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A Comprehensive Review of Milk Types for Infant Feeding

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A B S T R A C T

This paper provides a comprehensive overview of various milk types suitable for infant consumption, drawing upon current scientific literature and major health organization guidelines. This paper deals with the pattern across several countries ranging across the globe. It takes into account different mammals such as buffalo, goat, sheep, horse, reindeer, etc apart from cow and discusses the nutritional composition, developmental benefits, and potential risks associated with each of the different species of mammalian milk along with breast milk, infant formulas, and alternative milks at different stages of infant development. The emphasis is on highlighting the gold standard of infant nutrition, breast milk, while also addressing the appropriate use and considerations for other milk sources when breastfeeding is not possible or insufficient.

Introduction

Milk is said to be nature's perfect food. Milk has become part of our daily diet not only for children but also for adults. It is one of the most highly nutritive and natural part. Milk also has a therapeutic role to play when consumed (Nagpal *et al.,* 2012). Milk is an excellent source of vitamin B2, A, D and calcium (Harton and Myszkowska-Ryciak, 2018). Milk is absolutely necessary for both children and adults alike. Milk if not taken in the right proportion can lead to drastic ill effects both in childhood and adulthood. Smaller stature, lower bone mineral mass, and increased fracture risk before puberty are the ill effects of not having milk in children. For adults especially in women after menopause there is a higher risk of osteoporosis after 50 years. It is underlined that the consequences of age-related or postmenopausal bone loss on fracture risk depend on the level of peak bone mass achieved during childhood and adolescence and the rate of bone loss (Rizzoli *et al.,* 2010). Infant nutrition is a critical determinant of short-term health and long-term developmental outcomes. The type of milk an infant receives profoundly impacts their growth, immune system development, and overall well-being (Mogla Achal Maharaj Kishore, *et al.,* 2020). This paper aims to synthesize current scientific understanding regarding the various types of milk that can be fed to infants, emphasizing evidence-based recommendations from leading health authorities worldwide.

Breast Milk: The Gold Standard

Breast milk is universally recognized as the best optimal and most complete source of nutrition for infants particularly during the first six months of life (Lessen and Kavanagh, 2015). The World Health Organization (WHO) and UNICEF recommend exclusive breastfeeding for the first six months, followed by continued breastfeeding with appropriate complementary foods up to two years and beyond.

Nutritional Composition

Breast milk is a dynamic biological fluid whose composition adapts to the infant's changing needs as they grow. It provides a perfect balance of macronutrients (proteins, fats, carbohydrates), micronutrients (vitamins, minerals), and bioactive components crucial for development. Some of the important facts about Breast Milk are given as under:

Proteins

Breast milk contains a lower protein content than cow's milk, with a higher whey-to-casein ratio (approximately 60:40) which is considered easier for infants to digest. This lower protein load is less taxing on the immature infant kidneys and supports a slower, healthier growth trajectory, potentially reducing the risk of obesity and related health issues in adulthood. Proteins not only provides nutrients but at the same time they promote gut development (growth factors, lactoferrin) help in nutrients absorption (bile salt-stimulated lipase, amylase, alfa1-antitrypsin), and possess immune and antimicrobial activity (Mosca and Giannì, 2017).

Fats

Human milk is rich in mono- and polyunsaturated fatty acids (PUFAs), including essential fatty acids like arachidonic acid (ARA) and docosahexaenoic acid (DHA), which are vital for brain and eye development. Fat content is also influenced by the Body Mass Index. This can be inferred from the finding that the amount of saturated fatty acids and the ratio of n-6 to n-3 fatty acids are higher in overweight women's breast milk than in normal weight women's breast milk, after taking into account maternal diet also (Mosca and Giannì, 2017).

Carbohydrates

Lactose is the primary carbohydrate and the most abundant readily available energy source present in breast milk (Andreas *et al.,* 2015). 6.7g/100 ml is the concentration of lactose, while the other major carbohydrates are the human milk oligosaccharides. Concentration of the human milk oligosaccharides ranges between 1-10 g/L in mature milk and 15-23 g/L in colostrum (Mosca and Giannì, 2017). Role of the human milk oligosaccharides is that they act as prebiotics, fostering the growth of beneficial gut bacteria and supporting gut maturation.

