Nutritional needs of children & infants: Breastfeeding, supplementary & artificial feeding & weaning

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Abstract:
Infant and child nutrition plays a vital role in ensuring optimal growth, development, and long-term health outcomes. The first two years of life, often referred to as a critical developmental window, require adequate and balanced nutrition to support rapid physical and cognitive growth. This article examines the nutritional needs of children and infants with a focus on key feeding practices, including breastfeeding, supplementary feeding, artificial feeding, and weaning. Breastfeeding is highlighted as the most effective and recommended method of infant feeding due to its unique nutritional composition and immunological benefits. However, when breastfeeding is not feasible, artificial feeding using infant formula serves as an alternative, though it lacks certain protective factors. The introduction of supplementary or complementary feeding at around six months is essential to meet the increasing nutritional demands of infants, particularly for micronutrients such as iron and zinc. Weaning represents a crucial transition phase that requires careful planning to ensure appropriate food choices, hygiene, and feeding practices. Additionally, various socioeconomic, cultural, and educational factors influencing infant feeding practices are discussed.

Keywords:
Infant Nutrition, Breastfeeding, Complementary Feeding, Artificial Feeding, Weaning, Child Health, Nutritional Requirements, Infant Development, Feeding Practices, Early Childhood Nutrition.

1. Introduction:
The nutritional needs of infants and young children are fundamental for survival, growth, and overall development, forming the foundation of lifelong health and well-being (World Health Organization et al., 2023), and the first two years of life represent a critical developmental window often referred to as the "first 1000 days," during which appropriate nutrition plays a decisive role in shaping physical, cognitive, and metabolic outcomes (UNICEF et al., 2025). This period, extending from conception to a child's second birthday, is characterized by rapid growth and heightened vulnerability, making adequate nutrient intake essential for optimal brain development, immune function, and disease prevention (Hamner et al., 2022). As illustrated in Fig. 1, which presents a conceptual framework of infant nutrition, feeding practices follow a structured progression beginning with exclusive breastfeeding at birth, followed by the gradual introduction of complementary feeding, and eventually transitioning into a family diet by the end of two years, reflecting a continuum that aligns with global nutritional recommendations (Rawat et al., 2023). This stage-wise transition underscores the importance of adapting feeding practices to meet the evolving physiological and developmental needs of infants, ensuring that nutritional adequacy is maintained throughout early childhood (Vir et al., 2023). During infancy, the body undergoes rapid cellular growth and organ development, particularly in the brain, where essential nutrients such as proteins, fatty acids, vitamins, and minerals play a critical role in neurodevelopment and cognitive functioning (Sollena et al., 2026). Breastfeeding, especially exclusive breastfeeding for the first six months, provides optimal nutrition and immunological protection, reducing the risk of infections, improving survival rates, and contributing to better cognitive outcomes later in

life (World Health Organization et al., 2023). However, as infants grow, breast milk alone becomes insufficient to meet increasing nutritional demands, necessitating the timely introduction of complementary foods rich in essential micronutrients such as iron, zinc, and calcium to prevent deficiencies and support continued development (Likhar et al., 2022). The importance of appropriate feeding practices is further emphasized by evidence indicating that poor nutrition during this critical period is associated with adverse outcomes such as stunting, wasting, and increased susceptibility to infections, which collectively contribute to a significant proportion of child mortality worldwide (World Health Organization et al., 2023). In addition, early nutritional inadequacies may lead to long-term consequences, including impaired cognitive development, reduced academic performance, and an increased risk of chronic diseases such as obesity, diabetes, and cardiovascular disorders in adulthood (Black et al., 2021). The concept of nutritional programming further highlights how early-life nutrition can influence gene expression and metabolic pathways, thereby shaping health trajectories across the lifespan (Barker et al., 2018). Despite the recognized importance of optimal infant nutrition, global data indicate that a large proportion of infants do not receive adequate dietary diversity or feeding frequency, reflecting gaps in awareness, accessibility, and healthcare support systems (Victora et al., 2016). Socioeconomic factors, cultural beliefs, maternal education, and healthcare accessibility significantly influence feeding practices, often determining the quality and adequacy of infant diets (Bhutta et al., 2020). Therefore, ensuring proper nutrition during infancy requires a comprehensive approach that includes caregiver education, healthcare interventions, and policy support to promote optimal feeding practices. In conclusion, infant nutrition during the first 1000 days is a critical determinant of health, growth, and development, and the adoption of appropriate feeding strategies is essential to prevent malnutrition, enhance developmental outcomes, and ensure a healthy future for children (World Health Organization et al., 2023).

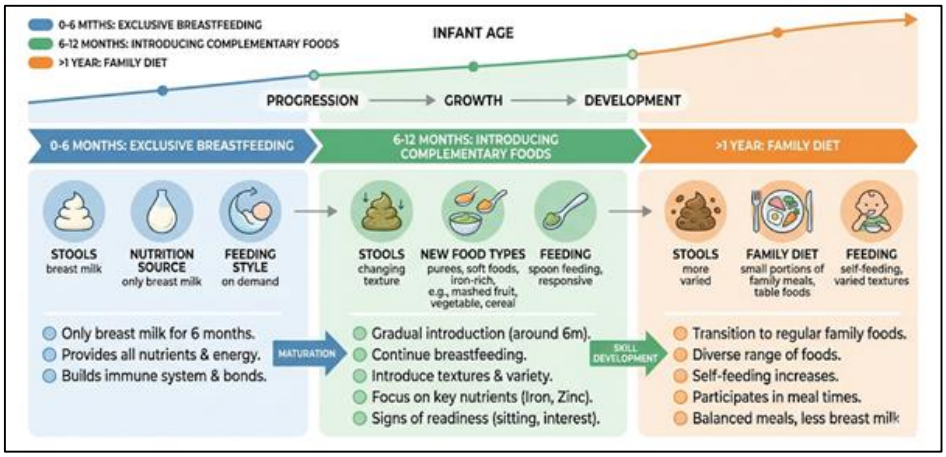


Figure. 1: Conceptual framework showing the progression of infant nutrition from exclusive breastfeeding to complementary feeding and family diet

2. Nutritional requirements of infants:

Infants have specific nutritional requirements that continuously evolve as they grow, reflecting rapid physiological, metabolic, and developmental changes that occur during early life (World Health Organization et al., 2023), and this dynamic progression is closely aligned with recommended feeding practices across different age groups to ensure optimal growth and development (UNICEF et al., 2022). Fig. 2 demonstrates the nutritional timeline from birth to 24 months, emphasizing exclusive breastfeeding during the first six months, followed by the gradual introduction of complementary foods alongside continued breastfeeding, thereby ensuring a balanced supply of nutrients during critical growth phases (Black et al., 2021). This timeline reflects internationally accepted guidelines that stress the importance of age-appropriate feeding to meet the increasing nutritional demands of infants while supporting immune function and cognitive development (Victora et al., 2016). During the initial months of life, breast milk provides sufficient nutrition. however, as infants grow, their energy and nutrient requirements increase, necessitating dietary diversification through complementary feeding (Bhutta et al., 2020). Macronutrients such as proteins, fats, and carbohydrates play a fundamental role in supporting infant growth, with proteins being essential for tissue building and cellular repair processes (Koletzko et al., 2019). Fats, particularly long-chain polyunsaturated fatty acids such as DHA, are crucial for brain maturation and visual development, highlighting their significance in early neurological outcomes (Innis et al., 2020). Carbohydrates, mainly in the form of lactose during infancy, act as the primary energy source, supporting metabolic activities and enhancing calcium absorption (Lönnerdal et al., 2017). Alongside macronutrients, micronutrients are equally critical in ensuring proper physiological functioning, as deficiencies during infancy can lead to long-term health complications (Dewey et al., 2021). Iron, for instance,

plays a vital role in hemoglobin formation and cognitive development, and its deficiency during infancy is associated with impaired learning abilities and behavioral issues (Pasricha et al., 2021).

