



A Comprehensive Review on Formulation of Baby Foods: Nutraceutical potential of Fruits, Vegetables, Cereals and Probiotics in Baby Food Preparation

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Abstract

Purpose of Review The purpose of this review is to thoroughly explore and document the potential uses of fruits and vegetables as baby food. It aims to achieve several key objectives, including the identification of phytochemical compounds present in fruits and vegetables, the assessment of their biological properties, and the examination of their practical applications in the baby food. Ultimately, this review seeks to provide a comprehensive understanding of how fruits and vegetables can be used as baby food and enhance food quality in terms of nutritional value.

Recent Findings Nutritional challenges in babies due to dietary factors have become an escalating issue in recent times. The incorporation of solid foods into a baby's diet is of utmost importance for their overall growth and well-being. Inappropriate dietary practices leads to nutrient deficiencies, food allergies, and obesity. Cereal foods gained prominence as a popular choice for complementary baby feeding due to their convenience, nutrient content, and ease of digestion. Fruits and vegetables are rich in vitamins, minerals, dietary fiber, and antioxidants, thus boost their immune system, regulates bowel, prevent constipation and makes babies healthier.

Summary Fruits, vegetables and cereal products are essential for wellbeing of developing babies compared to dairy and cereal based food products. Furthermore, inclusion of fruit, vegetable, and cereal-based (rice) ingredients in baby food acts as prebiotics for enhancing probiotic growth. Additionally, exposing babies to variety of flavors and textures promote babies to eat these nutritious food products.

Keywords Baby food · Cereals · Fruits · Nutraceutical · Probiotic · Vegetables

Introduction

The nutritious and nutraceutical rich diet is essential for babies during their growth and development. Early-life nutritional imbalances can affect health of babies and leads to obesity, diabetes, hypertension, ischemic heart disease,

and developmental delays in adults [1]. Among these, malnutrition is a contributing factor in roughly 60% of all fatalities among children under the age of five in developing nations [2•]. In 6–23 months old age range of children, malnutrition is most prevalent. This stage of life is "critical window" for promoting the best possible growth, health, and behavioral development because growth occurs at its fastest during the first year of life [3••]. Therefore, it is crucial to introduce nutrient-rich foods after six months of exclusive breastfeeding to complement continued breastfeeding, and gradually transition to the family diet after reaching two years of age in order to prevent growth faltering [4••]. During the initial 4–6 months of life, whether a baby is breastfed or formula-fed, their nutritional needs can be entirely met by milk [5]. However, after this time-frame, introducing complementary foods becomes necessary to provide additional energy and nutrients to support

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the infant's growth. Recently, numerous studies have been conducted on infant diets, both in developing and industrialized nations [1]. Complementary feeding (CF) significantly influences both early and later life nutrition, playing a crucial role in the health status and proper growth of babies. It is recommended to initiate the transition from breast milk to solid foods around 6 months of age, as breast milk alone becomes insufficient to fully meet the nutritional needs of the infant at this stage [5]. During the complementary feeding period, special attention is required to ensure adequate nutrition for babies. Recommended practices include introducing complementary foods at approximately half a year old baby ensuring an adequate meal frequency and appropriately sized portions, diversifying the diet, ensuring appropriate food texture, and observing safety measures during preparation, storage, and hygiene. This transition to solid foods signifies a significant milestone in baby's dietary journey. The World Health Organization and UNICEF recommend exclusive breastfeeding (EBF) for the initial 6 months of an infant's life, followed by the gradual introduction of supplementary foods, while also continuing breastfeeding up to and beyond the age of 2 years [6]. Recently, there has been a substantial increase in the accessibility and diversity of a new category of commercial supplementary foods specially crafted for infants and toddlers. These foods are usually pureed or semiliquid, and they come packaged in squeezable plastic pouches equipped with a spout and screw cap [7]. The primary appeal of these pureed pouch products lies in the convenience they bring to families. With a straightforward twist of the lid, the contents can be directly dispensed into babies mouth, or the babies can independently draw out the contents from the spout, facilitating fast and hassle-free feeding, particularly when on the move. This contemporary approach to infant feeding has garnered substantial favor, to the extent that reusable pouches are now on the market, enabling the feeding of homemade pureed baby food to infants via a squeezable bag [7].

This review discusses detailed information regarding the diet induced problems in babies. Additionally the current review discusses the role of fruits, vegetables, and cereals in development of nutraceutical rich baby food products.

Status of Baby Foods

The infant nutritional products market is expected to grow from USD 88.31 billion in 2023 to USD 125.67 billion by 2028. This growth represents a compound annual growth rate (CAGR) of 7.31% during the forecast period spanning from 2023 to 2028 [8]. The primary driver of this growth is the Asia Pacific region, which is experiencing the most significant market expansion. This upswing can be attributed

to various factors, including an upsurge in the number of employed mothers, a rise in family earning, an increased focus on infant health products, and a surge in the demand for organic baby foods. Sufficient intake of proteins, essential fatty acids, carbohydrates, vitamins, minerals, is important for growth and development of babies. This nutritious diet is crucial in supporting regular growth, physical and cognitive development, and fostering good health from infancy through childhood, adolescence, and beyond [9].

The introduction of complementary foods during childhood, which involves offering foods and liquids other than milk, has long-term implications for an individual's physical, cognitive, and socio-emotional health. In several developed societies, mothers typically begin with feeding infants pureed foods using a spoon, followed by a gradual transition to coarser-textured purees, finger foods (foods that can be eaten with hands), and eventually incorporating family foods into their diet [10]. Extensive evidence supports the notion that childhood is a crucial period influencing later-life, with early nutrition playing a major role in health of babies [11]. In the past, baby foods were predominantly homemade, usually pureed or mashed. However, the concept of mass production of baby foods emerged in 1928. During the late nineteenth to mid-twentieth centuries, infant feeding guidelines underwent changes, resulting in the introduction of solids at earlier ages, around 4–6 weeks old in the 1950s [12]. This shift in advice, coupled with an increased birth rate after the Second World War, prompted manufacturers to produce commercial baby foods as part of the canned goods industry, particularly in the USA. Initially, the commercial production of infant foods aimed to provide a consistent supply of fruits and vegetables throughout the year. However, over time, the variety of products has expanded significantly. Today, there is a diverse range of commercially prepared baby food products available, categorized according to the infant's stage/age and the type of food offered, including cereal products, baby snacks, and desserts, among others [13].

