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Review

Nutritional supplementation in pregnant, lactating women and young children following a plant-based diet: A narrative review of the evidence

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ABSTRACT

Plant-based diets are increasingly popular in contemporary society. While they are suitable for all life stages, there is a potential risk of nutrient deficiencies, particularly in omega-3 fatty acids, vitamins A, D, and B_{12}, zinc, iodine, selenium, choline, and creatine. During pregnancy and lactation, the nutritional demands increase significantly, making proper supplementation essential. Breastfeeding remains the optimal feeding method for infants, provided key nutrient needs are met through supplementation. A bibliographic search in Scopus, Web of Science, and PubMed focused on plant-based diets, supplementation, and key nutrients over the past 10 years. Studies involving diseases or duplicates were excluded, and data were analyzed from European and U.S. sources to assess nutrient supplementation trends. Micronutrient deficiencies during pregnancy and lactation can negatively impact infant neurological development. Vitamin A supports vision and immunity, while vitamin D aids fetal bone mineralization. Deficiency in vitamin B_{12} can lead to anemia and neurological issues. Zinc, iodine, selenium, omega-3 fatty acids (EPA and DHA), choline, and creatine also play critical roles in development and may require supplementation in plant-based diets. With careful planning, plant-based diets can meet nutritional needs during pregnancy, lactation, and childhood. Supplementation with key micronutrients, including choline and creatine, is essential for neurodevelopment and energy metabolism. Dietitians play a vital role in guiding individualized dietary plans, and further research is needed on optimal supplement dosages and long-term health effects.

Introduction

Dietary patterns based on plants, such as vegetarian and vegan diets—now more commonly referred to as "plant-based diets"—are gaining widespread recognition in both society and the scientific community. These diets exclude animal-based products for various reasons, including cultural, ethical, religious, or environmental motivations [1,2]. Plant-based diets typically consist of vegetables, fruits, legumes (including derivatives such as tofu, tempeh, and other alternatives), cereals and grains, nuts, seeds, plant-based oils, and depending on the specific diet, may include dairy, eggs, and honey [3–5].

Accurately quantifying the number of individuals and households following this dietary pattern in Spain is challenging due to the absence of comprehensive data. However, estimates suggest that the percentage is similar to that observed in countries like Italy and the United States, ranging between 1% and 10% [4,6]. Recent statistics reveal a growing trend in the adoption of plant-based diets within the Spanish population, with approximately 14% identifying as vegetarians, 4% as vegans, and 7–10% as flexitarians [7,8].

Numerous studies highlight the health benefits of plant-based diets, particularly in the prevention of chronic noncommunicable diseases, such as type 2 diabetes, cardiovascular disease, and certain types of cancer [9–11]. Existing evidence also supports the safety of these diets across all stages of life, including pregnancy, lactation, and childhood, without observing negative effects on

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growth or development [12–14]. However, some researchers emphasize the importance of monitoring specific nutrients, such as vitamins A, D, B_{12}, iodine, zinc, omega-3 fatty acids, choline, and creatine particularly during critical periods like pregnancy, lactation, or early childhood, when growth and development may be compromised [3,4,15–17].

During pregnancy and lactation, various metabolic changes occur, increasing the demand for energy and nutrients essential for fetus development and maternal health. Proper nutrition during these periods is vital to meet the nutritional needs of both the mother and the infant, and to establish healthy eating habits early in life [18,19]. The composition of breast milk is complex and dynamic, varying according to maternal diet. While evidence supports the adequacy of breast milk, even in plant-based diets, specific nutrient deficiencies, such as omega-3 fatty acids, may arise [20–26].

The lack of specialized healthcare professionals trained in plant-based nutrition is a current challenge affecting families who choose these dietary patterns [6].

One of the fundamental aspects of nutritional support for this population is the need for B_{12} supplementation, given its importance for health. Pregnant and lactating women, as well as infants and young children, are particularly vulnerable to nutritional deficiencies. Therefore, dietary adequacy and appropriate supplementation are crucial to ensure proper nutritional status [16,19,22,23,25–30].

The primary objective of this narrative review is to update the evidence on the use of supplements of vitamins A, D, and B_{12}, minerals such as zinc, iodine and selenium, omega-3 fatty acids, choline, and creatine in pregnant, lactating women, and young children following a plant-based diet.

Methodology

An exhaustive bibliographic search was conducted in the main databases (Scopus, Web of Science, and PubMed), using MeSH terms and keywords such as "vegetarian and/or vegan diet," "supplementation," "nutrients," "choline," "creatine," "vitamins," "minerals," "omega-3," "pregnancy and lactation," and "infancy." The search was conducted in both English and Spanish, covering human population studies from the past 10 years. Narrative reviews, systematic reviews, and meta-analyses were included, with the inclusion criteria focused on the date range and studies conducted in a "healthy" human population (without underlying pathology).

Search procedure

An initial search was conducted using the term "vegan diet" as a primary filter to identify relevant studies. The search was subsequently refined by incorporating the previously mentioned MeSH terms and keywords.

Inclusion criteria

- Studies published in the last 10 years.
- Studies conducted on healthy human populations.
- Articles in English and Spanish.
- Narrative reviews, systematic reviews, and meta-analyses.

Exclusion criteria

- Duplicate articles after applying filters.
- Studies where the intervention population had a disease.

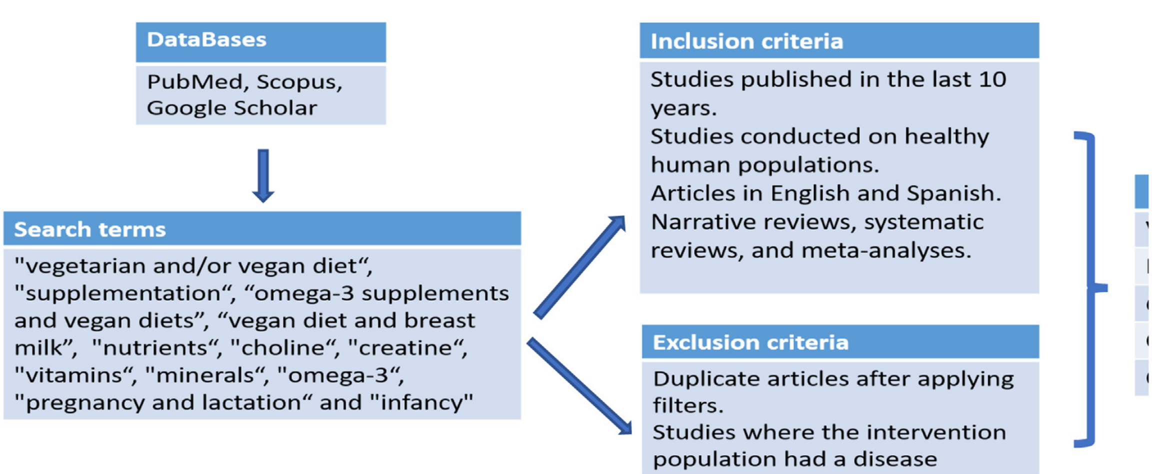
Nutritional composition data

Nutritional composition data were extracted from various databases:

- Europe: Moreiras Tuny et al., 2022, and BEDCA, 2024, Spain.
- USA: USDA, 2024.

Nutritional composition results were expressed in grams per 100 grams (g/100 g) or 100 milliliters (g/100 mL) of the edible portion (EP) depending on the food item. Due to the high heterogeneity of data related to nutritional composition, the source of the data was specified in each case.

Flow chart regarding selection method.



Data analysis

A descriptive analysis of the extracted data was conducted to identify patterns and trends in the nutritional supplementation of plant-based diets.

Results

The results obtained in the narrative review are presented in Table 1, which describes the information available to date on the need, or not, to consume the dietary supplements indicated in the flow chart included in the methodology, in certain physiological situations such as pregnancy, lactation or in the early stages of life if plant-based diets are followed. The table indicates the supplement and type of diet studied, the type of study carried out, the population in which the work was performed, and the main conclusions obtained.