Bioactive Components

Beyond basic nutrition, breast milk is a living fluid containing a wealth of bioactive components: Some of the major bioactive components present in breast milk are MFGM, -lactalbumin, lactoferrin, and osteopontin (Sánchez *et al.,* 2021).

Immunoglobulins and Antibodies

Provide passive immunity, protecting infants against infections and allergies. There is a direct corelation between concentration of TGF-_ present in breast milk and immunoglobulins present (Ogawa *et al.,* 2004).

Lactoferrin

An iron-binding protein with antimicrobial and immunomodulatory properties. This is said to be one of the most abundant in breast milk, and plays an important role in prevention of different infections in neonates (Parra-Saavedra *et al.,* 2022).

Growth Factors, Hormones, and Enzymes: Contribute to organ development, digestive processes, and overall physiological maturation.

Upon extensive research it has been found that there are numerous short-term and long-term benefits of breastfeeding including Reduced incidence of respiratory infections, ear infections, gastrointestinal illnesses, and sudden infant death syndrome (SIDS), enhanced cognitive development, lower risk of allergies, asthma, and certain chronic diseases later in life (e.g., type 1 diabetes, obesity, cardiovascular disease), promotion of a healthy gut microbiome, emotional bonding between mother and infant. Maternal health is benefitted by breastfeeding in general in the short and long term, with longer duration of breastfeeding being linked to lower rates of metabolic syndrome and malignancies (Maximino *et al.,* 2024).

Infant Formulas: Human Milk Substitutes

When breastfeeding is not possible, insufficient, or chosen not to be pursued, commercially available infant formulas serve as the primary alternative. These formulas are designed to mimic the nutritional composition of breast milk as closely as possible, although they cannot replicate the complex bioactive components.

Types of Infant Formulas

Cow's Milk-Based Formula (First Infant Formula)

The most common type, made from cow's milk that has been extensively modified to be suitable for infants. The protein content is adjusted, and additional nutrients like iron, vitamins, and minerals are added to meet infant requirements. First infant formulas are typically whey-dominant, aiming for an easier digestion.

They are suitable from birth and often recommended as the sole formula until 12 months. With easier digestion it was found that Gastro Intestinal symptoms improved over time (Taitz and Armitage, 1984).

Follow-on Formula

Designed for infants aged 6 months and older, often with higher energy and nutrient content. However, research suggests that switching to follow-on formula at 6 months offers no significant benefits over continuing first infant formula, and many health organizations advise against it.

Comfort Formula

Contains partially hydrolyzed (broken down) proteins, intended for babies with minor digestive discomforts like colic or constipation. It is not suitable for babies with diagnosed cow's milk protein allergy.

Extensively Hydrolysed Formula

Proteins are broken down into much smaller peptides or amino acids, making them suitable for infants with diagnosed cow's milk protein allergy.

Amino Acid-Based Formula: Composed of individual amino acids, used for infants with severe food allergies or malabsorption syndromes.

Goat's Milk Formula

An alternative to cow's milk formula, also suitable from birth. While some parents believe it's easier to digest, it still contains similar proteins to cow's milk and good for infants who are allergic to cow's milk protein.

Soy-Based Formula

Made from soy protein, typically used for infants with lactose intolerance or galactosemia. However, it is generally not recommended as a first-line choice for infants with cow's milk protein allergy due to potential cross-reactivity and the presence of phytoestrogens.

Key Considerations for Formula Feeding

Iron Fortification: Infant formulas should be iron-fortified to prevent iron deficiency anemia.

Preparation and Safety: Strict adherence to preparation instructions (sterilization, water temperature, accurate measurement) is crucial to ensure safety and prevent bacterial contamination.

No Evidence of Superiority Among Brands: There is no scientific evidence suggesting one brand of standard infant formula is superior to another.

Other Milk Types and Their Suitability for Infants

Beyond breast milk and infant formula, certain other milk types are often considered, but their appropriateness for infants varies significantly with age and specific nutritional needs.

Cow's Milk (Whole Milk): Under 12 Months: Whole cow's milk should not be given as a primary drink to infants under 12 months of age because of several reasons given below

High Protein and Mineral Content: Too much protein and minerals can be difficult for immature infant kidneys to process, potentially leading to dehydration and increased renal solute load.