Diet Induced Problems in Babies

Adequate nutrition plays a crucial role in the health and developmental well-being of children. Research suggests that undernutrition is a direct or indirect factor in at least 35% of deaths among children under the age of five. Moreover, undernutrition significantly contributes to disabilities, hindering the full developmental potential of surviving children. In developing countries, approximately 32%, equivalent to 186 million children under five, experience stunted growth, while about 10%, or 55 million, suffer from wasting [14]. Concerns related to diet-related issues in babies are significant for both parents and healthcare professionals. The

type and quality of food consumed by babies play a vital role in their growth and development. Studies have shown that inappropriate diet initiate several health problems, such as malnutrition, obesity, diabetes and gastrointestinal disorders.

Malnutrition is a common problem in babies that can be caused by an inappropriate diet. According to the World Health Organization, malnutrition is a condition that results from a lack of essential nutrients in the diet, including energy, protein, vitamins and minerals [15]. Kundu et al. [16] reported that malnutrition was prevalent in infants who were fed a low quantity diet such as one that was deficient in protein and vitamins. Malnutrition can lead to several health problems, including stunted growth, delayed cognitive development and increased susceptibility to infections [17]. Protein-energy malnutrition arises from inadequacies in protein, energy-rich foods, or both, in relation to the body's requirements. Research indicates a correlation between caries in the primary dentition and malnutrition in early childhood. Typically, deficiencies in dietary energy and protein tend to co-occur [18, 19].

Obesity is another diet- induced problem that is becoming increasingly common in babies. Obesity is a condition in which there is an excessive accumulation of body fat, leading to an increased risk of health problems such as diabetes, cardiovascular diseases and hypertension [20]. Mayhew et al. [21] reported that inappropriate feeding practice such as overfeeding or feeding high calorie foods can lead to early onset of obesity in babies. In this study it was found that babies who were fed high calorie formula or solids had a higher risk of becoming overweight or obese compared to those who were breastfed or fed low calorie foods.

Diabetes is a chronic condition that is caused by the body's inability to produce or use insulin effectively, leading to high levels of blood sugar. Diabetes can be diet induced especially in babies who are fed a high sugar diet. Clapin et al. [22] reported that a high sugar diet in infancy can lead to an increased risk of developing type-1 diabetes in childhood.

Additionally gastrointestinal disorders are a common problem in babies, and they can be diet induced. It has been reported that inappropriate feeding practices such as over feeding or feeding foods that are difficult to digest, can lead to gastrointestinal problems such as reflux, constipation and diarrhea. In this study it was found that babies who were fed a diet high in fiber, fat, or protein shows elevated risk of developing gastrointestinal problems compared to those who were fed a low-fiber, low fat, and low protein diet. It is essential for parents and healthcare professionals to ensure that babies are fed a balanced and appropriate diet that meets their nutritional needs [23].

In order to support a child's regular growth and proper development, it's crucial that their diet offers an adequate supply of energy while aligning with the prescribed

nutrient requirements. This entails integrating a diverse array of fruits and vegetables into their daily meals, with every meal including at least one portion of these food groups. The daily consumption of fruit purees for children of 1–3, years is 1 cup while as for adolescents two cups have been recommended. In the case of vegetables, the recommended intake varies from three-quarters of a cup for children aged 1–3 years to 3 cups for adolescents [24]. Insufficient consumption of fruits and vegetables has been associated with higher rates of various types of gastrointestinal, lung and genitourinary cancers [25]. Unhealthy food habits have contributed to approximately one-third of children and youth being overweight or obese. Information collected from 2009–2012 reveals that approximately one out of every three children aged 2–19 years was classified as either overweight or obese. Additionally, 8% of children aged 8–17 years received diagnoses of borderline hypertension, while 2% were found to have hypertension [26]. To address these issues, the USDA recommends incorporating seasonal and locally produced foods into meals while emphasizing the importance of a wide variety of vegetables and fruits to ensure the intake of a diverse range of nutrients. Crucial guidelines also encompass the restriction of added sugar and saturated fat to levels below 10% of daily caloric intake, and maintaining daily sodium intake at levels less than 2,000 mgs [26]. Another research indicates that a diet rich in fruits and vegetables during early childhood can result in a sustained high intake of these foods, offering numerous benefits for weight management and overall health later in life. Nevertheless, there is a growing trend where a rising percentage of young children are not meeting the recommended levels of fruit and vegetable consumption, posing a universal public health concern [27]. Additionally, children in the 2–5 age groups tend to incorporate a higher quantity of vegetables in their diet compared to adolescents [28].

Nutritional Requirements of Babies

Babies possess a restricted stomach capacity, and their energy needs per kilogram of body weight are approximately three times higher than those of adults [29]. Ensuring adequate nutrition during infancy and childhood is crucial because these life stages involve numerous physical, mental, and behavioral changes. These changes include rapid growth, weight gain, the development of cognitive and psychomotor skills, and a shift in food preferences. Consequently, infants and children need small yet sufficient quantities of food to supply the energy and nutrients necessary to meet their daily basic requirements [30].

Carbohydrate

Carbohydrate plays an important part in infant nutrition and development. Carbohydrate spare proteins to be completely utilized for muscle growth and tissue repair processes. Less than 6 months baby needs 110–120 kcal/kg/day and 1-year infant need 100 kcal/kg/day [29]. In the early stages of life, the minimum carbohydrate intake for infants, primarily from lactose, should constitute 40% of their total energy intake [31]. This proportion should gradually increase to 55% of their energy intake by the age of 2 years. Concerning complementary foods for infants and young children, there are specific guidelines to limit the total carbohydrate content. For vegetable juices and beverages derived from them, the total carbohydrate content should not surpass 10 g per 100 ml. For fruit juices, nectars, and drinks based on them, it should not exceed 15 g per 100 mL. In the case of dishes comprised solely of fruit, the threshold is established at 20 g per 100 g. When it comes to desserts and puddings, the upper limit is 25 g per 100 g. Moreover, for non-milk-based beverages, the total carbohydrate content should not surpass 5 g per 100 g. It's worth noting that there is a notable benefit to increasing dietary fiber intake [29].

