 2019f) and Z.2 = horseradish (adapted from Melisass's 2019).

pepper, in particular, Gernika green pepper, as well as red pepper, *guindilla* -in English, chili pepper-, chard, collard greens, lettuce, leek and green beans are remarkable. In Andalusia, on the other hand, cucumber, bean and eggplant are some of the vegetables that can be frequently found in the market. In both autonomous communities tomatoes are grown.

At the interstate level -within the same continent- we can do the same by taking as examples two states of the southern part of the American continent that are located at great distances from each other, such as Venezuela and Argentina. While in Venezuela, the cultivation of beans, cassava and Creole celery is quite common, in addition to potatoes, there is an abundance of squash and zucchini, two different species of squash, in Argentina (Government of Argentina 2019a). In both of these states, we may find garlic and onion as typical crops. If we consider two South American states that are close to each other, such as Colombia and Brazil, we also find differences in the vegetables that are harvested. Thus, in Colombia we may find *pimentón* –in English, paprika- (National Administrative Department of Statistics of Colombia, NADSC 2015a), peas (NADSC. 2015b) and big-headed onion (NADSC. 2016) and in Brazil Brazilian *okras* or *quiabos* -in English, lady's finger, a type of pepper-, savannah cucumber or *maxixe* and the *xuxu* -in English, squash- (Labor University of Toledo 2019). In both states, the cabbages are typically grown.

Finally, at the intercontinental level, we can glimpse these differences taking as models Japan, a state of the Asian continent, Australia, a state of the oceanic continent, and Russia, partially belonging to the Asian and European continents. Typical of Japan is the harvest of Japanese eggplant, bamboo, hakusai or Chinese cabbage and wasabi, for example (Martínez 2018). In Australia, on the other hand, broccoli, zucchini, artichokes and Brussels sprouts are commonly grown (Government of Western Australia 2019). Finally, beets, radishes and horseradishes are frequently cultivated in Russia (Food and Agriculture Organization of the United Nations, FAO. 2013; Growing Interactive, Ltd. 2019a). Table 3 shows a visually graphic representation of the variety of existing vegetables according to specific regions of the planet that has been considered in this section.

Locals of all these geographic regions have probably learned from very early in life, by means of the mechanisms

Figure 1. Images of typical dishes of the Basque Country or Euskadi (Spain): Gilda (top left), which has green *guindilla* -green chili pepper- and, sometimes, red pepper with *alegría* -in English, joy, this meaning that it is spicy-, which is imported from La Rioja; *piperrada -piper* is pepper in Basque- (top right), containing green and red peppers, tomatoes, onions and garlic; chard stalks stuffed with ham and cheese and green pepper sauce (bottom left) (inspired in Arguiñano 2019a) and *purrusalda* -in English, leek soup- (bottom right) (inspired in Arguiñano 2019b), which includes leeks, potatoes, carrots and onion. Both dishes and photographs have been made *ad hoc* by the author of this manuscript (Rohlfs Domínguez 2019).

Figure 2. Images of typical dishes of Andalusia (Spain): *gazpacho* (top left.), which mainly contains tomatoes; beans with ham (top right); eggplants with cane honey (bottom left). This photo has been altruistically taken and given by Mrs. Elena Ureña Cañada and fried battered zucchini (bottom right). The other dishes and photographs have been made *ad hoc* by the author of this manuscript (Rohlfs Domínguez 2019).

