

Practice of Exclusive Breastfeeding: A Narrative Review of Its Relevance and Added Value as a Public Health Strategy to Reduce the Double Burden of Malnutrition

Marcelle Essoyodou Kabassina¹, Tiatou Souho¹ , Damipie Bomboma¹, Elom Kouassivi Aglago², Ella Compaoré³, Abel Essowéréou Abli¹, Sabiba Kou'santa Amouzou¹

¹Laboratoire des Sciences Agronomiques et Biologiques Appliquées, Université de Kara, Kara, Togo

²Department of Epidemiology and Biostatistics, School of Public Health, Imperial College London, London, UK

³Laboratoire de Biochimie, Biotechnologie, Technologie Alimentaire et Nutrition, Université Joseph KI-ZERBO, Ouagadougou, Burkina Faso

Email: souhotia@yahoo.fr

How to cite this paper: Kabassina, M.E., Souho, T., Bomboma, D., Aglago, E.K., Compaoré, E., Abli, A.E. and Amouzou, S.K. (2026) Practice of Exclusive Breastfeeding: A Narrative Review of Its Relevance and Added Value as a Public Health Strategy to Reduce the Double Burden of Malnutrition. *Food and Nutrition Sciences*, 17, 375-399.

<https://doi.org/10.4236/fns.2026.174027>

Received: March 3, 2026

Accepted: April 24, 2026

Published: April 27, 2026

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Abstract

Among public health guidelines and strategies for optimal children's growth, exclusive breastfeeding in the first six months occupies a pivotal place. The present review provides an overview of the composition of human breast milk and the relevance of exclusive breastfeeding as a public health tool that can improve children's health as well as mother's wellbeing. Analyses encompass nutrients supply to children, children's immune system setting and maturation, cognitive and psychomotor development, epigenetic regulation, and microbiome establishment. The relevance of exclusive breastfeeding as a public health strategy is discussed before reviewing the level of application of this strategy worldwide. Furthermore, breastfeeding evaluation methods are presented alongside factors associated with exclusive breastfeeding practice.

Keywords

Exclusive Breastfeeding, Human Breast Milk, Children under 6 Months, Breast Milk Composition

1. Introduction

One of the most challenging targets to be attained by public health interventions for social development, especially in low- and middle-income countries, is to assure wellbeing to all children and reduce the mortality under five years old [1].

This objective is considered a priority globally as the development and evolution of any society is contingent on the presence of a healthy human capital. It is now well established that optimal nutrition in the first thousand days is a critical determinant of the health status of children, adolescents, and adults [2] [3]. Regarding specially the first 6 months of life, existing evidence substantially shows that exclusive breastfeeding confers significant benefits [4]. Exclusive breastfeeding protects the newborn against several communicable and noncommunicable pathologies and promotes optimal development of organs, growth, cognitive and psychomotor development [5] [6].

The World Health Organization (WHO) recommends exclusive breastfeeding for the first six months, followed by continued breastfeeding up to the age of two years old [7]. Breastfeeding, especially exclusive breastfeeding for six months, has a significant impact on reducing mortality from the two leading causes of infant death: diarrhea and pneumonia, as well as all-cause mortality [8]. Despite the efforts of this organization, general observations showed that exclusive breastfeeding for newborns is not followed in the same fashion in all regions as its initiation and duration is multifactorial and associated with factors such as living standards, social and religious considerations. Since the first publication of these recommendations a couple of decades ago, several studies have been carried out on breastfeeding and its effects on the mother and newborn dyads, as well as on approaches to implement and promote its practice. To encourage the practice of exclusive breastfeeding, the WHO, the United Nations Children's Fund (UNICEF) and ministries of health in several countries have initiated and supported the world breastfeeding week every year since 1992, during the first week of August.

As key tools in exclusive breastfeeding promotion programs, exclusive breastfeeding evaluation methods underwent several evolutions towards more precise, less invasive and reduced time. In this review, we analyze the relevance and epidemiology of exclusive breastfeeding before critically discussing factors limiting its practice as well as methods to evaluate the practice of exclusive breastfeeding and approached to implement it.

2. Methods

A literature search was performed using Pubmed and Scopus databases without any specific limitation regarding publication period. Several search syntaxes were used in order to cover the initial purpose of covering the main aspects that are relevant as key factors that can modulate the practice and the outcome of breastfeeding. The following search terms were used independently: "breast milk composition"; "breast milk" AND "nutrient" OR "micronutrient" OR "microRNA" OR "microbiome" OR "hormone"; "breastfeeding" AND "practice" OR "health outcome" OR "evaluation method".

No strict restriction regarding study design or population was applied in order to capture a broad range of scientific evidence related to breastfeeding practices and outcomes. Articles were considered eligible if they addressed aspects related

to breast milk composition, breastfeeding practices, health outcomes, or methods used to evaluate breastfeeding. Studies published in English or French were considered.