Discussion

Proper nutrition during pregnancy is essential for both the mother's health and the health of her offspring, as it is crucial to maintaining an optimal environment for fetal development. Pregnancy is a critical period during which the mother requires different amounts of nutrients to ensure a healthy pregnancy, promote optimal fetal development, and avoid "fetal tissue reprogramming," which may predispose the infant to chronic conditions throughout life [12]. Infants born to mothers with micronutrient deficiencies, who are exclusively breastfed, may be at risk for micronutrient deficiencies with possible implications for neurological development [31].

Vitamins

Vitamin A

Vitamin A is an essential nutrient for vision, growth, cellular differentiation, and signaling, maintaining muscle integrity, and supporting immune functions [32]. Regarding pregnancy and lactation, it is a crucial micronutrient as it is not only essential for morphological and functional development and ocular integrity, but also exerts systemic effects on the skeleton and various fetal organs [33].

Vitamin A deficiency is a significant cause of morbidity and mortality due to infectious diseases, diarrhea, measles, and visual problems, primarily affecting night vision (xerophthalmia). Prolonged deficiency can increase the risk of respiratory diseases (e.g., pneumonia), infections (e.g., measles and/or diarrhea), and anemia. In severe cases, it can increase the risk of death [34]. Some researchers suggest multiple roles for vitamin A in the immune system, including activation, differentiation, modulation, and the proper formation of pancreatic islets [35].

Animal-based foods are the main dietary source of vitamin A, as can be seen in Table 2. Some plant-based foods contain carotenoid precursors, but fortified foods have been shown to be insufficient to meet recommended intake levels [32,36]. The biological activity of vitamin A is expressed in retinol equivalents, where 1 μg of retinol is equivalent to 6 μg of beta-carotene. The recommended daily intake varies depending on the source consulted and can range from 250 to 450 μg for children and 490–1000 μg for adults. During pregnancy, the recommendation is 800 μg/day, which increases to 1300 μg during lactation [37]. The population reference intake for the European population can be seen in Table 3.

Moderate heat treatment can improve the bioavailability of carotenoids and their conversion into vitamin A, as it releases them from proteins they are bound to. Another way to improve bioavailability is by including foods rich in antioxidants, such as vitamin E, in the diet, which helps protect vitamin A, along with small amounts of fat. Other methods include cutting and crushing vegetables [38].

Some studies observe that vegetarian and vegan diets have lower vitamin A content compared to omnivorous diets, while others show similar or even higher levels. Despite these conflicting results, blood vitamin A levels do not show deficiency in these studies [39].

Regarding pediatric populations, many developing countries have implemented national health strategies to administer vitamin A supplements to infants and children [40]. Doses greater than 25 000 IU/kg in children have been linked to signs and symptoms of acute toxicity [41]. Additionally, when supplementing vitamin A, it is important to consider the daily tolerable upper intake level of 3000 μg/d [42].

Vitamin D

Vitamin D plays a critical role in maintaining bone health by stimulating calcium and phosphate absorption in the intestines through osteoclasts. At the renal level, it also induces calcium reabsorption from the glomerular filtrate. Vitamin D is involved in various other functions being studied, such as immunity, diabetes, and lung disease [43]

During pregnancy, vitamin D is essential for fetal development. Maternal 25-OHD crosses the placenta and is the primary form of vitamin D available to the fetus. This vitamin has three main functions: stimulating calcium absorption and transport necessary for fetal bone mineralization during the last trimester, contributing to fetal tolerance, and participating in numerous transcriptional regulations, especially in the placenta by regulating the expression of key genes associated with development. Vitamin D deficiency, defined as a concentration of 25-hydroxyvitamin D (25OHD) below 50 nmol/L (20 ng/mL), is a public health issue in many countries, with pregnant women considered at high risk. Maternal vitamin D deficiency may increase the risk of preeclampsia, preterm birth, small-for-gestational-age infants, intrauterine growth restriction, and gestational diabetes [44,45].

Dietary sources of vitamin D include fatty fish, egg yolk, full-fat cheeses, and butter. Some mushrooms, when exposed to ultraviolet (UV) radiation from sunlight or a UV lamp, can generate nutritionally relevant amounts of vitamin D [46]. Humans can also synthesize vitamin D in the skin through exposure to UVB rays, which convert endogenous cholesterol into its active form through two hydroxylation reactions (in the liver and kidneys). If sun exposure is limited or endogenous synthesis is reduced, dietary intake becomes essential. Following a vegetarian diet may limit adequate vitamin D intake, and deficiency of this vitamin is more prevalent among vegetarians and vegans [39,47].

In addition to supplementation and consumption of fortified foods, vitamin D status can be improved by increasing sun exposure, while taking necessary precautions to avoid skin damage [38].

Recommended daily vitamin D intakes range from 10 to 15 μg/d (1 μg of cholecalciferol equals 40 IU of vitamin D) as can be seen in table 2. The Canadian Pediatric Society recommends 200 IU/day for preterm newborns and 400 IU/day for other children during the first year of life. Total intakes of 1 to 14 mg/kg may cause toxicity, which can present as severe hypercalcemia, hypercalciuria, or nephrocalcinosis. To prevent toxicity, serum 25-hydroxyvitamin D levels should be monitored in infants and children receiving long-term vitamin D supplements. The American Academy of Pediatrics recommends that exclusively breastfed children receive 400 IU/day of vitamin D supplementation soon after birth and continue

Table 1
Characteristics of studies included in the narrative review

Nutrient/molecule	Study type	Population characteristics	Type on diet	Supplementation	Results/Conclusions	Study
Vitamin A/retinol	Narrative review (n = 114 references)	Pregnant women	Not specified	The benefit of maternal vitamin A supplementation was limited to children whose mothers received preformed vitamin A vs beta-carotene	Vitamin A is transferred to the baby via the placenta and, after birth, primarily through breast milk. Supplementation and food fortification during pregnancy are essential to ensure an adequate supply.	Maia et al. [33]
	Observational	Murines Tie2-Cre and Z/EG	Vitamin A deficient diet for rodents	Not specified	Vitamin A deficiency is possibly related to the pathogenesis of diabetes. Supplementation is a strategy to consider ensuring adequate levels.	Chien et al. [35]
	Systematic review (n = 141 references)	General adult population	Plant-based diets (vegetarian, vegan and flexitarian) and diets with foods of animal origin	Not specified	Plant-based diets can be nutritionally adequate, but require attention to potential deficiencies in vitamin B12, vitamin D, iron, and ω-3. Supplementation and consumption of fortified foods are recommended to ensure sufficient intake of these essential nutrients.	Neufingerl et al. [39]
Vitamin D	Review (n = 60 references)	Pregnant women, fetus and newborn	Not specified	Oral supplements of Vit D3, with different doses, in tablet, capsule or drop format	Vitamin D deficiency in pregnancy is associated with maternal and fetal complications. Supplementation is recommended to prevent deficiencies and improve maternal and child outcomes, especially in regions with a high prevalence of deficiency.	Agarwal et al. [44]
	Prospective cohort	Pregnant women with vit D deficiency (n = 182)	Not specified	No supplements were included.	Vitamin D deficiency in late pregnancy is associated with an increased risk of placental complications. Maintaining adequate vitamin D levels could prevent these complications.	Raia-Barjat et al. [45]
	Systematic review (n = 13 references)	Pregnant women in developing countries	Not specified	Oral vitamin D supplement (D2 and D3)	Vitamin D deficiency in pregnant women in developing countries is linked to neonatal complications and risks. Vitamin D supplementation may improve maternal and infant outcomes, especially in regions with high prevalence.	van der Pligt et al. [47]
	Narrative review (n = 14 references)	Pregnant women, newborns and young children	Not specified	Oral supplementation with vit D	Vitamin D deficiency in pregnancy affects maternal health, fetal development, and long-term child health. Supplementation during pregnancy is recommended to prevent these risks and ensure adequate maternal and child health.	Urrutia-Pereira et al. [48]
Vitamin B_{12}	Systematic review (n = 5 references)	Pregnant women	Vegetarians, vegans and omnivores	Oral or intramuscular (IM) B12 supplementation	Vitamin B_{12} supplementation during pregnancy improves maternal and infant health, especially in women with deficiency. It is recommended for pregnant women, particularly vegetarians or vegans, to prevent deficiency.	Finkelstein et al. [49]
	Cases and controls (n = 25 references)	Breastfeeding mothers and their babies (n = 50)	Vegan (n = 25) Omnivorous (n = 25)	No supplements were included.	An exclusive vegan diet in lactating mothers does not affect vitamin B_{12} concentrations in breast milk, and infants breastfed by vegan mothers are not at increased risk.	Juncker et al. [51]
	Narrative review	Pregnant women	Vegetarian or vegan	No specific supplementation is mentioned, but B12 supplementation is discussed.	Vitamin B12 deficiency in pregnancy, common in vegetarian and vegan women, can cause serious maternal and fetal consequences. Supplementation is recommended to prevent deficiencies and ensure a healthy pregnancy.	Rashid et al. [55]
Zinc	Review	Children and pregnant women	Vegan	Not contemplated	A well-planned vegan diet may be adequate, but requires ensuring vitamin B_{12}, vitamin D, ω-3, iron and calcium through supplements or fortified foods.	Koeder et al. [57]
	RCT	Pregnant and preconception women (n = 278)	Not specified	Supplement with vitamins B2, B6, B12 and D, as well as zinc, myoinositol and probiotics	Zinc supplementation before and during pregnancy increases its concentration in breast milk, improving nutritional status.	Han et al. [59]
	Review (n = 165 references)	Infants (0-12 months), toddlers (1-2 years)	Breast milk, infant formula, complementary feeding	Not specified	Breast milk is the best source of zinc, but in cases of deficiency, supplementation is necessary to prevent problems.	Ackland et al. [60]