Protein

A sufficient intake of dietary protein plays a vital role in maintaining cellular function, overall health, and promoting normal growth [29]. On the contrary, when there is a combination of protein deficiency and insufficient energy intake, it can result in protein-energy malnutrition, which is the most prevalent form of malnutrition globally [32]. The protein requirements for infants and young children rise as they grow older, with recommended daily allowances of 9.1 g for 6–8 months, 9.6 g for 9–11 months, and 10.9 g for 12–23 months [29]. Although breast milk serves as a significant source of daily protein for infants and young children, the introduction of complementary foods necessitates an increased protein intake from these foods. The suggested protein quantities for these foods are 1.9 g per day at 6–8 months (21%), 4.0 g per day at 9–11 months (42%), and 6.2 g per day at 12–23 months [33, 34]. Protein plays a vital role as a fundamental building block in the nutrient composition of complementary foods.

Fats and Lipids

Dietary fats have a significant role in fulfilling the nutritional requirements of infants and young children, serving as a source of energy, essential fatty acids, and fat-soluble vitamins (A, D, E, and K) [29]. In the initial six months of life, fat constitutes roughly 50% of the energy content in breast milk, acting as the primary

energy source for infants. As complementary foods are introduced, carbohydrates gradually take on the role of the main energy source, but fats continue to be vital for meeting the increasing energy requirements of the growing child [35]. Infants who consume limited breast milk should have complementary foods that contribute 34%, 38%, and 42% of their total energy needs in the form of dietary fats at ages six to eight, nine to eleven, and twelve to twenty-three months, respectively.

Minerals and Vitamins

Minerals and vitamins are vital for the growth and development of young children. Micronutrients, including zinc, iron and calcium, have a critical role in promoting ideal health, growth, and development in infants and young children [36, 37]. Calcium, phosphorus, and vitamin D are crucial for proper bone development, iodine is necessary for synthesizing thyroid hormones and brain myelination. Iron is essential for creating red blood cells and new tissues, and zinc significantly contributes to both growth and the regulation of the immune system [38]. Breast milk provides ample quantities of vitamins A, B, C, folate, iodine, and selenium for well-nourished mothers, resulting in limited to no need for these nutrients from complementary foods before 12 months [34, 39]. However, breast milk is relatively deficient in several other micronutrients, necessitating the inclusion of complementary foods to meet the growing child's nutritional requirements. Complementary foods are expected to provide a significant percentage of total daily requirements for micronutrients, ranging from 30 to 97%, depending on the specific nutrient and age group [34, 39].

Insufficient iron levels in infants can lead to irreversible brain damage, this leads to the recommended iron intake for the population being set at 11 mg per day during the 6–12 month period. This recommendation decreases to 7 mg per day starting from the second year [38, 40]. Similarly, the recommended zinc requirement is 2.9 mg/day for young infants, increasing to 4.3 mg/day in toddlers [38]. Sufficient calcium intake for the 6–12 month period is 280 mg per day, and this level rises to 450 mg per day during the second year. Food fortification enables them to attain the appropriate iodine intake level for their age, which is 90 µg per day [38]. The recommended phosphorus intake is 160 mg/day for infants aged 6–12 months, and it increases to 250 mg/day for toddlers [38, 40].

Vitamins play a crucial role in the growth and development of infants and children. Vitamin B comprises water-soluble nutrients that participate in various metabolic processes, facilitating the utilization of lipids, carbohydrates and proteins for energy production. These vitamins are essential for the development of all organs and systems, with a particular emphasis on the nervous

system. Since humans cannot synthesize B vitamins, they must introduce these nutrients into their diet [38]. Vitamin K plays a key role in activating clotting factors, and severe deficiency of it causes bleeding. Vitamin B2 is involved in oxidation–reduction reactions in metabolic pathways related to lipids, carbohydrates, and amino acids [41]. Vitamin B3 is a component of enzymatic cofactors that play a role in multiple oxidation–reduction metabolic reactions. It plays a key role in metabolizing carbohydrates, fats, and proteins, and it also contributes to the proper functioning of the nervous system, enhances circulation, and lowers blood cholesterol levels. A severe niacin deficiency can lead to pellagra, a condition characterized by dementia, dermatitis, and diarrhea [42]. Pyridoxine (Vit. B6) serves as a cofactor in the folate cycle and is crucial for the production of neurotransmitters like serotonin, dopamine, GABA, melatonin and norepinephrine. Vitamin C participates in enzymatic reactions, including the synthesis of carnitine, collagen, and norepinephrine. It also has a role in non-enzymatic processes, such as the neutralization of reactive oxygen species [43]. From the weaning stage, infants can obtain these vitamins through their diet. Furthermore, the detailed information regarding the deficiency signs and recommended doses of vitamins and minerals for infants and children are shown in Table 1.

Sources of Energy and Nutrients used in Baby Food

Food composition databases play a crucial role in estimating the energy, nutrient, and other dietary compound content of various foods. This data is essential for evaluating nutritional intakes and monitoring the effectiveness of dietary interventions and to decipher the role of the different dietary components in health and disease [44]. It is because of the importance of all the nutrients that the baby food should contain a balance from fruits, vegetables, cereals with added probiotics. The Important sources of Energy and nutrients are briefly discussed in detail as below;

Fruits

Baby foods incorporated with fruits serve as a vital source of energy, essential nutrients, fiber, vitamins, and minerals. Additionally, fruits provide good taste to the babies and hence these fruit based products can be liked by the babies [45]. Fruits play a pivotal role in preventing obesity and other chronic diseases because of the presence of various bio active components as shown in Fig. 1. Insufficient fruit intake has been highlighted as a contributing risk factor to global adult mortality. The formative years of childhood are critical for the development of eating behavior's and

Table 1 Deficiency signs, and required doses of vitamins and minerals for infants, children and adolescents [34, 40, 41]