Articles were included when they provided relevant information, while studies that were clearly unrelated to the topic were excluded after title, abstract, or full-text screening. References in the retained articles were also browsed, allowing additional documents, including reports and working documents from international institutions. The screening and selection process was conducted by at least two team members, and any disagreement regarding the inclusion of a study was resolved through discussion until consensus was reached.

Collected data were organized and analyzed in order to generate a narrative review. The evidence from the selected publications was synthesized narratively by identifying recurring themes and key findings across studies, which were then integrated to support the interpretation and conclusions of this review. The study was meant to provide a large view and elements to answer the following questions: i) Should breastfeeding-promoting programs be pursued? ii) What are the advantages of breastfeeding? iii) Which method should be used to evaluate the practice of breastfeeding?

3. Results and Discussions

3.1. Content of Human Breast Milk

Human breast milk (HBM) is a stable emulsion composed of a mixture of water and fat matters. It contains water (87.5%) and several macronutrients, micronutrients and certain bioactive factors [9]. It is a dynamic food with a composition related to the mother's nutrition and the time laps from the baby birth. During the breastfeeding period, the milk's composition varies to adapt to the child's changing nutritional needs [10]. It is an important source of energy (670 kcal/l). It contains nutrients and a variety of bioactive factors such as hormones, cytokines, leukocytes, immunoglobulins, lactoferrin, lysozyme, stem cells, human milk oligosaccharides, microbiota, and microRNAs [11]. Because of its ability to provide optimal nutrient intakes and numerous bioactive factors, breast milk is considered the optimal food for newborns.

3.1.1. Proteins

HBM contains 8 to 12 g/L proteins with caseins being the most abundant representing around 40% of all proteins in the milk. This protein content is below the average in other mammals; however, it is perfectly adapted to meet the enzymatic immaturity and specific protein needs of infants [12] [13]. Other proteins in HBM encompass various proteins with physiological functions, such as nutrition, anti-bacterial properties, immune system regulation, and promotion of digestion and nutrients absorption [14] [15]. Additionally, it contains specific proteins, including lactoferrin (which facilitates iron absorption and immune system function) and lysozymes. Furthermore, HBM contains vitamin and hormone transporters,

enzymes, immunoglobulins (especially IgA) and other proteins that provide immune protection or stimulate the child's immune system [16].

The bioactive proteins in breast milk play a role in digestion and nutrient absorption, but they also have enzymatic activities, facilitate the growth of many tissues and help infants reaction against pathogens [17]. Immunological factors include antibodies such as IgA, cytokines and immune cells (lymphocytes, leukocytes, neutrophils, etc) as well as antimicrobial proteins and peptides like lactoferrin and lysozymes [18].

3.1.2. Carbohydrates

Principal carbohydrates recorded in HBM are oligosaccharides and monosaccharides. The most abundant carbohydrate is lactose which is present at concentrations around 63 g/L whereas the whole carbohydrates content is around 75 g/L. Apart from lactose, the other carbohydrates are D-glucose, D-galactose, N-acetylglucosamine, L-fucose, and sialic acid [19]. Other oligosaccharides observed in the milk presents the particularity of having a lactose motif at their reducing end [20].

Human milk carbohydrates are well known for their role of energetic nutrients however, several functional activities of milk have been reported to be attributable to milk oligosaccharides. These oligosaccharides are likely prebiotic factors that promotes the proliferation of probiotic bacteria such as *Bifidobacterium* in the gastrointestinal tract of breastfed infants [20] [21]. In addition, they might confer to breastfed infants a passive protection regarding some pathogens. Indeed, by interfering in the process of pathogenic bacteria adherence with intestinal mucosa, they provide a nonspecific protection given that bacterial adherence is a necessary step in gastrointestinal infections with bacteria such as *Escherichia coli*, *Helicobacter jejuni*, *Shigella* strains, *Salmonella* species, *Vibrio cholerae* [22] [23]. Moreover, the HBM's oligosaccharides might have a systemic effect in addition to their local activity in the gut. This implies that these oligosaccharides are assimilated. In effect, several evidence show that these oligosaccharides play an important role in the postnatal brain development [24].

3.1.3. Lipids

Lipids in the milk constitute the highest source of energy in the milk contributing to ranges from 40 to 55 % of the milk's total energy [25]. Structurally, triglycerides are the most abundant lipids in the milk where free fatty acids, monoglycerides, diglycerides, phospholipids and cholesterol are also observed. These fat matters are grouped in lipidic globules with glycerides in the center and phospholipids at the surface stabilizing interactions with the aqueous phase of the milk [26] [27].