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Table 1 (*Continued*)

Nutrient/molecule	Study type	Population characteristics	Type on diet	Supplementation	Results/Conclusions	Study
	Systematic review and meta-analysis (n = 26 references)	General adult population	Vegetarian/vegan compared to omnivore	Not specified	Zinc deficiency is more common in women, vegans and in developing countries. Supplementation is recommended as a tool to improve intake values.	Foster et al. [64]
	Systematic review (n = 25)	Pregnant women and their babies	Not specified	Zinc iodide, zinc sulfate, combination supplements	There is insufficient evidence that zinc supplementation during pregnancy improves preterm birth, fetal or neonatal mortality, and birth weight.	Carducci et al. [67]
Iodine	Review	Pregnant and lactating women	Not specified	Different supplementation strategies, according to study	Iodine deficiency in pregnancy increases the risk of low birth weight, infant mortality, and poor cognitive development. Salt iodization is the most effective and cost-effective strategy to prevent deficiencies.	Zimmermann et al. [72]
	Secondary analysis of RCT	Pregnant women (n = 137) and their children (n = 113)	Inclusion of Atlantic cod (twice a week) or regular diet	Self-reported supplementation by participants	Breastfed infants have lower iodine status than formula-fed infants. Lactating women often have inadequate iodine intake, but no effects on thyroid function were observed. Iodine supplementation may be a strategy to consider.	Næss et al. [75]
Selenium	Observational transversal	Pregnant women (n = 59) and lactating women (n = 68)	Not specified. 24-hour food reminder	Supplements reported by participants	Selenium intake is a concern in pregnant and lactating women. Supplementation may be a strategy to consider.	Jin et al. [78]
	Narrative review	Cows and Sheep	Inadequate basal diet	Mineral supplement with Selenium / Selenium-enriched yeast or Selenium-enriched wheat.	Selenium supplementation during early pregnancy may influence nutrient utilisation by the fetus. High levels of selenium may improve pregnancy outcomes, but further research is needed in humans and other species. In sheep, high doses are safe and benefit development, highlighting the importance of evaluating their impact on gametes, fertilization and implantation.	Dahlen et al. [79]
	Observational	Pregnant women (n = 115)	Patients who reported any restrictive diet (rich in fish, vegetarian or vegan) were not included.	Supplemental intake of Se during pregnancy, using different types of supplements and doses. Organic and inorganic sources are included.	Pregnant women and newborns have low selenium levels, and self-reported supplementation was not effective. Moderate doses (>55 µg) are more effective than low doses. Recommendations should be individualised, including supplementation, and based on analyses, considering regional variability and the higher risk in people with chronic diseases, vegetarians and vegans.	Filipowicz et al. [80]
	Prospective cohort study	Pregnant Norwegian women (n = 71 728) with live births of singletons without congenital malformations	Not specified. A questionnaire on the frequency of consumption and use of dietary supplements is administered.	Dietary supplements reported by participants	Low maternal selenium intake may cause adverse neonatal outcomes, but this study found no clear association, unlike previous research. A varied diet and adherence to recommendations ensures adequate supply. Supplementation may be a strategy to consider.	Modzelewska et al. [82]
	Review (n = 22)	Pregnant women and mother-child pairs	Not specified	Nonuniform composition and dosage	Selenium supplementation in pregnancy is insufficient. Well-designed randomized controlled trials are required before its routine use can be recommended.	Biswas et al. [83]
	Systematic review (n = 32)	Pregnant women	Not specified	Selenium supplementation	Evidence on the effects of selenium supplementation during pregnancy and its relationship with preterm birth is limited.	McDougall et al. [84]

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Table 1 (*Continued*)

Nutrient/molecule	Study type	Population characteristics	Type on diet	Supplementation	Results/Conclusions	Study
Various nutrients (vitamins and minerals)	Review	Not specific. It refers to the first 1000 days of life, so fetuses and infants up to 2 years of age are assumed.	Review specific dietary regimens and their relationship to micronutrient status	Not specified	During the first 1000 days of life, micronutrient deficiencies can be prevented with nutritional counselling, food fortification, or supplementation, achieving a lifelong positive impact on child development.	Panzeri et al. [56]
	Review	Adult general population	Vegetarian	Does not specify. It does a review of important nutrients but does not consider supplementation.	Vegetarian diets are beneficial for health if well planned. Supplementation can be a useful strategy to ensure adequate intake of certain nutrients.	García-Maldonado et al. [38]
	Cross-sectional observational	NHANES 2007-2014 (n = 2823) infants and toddlers 0-23.9 months of age. NHANES 2011-2014 (n = 99) non-Hispanic Asian infants and toddlers	Not specified	They reported supplements of vitamin D, multivitamins (vitamin A, C and D, group B), minerals (Calcium, magnesium, iron, iodine and zinc), choline, folate	The use of dietary supplements is most common in children aged 12 to 23.9 months. Continued monitoring is needed to assess their relationship with health status and nutritional biomarkers.	Gahche et al. [29]
	Review	pregnant women and children	Not specified	Not specified	Iodine, selenium, iron, zinc, calcium and magnesium are essential for child growth. Supplementation, along with good dietary habits, is an important strategy to ensure proper development.	Farias et al. [62]
	Descriptive of a cohort	Polish pregnant women (n = 1252)	Not specified. Plant-based diets are excluded. Questionnaires are administered during the 1st and/or 2nd trimester of pregnancy.	Not specified. Questionnaires are administered during the 1st and/or 2nd trimester of pregnancy.	The diet of pregnant women lacks a balance of minerals and vitamins essential for fetal development and infant health. Supplementation may be necessary to prevent nutritional deficiencies.	Jankowska et al. [61]
	Review	Pregnant women	Not specified	Not specified	The maternal diet should cover the nutritional needs of the fetus and, after birth, meet those of the newborn, ensuring maternal and infant health. Supplementation and an adequate diet are essential.	García et al. [21]
	Observational	Questionnaires (n = 475)	Plant-based diets (vegetarian and vegan)	Asking about supplementation	The supplementation behaviour of healthcare professionals following a vegetarian or vegan diet may be of particular interest, as it can be assumed that there may be correlations with the quality of their own advice in the context of clinical patient care.	Jeitler et al. [28]
	Systematic review (n = 48)	Populations of interest were nonsupplement-consuming vegans in Europe (n = 12 096)	Comparison was any control diet, such as omnivores, vegetarians and semi-vegetarians.	Not specified	Low intake of vitamins B_2, niacin, B_{12}, D, iron, calcium and iodine cannot be overlooked. Further actions should be considered to prevent these potential deficiencies.	Bakaloudi et al. [65]
	Systematic review (n = 67)	The effect of supplementation on the composition of breast milk was studied.	Not specified	Suplementos minerales y vitaminicos	Maternal supplementation with vitamins, especially fat-soluble vitamins B_1, B_2 and C, influences the composition of breast milk. Vitamin supplements have a greater impact compared to minerals.	Keikha et al. [68]
	Systematic review (n = 9)	babies $<$ 4 months	Not specified	This Review focused on oral zinc supplementation in any form and dose. Trials with additional micro/macronutrients were considered.	Preventive zinc supplementation reduces mortality in premature neonates. Zinc deficiency and malnutrition remain a critical problem in low- and middle-income countries.	Irfan et al. [69]
	Observational	lactating women (n = 2055)	They compare the type of diet (vegetarian, vegan and omnivorous)	Participants were asked to report supplementation (iodine, vitamin B12 and DHA)	More than half of breastfeeding mothers use supplements, especially vegan ones, although they do not always include vitamin B_{12}. It is crucial to educate about the importance of micronutrient supplements to ensure optimal nutrition in mothers and babies.	Delgas et al. [70]