Vitamin	Deficiency	Infants (RDA)	Children/adolescents (RDA)
Vitamin A	Night blindness	150–300 µg/Kg/day	150 µg/day
Vitamin D	Ricket	400 IU/day	400–600 IU/day
Vitamin E	Cholestasis, liver damage	2,8–3,5 mg/day	11 mg/day
Vitamin K	Bleeding	10 µg/Kg/day	200 µg/day
Vitamin C	Mucosal bleeding, scurvy	10–25 mg/Kg/day	80 mg/day
Thiamine	Acidosis with increased lactate levels, Beri-beri	0,35–0,5 mg/Kg/day	1,2 mg/day
Riboflavin	mouth cancer, Mucosal congestion, eczema, blood deficiency	0,15–0,2 mg/Kg/day	1,4 mg/day
Pyridoxine	Eczema, convulsions, blood deficiency, mental distress, brain disorder	0,15–0,2 mg/Kg/day	1 mg/Kg/day
Niacin	Pellagra	4–6.8 mg/Kg/day	17 mg/day
Vitamin B12	Megaloblastic anemia, neurological disorders	0,3 µg/Kg/day	1 µg/day
Biotin B8	Fatigue, decreased muscle strength, restlessness, hair loss, eczema, lack of hunger, paleness, inflammation of tongue, queasiness, muscular discomfort, High cholesterol levels	5–8 µg/Kg/day	20 µg/day
Folic acid	Hyperhomocysteinemia, megaloblastic anemia	56 µg/Kg/day	140 µg/day
Mineral	Deficiency	Infants (RDA)	Children/adolescents (RDA)
Iron	Anemia	50–100 µg/Kg/day	50–100 µg/Kg/day
Zinc	Growth retardation, classic skin eruption	100–250 µg/Kg/day	50 µg/Kg/day
Iodine	Impaired thyroid function	1 µg/Kg/day	1 µg/Kg/day
Selenium (Se)	Macrocytic anemia, hypopigmentation, Myasthenia	2–3 µg/Kg/day	2–3 µg/Kg/day

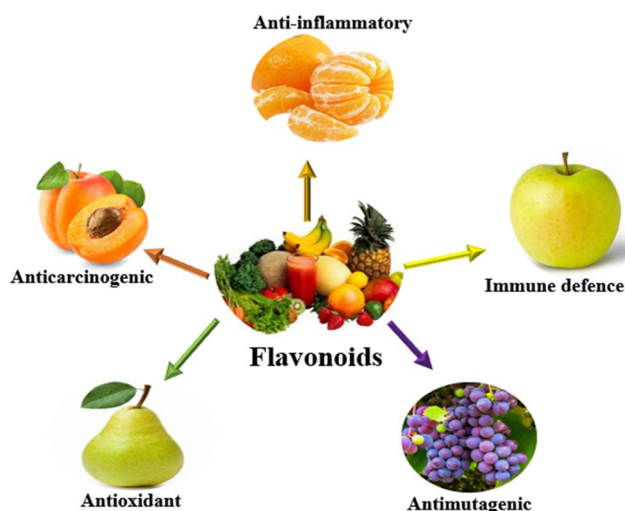


Fig. 1 Pictorial representation of benefits of flavonoids present in fruits

food preferences, offering a window to cultivate healthy dietary habits that persist into adulthood [46]. Ongoing research underscores the potential health advantages of shifting dietary patterns towards increased consumption of plant-based foods, promoting both individual well-being and environmental sustainability [47, 48]. Notably, elevated fruit consumption has been linked to reduced obesity risk and lower rates of chronic illnesses. Insufficient fruit intake is recognized as a contributing risk factor for adult mortality worldwide, accounting for approximately 2.6 million deaths each year [49]. While most research on the health impacts of fruit and vegetable intake focuses on adults, the formative childhood years present a crucial juncture for shaping eating behavior's and food preferences that endure into adulthood [46]. Fruits, categorized as a subgroup of vegetables containing seeds and pulpy tissue, are typically consumed raw for breakfast, as snacks, or as desserts. Vegetables, on the other hand, can be eaten raw or cooked as standalone dishes, mixed meals, or salads [46]. Owing to higher fiber, essential vitamins and minerals, fruits hold a prominent place in global food-based dietary guidelines (FBDGs), underlining their nutritional significance [50, 51]. The WHO recommends a daily minimum intake of 400 g (equivalent to five portions) of fruits and vegetables, excluding starchy tubers like potatoes, for maintaining general health [46, 52]. However, individual countries formulate their own FBDGs, and the Food and Agriculture Organization (FAO) compiles these guidelines into a comprehensive database [53].