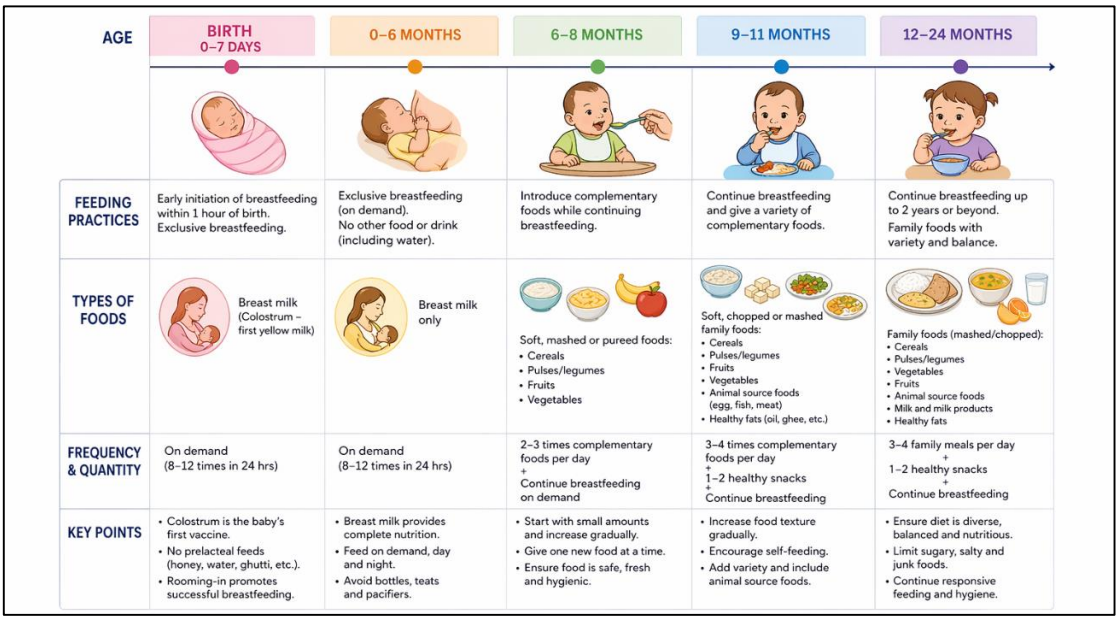


Figure. 2: Nutritional timeline illustrating recommended feeding practices from birth to 24 months including breastfeeding and complementary feeding stages

Similarly, calcium and vitamin D are essential for bone mineralization and skeletal growth, making them indispensable components of an infant's diet (Abrams et al., 2018). Zinc is another important micronutrient that contributes to immune function, cellular growth, and wound healing, thereby supporting overall health and resilience against infections (Hess et al., 2020). Vitamins such as vitamin A are essential for vision and immune response, while B-complex vitamins support energy metabolism and neurological development (Allen et al., 2019). The balance between macronutrients and micronutrients is crucial, as both deficiencies and excesses can disrupt normal growth patterns and increase the risk of developmental abnormalities (Prentice et al., 2018). Furthermore, nutritional needs during infancy are influenced by factors such as birth weight, growth rate, and health status, making individualized dietary approaches important in certain cases (Embleton et al., 2017). The introduction of complementary feeding at around six months is particularly significant, as breast milk alone becomes insufficient to meet the increasing demand for nutrients such as iron and zinc (Dewey et al., 2021). Table 1 demonstrates Recommended daily nutritional requirements of infants (0–12 months) including essential nutrients and their functions, Complementary foods should therefore be nutrient-dense, safe, and appropriate in texture to support both nutritional adequacy and developmental readiness (World Health Organization et al., 2023). Inadequate intake of essential nutrients during this period can lead to malnutrition, stunting, and compromised immune function, which may have long-term implications for health and productivity (Black et al., 2021). Conversely, appropriate nutrition supports optimal growth trajectories, enhances cognitive performance, and reduces the risk of chronic diseases later in life, highlighting the importance of evidence-based feeding practices (Bhutta et al., 2020).

Table. 1: Recommended daily nutritional requirements of infants (0–12 months) including essential nutrients and their functions

Nutrient	Requirement	Function
Protein	1.5–2 g/kg/day	Growth and repair
Fat	40–50% of energy	Brain development
Iron	11 mg/day	Prevent anaemia
Calcium	200–260 mg/day	Bone growth
Vitamin D	400 IU/day	Bone health

3. Breastfeeding:

Breastfeeding is widely considered the gold standard for infant nutrition due to its unparalleled ability to provide complete and balanced nourishment tailored specifically to the needs of infants (World Health Organization et al., 2023), and it plays a critical role in ensuring optimal growth, development, and survival during the early stages of life (UNICEF et al., 2022). As shown in Fig. 3, breast milk contains a unique combination of macronutrients, micronutrients, antibodies, enzymes, and bioactive compounds that are

specifically designed to meet the nutritional and immunological needs of infants, thereby making it the most suitable and natural source of nourishment (Ballard et al., 2017). This complex composition includes high-quality proteins that are easily digestible and essential for tissue growth and repair, ensuring that infants receive adequate support for their rapid physical development (Lönnerdal et al., 2017). In addition, breast milk is rich in essential fatty acids such as docosahexaenoic acid (DHA) and arachidonic acid (ARA), which are crucial for brain development, visual acuity, and overall neurological functioning during infancy (Innis et al., 2020). Lactose, the primary carbohydrate present in breast milk, serves as a key energy source and enhances calcium absorption, contributing to healthy bone development (Schaafsma et al., 2018). Furthermore, breast milk contains immunoglobulins, particularly immunoglobulin A (IgA), which play a vital role in protecting infants against infections by strengthening their immature immune systems (Victora et al., 2016). The presence of bioactive components such as hormones, growth factors, and enzymes further enhances the functional benefits of breast milk by supporting organ development, digestion, and metabolic regulation (Andreas et al., 2018). These components not only nourish the infant but also provide protection against a wide range of diseases, including respiratory infections, gastrointestinal disorders, and allergies, thereby reducing infant morbidity and mortality (Horta et al., 2016). Breastfeeding has also been associated with improved cognitive outcomes, as the nutrients and bioactive substances present in breast milk contribute to brain development and may enhance intelligence and learning abilities later in life (Rollins et al., 2016). In addition to its benefits for infants, breastfeeding offers significant advantages for mothers, including reduced risk of breast and ovarian cancers, improved postpartum recovery, and enhanced emotional bonding with the infant (Victora et al., 2016). The exclusivity of breastfeeding during the first six months of life is strongly recommended, as it provides all the necessary nutrients required for growth without the need for additional food or liquids (World Health Organization et al., 2023). However, despite its well-documented benefits, global breastfeeding rates remain suboptimal due to various barriers such as lack of awareness, cultural practices, maternal employment, and aggressive marketing of infant formula (UNICEF et al., 2022). Addressing these challenges requires comprehensive strategies, including public health interventions, maternal education, and supportive workplace policies that enable mothers to initiate and continue breastfeeding successfully (Rollins et al., 2016). Moreover, continued breastfeeding beyond six months, along with the introduction of complementary foods, ensures sustained nutritional support and further strengthens the immune system during early childhood (Ballard et al., 2017). The unique composition and multifaceted benefits of breast milk clearly establish breastfeeding as the most effective and beneficial feeding practice for infants, emphasizing the need for global efforts to promote, protect, and support breastfeeding as a fundamental component of child health and nutrition (World Health Organization et al., 2023).