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Table 1 (*Continued*)

Nutrient/molecule	Study type	Population characteristics	Type on diet	Supplementation	Results/Conclusions	Study
	Review	pregnant women	Does not specify. Discusses the importance of a varied and balanced diet to achieve the intake of certain nutrients	Not specified. Discusses the benefits of supplementation/fortification as a tool to meet the requirements of certain nutrients.	A balanced diet usually covers nutritional requirements during pregnancy, in some cases supplementation of essential nutrients is necessary.	Gernand et al. [74]
Ω-3 Fatty Acid	Multicenter prospective cohort	Pregnant women of diverse races (non-Hispanic white, non-Hispanic black, Hispanic, Asian/Pacific Islander) (n = 2802)	Not specified. Participants reported dietary intake over the past three months.	Supplementation was reported from conception. 9% of participants reported taking DHA/EPA supplements during the 1st trimester of pregnancy.	DHA/EPA supplementation during pregnancy is associated with significant benefits, including higher estimated fetal weight and increased head circumference compared with nonsupplemented women. In addition, newborns of supplemented mothers weighed, on average, 97 g more at birth. However, no differences were observed in mean gestational age or prevalence	Vafai et al. [90]
	Interdisciplinary prospective longitudinal study cohort	Pregnant Norwegian women (n = 247) at different gestation periods and from different geographical regions of Norway	Not specified. Participants reported dietary intake using a food frequency questionnaire.	In the questionnaire on frequency of consumption, they ask about the use of supplements, with a result of 2.5% of the sample reporting the consumption of ω-3 supplements.	A positive association was found between EPA, DPA, DHA, seafood intake, and ω-3 supplementation. Linoleic and alpha-linolenic acids were not associated with ω-6, ω-3 PUFA, or the variables studied.	Araujo et al. [91]
	Review	Not specified	Plant-based diets (vegetarian and vegan)	Supplementation was reviewed	High-dose flaxseed or echium seed oil supplements will not increase the ω-3 index. In contrast, microalgae oil supplementation increased ω-3 index levels in all studies analyzed.	Lane et al. [102]
	Review	Pregnant women, no sample specified. Article review	Not specified. Lower levels are reported in plant-based diets compared to omnivorous diets.	Not specified. However, a comparison of the ω-3 index in pregnant and lactating women with and without ω-3 supplementation, as well as the safety of these	Some pregnant women and women of childbearing age have a low intake of EPA and DHA. Taking ω-3 supplements improves their bioavailability. According to EFSA, up to 5 g/day of EPA and DHA are safe, highlighting the importance of ensuring adequate levels of these essential fatty acids in this population.	von Schacky et al. [104]
	Systematic review (n = 38 references)	Healthy individuals (including children aged 9 to 10 years) and with diverse pathology (n = 4136)	Does not evaluate diet	Much heterogeneity in the supplemented DHA/EPA-rich plant oils, as well as in the dose.	Plant sources of n-ω3-PUFA, such as ALA-rich foods, are key for those seeking alternatives to fish and fish oil. Although seaweeds are noted for their antioxidant content and cardiometabolic benefits, there is no clear evidence that they provide relevant amounts of n3-PUFA at usual doses.	Santos et al. [99]
	RCT Review	Adult humans	Comparisons by diet type: vegetarian-vegan/omnivorous/carnivorous	They also analyzed the energy and nutrient content of some supplements consumed by individuals with vegetarian-vegan diets.	Vegetarians and vegans consume more linoleic acid than omnivores but have low or no intakes of DHA and EPA without algae supplementation. To achieve an optimal ω-6:ω-3 balance of 4:1, they may require 2.2 to 4.4 g/day of ALA and reduce LA intake if it exceeds the recommended intake.	Burns-Whitmore et al. [98]
	Narrative review RCT (n = 7 references)	Women between 18 and 45 years old, supplemented with ω-3 during pregnancy and lactation	There is no dietary review or differentiation on the impact of the type of diet. In the articles included in the Review, only 1 referred to dietary intervention	Heterogenicity in the supplementation analyzed, only two articles specified the source (fish oil/corn or soybean oil). Heterogeneous dosage	Ω-3 (EPA and DHA) supplementation during pregnancy and lactation improves the fatty acid composition of breast milk, according to increasing evidence.	Puca et al. [22]

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Table 1 (*Continued*)

Nutrient/molecule	Study type	Population characteristics	Type on diet	Supplementation	Results/Conclusions	Study
	Observational	Pregnant women (n = 82)	Not specified. A questionnaire on consumption frequency is carried out	They were classified into 3 groups based on DHA/fish oil supplementation or placebo.	Maternal supplementation influences babies' fatty acids, which are essential for brain development.	Sherry et al. [24]
	RCT	Pregnant Hispanic women aged 22-35 years, at least 22–25 weeks of gestational age. Women were excluded if they had a diet that included polyunsaturated fatty acids or supplements of these.	Not specified. A dietary intervention was carried out on the consumption of vegetable oil.	No supplements were included.	Chia oil is an affordable and accessible option to increase ALA intake in countries with low fish consumption. Its consumption improves the EPA content in erythrocytes of pregnant mothers and increases DHA in their milk. In addition, it helps to optimize the LA/ALA ratio during the perinatal period.	Valenzuela et al. [25]
	Observational prospective	Japanese pregnant women (n = 116)	Not specified. A questionnaire was conducted on the intake of 58 foods and beverages.	A questionnaire was conducted to determine the presence of supplementation during pregnancy and its frequency.	Serum DHA and EPA levels were significantly associated with fish and seafood intake during the second and third trimester in unsupplemented participants. Women who took DHA and/or EPA supplements at least 5 times per week had higher serum levels of these fatty acids.	Wakabayashi et al. [106]
	Review	Pregnant women (n = 82)	Not specified	Not specified	Supplementation during pregnancy reports benefits for maternal health and also for offspring	Jiang et al. [107]
	Systematic review de RCTs (n = 13)	healthy general population and those with specific disease factors. Excluded: pregnant or breast-feeding women, infants and children or subjects with existing serious diseases that may affect fatty acid metabolism	Plant-based diet (vegetarian and vegan)	The included studies used a control or placebo of an oil from a different source (vegetable or marine origin)	Consumption of EPA and DHA, mainly from oily fish, offers significant health benefits, but recommendations for vegetarians and vegans are lacking. High doses of ALA from flaxseed and echium oils do not increase the ω-3 index and may reduce it, highlighting the importance of a direct source of EPA and DHA. Supplements of EPA and DHA derived from microalgae are essential to maintain optimal ω-3 index.	Lane et al. [102]
	RCT	Pregnant women (n = 300) and mother-infant dyads (n = 262)	Not specified	They were divided into two supplement groups. Half of the participants in this study will receive 200 mg of DHA to take daily. The other half of the participants will receive 800 mg of DHA to take daily. The source of the supplemented DHA is not reported.	Maternal–infant DHA equilibrium is not a reliable biomarker of insufficient status when maternal DHA is $>6\%$. However, the failure to achieve equilibrium when maternal DHA is below 6% in this study is consistent with previous population studies and is a likely indicator of low maternal DHA status.	Gustafson et al. [105]
	Review	Unspecified. Article review	Vegetarian diet	Not specified	Intake and plasma levels of EPA and DHA are lower in lacto-ovo vegetarians and vegans than in omnivores due to the absence of fish in their diets. DHA levels decrease over time in vegetarian diets, reflecting a low conversion of ALA to DHA. To improve this conversion, ALA intake can be increased and LA intake reduced, achieving an optimal ω-3/ω-6 balance. However, the most efficient option is to incorporate plant-based EPA and DHA supplements.	García-Maldonado et al. [38]