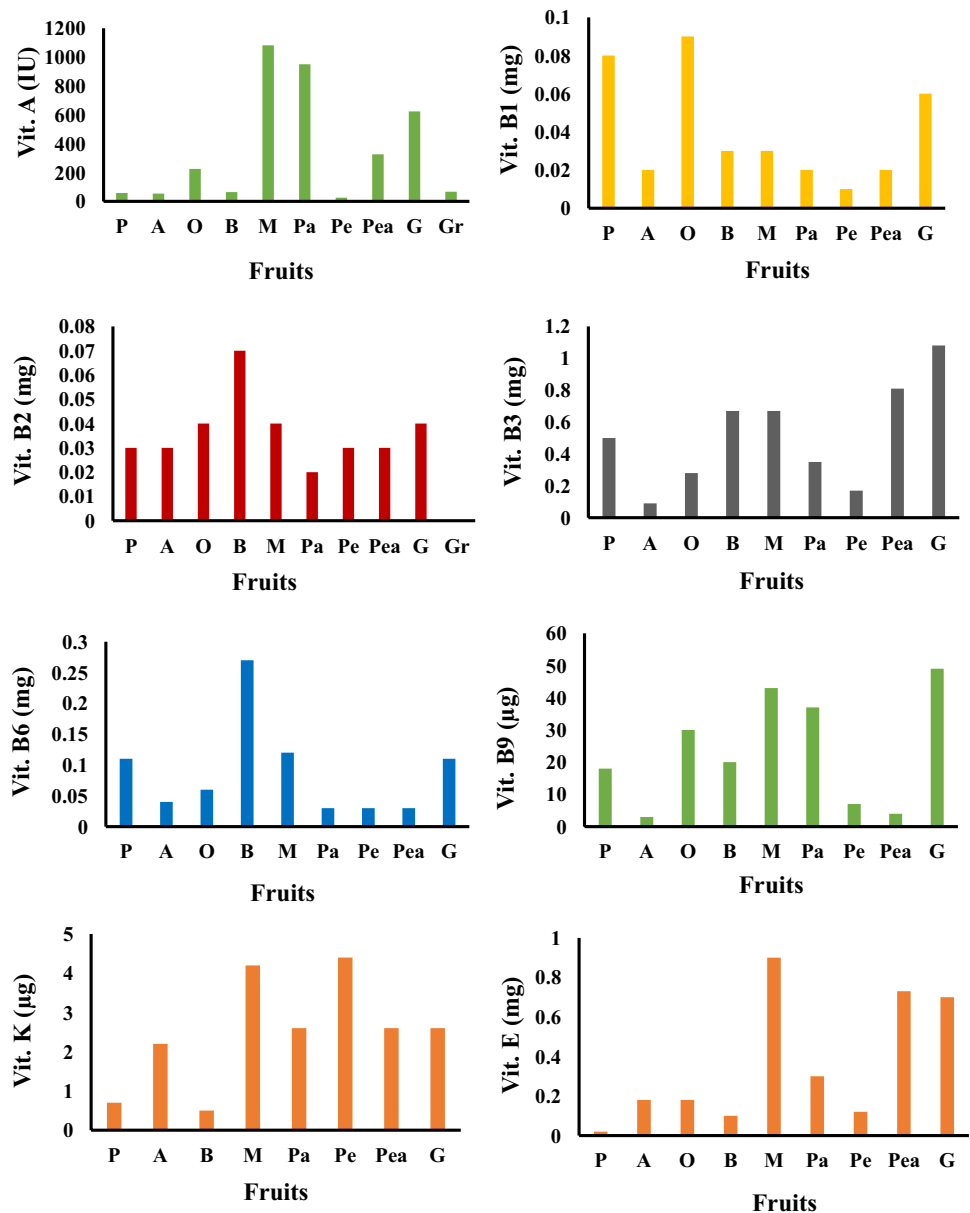
Various fruits have been utilized for the development of infant foods as fruits are rich sources of essential nutrients and bioactive components [54]. The fruits like apple, pear, apricot, plums etc. have been extensively

used in the development of baby foods. These fruits are rich sources of various sugars, vitamins, minerals, organic acids and fiber contents which are essential for the health of infants, babies and adolescents. Wani et al. [55] documented the presence of various minerals in apricots, with Zinc (Zn), Calcium (Ca), Copper (Cu), Iron (Fe), Magnesium (Mg), Sodium (Na), Manganese (Mn), Phosphorus (P), and Potassium (K) falling within the ranges of 0.5–6.74, 15.62–372.66, 0–0.82, 0.9–12.62, 23.35–64.29, 14.85–28.06, 0–0.98, 9–696, and 2,150–5,416.66 ppm, respectively. Fruits are also rich sources of vitamins, which can play a prominent role in growth and development of babies. The vitamin content of various Himalayan fruits are shown in the Fig. 2. The apricots are also rich sources of antioxidants which can help in reducing various ailments in the infants, babies and adolescents. The Margulam variety of the apricots contains 30.90 GAE/g total phenolics, 82.34% reducing power and 35.44% DPPH inhibition activity as stated by Wani et al. [55]. Campeanu et al. [57] reported highest nutrient content in Jonathan apple variety with vitamin C of 25.75–77 mg/100 g, phosphorus 0.15–0.235%, potassium 0.40–0.70%, calcium 2.5–7.8 mg/100 g and iron content of 0.20–0.28 mg/100 g. Akagic et al., [58] stated that pears are rich sources of carbohydrates and reported 59.2, 103.8, 79.4, 102.5, 116.9, 58.1, 89.7, 94.1, 86.9 and 75.0 g/kg total sugar from dolokrahan, takis, ahmetova, jeskovaca, hambarka, budaljaca, kacmorka, krakaca and sarajka president varieties of pear respectively. The pears are also rich sources of phenolic components, hydroxycinnamic acid (chlorogenic acid), glycosylated hydroquinone (arbutin), flavan-3-ols (epicatechin and catechin), and flavonols (quercetin 3-O-glucoside and quercetin 3-O-rutinoside) are major phenolic compounds in pears [54]. The plum cultivars like acanska Lepotica, Stanley, and Jojo [59] have shown a significant content of micro- and macro elements such as Ca, K, Mg, Zn, Fe, Cu, B, and Mn. These plum cultivars have been reported to be the rich sources of sugars, polyphenols, anthocyanins, and organic acids [60]. Trendafilova et al. [61] stated that plums are rich sources of sugars and organic acids and reported that wavit, janka, CF-667, ishtara and GXN-15 varieties of plums contain 1.60, 1.35, 1.19, 1.34 and 1.5 g/kg sucrose and 0.77, 0.75, 0.83, 0.73 and 0.89 g/kg malic acid respectively.

Vegetables

Vegetables are an important but under consumed part of a healthy diet. There is growing interest in promoting vegetable acceptance and consumption among infants to help establish life-long healthy eating patterns. Vegetables constitute a crucial yet underappreciated component of a wholesome diet.