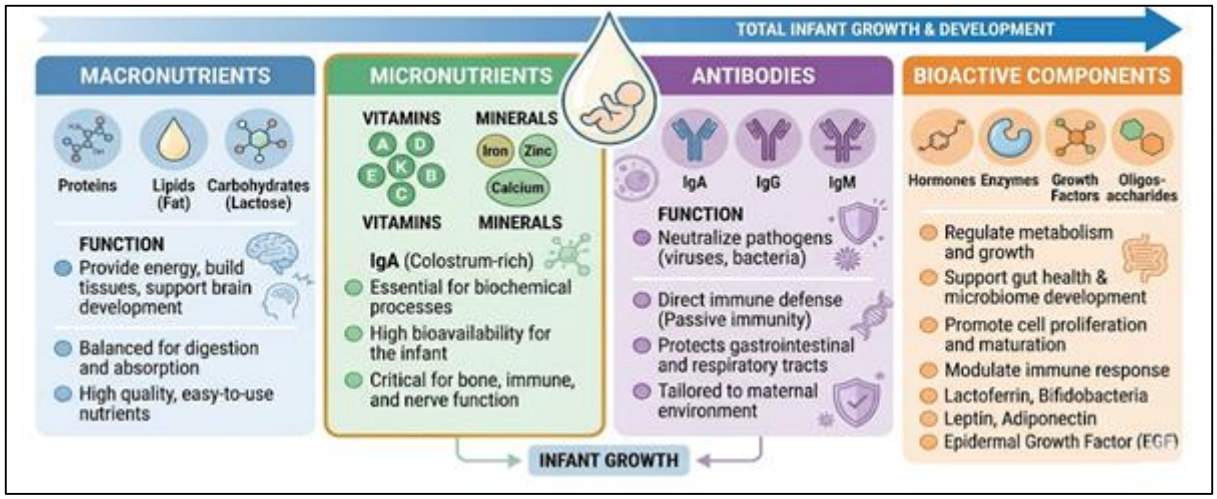


Figure. 3: Composition of breast milk highlighting macronutrients, micronutrients, antibodies, and bioactive components essential for infant growth

4. Importance of breastfeeding:

Breastfeeding offers numerous benefits for both infants and mothers, making it one of the most effective and natural interventions for improving early-life health outcomes (World Health Organization et al., 2023), and its role in enhancing survival, growth, and development has been consistently emphasized in global health recommendations (UNICEF et al., 2022). As illustrated in Fig. 4, which highlights the multidimensional benefits of breastfeeding, it significantly contributes to improved immunity, stronger emotional bonding, reduced risk of chronic diseases, and notable economic advantages, thereby supporting both individual and public health outcomes (Victora et al., 2016). Breastfeeding plays a crucial role in strengthening the infant's

immune system through the transfer of antibodies and bioactive compounds, which protect against a wide range of infections during the early stages of life (Ballard et al., 2017). It has been shown to reduce the incidence of common childhood illnesses such as diarrhea and respiratory infections, which remain leading causes of infant morbidity and mortality worldwide (Black et al., 2021). The protective effects of breast milk are particularly important in low- and middle-income countries, where access to healthcare and sanitation may be limited, making breastfeeding a cost-effective and life-saving intervention (Bhutta et al., 2020). In addition to physical health benefits, breastfeeding fosters a strong emotional bond between the mother and infant, promoting psychological well-being and secure attachment, which are essential for healthy social and emotional development (Rollins et al., 2016). Furthermore, breastfeeding has been associated with a reduced risk of chronic diseases such as obesity, type 2 diabetes, and cardiovascular conditions later in life, highlighting its long-term impact on health outcomes (Horta et al., 2016). From an economic perspective, breastfeeding reduces healthcare costs by lowering the incidence of illness and eliminating the need for expensive infant formula, making it a sustainable and accessible feeding option for families (Victora et al., 2016). In addition to the benefits for infants, mothers also experience significant health advantages as a result of breastfeeding, including faster postpartum recovery due to the release of oxytocin, which helps the uterus return to its pre-pregnancy state (Stuebe et al., 2017). Breastfeeding has also been linked to a reduced risk of breast and ovarian cancers, as well as a lower likelihood of developing type 2 diabetes and hypertension, thereby contributing to improved long-term maternal health (Chowdhury et al., 2015). Moreover, breastfeeding supports natural child spacing through lactational amenorrhea, which can have additional health and socioeconomic benefits for families (World Health Organization et al., 2023). Research further indicates that breastfeeding contributes to better cognitive outcomes and overall development in children, reinforcing its importance as a foundational component of early-life nutrition (Horta et al., 2016). Despite these well-established benefits, breastfeeding practices are often influenced by factors such as maternal education, cultural beliefs, workplace policies, and access to healthcare support, which can impact initiation and continuation rates (UNICEF et al., 2022). Therefore, promoting breastfeeding requires a comprehensive approach that includes education, community support, and policy interventions aimed at creating an enabling environment for mothers (Rollins et al., 2016).