The fat composition of HBM is diverse. Breast milk contains polyunsaturated fatty acids (PUFAs), essential fatty acids (EFAs), particularly linoleic acid and alpha-linolenic acid of the Omega 6 and Omega 3 families, respectively [28]. It also contains longer-chain polyunsaturated fatty acids, including arachidonic acid and docosahexaenoic acid [29]. Short chain fatty acids also are present in the milk and present the advantage of providing energy to breastfed infants and help in matu-

rating gastrointestinal tract. Additionally, although in small amounts, sphingomyelins are present in breast milk and seem to play a crucial role in the development of infants nervous system [30]. The average quantity of lipids in a liter of breast milk is estimated to be 35 grams. Additionally, HBM also contains a considerable amount of cholesterol, with levels ranging from 150 to 200 mg/L [31] [32].

3.1.4. Micronutrients

A significant proportion of HBM is composed of micronutrients essential for normal infant growth. Minerals in breast milk include sodium, calcium, magnesium, chloride, potassium, iron, zinc, chromium, manganese, copper, phosphorus, selenium, and iodine [33]. The most abundant mineral in both colostrum and mature milk is chloride (600 to 800 mg/L in colostrum and 400 to 450 mg/L in mature milk) followed by potassium (600 to 800 mg/L in colostrum and 400 to 550 mg/L in mature milk) and sodium (300 to 400 mg/L in colostrum and 150 to 250 mg/L in mature milk). Calcium and phosphorus, key elements necessary for bones formation, are important minerals in both colostrum and mature HBM [34] [35].

Minerals are required for many vital metabolic pathways including the building and maintenance of strong bones and teeth, the production of hematopoietic cells, the regulation of immune and nervous systems, muscles contraction, and the protection of cells from oxidative damages [36]. More information on milk's mineral composition including microelements such as manganese, iodine, selenium, copper and zinc is presented in the literature [34] [35].

HBM can adequately provide all vitamins requirements, provided that the mother's diet is balanced [29] [37] [38]. However, the most commonly abundant vitamins as presented in several studies include vitamins A, B1, B2, B6, B12, C, D, E, and K (Table 1).

Table 1. Human breast milk's content in vitamins (per 100 mL).

Vitamin	Concentration
Vitamin A	40 - 65 µg
Vitamin D	0.2 - 0.6 µg (8 - 24 IU)
Vitamin E	0.2 - 0.4 mg
Vitamin K	1.5 µg
Vitamin C	3 - 10 mg
Vitamin B1 (Thiamine)	14 µg
Vitamin B2 (Riboflavin)	40 µg
Vitamin B3 (Niacin)	160 µg
Vitamin B5 (Pantothenic Acid)	220 µg
Vitamin B6 (Pyridoxine)	12 µg
Vitamin B7 (Biotin)	8 - 10 µg
Vitamin B9 (Folate)	38 - 54 ng
Vitamin B12 (Cobalamin)	0.1 - 0.5 µg

3.1.5. Hormones and Growth Factors

Among the most extensively studied bioactive components, milk hormones occupy a central position. Several studies have detected the presence of various hormones in HBM, including leptin, adiponectin, gonadotropin-releasing hormone (GnRH), insulin, estrogen, androgens, gastrin, progesterone, resistin, ghrelin and Insulin-like Growth Factor 1 [39] [40]. The precise functions of these hormones remain to be fully elucidated; however, it is postulated that they play a role in various developmental and growth processes, offering protection to infants against certain diseases including obesity [40]-[43].

Leptin, a hormone secreted by adipocytes, was detected in human milk and proven to play several roles in infants' metabolic regulations. It is involved in the regulation of infant's food intake, energetic metabolism, fat accumulation and body composition from the earliest stages of development [43]-[45]. Recent studies have indicated that leptin, in interaction with other adipokines such as adiponectin, may play a role in the long-term metabolic programming and reprogramming of the newborn [42] [46]. Adiponectin is the most abundant adipose-specific protein, discovered in breast milk, and its multiple functions have only recently begun to emerge [47]. Ghrelin, another orexigenic hormone observed in breast milk has been shown to stimulate the secretion of growth hormone, increase appetite, and play a role in the regulation of body weight in newborns. It also plays a role in decreasing fat utilization and increasing adipose reserves, thus promoting normal infant growth [48] [49].

The insulin resistance associated hormone, resistin was found in human milk but its role in infants' metabolism is not well understood [50]. However, the umbilical serum resistin levels correlate positively with maternal serum resistin levels and negatively with neonatal birth weight [51]. This suggests that resistin may have a role in the control of fetal growth and may be involved in the regulation of appetite and the metabolic development of infants [41]. Insulin-like Growth Factor I (IGF-I), a polypeptide primarily produced by the liver, acts as the main mediator of growth hormone activity. Studies have identified growth factors in human milk, suggesting a potential role in promoting cell proliferation [52]. Additionally, IGF-binding proteins (IGFBPs) have been detected in the breast milk of both term and preterm infants [53]. The origin and function of obestatin, a peptide found in breast milk, are unclear, although it may influence appetite, gastrointestinal motility and neurobehavioral processes such as memory, sleep and anxiety [41]. Growth factors present in human milk play a critical role in facilitating the maturation of the intestinal mucosal barrier, providing both growth-promoting and protective effects to the immature neonatal gastrointestinal tract. In particular, vascular endothelial growth factor (VEGF), hepatic growth factor (HGF), and epidermal growth factor (EGF) are important contributors [29] [54].

