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Human Milk: An Ecologically Functional Food

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1. Introduction

Breast milk is a valuable renewable resource that is often overlooked. Breastfeeding provides optimum nutrition for infant growth and development. It is considered the first line of defense for newborns because it is rich in soluble and cellular components that protect against gastrointestinal and respiratory infections (Hanson, 2001). Breastfeeding also has an economic value because it is one of the most efficient, cost-effective strategies to promote maternal and child health. In addition to being the safest and most natural way to feed a neonate, breastfeeding has been proven to protect neonates from a wide range of infectious and noninfectious diseases.

Extensive research using sophisticated epidemiologic methods and modern laboratory analyses has documented the diverse and compelling advantages conveyed by breastfeeding and the use of human milk for infant feeding. These advantages include health, nutritional, immunological, developmental, psychological, social, economic and environmental benefits (Honorio-França et al.,1997, Honorio-França et al., 2001, Hanson 2007, França et al., 2010, França et al., 2011a, França et al., 2011b). Several countries have published policy statements about breastfeeding and the use of human milk. Significant advances have subsequently occurred in both science and clinical medicine.

However, the ecological role of breastfeeding has not been extensively studied. Human milk is a unique food because it is produced and delivered to the consumer without pollution or wasteful packaging. It is a renewable resource and is beneficial in terms of nature conservation. Formula feeding, which is the substitute for breastfeeding, adversely affects the environment by depleting nonrenewable natural resources and causing damage at every stage of production, distribution and use (Hibbeln, 2002).

On the other hand, the environmental damage has been associated with the routine industrial and agricultural practices that are necessary for formula production. These industrial practices promote the destruction of areas covered by natural vegetation; waste electrical energy during the manufacturing process; accumulate a variety of packaging materials, such as aluminum and plastic; consume fuels for transportation and, finally, contribute to the expenditure of energy and water for formula preparation in millions of households (Krausmann, 2004).

Another important consideration is the presence of environmental contaminants in human milk. Some studies have reported high levels of environmental contamination in breast milk. These studies have focused on toxicants in human milk and their potential adverse effects on the breastfeeding child. However, the presence of environmental contaminants in human milk does not negate the advantages of breastfeeding (Lederman, 1996). Reduced breastfeeding would lead to increased infant mortality, increased demands on the health care system and an increased need for hard currency to buy more substitute infant foods, all of which would damage the environment. Rather than promoting formula feeding, public health professionals should mobilize the existing concerns about infant exposure to environmental contaminants through breast milk to help increase support for reducing the toxic environmental exposures of humans of all ages.

This chapter cites substantial new research on the importance of breastfeeding and describes the relationship between milk quality and various environmental, immunological, biochemical, pathophysiological and cultural factors. The chapter also discusses the environmental impacts of formula feeding and the environmental contaminants that affect milk quality and breastfeeding.

2. Cultural and behavioral aspects of breastfeeding

Breastfeeding has always been the gold standard for infant feeding. Throughout recorded human history, various populations recognized that breastfeeding was associated with reduced infant mortality, and evidence indicates that some populations did not survive due to artificially feeding their young (Eglash & Montgomert, 2008).

During the industrial revolution of the 20th century, many women left their children during the day to work in cities, and many children were fed not only with cow's milk but also a new product: infant formula. With pasteurization and refrigeration, the very high mortality rate of artificially fed infants declined, and artificial feeding became more popular.

Mothers assumed that formula feeding was a desirable modern option. Advertisements promoted the bottle as convenient and undermined the confidence of many mothers in their ability to feed their children. Although breastfeeding is considered instinctive, natural, and organic, some societal myths and taboos exist that should be abolished because they discourage mothers from breastfeeding their children. These myths include that the breasts sag or become deformed, stretch marks appear, the milk does not satisfy the infant, premature or low birth weight infants cannot be breastfed, the milk dries up, and breastfeeding mothers cannot exercise. The lack of knowledge among mothers led to them choosing not to breastfeed their children (Fujimori et al., 2008).

Although breastfeeding is a natural act, it is also a learned behavior. Research has shown that both mothers and health professionals need constant encouragement and support to maintain proper breastfeeding practices (Kent, 2007). Weaning is a social process, and as such, it should not be seen as an isolated, unicausal, timely act, except in very rare cases. Studies have shown that mothers and health care workers often cite the actual process of weaning as the "final cause". Weaning calls attention to the importance of "associated causes" (e.g., a "lactation crisis") that could lead to an interruption in breastfeeding for hours or days (Rea, 2004). Additional research should focus on the basic factors that trigger the weaning process and address the associated factors because without these factors, the terminal act does not occur (i.e., stopping the feeding of breast milk), and the weaning process is not entirely elucidated.

With increased scientific evidence of the risks of formula feeding and the incomparable benefits of breastfeeding, health organizations worldwide have published policy statements that affirm the importance of breastfeeding and the risks of artificial feeding for all populations. There is a growing movement among women and health professionals in many countries to re-establish infant feeding at the breast as the norm.