Fig. 2 Vitamin content of fruits generally used for baby foods, P(Pine apple), A(Apple), O (Orange), B (Banana), M (Mango), Pa (Papaya), Pe (Pear), Pea (Peach), G (Guava), [3••,4••, 5–7, 9, 56]



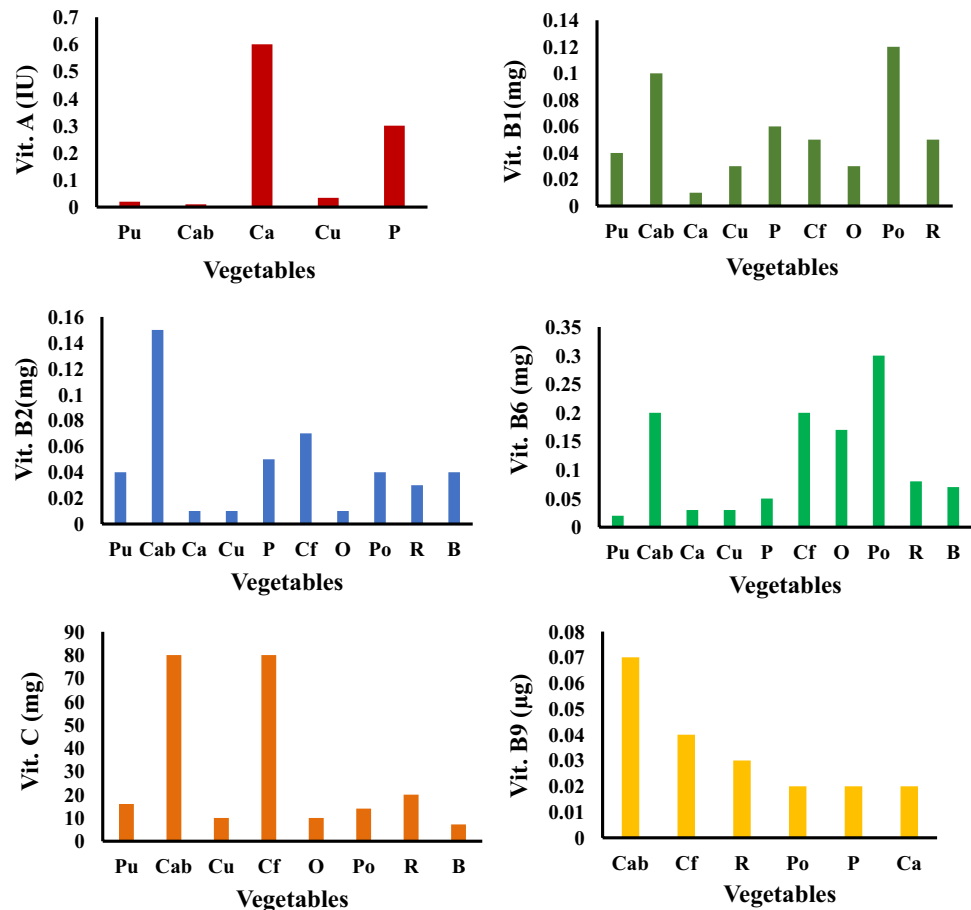
There is a growing push to enhance the acceptance and consumption of vegetables among infants, as this can establish lifelong patterns of healthy eating. The advantages of incorporating vegetables into one’s diet are numerous. The Dietary Guidelines for Americans (2015–2020) recommend a diverse array of vegetable subgroups for optimal health, encompassing dark green, red and orange, legumes, starchy, and other varieties. However, over 80% of Americans aged one and above fall short of the recommended vegetable intake [62]. While the benefits of vegetable consumption from childhood onward are well-established, children tend to have limited vegetable intake. One potential barrier to introducing vegetables early in life is their bitter taste. Infants generally exhibit openness

to new tastes, making it possible for them to readily accept vegetable flavors if introduced early. This initial experience significantly shapes their food preferences in later childhood. This is why complementary feeding guidelines encourage the introduction of fruits and vegetables as initial foods [63]. To encourage better dietary health, the World Health Organization advises a daily consumption of a minimum of five servings (equal to 400 g) of fruits and vegetables [52]. However, in Sub-Saharan Africa, daily intake falls below 200 g [64], leading to an estimated 27% of deaths being attributed to insufficient fruit and vegetable consumption [65]. On a global scale, only slightly more than half (52%) of young children achieve the minimum meal frequency, and less than a third (29%) reach

the minimum dietary diversity threshold [66]. This results in increased malnutrition risk due to low meal frequency and micronutrient deficiency risk due to inadequate dietary variety. Vegetables play a pivotal role in a balanced children's diet, furnishing essential nutrients for growth and health [67, 68]. More than 50% of the most economically disadvantaged children between the ages of 6 and 23 months have not been introduced to vegetables [69]. When these foods are offered, children tend to favour fruits over vegetables possibly due to fruits' appealing sweetness and greater accessibility [70, 71]. The consumption of dark green vegetables, particularly among infants, is significantly limited according to data obtained from surveys such as the Feeding Infants and Toddlers Survey conducted in the United States [72]. The specific health benefits associated with vegetable consumption stem from bioactive components such as vitamins (A, C, E, K, folic acid), minerals (Mg, Ca, Zn, K), dietary fiber, and crucially, phytochemicals like flavonoids and carotenoids that exert anticarcinogenic and anti-inflammatory effects [73]. The vitamin content of various Himalayan based vegetables are shown in the Fig. 3. Consuming diets abundant in green leafy vegetables and those containing vitamin C has been associated with a decreased risk of developing coronary heart disease [74].

Phytochemicals derived from vegetables play a role in suppressing DNA damage caused by oxidative stress, a significant contributor to the development and progression of neurodegenerative diseases. The consumption of specific vegetables, recognized for their robust antioxidant properties, bestows both cognitive and physical health benefits, which are particularly critical for children residing in regions of the global south. Therefore, adhering to a well-balanced diet abundant in vegetables is acknowledged for its potential to mitigate the risk of various non-communicable diseases. Nevertheless, to fully harness the health-promoting advantages, substantial quantities of plant-based foods should be ingested in diverse forms. Vegetables stand out due to their higher fiber content and lower levels of sugar, sodium, fat, cholesterol, and energy density [68, 75, 76]. Despite the well-documented advantages of incorporating a range of vegetables in one's diet, challenges persist in elevating vegetable intake in comparison to fruit consumption [77]. The factors contributing to low vegetable consumption among children, relative to fruits, encompass limited availability, elevated costs, and a universal aversion associated with sensory attributes like bitterness

Fig. 3 Vitamin content of Vegetables generally used for baby foods, Pu (Pumpkin), Cab (Cabbage), Ca (Carrot), Cu (Cucumber), P (Peas), O (Onion), Po (Potato), R (Radish), B (Beet root), Cf (Cauliflower), [3••, 25, 51]



and unfamiliar textures [78]. Consequently, the phase of complementary feeding offers a strategic window for introducing vegetables, aiming to instil a liking and acceptance of these foods in children before their eating habits solidify and become resistant to change [79]. In a nutshell, even though their acknowledged health benefits and environmental merits as constituents of a plant-based diet are well-established, the consumption of vegetables continues to be inadequate. Therefore, advocating for increased vegetable intake during the initial 1000 days from conception could serve as a mechanism to foster familiarity even prior to the introduction of solid foods.