Low Iron Content and Poor Absorption: Cow's milk is low in iron and can interfere with iron absorption from other foods, increasing the risk of iron deficiency anemia and gastrointestinal blood loss.

Lack of Essential Fatty Acids: It does not provide the optimal balance of fatty acids necessary for infant brain and nervous system development.

Potential for Allergy: Early exposure may increase the risk of developing cow's milk protein allergy in some infants.

Over 12 Months: After 12 months of age, whole pasteurized cow's milk can be introduced as a main drink. Whole milk is recommended until age two to ensure adequate fat intake for brain development. Skimmed or 1% milk should not be given as a main drink until age five.

Goat's and Sheep's Milk (as a Drink): Similar to cow's milk, pasteurized goat's or sheep's milk should not be given as a main drink to infants under 12 months due to similar nutritional imbalances and potential for allergies.

They can be used in cooking for babies over 6 months, provided they are pasteurized. Goat's milk is deficient in vitamin B12, folic acid and even vitamin B & C (Vitoria, 2017).

Plant-Based Beverages (e.g., Soy, Rice, Oat, Almond Milks)

These beverages are generally not suitable as a primary milk source for infants under 12 months. They often lack the essential nutrients (protein, fat, vitamins, minerals) found in breast milk or infant formula to support healthy infant growth and development.

Soy beverages have found to have caused rickets and in case of rice beverages feeding the infants eventually led to kwashiorkor disease (Gantner *et al.,* 2015). Fortified versions may exist, but their nutritional profile is often inadequate compared to infant formula. Consult with a paediatrician before considering their use.

After 12 months, some fortified plant-based milks can be introduced as part of a varied diet, but their nutritional adequacy should be carefully assessed.

Condensed, Evaporated, and Dried Milk

These forms of milk are never suitable for infant feeding due to their altered nutritional composition and processing, which makes them inappropriate and potentially harmful for young babies.

The description of the various types of milk from different species given above is a qualitative one. Similarly, there were studies conducted quantitatively for the different species given above and quantitative analysis was simultaneously carried out. Analysis was carried out for several parameters such as TDM (g/100 g), Fat (g/100 g), Protein (g/100 g), Lactose (g/100 g), Ash (g/100 g), Energy (kJ/100 g) and the results were accordingly tabulated. It was found that lactose content was the highest in milk from women, mares, and donkeys (≥5.8 g/100 g) and lowest in milk from buffalos and goats (≤5 g/100 g). Protein content (0.9-1.9 g/100 g) was the lowest in women milk. The protein content of milk from mares and donkeys was intermediate (≥0.7 g/100 g), while milk from ruminants had the greatest protein content. The greatest protein content was found in milk from ewes (to 7 g/100 g). Also, there was a wide range of values for fat content. From ruminants, the greatest fat content was in milk from buffalos (max value 15 g/100 g) and the lowest in milk from cows (min value 3.3 g/100 g). The low-fat content was found in milk from donkeys and mares. The fat content of women milk (2.1-4 g/100 g) was greater than that of non-ruminants, but less than that of ruminants. Size of the milk fat globule was another factor which was compared amongst different species and it was found that smallest diameter is found for milk fat globules in mare's milk. (ranging from 2 to 3 µm). The largest diameter is associated to milk fat globules in buffalo's milk (ranging from 5 to 8.7 µm;). At the same time there was found to be a direct linear and positive correlation between the fat globule size and the fat content of milk. Fatty acids profile amongst different species was also studied. There were two major findings that could be found out: The amount of cholesterol in ruminants' milk (13.1-31.4 mg/100 mL from cows, 14-29.0 mg/100 mL from ewes, 10.7-18.1 mg/100 mL from goats, and 4-18.0 mg/100 mL from buffalos) was similar to milk from women.