Figure 3. Images of typical dishes from different countries: Japanese stir fry vegetables, which contains Japanese eggplant, shiitake mushroom, bamboo shoots, Green onions and soy sauce (top left); *okras sudadas* -in English, sweaty *okras* or lady's finger- (Brazil), which is based on Brazilian okras and crushed natural tomato (top right); cooked yucca (Venezuela), with yucca, onion, garlic and lemon juice (bottom left) and beet cream, a variant of the so-called *Borscht* (Russian) (bottom right.). Both dishes and photographs of these dishes have been made *ad hoc* by the author of this manuscript.

of exposure to the flavors that have been previously described, to like the taste of *their* vegetables and prefer these vegetables over others that are not available in these regions, either because they are not imported or grown there. In other words, they have learned to like vegetables that are familiar to them because they have consumed and tasted these vegetables over and over again from an early age, since these vegetables have been always available in these regions. As a result, locals of these regions have ended up incorporating these vegetables into their regular diet during adult life, this leading to creation of certain dishes that have become part of the typical gastronomy of these geographical areas, in which they live. In fact, the set of gastronomic recipes of a given geographic region is usually composed of typical dishes of the area that are made from combinations of different ingredients, including the identified vegetables. Figures 1–3 show some of these typical dishes of particular countries of the world.

These are dishes that include vegetables of which flavors presumably are those flavors or similar flavors which locals have repeatedly been exposed to from early in life. The vegetables of these dishes are the vegetables that locals have learned to accept and like as a result of the described early repeated exposure; which locals have developed preferences for, and of which consumption has become a food habit related to vegetable consumption. Presumably, these are the vegetables that locals have also continued and continue to consume as adults, given that the eating habits that have been established early in life can carry over into adulthood. Consequently, these are the vegetables that locals have learned to cook giving raise to particular vegetables-composed dishes. Therefore, these are the vegetables offered to their offspring, that is, their children at different meals of the day, either at home if children usually eat at home or at school if they usually eat at the school. This is probably the way in which preferences for particular vegetables and particular recipes of vegetables-composed dishes have been transmitted to posterior generations over time.

Focusing on the flavor attribute of vegetables, there are vegetables that are bitterer than other vegetables. For example, chards, spinach or broccoli are particularly bitter in comparison to carrot, beet or aubergine, which are

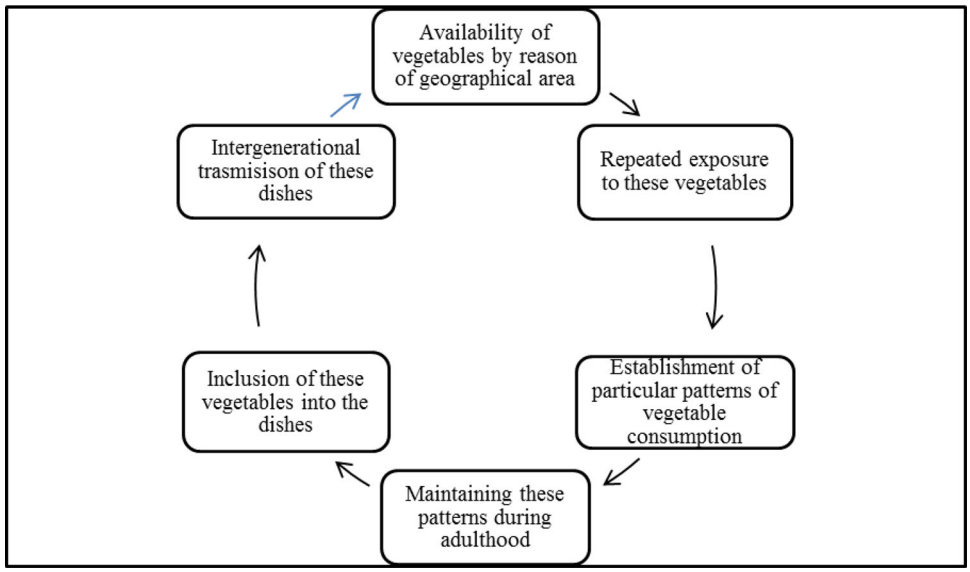


Figure 4. Graphical representation of the origin, establishment, maintaining and intergenerational transmission of particular patterns of vegetable consumption and dishes that include the particular vegetables that are available in a given geographical area of the world.

usually sweeter. Therefore, if a given child is repeatedly exposed to one type of vegetables, for example, bitter-tasting vegetables in a higher extent than other vegetables, such as sweet-flavored vegetables at the right time that child will tend to accept, like and prefer the first group of vegetables over the second group of vegetables.