Breastfeeding babies and mothers are healthier, and breastfeeding has been shown to decrease health care costs for families, employers, and society. The education of health care professionals who work with mothers and infants regarding the dynamics of breastfeeding is necessary to allow them to effectively assist mothers. The recommendations suggest that every breastfeeding mother should have a health care professional observe at least one feeding while she is in the hospital or birthing center to ensure the proper transfer of milk to the baby and to decrease the risk of premature weaning (Bishara et al., 2008).

3. Maternal pathophysiological characteristics and breastfeeding: Influence during lactation

Mothers are the only source of nutrients for the fetus during development. Maternal nutritional deficiencies can engender a lack of critical nutrients during pregnancy with adverse consequences for both mother and infant.

The nutritional status of mothers should be evaluated during breastfeeding because it can affect the composition of the breast milk. It is particularly important for breastfeeding mothers to eat a well-balanced diet (Azizi & Smyth, 2009).

Deficiencies of iron and other minerals have been shown to have immunological and biochemical effects. The complexity of human milk makes it the ideal food source for babies for at least the first 6 months of their life. This early nutrition is an important environmental input that can exert lifelong effects on the metabolism and development of the child. The amount and composition of human milk is probably dependent of the diet of the mother (Shehadeh et al., 2006). Milk composition changes during lactogenesis and these changes can be used as biochemical markers of the onset of milk secretion. Importantly, normal infant development is sustained by the balanced gain of fat and calories provided by breastfeeding (França et al., 2010). Human colostrum is rich in biologically active molecules, which are essential for antioxidant functions. The soluble components of these molecules act in a child's gut without provoking an inflammatory response.

The relationship between the components of human milk and the maternal pathophysiological characteristics is a matter of debate. Some studies have suggested that maternal characteristics cause variations in the components of colostrum and milk, whereas others have reported that these changes in milk composition are caused by nutritional and disease maternal status (AAP, 2005, Zhanga et al., 2010).

Studies have attempted to elucidate the effects of lactation on maternal glucose metabolism. In this chapter, we address the effects of maternal hyperglycemia on the biochemical and immunological composition of colostrum (Morceli et al., 2011).

Colostrum has a low protein concentration in diabetic women, whereas in normoglycemic women, the protein levels are within the reference limits. In fact, protein and glucose levels in the colostrum of diabetic women are likely maintained at normal levels and at a constant ratio with capillary concentrations, which suggests that adequate glycemic control can correct any abnormalities in milk composition (Morceli et al., 2011, França et al., 2011b). The improper control of glycemia may have undesirable consequences, such as compromised breastfeeding due to a delayed lactogenesis transition from phase I to phase II (Oliveira et al., 2008).

The production of milk components changes in diabetic mothers due to alterations in glucose metabolism. Therefore, adequate maternal glycemic control is crucial in diabetic mothers to ensure both that the nutritional needs of their newborns are met and that the immunologic components are properly provided. Despite the potential abnormalities in the breast milk of women with diabetes or nutritional deficiencies, these women should be strongly encouraged to breastfeed their children (Morceli et al., 2011, França et al., 2011b). Not only is breast milk an excellent food source for newborns, it also decreases the high rates of maternal and infant complications. In addition, the growth rate of breastfed infants is related to the total amount of milk they consume rather than the concentration of fat, proteins or carbohydrates in the milk.

The importance of both maternal health and the role of breastfeeding in child development necessitate the development of new public health policies to promote nutrition education for mothers at risk of disease and to ensure high-quality milk for their children.

4. Influence of intrinsic factors on breastfeeding

The volume of breast milk produced does not vary significantly between population groups, with mothers in developing countries producing as much milk as mothers in developed countries.

Breastfeeding is economically valuable because it is one of the most efficient, cost-effective strategies for providing health benefits to both mothers and newborns. The composition of breast milk is dynamic, and it is influenced by intrinsic factors. The chemical composition of breast milk changes over time according to the nutritional needs of the infant; i.e., it adjusts to pregnancy stage (prepartum and postpartum) and time of day (night and day). The breast milk produced for premature infants has more protein and additional factors to protect the infant until the 30^{th} postpartum day (Delneri et al., 1997). Breast milk can be classified as early lactation (260 days of gestation), colostrum (1 to 7 days postpartum), transitional milk (7 to 15 days postpartum) and mature milk (after 15 days postpartum – Kent, 2007).

Colostrum is a yellow, viscous fluid rich in immunoglobulins, proteins, fat-soluble vitamins, minerals and leukocytes. Transitional milk is rich in proteins, enzymes, vitamins and minerals but has a lower leukocyte concentration. Mature milk consists mainly of water, which is sufficient for the needs of the child, in addition to proteins, carbohydrates, lipids, minerals and vitamins.

The constitutional differences of breast milk in the postpartum period suggest that this secretion shows chronobiological variation. Breastfeeding is important to ensure an adequate passive transfer of immunity and intake of nutritional components. Human colostrum and breast milk change as a function of both time of day and milk maturation, and this variation is important to mothers and to those responsible for the collection and distribution of milk in a human milk bank (França et al., 2010).