The saturated fatty acids (SFA) and monounsaturated fatty acids (MUFA) were lower in milk from non-ruminants compared to that of ruminants, while the percentage of unsaturated fatty acids was higher. The amount of C-18:2 and C-18:3 was remarkably higher in milk of non-ruminants in comparison to ruminants. The cholesterol content was similar in milk from ruminants and women. However, cholesterol in milk from non-ruminants was notably lower (Roy *et al.,* 2020). In another study it was found that Ruminant milks have higher protein and fat contents, compared with human milk and other nonruminant milks. Human milk on the other hand contains much higher amounts of total lactose-derived oligosaccharides than milk from other species (Table 1). Similarly, milk is also known to have a relatively higher oligosaccharide content, the composition of which is considered to be similar to that of human milk.

Results and Discussion

Upon comparison it was found that remarkable differences among energy value, fat, lactose, protein and ash content were found when various milk species were compared as shown in Table 1 above. Some similarities among milk from ruminants (cow, buffalo, goat and ewe) and non-ruminants (mare, donkey). The structure of fat globule membranes, which significantly affects fat digestibility, contains similarities among milk from non-ruminants and women, while the same structure differs significantly in ruminants. The size of fat globules, which also affects fat digestibility, differs significantly among species and is highly correlated to the milk fat content. The diameter of the milk fat globule membrane is found in the range of 0.2 to 15μm (Achal Mogla *et al.,* 2020). The size of these fat globules varies among milk from different species; goat, sheep, camel, and equine (horse and donkey) milk have higher proportions of smaller size fat globules compared to cattle milk The amount of triacylglycerols was notably higher in milk from ruminants and women compared to milk from mares and donkeys, while the amounts of free fatty acids and phospholipids were notably lower. The triacylglycerol structure, affecting fat absorption, was found to be similar in milk from women and nonruminants. The saturated fatty acids (SFA) and monounsaturated fatty acids (MUFA) were lower in milk from non-ruminants compared to that of ruminants, while the percentage of unsaturated fatty acids was higher. The amount of C-18:2 and C-18:3 was remarkably higher in milk of non-ruminants in comparison to ruminants. The cholesterol content was similar in milk from ruminants and women. However, cholesterol in milk from non-ruminants was notably lower. Collectively, the overall milk composition, fat globule structure, and digestibility, suggests that milk from non-ruminants' milk might be more suitable source of human nourishment than milk from ruminants.

In Conclusion, Breast milk remains the unparalleled ideal for infant nutrition, offering a complete and dynamic source of nutrients and protective factors. When breastfeeding is not feasible, iron-fortified infant formulas are the recommended alternative, carefully designed to meet the unique nutritional needs of growing infants. The introduction of whole cow's milk or other animal milks should be delayed until after 12 months of age, and plant-based beverages are generally not suitable as primary milk sources for infants. Adherence to established feeding guidelines and consultation with healthcare professionals are paramount to ensuring optimal nutritional outcomes for infants.

Table.1 General Composition (g 100 mL−1) of milk from different mammalian species.

Properties	Cattle	Buffalo	Goat	Sheep	Red	deer*	Camel	Horse	Donkey
Total solids	11.8–13.0	15.7–17.2	11.9–16.3	18.1–20.0	20.0–30.5	11.9–15.0	9.3–11.6	8.8–11.7	10.7–12.9
Protein	3.0–3.9	2.7–4.7	3.0–5.2	4.5–7.0	5.9–10.6	2.4–4.2	.4–3.2	1.4–2.0	0.9–1.9
Fat	3.3–5.4	5.3–9.0	3.0–7.2	5.0–9.0	6.6-19.7	2.0–6.0	0.3–4.2	0.3–1.8	2.1–4.0
Lactose	4.4–5.6	3.2–4.9	3.2–5.0	4.1–5.9	2.6-6.2	3.5–5.1	5.6–7.2	5.8–7.4	6.3–7.0
Ash	0.7–0.8	0.8–0.9	0.7–0.9	0.8–1.0	1.04–1.18	0.69–0.9	0.3–0.5	0.3–0.5	0.2–0.3
Oligosaccharides	0.003–0.006	No data	0.025–0.030	0.002–0.004	No data	No data	No data	No data	0.500–0.800

Author Contributions

D. K. Chaturvedi: Investigation, formal analysis, writing—original draft. Mogla Achal Maharaj Kishore: Validation, methodology, writing—reviewing.

Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical Approval Not applicable.

Consent to Participate Not applicable.

Consent to Publish Not applicable.

Conflict of Interest The authors declare no competing interests.

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