Cereals

Cereals are rich sources of protein, carbohydrate, minerals and vitamins crucial for the growth and advancement of babies [80]. In numerous countries, infant cereals are commonly introduced as the initial foods during the complementary feeding phase [79, 81]. The decision to initiate complementary feeding with infant cereals can be elucidated for several reasons.

- a) Cereals offer a valuable source of energy, crucial at around six months of age when exclusive breastfeeding becomes insufficient to meet the infant's nutritional needs [82]. Furthermore, cereals supply substantial amounts of proteins and carbohydrates, while also containing minerals, vitamins, and bioactive compounds [83].
- b) Cereals are an excellent vehicle for iron fortification [84, 85]. Thus, introducing infant cereals aligns with the depletion of an infant's iron stores at the start of complementary feeding [86].
- c) Cereals contribute non-digestible carbohydrates that play a role in shaping a mature gut microbiota by promoting the *Bacteroides* population [87]. Changes in gut microbiota of babies have been noted during weaning when various cereals, such as wheat, sorghum, rice, or oats, are introduced [88], additionally, increased quantities of complex carbohydrates in infant cereals have been shown to amplify the fermentative potential of the gut microbiota in infants ranging from six to ten months in age [89].
- d) Cereals have a mild taste, semi-solid texture, and consistency that suit the transition from milk to accepting solid foods. Although cereals play a vital role in the nutrition of infants and young children, there is a lack of agreement among pediatric organizations when it comes to determining the suitable cereal consumption, the types of cereals, and the degree of cereal processing (refined cereals versus whole grain).

In Europe, the European Society for Pediatric Gastroenterology, Hepatology, and Nutrition “ESPGHAN” provides a recommendation to introduce complementary foods rich in iron, including cereals, starting from the age of four months while continuing breastfeeding [90, 91]. Likewise, the European Food Safety Authority “EFSA” suggests the introduction of iron-rich foods after the age of four to six months [92]. In contrast, New Zealand and the United States both advise against the introduction of cereals before six months of age [93]. Moreover, different countries convey their guidance regarding cereal consumption through various metrics, such as servings [94], tablespoons [95], or precise grams [93, 96], notably, both Europe and the US have organizations that refrain from specifying exact quantities [90, 91]. France and Spain advise introducing gluten-free cereals to infants between the ages of five to six months [97], ESPGHAN on the other hand, suggests that gluten may be introduced to babies between the ages of four and 12 months [91]. Infant rice cereals hold popularity as the initial complementary food in the Ireland and United Kingdom [98, 99]. In numerous cases throughout the Baltic and Nordic regions, oats are the preferred choice for the initial introduction of solid food for babies [100, 101]. However, Rice and maize are being the usual cereals used in the weaning foods [102]. In Spain, the primary choices for infant cereals are wheat and rice [93]. As per the findings of the Feeding Infants and Toddlers Study conducted in the United States, the most common sources of starch for infants and young children are iron-fortified infant cereals, predominantly made from rice or oats [84, 103]. Likewise, in Canada, the consumption of infant cereal predominantly revolves around choices that are based on rice [104], whereas mothers in African countries appear to begin with maize porridges [105, 106]. It is frequently uncertain to what extent the cereals used in infant cereal formulations should be processed, whether whole grain or refined. The Dietary Guidelines for Americans “2015–2020” promote the intake of nutrient-rich foods, with a specific focus on whole grains, for children between the ages of one to 18, aiming to increase dietary fiber, support healthy digestive function, and reduce the likelihood of chronic diseases. This recommendation suggests consuming 1.5 to four ounce-equivalents of whole grains in this age group [107].

Importance of Probiotics in Babies Health

As our society increasingly prioritizes health, there is a growing awareness and elevated concerns regarding diet, nutrition, and the safety of our food, all with the ultimate goal of improving our overall quality of life. The current

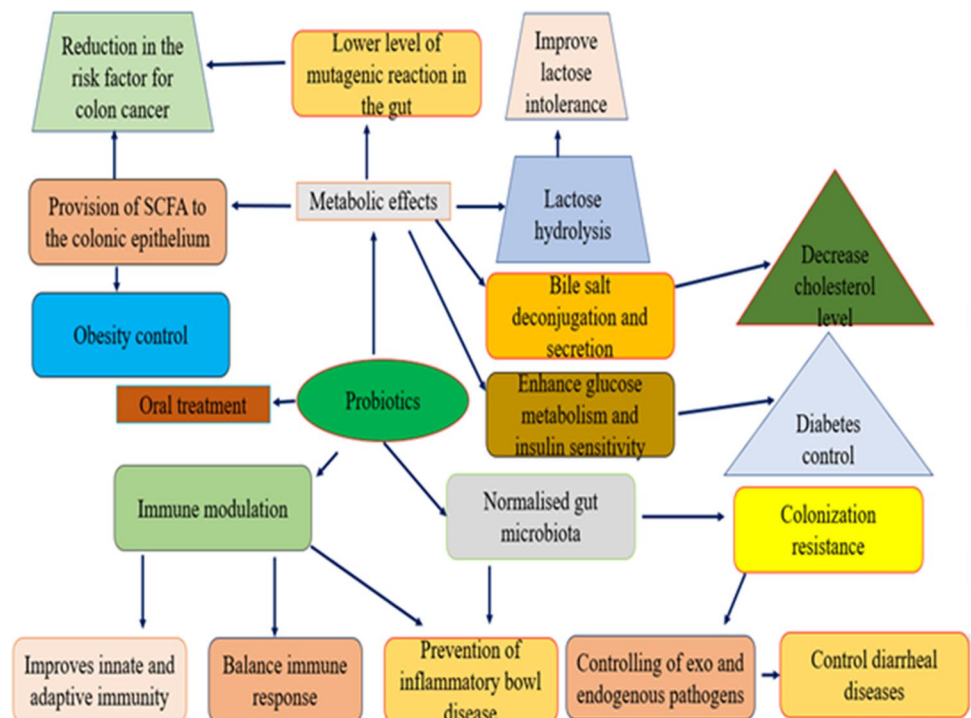
global pandemic involving severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) has underscored the significance of nutritional status as a risk factor for severe diseases, including malnutrition obesity [108]. Given this context, the role of healthy, nutritious, and functional foods has become crucial in strengthening the immune system to fight against illnesses [109].