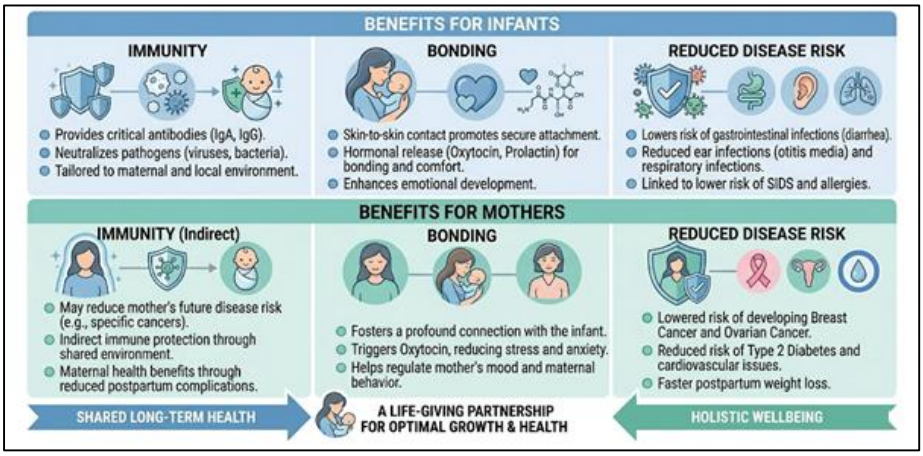


Figure. 4: Benefits of breastfeeding for both infants and mothers including immunity, bonding, and reduced disease risk

5. Duration and recommendations:

Health authorities strongly recommend exclusive breastfeeding for the first six months of life, followed by continued breastfeeding along with appropriate complementary feeding up to two years of age or beyond, as this practice ensures that infants receive adequate and balanced nutrition during their most critical developmental stages (World Health Organization et al., 2023). Exclusive breastfeeding during the first six months provides all the essential nutrients required for optimal growth, including proteins, fats, carbohydrates, vitamins, and minerals, while also supplying bioactive compounds that enhance immunity and protect against infections (UNICEF et al., 2022). This period is particularly important because the infant's digestive and immune systems are still developing, and breast milk offers a safe, hygienic, and easily digestible source of nutrition that reduces the risk of gastrointestinal and respiratory diseases (Victora et al., 2016). Studies have consistently shown that infants who are exclusively breastfed for six months have lower rates of morbidity and mortality compared to those who are partially breastfed or formula-fed, highlighting the protective role of breast milk in early life (Black et al., 2021). In addition to providing complete nutrition, exclusive breastfeeding promotes optimal cognitive development due to the presence of essential fatty acids such as DHA, which play a crucial role in brain growth and neurological function (Innis et al., 2020). After six months

of age, however, the nutritional requirements of infants increase, particularly for micronutrients such as iron and zinc, which cannot be sufficiently supplied by breast milk alone, making the introduction of complementary feeding necessary (Dewey et al., 2021). Complementary foods should be nutrient-dense, safe, and age-appropriate, and they should be introduced gradually while continuing breastfeeding to ensure that the infant receives a balanced diet that meets increasing energy and nutrient needs (World Health Organization et al., 2023). Continued breastfeeding beyond six months remains important because breast milk continues to provide significant nutritional and immunological benefits, including protection against infections and support for ongoing growth and development (Ballard et al., 2017). The combination of breastfeeding and complementary feeding has been shown to improve overall dietary quality and contribute to better health outcomes, including reduced risk of malnutrition and enhanced immune function (Bhutta et al., 2020). Furthermore, extended breastfeeding up to two years or beyond is associated with long-term health benefits such as reduced risk of chronic diseases, improved cognitive performance, and stronger emotional bonding between mother and child (Horta et al., 2016). Despite these recommendations, global adherence to exclusive and continued breastfeeding remains suboptimal due to various barriers, including lack of awareness, cultural practices, maternal employment, and limited access to breastfeeding support services (UNICEF et al., 2022). Addressing these challenges requires coordinated efforts at individual, community, and policy levels, including maternal education, workplace support for breastfeeding mothers, and the promotion of breastfeeding-friendly environments (Rollins et al., 2016). Healthcare professionals play a crucial role in guiding and supporting mothers to initiate and sustain breastfeeding practices, ensuring that they understand the importance of exclusive breastfeeding and the timely introduction of complementary foods (World Health Organization et al., 2023). In addition, public health programs aimed at improving infant feeding practices can significantly contribute to reducing child mortality and improving overall health outcomes (Black et al., 2021).

6. Supplementary feeding:

Supplementary feeding becomes necessary when breast milk alone is no longer sufficient to meet the increasing nutritional demands of the growing infant, particularly after six months of age when rapid physical and cognitive development requires additional energy and micronutrients (World Health Organization et al., 2023). As illustrated in Fig. 5, which presents various types of complementary foods such as cereals, fruits, vegetables, and protein-rich sources, these foods are gradually introduced to ensure a balanced and diversified diet that supports optimal growth and development (UNICEF et al., 2022). The transition to complementary feeding marks a critical phase in infant nutrition, as it bridges the gap between the nutrients provided by breast milk and the higher nutritional requirements of the infant at this stage (Dewey et al., 2021). Complementary foods should be soft, easily digestible, and appropriate for the infant's developmental readiness, ensuring that they can be safely consumed without increasing the risk of choking or digestive issues (Fewtrell et al., 2017). These foods must also be nutrient-dense, particularly rich in essential micronutrients such as iron, zinc, and calcium, which are crucial for preventing deficiencies and supporting physiological functions (Bhutta et al., 2020). Iron is especially important during this period, as the infant's natural iron stores begin to deplete after six months, increasing the risk of anemia if not adequately supplemented through diet (Pasricha et al., 2021). Similarly, zinc plays a vital role in immune function and cellular growth, while calcium and vitamin D contribute to bone development and skeletal health (Hess et al., 2020). The introduction of a variety of foods also helps in developing taste preferences and promoting healthy eating habits, which can have long-term implications for dietary behavior and nutritional status (Nicklaus et al., 2017). The goal of complementary feeding is not only to provide additional energy and nutrients but also to ensure a gradual transition from exclusive milk feeding to a more diverse and balanced diet, while continuing breastfeeding as the primary source of nutrition (World Health Organization et al., 2023). Continued breastfeeding during this period remains essential, as it still contributes significantly to the infant's nutritional intake and provides ongoing immunological protection against infections (Ballard et al., 2017). Proper feeding practices, including appropriate meal frequency, portion size, and food consistency, are critical to ensuring that infants receive adequate nutrition without compromising safety or digestion (UNICEF et al., 2022). Inadequate complementary feeding practices, such as delayed introduction, low dietary diversity, or poor food quality, can lead to malnutrition, stunting, and impaired cognitive development, which may have long-term consequences on health and productivity (Black et al., 2021). On the other hand, timely and appropriate complementary feeding has been associated with improved growth outcomes, better immune function, and enhanced developmental milestones (Bhutta et al., 2020). Hygiene and food safety are also essential considerations during complementary feeding, as infants are particularly vulnerable to infections caused by contaminated food or water (World Health Organization et al., 2023). Caregivers must ensure proper food preparation, storage, and feeding practices to minimize the risk of illness and support healthy development (Fewtrell et al.,

2017). Furthermore, cultural practices, socioeconomic conditions, and maternal knowledge significantly influence complementary feeding behaviors, highlighting the need for targeted education and community-based interventions to promote optimal feeding practices (UNICEF et al., 2022). Healthcare professionals play a vital role in guiding caregivers on appropriate feeding techniques, food choices, and feeding frequency, ensuring that infants receive balanced and adequate nutrition during this critical stage (Dewey et al., 2021).