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Table 1 (*Continued*)

Nutrient/molecule	Study type	Population characteristics	Type on diet	Supplementation	Results/Conclusions	Study
Choline	Original article	Pregnant women cohort, belonging to a phase III, randomized, longitudinal, double-blind, single-centre trial	Not specified. A food frequency questionnaire was conducted.	Does not inform about supplementation	Eggs, rich in nutrients such as choline, have positive associations with fetal neurodevelopment. It is recommended that their consumption be encouraged in pregnant women.	Christifano et al. [111]
	Review (n = 26 references)	Women aged 16 to 50 years (nonpregnant women, pregnant women or breastfeeding women)	Not specified. Assess choline intake using frequency of consumption questionnaires	Includes vitamin supplements combined with dietary intake	The average choline intake in women worldwide is lower than the IOM and EFSA recommendations. Furthermore, intake levels are not higher in pregnant or lactating women compared to nonpregnant women.	Derbyshire et al. [118]
	Systematic review (n = 9 ECAs)	pregnant women	Not specified	Heterogenicity of supplements (choline chloride, choline bitartate and phosphatidylcholine) and dosage, with variation between 450 mg and 2,800 mg per day	Choline supplementation during pregnancy improves cognitive abilities in offspring. Its effectiveness depends on the form of choline used (chloride or bitartrate), the dose and the duration of supplementation.	Heras-Sola et al. [109]
	Review	pregnant women	Not specified	Reviews the evidence for choline supplementation of different molecules: choline bitartate, phosphatidylcholine, choline chloride, L-alpha glycerylphosphorylcholine and cytidine 5′-phosphocholine, as well as supplementation guidelines	Choline supplementation helps reduce the risk of neural tube defects, improves cognitive development in offspring, and benefits maternal health.	Jaiswal et al. [120]
	Observational	breastfeeding women (n = 74)	Groups are made according to their reported dietary intake as vegans (n = 26), vegetarians (n = 22) or omnivores (n = 26). A questionnaire on consumption frequency is collected.	Not specified	Choline concentrations in breast milk did not vary by maternal diet, although they were higher in the vegan group. A plant-based diet does not pose a risk for low concentrations of water-soluble choline in breast milk.	Perrin et al. [115]
	Observational	Pregnant women (n = 94)	Not specified. A frequency of consumption questionnaire is carried out to determine choline intake.	Placebo trial. Women were randomly assigned to receive a prenatal micronutrient supplement with (800 μg) or without (0 μg) folic acid. The supplement did not contain choline.	The average intake of choline during pregnancy was 401 mg/day, with no significant changes between the start and end of pregnancy. However, few women achieve the recommended daily intake, highlighting the need to improve consumption.	Probst et al. [119]
	Prospective	Pregnant women (n = 315)	Not specified. A questionnaire on consumption frequency is carried out.	Not specified. Questionnaire on prenatal and pregnancy supplementation is conducted	Most women used vitamin B supplements before and during pregnancy. Dietary intakes of choline were below the recommended level, highlighting the importance of prenatal supplementation as a key source of folate, vitamin B_6, and B_{12}. Given the essential role of choline in a healthy pregnancy, research into the benefits and risks of including it in prenatal supplements is warranted.	Masih et al. [110]

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Table 1 (*Continued*)

Nutrient/molecule	Study type	Population characteristics	Type on diet	Supplementation	Results/Conclusions	Study
	Review	Pregnant women (n = 133)	Not specified. The results of the “National Nutrition Survey in the adult, elderly and pregnant population” (ENALIA-2) in Spain are analyzed	Not specified	Need to improve the nutritional intake and nutritional status of pregnant women. There is an urgent need to implement strategies such as improving diet, using fortified foods and personalizing nutritional supplements.	Requejo et al. [18]
Creatine	Systematic review (n = 9)	Comparison between vegetarians and omnivores	Comparison between vegetarians and omnivores	Intervention with creatine monohydrate supplementation	Creatine supplementation is especially beneficial for vegans, due to their lower creatine stores, resulting in greater gains with supplementation. It also improves performance in vegetarians and omnivores.	Kaviani et al. [121]
	Descriptive	Women were eligible to participate if they were ≥18 years old, had had a singleton pregnancy (n = 25 women and n = 20 couples)	Not specified. The results of the “National Nutrition Survey in the adult, elderly and pregnant population” (ENALIA-2) in Spain are analyzed	They asked about creatine monohydrate supplements during pregnancy	Nutritional supplementation is common and accepted among pregnant women, who are usually informed about recommended supplements. They would consider new supplements if they are recommended by health professionals, prioritizing safety, benefits, and efficacy. Specific education is essential to promote compliance with new supplements, such as creatine monohydrate.	de Guingand et al. [124]
	Observational	murine, breed: albino Sprague-Dawley	Not specified	Two intervention groups are performed: creatine supplementation and no supplementation.	Creatine supplementation during pregnancy may accelerate neuronal maturation, improving the extension and complexity of dendritic trees in offspring. Furthermore, it may modulate the expression and kinetics of ion channels, with effects that persist into adulthood.	Sartini et al. [125]
	Observational	Merino sheep, Border-Leicester breed	Not specified	Two intervention groups are performed: creatine supplementation and no supplementation.	Creatine supplementation to the fetus improves cellular metabolic stability and reduces the efflux of reactive oxygen species in the fetal brain after an acute asphyxial event.	Tran et al. [127]
	Review	women	Not specified	Not specified. Review of the evidence	Creatine supplementation offers potential benefits for women, improving muscle health, bone density, metabolism and mood.	Smith-Ryan et al. [128]

Table 2
Major sources of vitamins (B_{12}, A, and D) and minerals (zinc, iodine)