In summary, hormones, growth factors, and metabolites present in breast milk interact to form a complex functional network, impacting the infant's overall development beyond the nutritional aspects alone. Nevertheless, despite substantial progress in the characterization of these compounds, their precise mechanisms of

action and long-term effects remain largely unresolved.

3.1.6. Microbes in Human Breast Milk

HBM has long been considered sterile, but recent studies have shown that it is a rich source of microbes that can have an impact on infants' health [55]. Microbes observed in the milk are mostly composed of mother's skin commensal flora elements, mother's digestive tract's bacteria and microbes of the child's mouth. They may also derive from the maternal mucosa-associated lymphoid tissue through a specialized homing mechanism. In this process, dendritic cells and macrophages are thought to transport microbes from the mother's mucosal surfaces to the lactating mammary gland. This microbiome is dynamic and factors implied in its composition are still not well understood. Some evidence suggests that lactation stage, mother's body mass index, mother's diet, and mother's antibiotic use play an important role in the modulation of milk microbiome [56]. Microbes in human milk play an important role in regulating cytokine production in the enteric nervous system and maintaining mucosal immune function in the infant [55] [57].

Given the major contribution of the mother's milk microbiome in the establishment of the child's gastrointestinal microbiome and its modulating effect on the child's immune system, it is determinant to avoid the disruption of milk microbiome that could alter the microbial balance, especially during the first 100 days of life [55]. However, it is important to take into consideration, the fact that pathogens can be transmitted from the mother to the child through breastfeeding. Indeed, viruses like human immunodeficiency virus, human papillomaviruses, Epstein Barr virus, cytomegalovirus, Human T-lymphotropic virus type 1, and Ebolavirus are pathogens that can be vertically transmitted from mothers to their breastfed children [58]-[60]. It is therefore recommended to stop breastfeeding when these pathogens are diagnosed.

However, recommendations regarding breastfeeding differ depending on the type of infection, maternal treatment, and clinical context, and should be guided by international guidelines and a careful assessment of risks and benefits [6] [61] [62].

3.1.7. MicroRNAs in Human Breast Milk

Epigenetic phenomena perform in a filigree manner a governance activity supervising a very wide range of metabolic reactions through mechanisms including histone modifications (acetylation, phosphorylation, methylation, and ubiquitylation), DNA folding, DNA methylation, acetylation, non-coding RNA such as microRNAs, etc... The epigenome is established early before birth, but it is regulated throughout the whole life with modifications and adaptations related to the age and the environment [63].

It appears that infants' epigenetic reactions could be influenced and potentially modulated or regulated through HBM. One of the most documented pathways of infant's epigenetics regulation is through microRNAs that have been shown to be present in an abundant amount in breast milk [64]. Despite the fact that these

microRNAs are exogenous to the infant, it is hypothesized that these small oligonucleotides may be absorbed by the infant's cells given that microRNAs are well known to be transferable from one cell to another in cell-to-cell communications or delivered through exosomes [65]. It is therefore possible that these microRNA observed in the milk may be absorbed by infant's cells and may exert their post-transcriptional regulation effect. However, direct evidence of their functional uptake and epigenetic effects in human infants remains limited [66]. It has been shown that the microRNA composition in the milk depends on several factors including mother's diet, maternal age, race, parity, mother's metabolic condition such as body mass index, gestational diabetes [67]. Overall, it is suggested that breast feeding may be also a way for the mother to transmit her epigenomic reactions to the infant.

The precise role of these breast milk containing microRNAs are not well known but it is established that they may play an essential role in the maturation of the immune system in infants, may protect against several pathogens by inhibiting their replication and also may help in shaping intestinal epithelial cells [35] [68]. In addition, some miRNAs may play a role in remodeling immune responses against microbial infections [69]. There is increasing interest in their potential ability to be transferred to offspring, as well as their specific involvement in the benefits of breast milk in the infant [70] [71].

3.2. Dynamics in the Composition of Breast Milk

With its unique composition of nutritional elements, immune and anti-infective factors, and enzymes, HBM covers the crucial developmental needs of early life [26]. Colostrum is the initial milk secreted by the mammary glands immediately after delivery, and is distinct in appearance, composition, and volume. The first days postpartum, colostrum appears typically thick with a yellow hue and is produced in low quantities [72]. Colostrum is recognized for its role in building up and strengthening the immune system of the newborn. In addition to its rich content in energy, minerals and vitamins, colostrum contains several antibodies. Colostrum also contains a substantial quantity of proteins, directly assimilable sugars (oligosaccharides), vitamins, minerals, and amino acids [72] [73]. Following this initial period, the secretory activation phase ensues, which is characterized by a "milk rush". This results in the mammary glands producing milk in greater volume [74]. This transitional milk, which is white-orange in color and less dense, is particularly rich in sugars and fats. It is considered that maternal milk is fully mature around one month after delivery [75]. This milk is designated as mature due to its relatively stable composition at this stage, despite continued influence from various parameters [74]. As the infant develops, the volume of milk produced continues to increase. Its composition then corresponds to the infant's age and needs. The quantity and quality of breast milk vary according to the mother's daily diet [76]. Despite the variability in composition, breast milk remains an optimal source of nutrition for infants, providing the nutrients and protective factors nec-

essary for their growth and development.