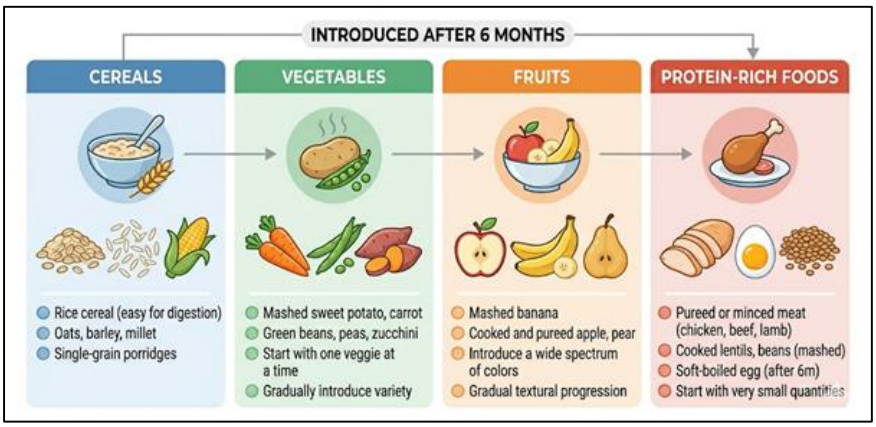


Figure. 5: Types of complementary foods introduced after six months such as cereals, fruits, vegetables, and protein-rich foods

7. Principles of supplementary feeding:

The introduction of complementary foods should follow well-defined principles to ensure both safety and nutritional adequacy during this critical phase of infant development, as inappropriate feeding practices can increase the risk of malnutrition, infections, and food-related complications (World Health Organization et al., 2023). Complementary feeding should begin at around six months of age when breast milk alone is no longer sufficient to meet the infant's growing nutritional requirements, making the timely introduction of additional foods essential for continued growth and development (UNICEF et al., 2022). Foods should be introduced gradually and one at a time, allowing caregivers to monitor the infant's tolerance and identify any potential allergic reactions or digestive issues, thereby ensuring a safe transition to a more diversified diet (Fewtrell et al., 2017). This gradual approach also helps infants adapt to new tastes, textures, and feeding patterns, which is important for developing healthy eating behaviors and acceptance of a variety of foods (Nicklaus et al., 2017). Hygiene is a critical aspect of complementary feeding, as infants are particularly vulnerable to foodborne infections due to their immature immune systems, and therefore all foods must be prepared, stored, and served in a clean and safe environment to minimize the risk of contamination (World Health Organization et al., 2023). Proper handwashing, the use of clean utensils, and safe food handling practices are essential to prevent illnesses such as diarrhea, which can significantly impact nutritional status and overall health (Bhutta et al., 2020). In addition to safety considerations, the nutritional quality of complementary foods is of paramount importance, as infants require nutrient-dense foods that provide sufficient energy and essential micronutrients to support rapid growth and development (Dewey et al., 2021). Iron-rich foods are particularly important at this stage, as the natural iron stores that infants are born with begin to deplete after six months, increasing the risk of iron deficiency anemia if adequate dietary sources are not provided (Pasricha et al., 2021). Foods such as fortified cereals, legumes, green leafy vegetables, and animal-source foods are recommended to ensure sufficient iron intake and support cognitive development (Allen et al., 2019). Zinc is another essential micronutrient that supports immune function and cellular growth, and its inclusion in complementary foods is important for maintaining overall health (Hess et al., 2020). The inclusion of a wide variety of foods from different food groups helps ensure that infants receive a balanced intake of nutrients, including vitamins, minerals, and essential fatty acids, which are necessary for proper physiological functioning (Prentice et al., 2018). Dietary diversity not only meets nutritional requirements but also promotes the development of healthy eating habits, reducing the likelihood of food preferences that may limit nutrient intake later in life (Nicklaus et al., 2017). Continued breastfeeding alongside complementary feeding remains essential, as breast milk continues to provide significant nutritional and immunological benefits during this stage (Ballard et al., 2017). Feeding frequency, portion size, and food consistency should be adjusted according to the infant's age and developmental readiness to ensure that nutritional needs are met without compromising safety (World Health Organization et al., 2023). Inadequate complementary feeding practices, such as delayed introduction, insufficient dietary diversity, or poor food quality, can result in malnutrition, stunting, and impaired cognitive development, which may have long-term consequences on health and productivity (Black et al., 2021), Table 2 demonstrates the Age-wise complementary feeding schedule showing types of foods and

feeding frequency across developmental stages. On the other hand, appropriate complementary feeding practices have been shown to improve growth outcomes, enhance immune function, and support developmental milestones (Bhutta et al., 2020). Caregiver knowledge and education play a crucial role in ensuring proper feeding practices, as informed caregivers are more likely to adopt safe, nutritious, and age-appropriate feeding strategies (UNICEF et al., 2022). Therefore, promoting awareness and providing guidance through healthcare systems and community-based programs is essential for improving complementary feeding practices and ensuring optimal infant nutrition (Dewey et al., 2021).

Table. 2: Age-wise complementary feeding schedule showing types of foods and feeding frequency across developmental stages

Age	Food Type	Frequency
6–8 months	Pureed foods	2–3 times/day
9–11 months	Semi-solid foods	3–4 times/day
12–24 months	Family foods	3 meals + snacks

8. Artificial feeding (Formula Feeding):

Artificial feeding is employed when breastfeeding is not possible, insufficient, or contraindicated due to medical, social, or personal reasons, and it serves as an alternative method to ensure that infants receive adequate nutrition for growth and development (World Health Organization et al., 2023). As illustrated in Fig. 6, which categorizes different types of infant formula including cow milk-based, soy-based, and hydrolyzed formulas, these products are specifically designed to meet the diverse nutritional and medical needs of infants who cannot be exclusively breastfed (Koletzko et al., 2019). Cow milk-based formulas are the most commonly used and are modified to resemble human milk in terms of protein composition and digestibility, while soy-based formulas are often recommended for infants with lactose intolerance or specific dietary preferences (Vandenplas et al., 2017). Hydrolyzed formulas, on the other hand, contain proteins that are broken down into smaller peptides, making them suitable for infants with allergies or gastrointestinal sensitivities (Osborn et al., 2017). Modern infant formulas are carefully formulated to mimic the nutritional composition of breast milk, containing essential macronutrients such as proteins, fats, and carbohydrates, along with vital micronutrients including vitamins and minerals necessary for infant growth and development (Koletzko et al., 2019). In particular, formulas are enriched with essential fatty acids such as docosahexaenoic acid (DHA) and arachidonic acid (ARA), which play a significant role in brain development and visual function, thereby supporting cognitive outcomes similar to those observed in breastfed infants (Innis et al., 2020). Additionally, infant formulas are fortified with iron to prevent iron deficiency anemia, a common concern during infancy, especially in formula-fed infants (Pasricha et al., 2021). Despite these advancements, artificial feeding does not fully replicate the immunological and bioactive properties of breast milk, as it lacks antibodies, enzymes, and certain growth factors that contribute to immune protection and disease prevention (Ballard et al., 2017). As a result, formula-fed infants may have a higher risk of infections such as diarrhea and respiratory illnesses compared to breastfed infants, particularly in environments with poor sanitation and limited healthcare access (Black et al., 2021). Proper preparation and handling of infant formula are therefore critical to ensure safety and prevent contamination, as improper dilution, unclean water, or unhygienic feeding practices can lead to serious health complications (World Health Organization et al., 2023). Furthermore, artificial feeding requires careful adherence to feeding guidelines, including appropriate quantity, frequency, and preparation methods, to ensure that infants receive balanced nutrition without the risk of overfeeding or underfeeding (Vandenplas et al., 2017). From a practical perspective, artificial feeding offers certain advantages such as convenience, flexibility, and the ability for other caregivers to participate in feeding, which can be beneficial in cases where mothers are unable to breastfeed due to work commitments or health conditions (UNICEF et al., 2022). However, it is generally more expensive than breastfeeding and may place a financial burden on families, particularly in low-resource settings (Victora et al., 2016). In addition, the absence of the natural bonding experience associated with breastfeeding may have implications for emotional connection, although responsive feeding practices can help mitigate this effect (Rollins et al., 2016). Healthcare professionals play a crucial role in guiding parents on the appropriate selection and use of infant formulas, ensuring that feeding practices are safe, nutritionally adequate, and tailored to the infant's specific needs (Koletzko et al., 2019). Moreover, public health policies emphasize that artificial feeding should be used as a substitute only when necessary, and breastfeeding should be promoted and supported whenever possible due to its superior benefits (World Health Organization et al., 2023).