As the availability of a certain vegetable depends, at least partially, on the geographical area where the exposure takes place, that is, where the mother lives, we may deduce that, due to the above-mentioned reasons, it is far more likely to find bitter vegetables or some of them in a higher extent in some geographic regions over other regions of the planet, and the same may be happening with sweet vegetables. This would mean that not only the type of vegetables -bitter *vs.* sweet- and the time of the exposure -prenatal *vs.* postnatal (breastfeeding)- would play a key role in the origin of particular patterns of child vegetable consumption -those based on consumption of bitter vegetables *vs.* those based on consumption of sweet vegetables *vs.* mixed patterns of vegetable consumption- but also the geographic region in which the mother lives, that is, in which the exposure to vegetables occurs. We recommend testing this hypothesis in the future (Hypothesis 2). In this sense, it has been reported that mothers' high vegetable consumption is associated with high rates of home vegetable availability (i.e. Bryant et al. 2011), which probably implies geographic vegetable availability. Availability or unavailability of particular vegetables due to geographic reasons is especially important because it has been found that some vegetables stand out more than others in being protective against some types of cancer, such as breast, ovarian, lung and pancreatic cancer and cancers related to the digestive tract and system. Protective vegetables are, for instance, cruciferous vegetables i.e. cabbage, broccoli, leaf mustard, chard, Chinese leaves (Mori et al. 2019), tomatoes, chili, shiitake mushroom (Cao et al. 2019) and ginger (Alsherbiny et al. 2019). Most of these protective vegetables are bitter.

We suggest here, at least, at a theoretical level, that the concatenation of these six processes: 1) availability of particular vegetables in a given geographic region via cultivation or importation thanks to a series of climatic and political factors that favor it, 2) early -at prenatal or breastfeeding developmental phases- repeated exposure to these vegetables, 3) subsequent establishment of particular patterns of acceptance and liking of and preferences for these vegetables early in life, 4) maintaining these patterns during adulthood, 5) incorporation of these vegetables into the dishes of the gastronomic recipes of that geographic region and 6) intergenerational transmission of these patterns of vegetable consumption and these recipes from one generation to the next one might partially and hypothetically explain the cycle of development, perpetuation and inter-generational transmission of certain eating habits, in particular, those based on consumption of particular vegetables as well as particular recipes that include these vegetables, which, in turn, are characteristic of the given geographic area in which they are grown or to which they are imported (Figure 4).

To scientifically confirm the display of this cycle (Hypothesis 3), monitoring of the evolution of patterns of consumption of vegetables of different generations and of the vegetables-composed recipes of the population of study should be done. Additional comparisons among populations of different geographic regions, that is, cross-cultural studies are also recommended here. Doing this would contribute to the understanding of the determinants of vegetable (non) consumption in children of different populations, which might be useful to design interventions to promote this consumption.

What has been exposed in this section leads us to wonder, whether there is an inequality in the world regarding availability of vegetables that are especially protective against cancer because of the mother's place of residence, a variable that might have an impact on the type of vegetables that are imported and/or grown there and even on whether or not such vegetables are imported and/or grown there, and thus

on child vegetable consumption. It has been well documented that a low vegetable consumption is associated with low affordability of vegetables and people's poverty, especially in low-income countries, such as in some African countries (i.e. Asfaw 2008; Miller et al. 2016). This finding puts the focus, at least partially, on people's decisions about how they are leading their life, what kind of work they are carrying out, etc. However, our question, which intends to put the attention on factors that are out of people's direct control, such as political decisions regarding the use of a country's farmland, climatic conditions, etc. remains open. To answer to that question, a world map should be drawn up to show what type of vegetables is grown and/or imported for human consumption to each geographic region of the planet. In this way, possible deficiencies in the cultivation of vegetables that are especially protective against cancer might be identified. Once these deficits were identified, measures could be taken against them. Vegetable availability probably do depend both on people's decisions about their life and external factors, such as the land use policy of a country.