3.3. Effect of Breastfeeding on Infants and Maternal Health

Newborns are recommended to be breastfed within one hour after birth and be exclusively breastfed for the first six months of life. Exclusive breastfeeding means that infants receive only breast milk, without any additional food or liquid, including water [7] [77]. It is now well documented that the consumption of water, herbal teas, porridges, and solid foods by infants under 6 months carries an elevated risk of diarrhea morbidity and mortality [78]. Globally, enhanced breastfeeding practices could prevent deaths of thousands of children annually, with over half of these deaths occurring in infants under six months of age [79].

Apart from being advantageous to infants' wellbeing, exclusive breastfeeding has many benefits for the physical and emotional health of mothers as it strengthens the mother—child emotional bonds, and helps mothers to recover and prevent bleeding [80] [81]. Furthermore, it delays the resume of menstrual cycle, improves uterine involution, reduces the risk of postpartum depression by regulating cortisol circadian rhythms, and reduces the risk of breast and ovarian cancers [82]-[85]. Moreover, research has demonstrated that mothers who choose to breastfeed tend to lose more weight and present reduced risk of type 2 diabetes, cardiovascular diseases, and metabolic syndrome [86] [87].

3.4. Breastfeeding and the Double Burden of Malnutrition

Exclusive breastfeeding (EBF) is increasingly recognized as a key early childhood intervention to address the double burden of malnutrition (DBM), defined as the coexistence of undernutrition, micronutrient deficiencies and overweight/obesity over the life course. These different forms of malnutrition are interconnected by complex mechanisms operating throughout the life cycle, from infancy to adulthood [88].

EBF significantly reduces the incidence and severity of infections, particularly diarrheal and respiratory diseases, through the transfer of immunoglobulins, human milk oligosaccharides, and other bioactive factors. This protection reduces nutritional losses, preserves the integrity of the intestinal mucosa, and improves nutrient absorption, thereby breaking the vicious cycle of infection-malnutrition, the primary determinant of stunting and micronutrient deficiencies [89]. Exclusive breastfeeding also plays a key role in metabolic programming. With its specific composition and bioactive factors, breast milk modulates insulin sensitivity, adipocyte differentiation, and satiety signals. These mechanisms are particularly important in contexts where early undernutrition is followed by exposure to high-calorie diets, leading to the emergence of the double burden of malnutrition [88]. Meta-analyses conducted in this context show that exclusive breastfeeding and its duration are associated with a significant reduction in the risk of overweight and obesity in children [90] [91]. Exclusive breastfeeding influences later eating habits as well as behavioral regulation of energy intake. Breastfed infants are more likely

to develop the ability to self-regulate hunger and satiety than bottle-fed infants, who are at higher risk of overeating. Furthermore, exclusive breastfeeding is associated with a more appropriate introduction of complementary foods, both in terms of timing and nutritional quality, which limits early exposure to ultra-processed and energy-dense foods. Longitudinal studies also indicate that exclusive breastfeeding for at least the first six months is associated with a reduced risk of overweight and obesity through adolescence and into early adulthood [92]. Furthermore, recent data suggest that suboptimal infant feeding practices may simultaneously increase the risk of undernutrition and overweight, thereby illustrating the central role of nutrition during the first 1,000 days of life in the development of DBM. For example, cohort studies have shown that not breastfeeding is associated with an increased risk of underweight and obesity during early childhood [93].

3.5. Epidemiology of Exclusive Breastfeeding

Breastfeeding can take many forms, depending on medical indications, the mother's personal preferences or contextual constraints (Figure 1). Although exclusive breastfeeding is recommended as the optimal feeding standard for infants under 6 months, its practice varies considerably around the world and constitutes a complex area of study due to multiple factors that can modulate its practice.