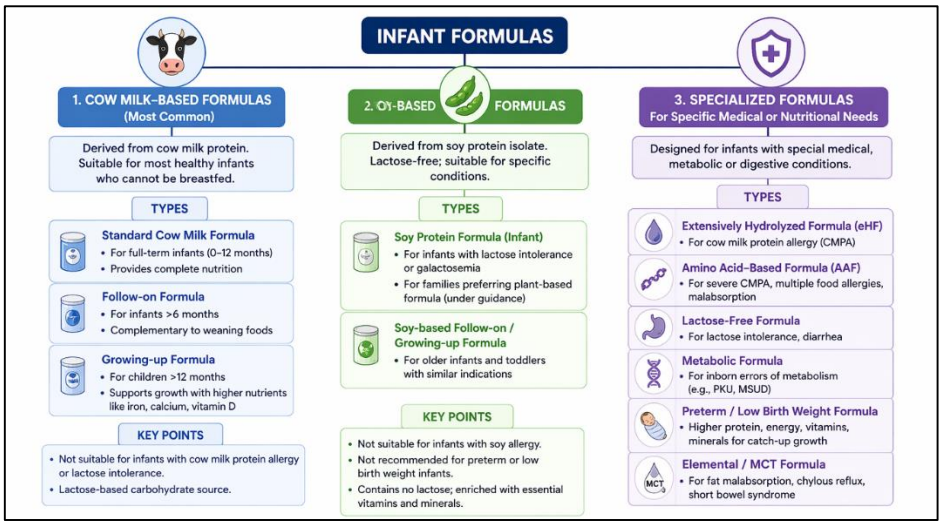


Figure. 6: Classification of infant formulas including cow milk-based, soy-based, and specialized formulas for different nutritional needs

9. Advantages and disadvantages:

Artificial feeding offers significant flexibility and convenience, particularly for working mothers who may find it challenging to maintain exclusive breastfeeding due to time constraints, workplace limitations, or health-related issues (UNICEF et al., 2022), and it allows other caregivers such as fathers or family members to actively participate in feeding, thereby distributing caregiving responsibilities and supporting maternal well-being (Rollins et al., 2016). This shared feeding approach can help ensure that infants receive consistent nutrition even in the absence of the mother, making artificial feeding a practical option in many modern family settings (Victora et al., 2016). Infant formulas are designed to provide adequate levels of essential nutrients required for growth and development, including proteins, fats, carbohydrates, vitamins, and minerals, which help support the infant's basic nutritional needs (Koletzko et al., 2019). In particular, the fortification of formulas with micronutrients such as iron and essential fatty acids like DHA contributes to supporting brain development and preventing nutritional deficiencies (Innis et al., 2020). However, despite these advantages, artificial feeding has several limitations when compared to breastfeeding, primarily due to the absence of immune-protective components that are naturally present in breast milk (Ballard et al., 2017). Breast milk contains antibodies, enzymes, and bioactive compounds that play a critical role in protecting infants against infections and enhancing their immune system, benefits that cannot be fully replicated in formula (World Health Organization et al., 2023). As a result, formula-fed infants may have a higher susceptibility to infections such as diarrhea, respiratory illnesses, and ear infections, particularly in environments where sanitation and hygiene are not adequately maintained (Black et al., 2021). The risk of infections associated with formula feeding is further increased if preparation practices are not strictly followed, as improper dilution, use of contaminated water, or unclean feeding equipment can introduce harmful pathogens (World Health Organization et al., 2023). Therefore, maintaining strict hygiene practices is essential when using infant formula, including proper sterilization of feeding bottles, accurate measurement of formula, and safe storage of prepared feeds (Vandenplas et al., 2017). In addition to health concerns, artificial feeding is relatively expensive compared to breastfeeding, as it involves the ongoing cost of purchasing formula, feeding equipment, and clean water, which may impose a financial burden on families, especially in low- and middle-income settings (Victora et al., 2016). The economic implications of formula feeding extend beyond individual households, as increased healthcare costs may arise due to higher rates of illness among formula-fed infants (Bhutta et al., 2020). Furthermore, artificial feeding does not provide the same level of emotional bonding experienced during breastfeeding, although responsive feeding practices and caregiver interaction can help support emotional development (Rollins et al., 2016). It is also important to note that improper feeding practices, such as overfeeding or underfeeding, may occur if caregivers are not adequately informed about appropriate feeding guidelines, potentially leading to issues such as excessive weight gain or nutritional deficiencies (Koletzko et al., 2019). Healthcare professionals play a crucial role in educating caregivers about the safe and appropriate use of infant formula, ensuring that feeding practices are aligned with recommended standards and tailored to the infant's specific needs (World Health Organization et al., 2023). While artificial feeding serves as an important alternative when breastfeeding is not feasible, it should be approached with caution and supported by proper knowledge, resources, and hygiene practices to minimize risks and ensure optimal infant health outcomes (Black et al., 2021).