Final remarks and recommendations for future research

We know that there is a serious problem in relation to children's low vegetable consumption. For this reason, we wanted to understand two specific aspects of child vegetable consumption. The particular effects that the repeated exposure to vegetable-related flavors during prenatal gestation and breastfeeding has on children's vegetable acceptance and liking and thus vegetable consumption, on the one hand, and the relevance that the availability of certain vegetables over others, depending on the geographic location, has on learning and perpetuation of particular patterns of vegetable consumption over time, on the other hand.

Regarding the first objective, and in view of the evidence revised here, we may conclude that child's early experiences -during the prenatal and breastfeeding phases of development- with the flavors of vegetables may lead to changes, in particular, increases in children's acceptance and liking of and preference for the vegetables provided to the children during those experiences. However, such changes might depend on the particular flavor of the vegetable -bitter *vs.* sweet- probably together with the time of exposure -prenatal *vs.* breastfeeding-. This should be tested in the future, which would require manipulation of the vegetable type and the time of exposure. This would mean that if the child is exposed to bitter vegetables, such as Brussels sprouts at the right time or age the child may show a higher acceptance of and preference for that vegetable and other bitter vegetables than for other vegetables, i.e. sweet ones and non-exposed children. The same would happen if the vegetables in question were sweet.

Regarding the second objective, this review has identified that certain factors, such as climatic and logistic conditions may determine a certain type of vegetables to be imported to and/or grown in a given geographic area at the expense of others, this leading to a geographic diversity in relation to the vegetables that are available for and consumed by the mothers, and thus their children are exposed to. For this reason, in addition to the flavor of the vegetable and the time of the exposure, geographic availability of vegetables might be also having an impact on children's vegetable consumption, in particular, on the type of the vegetable that is consumed by the mothers, and thus their children are exposed to, which also should be empirically tested in the future. In this sense, it is also recommended here to identify worldwide deficiencies in the availability of vegetables that are especially protective against cancer that may be associated with geographic reasons, that is, climatic or political conditions of a given area, in order to implement effective measures for solving this problem.

As a result of addressing the two described objectives, we also suggest here the existence of a cycle of processes that would theoretically explain the origin and perpetuation over time of food patterns based on the regular consumption of certain vegetables and the creation of typical vegetables-composed dishes in a particular human group or population. This cycle would begin with availability of particular vegetables through cultivation or importation as a function of the geographic area of study and would end with intergenerational transmission of particular patterns of vegetable consumption and recipes of vegetables-composed dishes to the next generation, going through early -during prenatal and breastfeeding phases of development- repeated exposure to the cultivated and/or imported vegetables, subsequent acquisition of particular patterns of vegetable consumption in early life, posterior display of these particular patterns of vegetable consumption during adulthood, inclusion of these vegetables into the dishes and even creation of new ones and, finally, intergenerational transmission of these particular patterns of vegetable consumption and recipes of vegetable-based dishes. As there is a geographic diversity of vegetables, we suggest that the main vegetables of the cyle are different in different geographic regions of the planet. Future research of this cycle is highly recommended, which would require comparison of patterns of vegetable consumption and vegetables-based dishes or recipes among different human groups or populations of different geographic areas of the world.

Confirmation of the hypotheses addressed here would contribute to better understand and encourage children's vegetable consumption as well as to solve possible deficits related to vegetable availability worldwide. The principal contribution of this review is to enhance awareness within the scientific community of the need for increasing vegetable availability worldwide in order to ensure provision of appropriate exposures to vegetables for children as well as development of suitable cycles of origin and perpetuation over time of patterns of vegetable consumption and vegetables-composed dishes.

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Conflict of interest

there is no conflict of interest to declare.

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