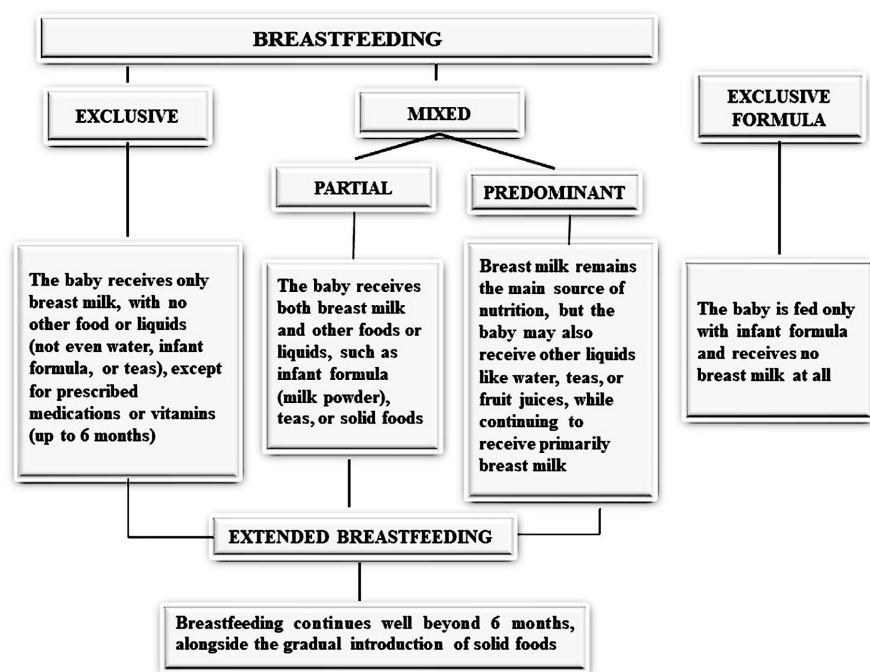


Figure 1. Type of breastfeeding.

At the global level, exclusive breastfeeding for infants under 6 months of age is practiced in ranges around 48% with low- and middle income countries showing the highest levels [94]. Variations in exclusive breastfeeding rates can be attributed

to cultural, socioeconomic, educational, and health practices factors. **Table 2** shows the rates of exclusive breastfeeding practice in 202 countries [95].

Table 2. Prevalence of exclusive breastfeeding in 2025 around the world.

Continents	Countries	Study Year	EBF Rate (%)	Evaluation Method
AFRICA	Algeria	2019	28.6	MICS
	Angola	2015	37.4	DHS
	Benin	2018	41.4	DHS
	Botswana	2017	30	Other
	Burkina Faso	2021	51.3	DHS
	Burundi	2022	85	SMART
	Cabo Verde	2018	41.8	DHS-Style
	Cameroon	2018	39.4	DHS
	Central African Republic	2019	36.2	MICS
	Chad	2022	7.4	SMART
	Comoros	2022	22.6	MICS
	Congo	2014	32.9	MICS
	Cote d'Ivoire	2021	34	DHS
	Democratic Republic of the Congo	2023	52.5	DHS
	Djibouti	2012	12.4	PAPFAM
	Egypt	2021	40.2	DHS-Style
	Equatorial Guinea	2011	7.4	DHS
	Eritrea	2010	68.7	Other
	Eswatini	2021	54	MICS
	Ethiopia	2019	58.8	IDHS
	Gabon	2020	19.4	DHS
	Gambia	2020	53.6	DHS
	Ghana	2022	52.6	DHS
	Guinea	2022	43.7	SMART
	Guinea-Bissau	2019	59.3	MICS
	Kenya	2022	59.7	DHS
	Lesotho	2024	60.7	DHS
	Liberia	2019	55.2	DHS
	Madagascar	2021	54.4	DHS
	Malawi	2020	64.1	MICS
	Mali	2024	40.3	DHS
	Mauritania	2020	40.9	DHS
Morocco	2017	35	PAPFAM	

Continued

	Mozambique	2022	55.5	DHS
	Namibia	2013	48.3	DHS
	Niger	2022	24.5	SMART
	Nigeria	2024	28.8	DHS
	Rwanda	2020	80.9	DHS
	Sao Tome and Principe	2019	63.1	MICS
	Senegal	2023	34.4	CDHS
	Sierra Leone	2021	50.9	SMART
AFRICA	Somalia	2018	33.7	DHS-Style
	South Africa	2016	31.6	DHS
	South Sudan	2010	44.5	MICS
	Sudan	2014	54.6	MICS
	Togo	2017	64.3	MICS
	Tunisia	2018	13.5	MICS
	Uganda	2016	65.5	DHS
	Zambia	2024	64.1	DHS
	Zimbabwe	2024	42.4	DHS
	Afghanistan	2022	63.3	MICS
	Armenia	2016	44.5	DHS
	Azerbaijan	2023	18.4	MICS
	Bangladesh	2022	53.3	DHS
	Bhutan	2015	53.2	NNS
	Cambodia	2021	50.3	DHS
	China	2017	35.1	Other
	Democratic People's Republic of Korea	2017	71.4	MICS
	Georgia	2018	20.4	MICS
	India	2020	63.7	DHS
ASIA	Indonesia	2017	50.7	DHS
	Iran (Islamic Republic of)	2017	47.4	NNS
	Iraq	2018	25.8	MICS
	Jordan	2023	23.9	DHS
	Kazakhstan	2015	37.8	MICS
	Kyrgyzstan	2018	45.6	MICS
	Lao People's Democratic Republic	2023	50.6	MICS
	Lebanon	2023	22.7	NNS
	Malaysia	2016	40.3	Other
	Maldives	2017	63	DHS