10. Weaning (Introduction to Solid Foods):

Weaning is the process of introducing solid or semi-solid foods into an infant's diet while gradually reducing dependence on breast milk or formula, marking a crucial transition in early childhood nutrition that supports continued growth and development (World Health Organization et al., 2023), and this phase requires careful planning to ensure that the infant's increasing nutritional needs are adequately met (UNICEF et al., 2022). As illustrated in Fig.7, which demonstrates the stages of weaning, the process involves a gradual progression from liquid feeding to semi-solid foods and eventually to solid foods, reflecting the infant's developmental readiness and ability to handle different food textures (Fewtrell et al., 2017). This transition typically begins around six months of age, when infants exhibit readiness signs such as the ability to sit upright with support, improved head and neck control, and a growing interest in food, all of which indicate that the digestive and neuromuscular systems are sufficiently developed to process solid foods (Dewey et al., 2021). Proper timing of weaning is essential, as early introduction of solid foods before four months may increase the risk of infections and allergies, while delayed introduction beyond six months may lead to nutritional deficiencies, particularly in iron and zinc (Bhutta et al., 2020). During the weaning process, the selection of appropriate foods is critical, with an emphasis on nutrient-dense options that provide adequate energy, proteins, fats, and essential micronutrients necessary for rapid growth and development (Black et al., 2021). Initially, foods should be soft, mashed, or pureed to ensure easy swallowing and digestion, gradually progressing to thicker textures and finger foods as the infant develops chewing and self-feeding skills (Nicklaus et al., 2017). The inclusion of iron-rich foods is particularly important during this stage, as the infant's natural iron stores begin to decline after six months, increasing the risk of anemia if dietary intake is insufficient (Pasricha et al., 2021). In addition, a diverse range of foods, including fruits, vegetables, cereals, and protein sources, should be introduced to ensure balanced nutrition and to encourage acceptance of different tastes and textures, which can influence long-term dietary habits (Prentice et al., 2018). Continued breastfeeding or formula feeding alongside complementary foods remains important during the weaning period, as milk continues to provide a significant proportion of the infant's nutritional requirements and offers ongoing immunological protection (Ballard et al., 2017). Hygiene and food safety are also critical considerations during weaning, as infants are highly susceptible to infections, and therefore food must be prepared, stored, and served in a clean and safe environment to prevent contamination (World Health Organization et al., 2023). Feeding practices during weaning should be responsive and supportive, allowing infants to explore food at their own pace while ensuring that adequate nutrition is provided, thereby promoting healthy eating behaviors and preventing feeding difficulties (UNICEF et al., 2022). Improper weaning practices, such as inadequate dietary diversity, inappropriate food consistency, or poor feeding frequency, can result in malnutrition, stunted growth, and delayed cognitive development, highlighting the importance of proper guidance and caregiver education (Black et al., 2021). Cultural beliefs, socioeconomic factors, and caregiver knowledge significantly influence weaning practices, making it essential to provide targeted education and support through healthcare systems and community programs (Bhutta et al., 2020). Healthcare professionals play a key role in guiding parents on appropriate weaning practices, including the timing, type, and quantity of foods to be introduced, ensuring that infants receive balanced and adequate nutrition during this critical transition phase (Dewey et al., 2021).

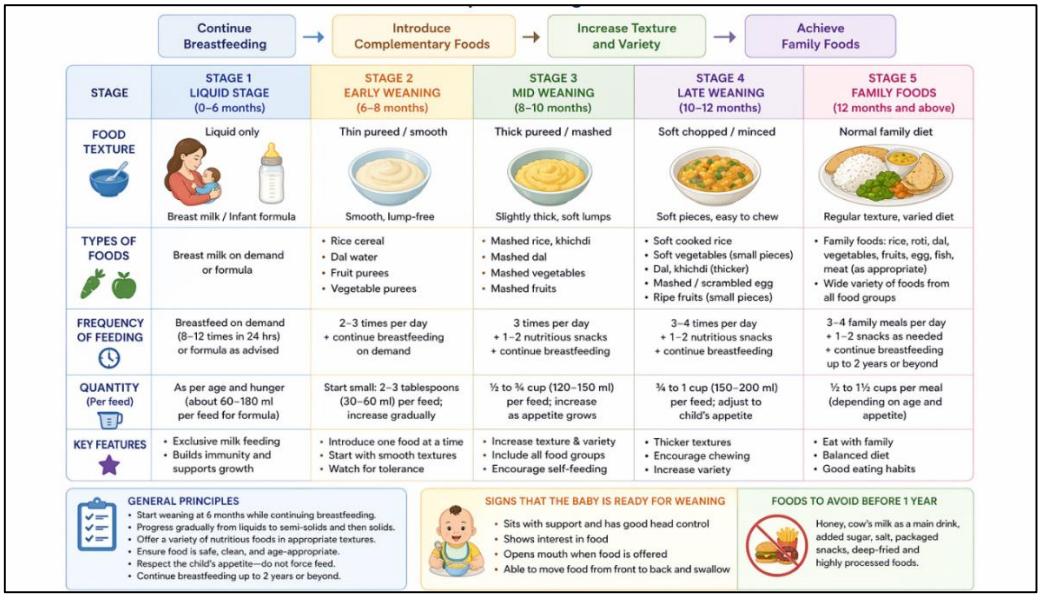


Figure. 7: Stages of weaning showing the gradual transition from liquid feeding to semi-solid and solid foods

11. Types of weaning:

Different approaches to weaning include traditional spoon-feeding, baby-led weaning, and mixed methods, each offering distinct advantages and challenges that should be carefully considered based on the infant's developmental readiness, nutritional needs, and caregiver preferences (World Health Organization et al., 2023), and selecting an appropriate weaning method is essential for ensuring a smooth transition from milk to solid foods while maintaining adequate nutritional intake (UNICEF et al., 2022). Traditional spoon-feeding is the most commonly practiced method, in which caregivers provide pureed or mashed foods to the infant using a spoon, allowing controlled feeding and ensuring that the infant consumes sufficient quantities of nutrients necessary for growth and development (Fewtrell et al., 2017). This method is particularly beneficial in monitoring portion sizes and nutrient intake, especially for micronutrients such as iron and zinc, which are critical during the weaning period (Dewey et al., 2021). In contrast, baby-led weaning is an approach that encourages infants to self-feed using finger foods, promoting independence, motor skill development, and the ability to regulate appetite according to hunger and satiety cues (Brown et al., 2017). This method allows infants to explore different textures and flavors at their own pace, potentially leading to improved acceptance of a variety of foods and healthier eating behaviors later in life (Nicklaus et al., 2017). However, concerns associated with baby-led weaning include the risk of choking and the possibility of inadequate nutrient intake if appropriate foods are not offered, particularly for iron-rich options (Cameron et al., 2018). Therefore, careful supervision and appropriate food selection are essential when adopting this approach to ensure safety and nutritional adequacy (World Health Organization et al., 2023). Mixed methods, which combine elements of both traditional spoon-feeding and baby-led weaning, are increasingly recommended as they provide a balanced approach that allows caregivers to ensure sufficient nutrient intake while also encouraging self-feeding and independence (UNICEF et al., 2022). This flexible approach can be adapted to suit the infant's developmental stage and individual preferences, making it a practical and widely accepted method in diverse cultural and socioeconomic settings (Brown et al., 2017). Regardless of the chosen method, the readiness of the infant is a key factor in determining the success of weaning practices, as infants must demonstrate physical and developmental milestones such as the ability to sit upright, coordinate hand-to-mouth movements, and safely swallow solid foods (Dewey et al., 2021). Table 3 summarized Comparative analysis of breastfeeding, formula feeding, and mixed feeding methods with their advantages and disadvantages. Nutritional adequacy remains a central consideration across all weaning approaches, as inadequate intake of essential nutrients during this period can lead to deficiencies, stunting, and impaired cognitive development (Black et al., 2021). Therefore, caregivers must ensure that the infant's diet includes a variety of nutrient-dense foods, particularly those rich in iron, calcium, and essential fatty acids, to support optimal growth and development (Bhutta et al., 2020). Hygiene and food safety are equally important across all methods, as improper food handling or preparation can increase the risk of infections, which may negatively impact the infant's health and nutritional status (World Health Organization et al., 2023). Cultural practices, caregiver knowledge, and socioeconomic factors also play a significant role in influencing the choice of weaning method, highlighting the need for tailored guidance and support from healthcare professionals (UNICEF et al., 2022). Healthcare providers can assist caregivers by offering evidence-based recommendations on appropriate weaning strategies, food selection, and feeding techniques, ensuring that infants receive safe and adequate nutrition during this critical transition phase (Dewey et al., 2021).