Consumer preferences have led various stakeholders in the food industry to shift their focus toward producing foods with enhanced health benefits. Functional foods, which extend beyond basic nutrition to provide additional health advantages, are considered as the future of food. For a food product to be classified as functional, it must adhere to specific criteria, including compliance with a country's food safety regulations or international standards, confirmation of the positive health advantages when incorporated into a well-rounded diet, as well as ease of access. Examples of functional foods include dietary supplements, prebiotics, probiotics, vitamins, dietary fiber, antioxidants, and other phytochemicals [110]. Probiotics, when consumed in sufficient amounts, confer health benefits to the host. These effects, observed after consuming probiotics in various food forms, include maintaining intestinal balance [111], enhancing the immune system [112], reducing cancer risks [113], assisting in the digestion of lactose [114], and other positive interactions between host and microorganisms, such as preventing diabetes, cardiovascular diseases, and allergic reactions [115]. Foods and beverages enriched with probiotics,

considered as upcoming dietary options, have garnered significant consumer interest. This surge in popularity has propelled the global probiotics market to attain a value of 42.55 billion USD in 2017, with a projected increase to 94.48 billion USD by 2024. The Asia-Pacific region leads this growth, while Europe has seen a slower expansion of probiotic foods and beverages due to regulations concerning health claims [116].

Babies have a developing immune system that is susceptible to infections, and the use of probiotics in baby food has been shown to reduce the risk of infections such as diarrhea [117]. Probiotics have also been shown to improve the bioavailability of nutrients in baby food. The gut microbiota plays a crucial role in nutrient absorption and the use of probiotics in baby food has been shown to enhance nutrient absorption and promote overall health in infants [118]. The role of probiotics in prevention of diseases and enhancing immune system of babies is shown in the Fig. 4. Probiotics are being explored as a preventive measure to address potential health concerns in infants. However, the general use of probiotics has resulted in their inclusion in a wide range of products designed to support infant well-being. Within this landscape, the specificity, safety, and effectiveness of individual probiotic strains remain insufficiently defined. Among these strains, *Bifidobacterium breve* (M-16 V) is noteworthy as a commonly used probiotic in infant-related applications. It stands out as a well-established probiotic choice for infants. Research has indicated that

Fig. 4 Importance of probiotics in preventing from diseases






M-16 V shows promise in providing protection to infants against serious conditions like necrotising enterocolitis and allergic diseases [119]. Various other studies like randomized controlled trial conducted by Lin et al. [120] have provided compelling evidence that supplementing with *Bifidobacterium breve* can be instrumental in mitigating the likelihood of gastrointestinal problems in infants. *Lactobacillus rhamnosus* represents another vital probiotic strain employed for infants. This probiotic is acclaimed for its ability to modulate the immune system, which can contribute to lowering the chances of allergies and infections among infants. Introducing *Lactobacillus rhamnosus* through supplementation can lead to a reduction in the occurrence of atopic dermatitis in infants [121]. Another probiotic strain *Bifidobacterium infantis* finds common usage in infant formula. It plays an indispensable part in enhancing the digestive processes and overall gastrointestinal well-being of infants. Research conducted by Saturio et al. [122] demonstrated that incorporating *Bifidobacterium infantis* into the formula for infants positively influenced the composition of their gut microbiota. Table 2

Conclusion and future perspective

Fruit, vegetable, and probiotic based baby foods offer a nutritious and natural option for parents looking to provide their babies with a healthy start. The benefit of incorporating these foods into baby's diet include essential vitamins and minerals, low calorie content, and the addition of beneficial probiotics that aid in digestion and improve immunity. Furthermore, these types of baby foods are often free from harmful additives and preservatives, which can be found in many processed foods. However, parents should exercise caution when selecting baby food products and ensure that they contain natural ingredients. Overall, fruit, vegetable and probiotic based baby foods offer a convenient and healthy solution for parents who want to promote their baby's growth and development. There is great scope in the development of baby food and food products based on fruit, vegetable, cereal and probiotic constituents. Furthermore the limit of fruit, vegetable, cereal and probiotics in baby food formulations need to be investigated. Additionally, proper investigations are required to evaluate the presence of pesticide residues and various antinutritional factors in these baby food products.

Table 2 Importance of fruits, vegetables and probiotics in babies health

Category	Importance	References
 Fruit	Provide essential vitamins and minerals, rich in fiber for digestive health, introduce different flavors and textures	[123], [124], [125], [126], [127], [137], [138], [139], [140]
 Vegetable	Vegetables are rich source of vitamins, minerals, and antioxidants, encourages optimal growth and development in babies, facilitate the formation of nutritious dietary patterns, vegetables play a pivotal role in a balanced children's diet, furnishing essential nutrients for growth and health	[79], [80], [128], [129], [130], [131], [132], [133], [141], [142], [143]
 Probiotics	Probiotics assist in maintaining gastrointestinal well-being and bolstering the immune system, reduces the risk of gastrointestinal issues, aids in the digestion and absorption of nutrients	[134], [135], [136], [144], [145], [146]

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Data Availability No datasets were generated or analysed during the current study.

Declarations

Competing Interests The authors declare no competing interests.

Human and Animal Rights The article does not contain any studies with humans or animal subjects performed by any of the authors.

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- Of importance
- Of major importance

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