Continued

	Mongolia	2023	51.1	MICS
	Myanmar	2016	51.2	DHS
	Nepal	2022	56.4	DHS
	Oman	2017	23.2	NNS
	Pakistan	2018	47.8	NNS
	Philippines	2022	40.9	DHS
	Qatar	2012	29.3	MICS
	Sri Lanka	2016	80.9	DHS-Style
ASIA	State of Palestine	2020	38.9	MICS
	Syrian Arab Republic	2019	28.5	SMART
	Tajikistan	2023	40.8	DHS
	Thailand	2022	28.6	MICS
	Timor-Leste	2020	65	NNS
	Turkmenistan	2019	56.5	MICS
	Türkiye	2018	40.7	DHS-Style
	Uzbekistan	2021	25.2	MICS
	Viet Nam	2020	45.4	MICS
	Yemen	2013	9.7	DHS
	Albania	2017	36.5	DHS
	Belarus	2019	21.7	MICS
	Bosnia and Herzegovina	2012	18.2	MICS
	Croatia	1996	23.5	MICS
EUROPE	Montenegro	2018	19.5	MICS
	North Macedonia	2019	27.5	MICS
	Republic of Moldova	2012	36.4	MICS
	Romania	2004	15.8	RHS
	Serbia	2019	23.6	MICS
	Ukraine	2012	19.7	MICS
	Argentina	2011	32	MICS
	Barbados	2012	19.7	MICS
	Belize	2015	33.2	MICS
NORTHERN AMERICA; LATIN AMERICA AND THE CARIBBEAN	Bolivia (Plurinational State of)	2016	55.7	DHS-Style
	Brazil	2019	45.8	NNS
	Colombia	2016	36.7	NNS
	Costa Rica	2018	25.3	MICS
	Cuba	2019	40.6	MICS
	Dominican Republic	2019	15.8	MICS

Continued

	Ecuador	2004	39.6	RHS
	El Salvador	2021	45.3	Other
	Guatemala	2021	58.5	NNS
	Guyana	2019	28.5	MICS
	Haiti	2017	39.9	DHS
	Honduras	2019	30.2	MICS
	Jamaica	2022	33	MICS
NORTHERN AMERICA; LATIN AMERICA AND THE CARIBBEAN	Mexico	2021	35.9	Other
	Nicaragua	2012	31.7	Other
	Panama	2013	21.5	MICS
	Paraguay	2016	29.6	MICS
	Peru	2023	70.1	DHS-Style
	Saint Lucia	2012	3.5	MICS
	Suriname	2018	8.9	MICS
	Trinidad and Tobago	2022	30.5	MICS
	Turks and Caicos Islands	2020	-	MICS
	United States	2018	25.8	NHANES
	Uruguay	2018	57.7	Other
	Venezuela (Bolivarian Republic of)	1998	7.1	Other
	Fiji	2021	42.9	MICS
	Kiribati	2018	63.6	MICS
	Marshall Islands	2017	43.1	MICS- Style
	Nauru	2007	67.2	DHS-Style
OCEANIA	Papua New Guinea	2017	59.7	DHS
	Samoa	2019	51.7	MICS
	Solomon Islands	2015	76.2	DHS-Style
	Tonga	2019	39.6	MICS
	Tuvalu	2019	43.8	MICS
	Vanuatu	2023	75.9	MICS

3.6. Factors Limiting the Practice of Exclusive Breastfeeding

Despite its numerous advantages, exclusive breastfeeding encounters several obstacles in its applicability. Indeed, number of factors including sociodemographic and individual factors, access to care, beliefs, perceptions, education and social norms can limit mothers in their adoption of exclusive breastfeeding [96]. One of the most impactful limiting factors is the lack of information about exclusive breastfeeding but the professional obligations lead many mothers to abandon this practice. In addition, several mothers reported their fear to undergo morphologi-

cal changes such as breast ptosis related to breastfeeding. Mothers who work in public sometimes feel an embarrassment to breastfeed their infants leading them to opt for partial breastfeeding instead. This factor underlines the necessity to provide appropriate space for breastfeeding in public spaces and at work [97].

Mothers that do not exclusively breastfeed their infants have also pointed the delay in lactation, the production of insufficient amount of milk, breast pain and abscesses, twin pregnancies as obstacles to breastfeeding [98]. Availability of milk substitutes in some regions, especially in high-income countries and urban regions in low- and middle-income countries constitute a limiting factor to breastfeeding. Moreover, the use of substitutes is considered as modern in some regions [99] [100].