Table. 3: Comparative analysis of breastfeeding, formula feeding, and mixed feeding methods with their advantages and disadvantages

Feeding Method	Advantages	Disadvantages
Breastfeeding	Natural, immunity	Time-dependent
Formula Feeding	Convenient	Expensive, infection risk
Mixed Feeding	Flexible	Feeding confusion

12. Factors influencing infant feeding practices:

Infant feeding practices are influenced by a complex interplay of multiple factors that determine not only the choice of feeding method but also the quality, frequency, and adequacy of nutritional intake during early childhood (World Health Organization et al., 2023), and these determinants play a critical role in shaping growth, development, and long-term health outcomes (UNICEF et al., 2022). As illustrated in Fig. 8, which highlights key determinants such as socioeconomic status, cultural beliefs, maternal education, and access to healthcare services, these factors collectively influence feeding behaviors and decisions at both household and community levels (Bhutta et al., 2020). Socioeconomic status is one of the most significant determinants, as families with limited financial resources may face challenges in accessing diverse and nutrient-rich foods,

leading to inadequate dietary intake and increased risk of malnutrition (Black et al., 2021). In contrast, higher socioeconomic status is often associated with better access to healthcare, education, and nutritional resources, which can support optimal feeding practices (Victora et al., 2016). Cultural beliefs and traditional practices also play an important role in influencing infant feeding behaviors, as certain customs may either promote or hinder recommended practices such as exclusive breastfeeding or timely introduction of complementary foods (Kavle et al., 2017). For example, misconceptions regarding colostrum or early introduction of solid foods may negatively impact infant nutrition and health outcomes (UNICEF et al., 2022). Maternal education is another key determinant, as mothers with higher levels of education are more likely to have better knowledge of appropriate feeding practices, hygiene, and nutritional requirements, which positively influences infant health (Bhutta et al., 2020). Educated mothers are also more likely to seek healthcare services and follow evidence-based guidelines, thereby improving feeding practices and reducing the risk of malnutrition (Black et al., 2021). Access to healthcare services further contributes to shaping feeding practices, as regular contact with healthcare providers enables caregivers to receive guidance, counseling, and support regarding breastfeeding, complementary feeding, and overall child nutrition (World Health Organization et al., 2023). Healthcare interventions, including antenatal and postnatal counseling, play a crucial role in promoting optimal feeding practices and addressing common challenges faced by caregivers (Rollins et al., 2016). In addition to these primary determinants, factors such as maternal employment, family support systems, and exposure to media and marketing also influence feeding decisions, particularly in relation to the use of infant formula and early weaning practices (UNICEF et al., 2022). Working mothers, for instance, may face difficulties in maintaining exclusive breastfeeding due to time constraints and lack of workplace support, leading to increased reliance on artificial feeding (Victora et al., 2016). Similarly, aggressive marketing of infant formula products can influence caregiver perceptions and practices, sometimes undermining breastfeeding despite its well-established benefits (World Health Organization et al., 2023). Environmental factors such as sanitation, access to clean water, and food safety conditions are also critical, as poor hygiene can increase the risk of infections, particularly during complementary feeding stages (Bhutta et al., 2020). Understanding these multifaceted influences is essential for designing effective nutritional interventions and public health strategies aimed at improving infant feeding practices and overall child health outcomes (Black et al., 2021). Tailored interventions that address socioeconomic disparities, cultural beliefs, and educational gaps can significantly enhance the adoption of recommended feeding practices (Kavle et al., 2017). Community-based programs, caregiver education initiatives, and policy-level support such as maternity leave and breastfeeding-friendly workplaces are essential components of a comprehensive approach to improving infant nutrition (UNICEF et al., 2022). Healthcare professionals play a pivotal role in this process by providing evidence-based guidance and continuous support to caregivers, ensuring that feeding practices align with recommended standards (World Health Organization et al., 2023).

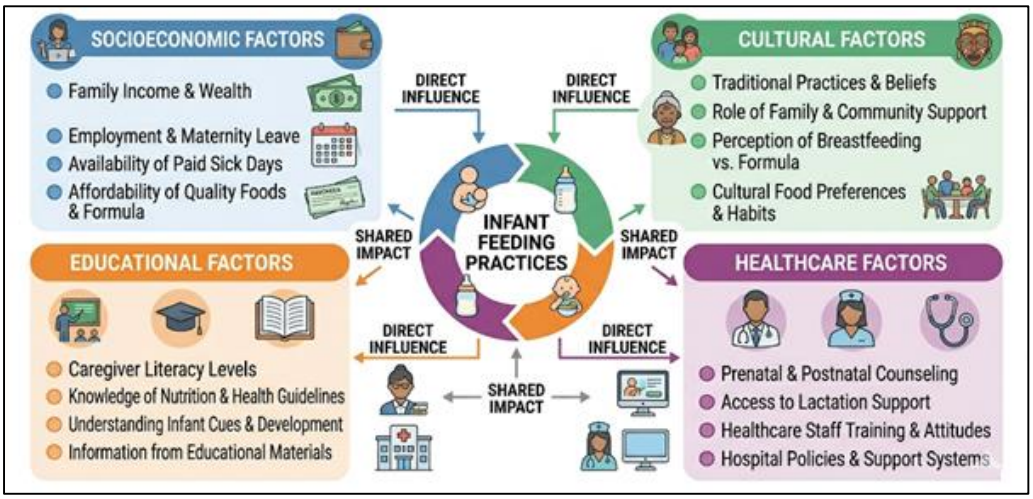


Figure. 8: Determinants influencing infant feeding practices including socioeconomic, cultural, educational, and healthcare factors

13. Conclusion:

Infant nutrition plays a fundamental role in ensuring healthy growth, optimal development, and long-term well-being, particularly during the critical early years of life. Breastfeeding remains the most recommended feeding method due to its unique nutritional composition and immunological benefits, providing essential nutrients and protection against infections. However, in situations where breastfeeding is not feasible, supplementary and artificial feeding serve as important alternatives to meet the nutritional needs of infants. The timely

introduction of complementary foods around six months is crucial to address increasing energy and micronutrient requirements, especially for nutrients such as iron and zinc. Proper weaning practices, including the selection of age-appropriate, safe, and nutrient-dense foods, ensure a smooth transition from milk to solid foods while supporting overall development. Furthermore, infant feeding practices are influenced by various factors such as socioeconomic status, cultural beliefs, maternal education, and access to healthcare, highlighting the need for a comprehensive approach to improving nutrition. Promoting awareness, providing education, and offering continuous support to caregivers are essential steps toward enhancing feeding practices. Ultimately, adopting appropriate infant nutrition strategies can significantly reduce malnutrition, improve health outcomes, and contribute to the development of a healthier future generation.

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