Vitamin B_{12}	μg/100 g
Raw beef tenderloin	13.00
Raw pork liver	25.00
Raw lamb liver	75.00
Raw chicken liver	31.00
Raw veal liver	75.00
Raw veal tongue	16.00
Raw lamb sweetbreads	6.00
Raw kidneys	31.00
Raw pork liver foie-gras (30% fat)	12.00
Raw pork liver foie-gras (42% fat)	12.00
Raw egg yolk	6.90
Vitamin A (Eq retinol)	μg/100 g
Raw pork liver	17 595.00
Raw lamb liver	20 000.00
Raw chicken liver	11 500.00
Raw veal liver	13 524.00
Raw pork liver foie-gras (30% fat)	8300.00
Raw pork liver foie-gras (42% fat)	8300.00
Raw eel	1000.00
Raw elver	1000.00
Not salt added butter	750.00
Vitamin D	μg/100 g
Raw elver	110.00
Raw tuna	25.00
Raw herring	22.50
Raw congrio	22.00
Raw bonito	20.00
Raw ponfret	16.00
Raw jack mackerel	16.00
Zinc	mg/100 g
Raw oysters	52.00
Chocolate-coated puffed rice	18.70
Wheat bran	16.20
Seeds, cardamom	7.47
Iodine	mg/100 g
Dried kombu algae	44 0670.00
Dried wakame algae	16 830.00
Iodized table salt	6000.00
Dried nori algae	1470.00
Raw mullet	330.00
Whole cow milk	0.38
Selenium	μg/100 g
Animal products:	
Smoked cod	147.80
Veal kidney	93.00
Raw tuna	82.00
Cuttlefish	65.00
Oyster	63.70
Mussel	56.00
Scallop	51.00
Whole cow milk	1.40
Vegetable products:	
Wheat bran	77.60
Sunflower seed	62.20
Sesame seed	49

Values obtained from Food Composition Tables: Moreiras O et al., 2024 and BEDCA, 2024.

supplementation throughout development into adolescence. Large-scale studies in different geographic areas are needed to better understand the true role of vitamin D in maternal health and fetal “imprinting” [48].

Vitamin B_{12}

This water-soluble vitamin plays a crucial role in DNA synthesis and methylation, folate metabolism, and erythropoiesis, and is essential for proper neurological functioning. Vitamin B_{12} status during the first year of life is directly associated with neurocognitive development, including social, visuospatial, and motor skills [49].

Vitamin B_{12} deficiency is a significant global public health problem, with higher prevalence in the elderly, pregnant women, and young children. This deficiency can be caused by restrictive diets (e.g., vegan diets), malabsorption issues, or the use of certain medications. Clinically, vitamin B_{12} deficiency is associated with megaloblastic anemia and neurological symptoms, though less typical symptoms can also occur [50].

In pregnant women, vitamin B_{12} deficiency may result in preeclampsia, spontaneous abortion, intrauterine growth restriction, preterm birth, low birth weight, and neural tube defects (defects in the brain or spinal cord) in the baby. Additionally, studies show that vitamin B_{12} levels in breast milk are strongly influenced by maternal blood levels [49].

Infants born to mothers with a B_{12} deficiency, especially those following vegan/vegetarian diets, are at high risk of developing megaloblastic anemia and neurological abnormalities. In rare cases, genetic defects in absorption or metabolism may also contribute to Vitamin B_{12} is found exclusively in animal-derived foods and microorganisms, including yeast. The richest source of B_{12} is liver, though it is also present in eggs, milk, meat, fish, and some algae (see Table 2). Fortified or enriched foods can also provide this vitamin [37]. Studies in breastfeeding mothers on vegan diets have shown altered breast milk composition, with lower total fat and lower concentrations of vitamins D and B_{12} [51].

Estimated recommended intakes of vitamin B_{12} vary by age, ranging from 0.3 to 1.9 μg/day for children aged 0–13 years, and between 2.1 and 4 μg/day during adolescence [52–54]. No upper intake limit has been established for this vitamin [42].

During pregnancy and lactation, additional cobalamin intake is recommended, reflecting its accumulation in fetal tissues and transfer to breast milk. Intakes of 4.5–5 μg/day are proposed, with an additional 0.5 μg/day over the amount recommended for non-pregnant women [54]. Women at high risk of deficiency, particularly those following vegan/vegetarian diets, should take supplements during pregnancy and lactation [55]. Vitamin B_{12} supplementation during pregnancy may provide long-term health benefits for both the mother and child. For infants, a dose of 0.4 μg/day is recommended during the first six months, increasing to 0.5 μg/day up to three years [56]. The amount of B_{12} in supplements can vary widely, and a review by Finkelstein et al. (202494) concluded that while B_{12} supplementation during pregnancy improves maternal B_{12} status, its long-term effects on maternal and infant health outcomes remain unclear [49,57].

Minerals

Zinc

Zinc (Zn) is an essential micronutrient for immune function, particularly in early life when the immune system is still maturing [58]. It plays a role in numerous cellular processes, and its requirements increase during pregnancy and lactation [59]. Zinc deficiency can increase susceptibility to infections such as diarrhea, pneumonia, and malaria, and it has also been shown to induce epigenetic effects in offspring [60].

Approximately 18% of pregnant women are zinc deficient, which can negatively affect fetal health, leading to preterm births, growth retardation, and impaired neurodevelopment. Zinc deficiency has also been linked to alterations in the regulation of T regulatory cytokines, increasing the risk of infections and impairing neonatal health and development [61,62].

Table 3
Reference intakes and adequate intakes for omega-3 fatty acids, vitamins (B12, A, and D), minerals (iodine and zinc), and choline in infants, pregnant, and lactating women

	Adequate intakes (AI)							Population reference intakes (PRIs)	
	Omega-3 fatty acids		Vitamins (µg/day)		Minerals (µg/day)		Other (mg/day)	Minerals (mg/day)	Vitamins (µg/day)
	ALA (%RE*)	EPA+DHA (mg/day)	Vitamin B_{12}	Vitamin D	Iodine	Selenium	Choline	Zi†nc†	Vitamin A (RE§)
Infants (Until 11 months)	0.5	100 only DHA	1.5	10	70	15	160	2.9	250
Toddlers (1–3 years)	0.5	250	1.5	15	90	15	140	4.3	250
General population both genders	0.5	250	4	15	150	70	400	6.2–10.2†	490
Pregnant (>18 years)	0.5	250 + 100–200 only DHA	4.5	15	200	70	480	7.5–12.7† +1.6	700
Lactating (>18 years)	0.5	250 + 100–200 only DHA	5	15	200	85	520	7.5–12.7† + 2.9	1300

*Daily energy requirement.
§Retinol equivalents.
†Zinc PRIs are provided for four levels of phytate intake (LPI): 300, 600, 900, and 1200 mg/day.
EFSA Dietary Reference Values (EFSA 2017).

Zinc's main dietary sources include animal products such as meat, shellfish, eggs, and dairy. In table 2 can see foods of animal origin with a high content of this mineral. Plant-based diets can also provide zinc, particularly through seeds, but its bioavailability in plant-based diets may be compromised by the presence of antinutrients such as phytates [39,63]. This has been observed in studies showing reduced zinc intake in individuals following plant-based diets [64,65]. Therefore, dietary intake needs to be adjusted to ensure adequate levels of this mineral, as shown in Table 3 [66].

Zinc deficiency during pregnancy is associated with complications in childbirth. During lactation, zinc concentrations in breast milk decrease after the first months, which can contribute to deficiencies in infants, especially if complementary feeding is not properly adapted [62]. Ackland et al. (2016) found that zinc levels in human milk were not correlated with maternal plasma zinc levels, suggesting that maternal zinc levels may not influence zinc transfer to breast milk [60]. However, other studies confirm that zinc concentrations in breast milk are partially influenced by maternal supplementation during preconception and pregnancy [59,67]. This supports the idea that zinc supplementation may be justified from preconception through lactation [68,69].

Iodine

Iodine (I) is an essential micronutrient for the production and proper function of thyroid hormones, as well as for fetal neurological development during pregnancy, and for infants and young children. Adequate maternal iodine supply is crucial because it directly affects the iodine concentration in breast milk [70].

Iodine deficiency can manifest as a spectrum of disorders depending on severity, including reduced fertility, increased risk of stillbirth, spontaneous abortion, perinatal and infant mortality, fetal growth restriction, and impaired brain development, resulting in intellectual disabilities, speech and hearing difficulties, stunted growth, and, in severe cases, cretinism [71].