All these mentioned limiting factors show that interventions to improve the level of exclusive breastfeeding practice should take into consideration several aspects of mothers' life as well as social influence persons in addition to information sessions provided only to mothers

3.7. Methods for Assessing Exclusive Breastfeeding

The most commonly used method for the assessment of exclusive breastfeeding rates is the 24-hour recall. It consists on questioning mothers about all foods and liquids given to their infants in the previous 24 hours. In these surveys, a child is considered exclusively breastfed only if no food or liquid (including water) other than breast milk was consumed during the recall period [95]. The questionnaire approach is subject to social desirability bias which can be minimized by using additional evaluations such as anthropometry. Another limitation of the data produced by breastfeeding assessment surveys is the absence of a database on the amount of milk consumed by babies and the nutritional status of mothers. Furthermore, determining the amount of milk consumed by an infant is a methodological challenge. The conventional method for quantifying milk consumption is the differential weighing by measuring the weight of infants before and after each feeding. This method is time-consuming and can disrupt breastfeeding in addition to being an imprecise method of assessing milk intake in infants [101].

Evolutions in nuclear sciences allowed the development of a more robust method to measure milk intake. The method is based on the administration of deuterium to the mother and the quantification of the stable isotope tracer in infant's biologic fluids (saliva or urine). The method relies on the fact that the absorbed deuterium is diluted in the mother's body water including milk. During breastfeeding, the infant absorbs the deuterium which will also get diluted in the infant's water compartment so that, quantifying this deuterium in the infant's saliva or urine provides precise data on the quantity of consumed milk [102]. After several test studies, this method is now well established as a robust tool for the assessment of daily milk intake [103] [104]. In addition to providing quantitative data on consumed milk, the isotopic technique can also provide qualitative data on consumed milk. Indeed, it could help obtain data regarding the content of some nutrients as well as some toxic compounds including pesticides or trace el-

ements [105] [106].

The isotopic technique does not interfere with the infant's normal feeding schedule and allows for the estimation of the amount of water consumed by the infant, thus excluding water from sources other than breast milk and the mother's body composition. Its preciseness makes it the best tool to evaluate implementation programs and confirm the data obtained using the conventional 24 h recall [107]. It is important to mention that mothers have been shown to significantly overestimate their practice of exclusive breastfeeding whereas the deuterium dilution technique provides more precise data. Furthermore, this technique provides data on mothers' body composition as well as the influence of the body composition of these mothers on the quantity of breast milk consumed by their infants.

The availability of the IAIE database on breast milk intake that gathers data from around world obtained using this method increases the relevance of this technique as it allows better epidemiologic studies [108]. The method presents some limitations especially for its application in large scale studies in low- and middle-income countries where it is difficult to have access to deuterium oxide and equipment for its quantification. Among the two applicable platforms for deuterium quantification, the Fourier transform infrared spectrometry (FTIR) represents the most accessible and easily implementable system in comparison to isotopic mass spectrometry [109]. Overall, isotopic methods provide accurate results on water consumption from milk and other sources and mother's body composition. The technique generates a lot of data that can be used to evaluate breastfeeding practice but also the nutritional status of both mother and infant.

Different methods can be used to assess exclusive breastfeeding (EBF), depending on the objective of the evaluation. The 24-hour recall method is widely used in large-scale surveys and routine surveillance due to its simplicity, low cost and minimal logistical requirements, which make it suitable for population-level monitoring [110]-[112]. However, it may overestimate EBF prevalence because it only captures recent feeding practices [111] [113] [114].

In contrast, isotopic techniques, such as the deuterium oxide dose-to-mother method, provide a more objective, quantitative assessment of breast milk intake over a defined period and can identify non-breast milk water intake [112] [115] [116]. These methods are particularly valuable in research settings and program evaluations where precise measurement is required.

From an operational perspective, the 24-hour recall method requires trained interviewers and standardized questionnaires, whereas isotopic methods require specialized training, controlled dosing procedures, repeated sample collection over several days and access to laboratory infrastructure for isotope analysis [112] [115]. Therefore, the choice of method should balance accuracy needs with feasibility, resources, and the intended use of the data.

4. Conclusions

HBM is a dynamic nutritious food that is formed with the intend to provide in-

infants with all they need for proper development. Given its composition, this milk is not only a source of nutrients for infants, it is also an ideal route by which mothers continue to physiologically take care of their infants by helping in establishing the immune system and initiating epigenetic regulation as well as microbiome functions.

Given these advantages, exclusive breastfeeding during the first six months after birth is a relevant recommendation and national public health authorities should incorporate it in their priority actions. Exclusive breast feeding should therefore be evaluated regularly in order to shape public health strategies for effective outcomes, at least regarding the health of under five years old infants. This evaluation needs to be precise, non-invasive, cost effective, and minimize bias.

Acknowledgements

Conception and design of the study: MEK, TS./Acquisition of data: MEK, TS, DB./Data analysis and interpretation: MEK, TS, DB, EKA, EC, AEA, SKA./Article writing: MEK, TS, DB, EKA, EC, AEA, SKA./All authors read and approved the final version of this manuscript.

Conflicts of Interest

The authors declare no competing interests.

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