Pregnant and lactating women are particularly vulnerable to iodine deficiency due to increased needs that rise by more than 50% during pregnancy [72]. Severe maternal iodine deficiency has been associated with cretinism and impaired neurological development in children, as well as with obstetric complications [23].

Adequate iodine intake is critical during pregnancy and lactation, as well as in subsequent stages of growth. Urinary iodine levels are the most used indicator to monitor iodine intake, as over 90% of ingested iodine is excreted through urine [73].

Iodine levels in breast milk largely determine its bioavailability, affecting exclusively breastfed infants, whose iodine needs are high due to thyroid hormone turnover rates [74,75].

Dietary iodine sources include fish, algae, and dairy products (can see in Table 2). Iodized salt is an effective strategy to prevent iodine deficiency, but studies in Spain show that most pregnant and lactating women are iodine deficient, indicating that iodized salt is used inconsistently and may not provide sufficient iodine for sensitive populations [23,76]. Recently, the consumption of iodine-rich seaweed has increased due to the influence of Eastern cuisine in Western regions. However, seaweed consumption is not recommended for pregnant women, lactating mothers, and children due to the high iodine content and potential exposure to heavy metals [77].

The dietary limitations of plant-based diets may restrict iodine sources, as iodine is predominantly found in animal products. Therefore, fortification or supplementation may be necessary to ensure adequate iodine intake, particularly during pregnancy and lactation [16].

Selenium

Selenium (Se) is an essential micronutrient involved in antioxidant status and, together with iodine, thyroid function. Deficiency or excess of selenium is associated with gonadal insufficiency and gamete dysfunction, which can lead to embryo implantation errors, embryonic developmental issues, and even infertility [65,78,79].

During pregnancy, selenium deficiency is linked to a higher risk of gestational hypertension, gestational diabetes, and other complications such as preterm birth, spontaneous abortion, and low birth weight. Selenium is crucial for proper neurological development in newborns and for preventing postpartum thyroiditis and depression in mothers [80]. Reference values for selenium intake are shown in Table 3, where it is evident that selenium requirements during lactation are higher than in the general population [66].

Dietary sources of selenium are mainly animal-based foods, including meats, fish, shellfish and dairy products, although there are also plant-based products with high concentrations of this nutrient (see Table 2). Brazil nuts are a notable plant-based source of selenium, but the selenium content in plant foods depends on environmental factors affecting soil concentration [81]. Selenium intake should be considered in individuals following plant-based diets, as they may be at higher risk of deficiency compared to omnivores [80].

Low maternal selenium intake could contribute to adverse neonatal outcomes. However, some studies have not found associations between continuous selenium intake or blood selenium concentrations and adverse neonatal outcomes [82].

Selenium supplementation during pregnancy may be beneficial, reducing the incidence of preeclampsia/hypertension induced by pregnancy, gestational diabetes, intrauterine growth restriction, premature rupture of membranes, postpartum depression, and postpartum thyroid dysfunction. It may also influence breast milk composition and affect fetal lipid and bilirubin levels. However, the results are mixed, and currently, there is insufficient information to safely recommend selenium supplementation during pregnancy and the postnatal period [78,83,84].

Omega-3 fatty acid

Omega-3 polyunsaturated fatty acids, such as eicosatetraenoic acid (EPA, C20:5) and docosahexaenoic acid (DHA, C22:6), are essential nutrients derived from alpha-linolenic acid (ALA, C18:3), and have been shown to provide numerous health benefits. These include supporting neurodevelopment, promoting fetal growth, and preventing noncommunicable diseases such as diabetes and cardiovascular conditions [85–90].

The primary sources of these fatty acids are marine products, such as certain fish and seafood [91–93]. However, there are plant-based sources of omega-3 fatty acids, including walnuts, chia seeds (*Salvia hispanica*), flaxseeds (*Linum usitatissimum*), and their oils [25,94,95]. The plant-based sources mainly provide ALA, but the conversion of ALA to EPA and DHA in the human body is limited and influenced by individual factors. Therefore, regular consumption of these plant-based sources is essential to meet dietary ALA intake recommendations (minimum 0.5% of energy intake). However, the amount of EPA and DHA obtained from these sources may not meet the adequate intake (AI) levels for EPA and DHA [66,85,96].

Currently, the available information on the nutritional composition of new plant-based products in nutritional databases is limited. As shown in Table 4, most of the data on omega-3 polyunsaturated fatty acids focus on marine products, while plant-based sources are less documented. Although the dietary sources and benefits are well-known, achieving adequate EPA and DHA intake solely through the diet remains challenging, especially since no dietary reference intake (DRI) for these fatty acids has been established.

To meet the acceptable intake (AI) for EPA and DHA (250 mg/day), it is recommended to consume 2–3 servings of fatty fish per week [97]. However, no specific serving recommendations are available for plant-based sources. This highlights the need for further research to determine dietary intake levels and establish recommended servings of plant-based foods that can meet the nutritional needs of those who do not consume fish for ethical or medical reasons.

It has been observed that individuals following plant-based diets tend to have lower plasma DHA levels compared to those following omnivorous diets that include fatty fish [16,17,21]. In this regard, plant-based supplements, such as those derived from algae, may be a viable option to improve the intake of these nutrients [22,98,99].

Although plant-based diets have been shown to be safe at any life stage, including pregnancy and lactation [100], plant sources of omega-3 fatty acids may not be sufficient to meet nutritional needs. Supplementation with marine algae-derived DHA, as an alternative plant-based source of DHA, was studied in a review by Li and colleagues (2021), which concluded that the bioactivity of DHA was not determined by its source [101]. Other studies have shown that supplementation with plant-based omega-3 fatty acids, especially those from microalgae, was effective in increasing serum DHA levels in people following plant-based diets [38,102].

Low EPA and DHA intake among pregnant women or women of childbearing age is common in various regions, leading to low levels of these fatty acids in erythrocytes (a reference biomarker) and increasing the risk of preterm birth by not meeting fetal needs [103,104]. Maternal-infant balance occurs when DHA in the umbilical cord blood is less than or equal to maternal DHA at delivery. This may be an indicator of optimal fetal neurodevelopment [105]. This has also been observed during lactation, where omega-3 fatty acid concentrations in breast milk are correlated with maternal intake [20]. Several studies have shown that omega-3 supplementation can raise serum levels and contribute to adequate intake in breastfed infants [24,25,106,107].

After reviewing the available evidence, omega-3 polyunsaturated fatty acid supplementation during pregnancy and lactation, combined with an adequate diet, appears to be a safe and effective option to ensure sufficient intake for both the mother and the fetus or infant, regardless of whether the supplements are derived from animal or plant sources.

Table 4
Omega-3 fatty acid content in selected animal and plant-based foods (g/100 g)

Food item	Total polyunsaturated fatty acids (PUFA n-3)	EPA content	DHA content	ALA content
Plant-based foods				
Rapeseed oil	27.15 ± 1.21[c]	-	-	9.12 ± 1.24[c]
Golden flaxseed oil	66.00[b]	-	-	55.47[b]
Chia oil	23.70 [d]	-	-	17.80 [d]
Shelled walnuts	43.7[a]	0.03[a]	0.04[a]	1.48[a]
Alimentos de origen animal				
Raw herring	2.40[a]	0.57[a]	0.54[a]	0.19[a]
Raw anchovy	2.18[a]	0.70[a]	1.19[a]	0.12[a]
Raw tuna	1.32[a]	0.10[a]	0.65[a]	0.007[a]
Raw bonito	2.60[b]	-	-	0.13[b]
Raw boquerón	2.18[a]	-	1.19[b]	0.12[b]
Raw mackerel	2.47[a]	0.27[a]	0.80[a]	0.037[a]
Raw crab and similar	2.42[b]	0.99[b]	0.46[b]	0.21[b]
Raw shrimp and similar	0.43[b]	0.21[b]	0.15[b]	0.01[b]
Raw jurel	0.40[a]	0.08[a]	0.21[a]	0.02[a]
Raw nécoras and similar	2.42[b]	0.15[b]	0.47[b]	0.21[b]
Raw salmon	3.10[a]	0.53[a]	0.96[a]	0.08[a]
Raw sardines	2.28[a]	0.26[c]	0.68[a]	0.026[a]
Raw trout	1.83[a]	0.31[a]	0.92[a]	0.13[a]

[a]Values obtained from the BEDCA database.
[b]Values obtained from Food Composition Tables: Moreiras O et al., 2022.
[c]Mean values and standard deviations (SD) obtained after consulting data from BEDCA and Moreiras et al., 2022.
[d]Values obtained from the USDA database. Cells with "-" indicate absence of data.

Other dietary components of interest

Choline

Choline is an essential nutrient for health, involved in various bodily functions such as neurotransmission and cognitive function, modulation of gut microbiota composition, hepatic metabolism, cell growth, and membrane transport. Although choline can be synthesized endogenously, this production is insufficient to meet nutritional requirements, meaning that it must be obtained through the diet. Despite its importance, there is a high prevalence of insufficient choline intake in the general population [108−110].

The primary dietary sources of choline are animal-based foods, including organ meats, fish, dairy products, and eggs. Eggs are a significant source of this nutrient, and their consumption should be considered during pregnancy, provided the woman follows an omnivorous diet [111]. Choline can also be found in notable amounts in plant-based foods such as cruciferous vegetables and beans; however, these sources alone are insufficient to meet the recommended intake levels. As a result, individuals following plant-based diets may be at a higher risk of choline deficiency [112−114].

However, evidence suggests that plant-based diets do not necessarily increase the risk of low choline levels. For example, Perri and colleagues (2020) found no significant differences in choline concentrations in the breast milk of omnivorous, vegetarian, and vegan mothers [115].

Recommended choline intakes for different life stages are listed in Table 3, as well as in the document published by the European Food Safety Authority (EFSA) [116]. These recommendations are similar to those from the Institute of Medicine [112].

Information about the choline content of various foods is limited, which complicates estimates of dietary intake. Data from Spanish food composition tables do not include choline content, making it difficult to estimate dietary intake of this nutrient [18].

Numerous studies have highlighted the importance of this nutrient during the reproductive cycle, as well as during pregnancy and lactation. A study by Masih and colleagues (2015) observed insufficient choline intake in pregnant women in Canada, a finding that was consistent with other studies conducted at the global level [110,117]. In Spain, a study concluded that choline intake during pregnancy was likely inadequate, which may be attributed to the lack of information in food composition databases [18].

Among breastfeeding women, the total amount of choline in breast milk is reported to depend on dietary intake and whether supplementation is used. For exclusively breastfed infants, breast milk is the only dietary source of choline [112,118].

The review by Derbyshire and colleagues (2021) reported highly heterogeneous results concerning average dietary choline intake across different countries. These differences may be due to inadequate nutrient composition data, poor integration of choline in dietary surveys, limited awareness among healthcare professionals and the general population, and the lack of official supplementation recommendations [118]. Later, Probst and colleagues (2022) published data on the average choline intake among pregnant women in Australia, supporting the finding that dietary choline intake remains significantly deficient [119].

A recent study concluded that choline is a crucial nutrient not only for fetal development and growth but also for safeguarding maternal health. It is necessary to increase awareness campaigns to inform pregnant women about the importance of this nutrient, as well as to incorporate choline recommendations into official dietary guidelines, ensuring equitable access to choline supplements [120].

Therefore, supplementation is warranted to ensure adequate choline intake, given the difficulty of obtaining sufficient amounts exclusively from the diet, especially considering the limited information available on choline content in food composition tables.

Creatine

Creatine is a compound derived from muscle proteins that is present in omnivorous diets. However, creatine reserves are limited in individuals following plant-based diets, meaning that supplementation may be a strategy for maintaining adequate creatine levels in both the general population and athletes [121,122].

Creatine monohydrate is one of the most studied dietary supplements, with substantial evidence supporting its long-term safety across various populations (with maintained doses ranging from 0.3 to 0.8 g/kg/day) without reported adverse effects [123].

The benefits of creatine supplementation are not limited to athletic performance, where its ergogenic potential for physical performance and injury prevention is well-documented. It has also shown various applications for health across different stages of life and in different populations (from infancy to old age, regardless of clinical status), supporting rehabilitation and neuroprotection in spinal cord injuries, neurodegenerative diseases, or the management of chronic diseases such as ischemic heart disease and stroke, as well as in the prevention and treatment of diabetes [123,124].

Other research has also explored the effect of creatine supplementation on neuronal plasticity in the hippocampus in murine models [125]. Recently, creatine supplementation has been studied for its potential to prevent hypoxic-ischemic pathology and support neurological development in fetal sheep, demonstrating improvements in hypoxemia levels, cellular bioenergy, and astrogliosis within the corpus callosum, thereby acting as a protective factor against hypoxia [126,127].

In humans, a review by Muccini et al. examined the involvement of creatine in reproductive metabolism and bioenergy, as well as its role during pregnancy and in newborn health. This review highlighted creatine's importance in the metabolism of reproductive organs and the fetoplacental unit [126].

These findings were further supported by another review by Smith-Ryan and colleagues (2021), which addressed various important aspects across the different stages of a woman's life, including postpartum depression and mood regulation, as well as changes in estrogen levels that, as a side effect, lead to decreased bone density, skeletal muscle changes, and reduced muscle strength during menopause [128].

Although the available evidence on the use of creatine supplementation during pregnancy as a prophylactic measure for fetal neurological disease is limited, research suggests that controlled use of creatine supplements could be a useful and safe therapeutic tool for the mother-fetus unit. Supplementation may help maintain and preserve cellular creatine reserves, acting as a preventive factor against premature fetal neurological pathology, while also supporting the overall health of the mother and her offspring.

Conclusions

Plant-based diets are a healthy and nutritionally adequate dietary pattern, provided that careful planning ensures all nutritional requirements are met, especially during vulnerable life stages such as pregnancy, lactation, and early childhood. The inherent limitation of these dietary patterns is the exclusion of animal-based foods, which are the primary sources of certain key nutrients. This can lead to nutritional inadequacies during stages where the need for specific nutrients is higher.

The existing scientific evidence supports the safety and efficacy of supplementation with specific micronutrients, such as vitamin B_{12}, vitamin D, iodine, and zinc. However, results regarding vitamin A are mixed across the studies reviewed. Adequate supplementation with omega-3 fatty acids (EPA and DHA) can prevent various health complications. It is recommended to monitor plasma levels of EPA and DHA in women following plant-based diets during pregnancy and lactation to ensure sufficient intake of these nutrients and establish daily recommended intakes (DRI). Supplementation with plant-based omega-3 sources is a viable option to achieve the recommended intake (250 mg/day of EPA + DHA) as part of a healthy diet complemented by ALA-rich foods.

Achieving adequate choline intake through diet alone can be complex, so supplementation may be justified. Creatine supplementation could also act as a preventive factor for premature fetal neurological pathology and promote the overall health of both the mother and the child.

In this context, dietitian-nutritionists, as healthcare professionals with recognized competencies according to the Law on the Regulation of Health Professions in Spain (LOPS), are responsible for adapting dietary patterns to everyone's specific case, ensuring adequate nutrient intake and preventing potential deficiencies.

Educational strategies must be developed for women who choose a plant-based diet during pregnancy, lactation, and for their children, helping them follow a safe and healthy diet. Further research is required to determine the optimal dosage of each supplement and evaluate the long-term impact of supplementation on the health of mothers and their children.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

María Pilar Herrero Jiménez: Writing – review & editing, Writing – original draft, Methodology, Investigation, Data curation, Conceptualization. **Susana del Pozo de la Calle:** Writing – review & editing, Writing – original draft, Validation, Supervision. **Carmen Cuadrado Vives:** Writing – review & editing, Writing – original draft, Validation. **Daniel Escobar Sáez:** Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Data curation, Conceptualization.

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