Intrinsic factors are responsible for the daily fluctuations in milk composition that increase progressively up to 3 months postpartum, and one theory posits that one of the roles of such rhythms in milk composition is to stabilize the circadian system of the newborn at a time when other means of stabilization (i.e., those functioning in adults), such as the rest-activity cycle, have not yet developed fully.

The temporal influence on circadian rhythms in the cellular, immunological and biochemical components of human milk suggests that human milk presents chronobiological variation that is influenced by changes during the postpartum period. The adjustment to pregnancy stage (prepartum and postpartum) and time of day (night and day) in the composition of human milk suggests an auxiliary physiological mechanism for the defense of the infant against infections because there is a predominance of immunological components in milk in the daytime when infants are most vulnerable due to contact with infectious agents. This variation might represent both an additional breastfeeding mechanism to improve newborn adaptation to environmental changes and an endogenous force promoting the establishment of biological rhythmicity in humans (França et al., 2010).

5. Immunological and environmental factors in human milk

In considering the immunological significance of the infant immune system, the maternal immune system, and the interaction between the two, various concepts and models must be considered, including innate and adaptive immunity, mucosal immunity, inflammatory and anti-inflammatory responses, active versus passive immunity, dose-response relationships, and the dynamic nature of acute immune responses.

The mucosal epithelia of the gastrointestinal, upper and lower respiratory, and reproductive tracts cover a surface area over 200 times greater than that of the skin. These surfaces are especially vulnerable to infection due to their thin, permeable barriers. The mucosal surface has many physiologic functions. The most important function of the collective mucosal surfaces is immunological: protection against microorganisms, foreign proteins, and chemicals as well as immune tolerance to many harmless environmental and dietary antigens.

Human milk has mucosal immunologic components that can change or interact with the environment and provide benefits for the infant (Brandzaeg, 2010). The most important contribution to the dynamic nature of breast milk is the mucosal associated lymphoid tissue (MALT) system. When an infant and mother are exposed to a potential pathogen within their environment, the mature maternal immune system can react more quickly and effectively than that of the infant. It is the dynamic nature of breast milk, with all its bioactive factors, and the interaction between the infant and maternal immune systems through breast milk that makes human breast milk a truly unique, incomparable, and ideal source of nutrition for infants.

The composition of milk is modified during feeding and according to any diseases experienced by the mother. Newborns lack the ability to launch effective immune responses against microorganisms, and for several months after birth, the primary defense against infections is the passive immunity provided by maternal antibodies. Colostrum and human milk have been thoroughly studied in recent years, ever since their protective role against infections was confirmed (Honorio-França et al., 1997, Honorio-França et al., 2001, França-Botelho et al., 2006, Lawrence & Pane, 2007, França et al., 2011a, França et al., 2011b). Human milk was first used clinically as a vehicle for the transfer of passive immunity, but its immune components are now known to be highly immunoreactive, exhibiting time-dependent alterations.

Human milk contains several immunoreactive proteins (e.g., IgA, IgG, IgM, C4, C3 and others) but is particularly rich in secretory IgA (SIgA). SIgA protects against a number of microorganisms by acting as an opsonin, blocking bacterial adherence to epithelial cells, neutralizing toxins and preventing viral infections (Honorio-França et al., 1997, Hanson, 2007). These functions are complemented by the antibodies IgM and IgG and particularly by complement proteins C3 and C4. SIgA in breast milk serves as an optimal antigen-targeted passive immunization of the gut of the breastfed infant. Breastfeeding is therefore the best defense against mucosal infection in developing countries. The protection offered by breast milk depends not only on levels of immunoglobulin or other immunoreactive proteins but also on the amount, timing and type of milk consumed by the infant.

In addition to antibodies, soluble bioactive components and anti-infectious factors, human colostrum also contains large amounts of viable leukocytes (10^9 cells / mL in the first days of lactation), especially macrophages and neutrophils. These cells produce free radicals and have phagocytic and bactericidal activity (Honorio-França et al., 1997, Honorio-França et al., 2001, França et al., 2011a, França et al., 2011b). In bacterial infections, phagocytes are known to be the main cell lineage in the host's defense.

Colostral phagocytes exhibit phagocytic activity and may be activated by stimulatory signals generated by milk antibodies, especially during the interaction between SIgA and its Fc receptor. These cells produce oxygen free radicals and present bactericidal activity after opsonization with SIgA with a rate equivalent to that of phagocytes from peripheral blood (Honorio-França et al., 2001; França et al., 2011b).

The significance of the biological activity of the soluble and cellular components present in human milk is of great importance because human milk contains the highest amount of these immunoreactive proteins and may represent a complete micro-environment in which both soluble and cellular components act together.

The rich nutrition provided by breast milk in early nutrition has lifetime beneficial effects on metabolism, growth, immunity, neurodevelopment and major disease processes. Breast milk also provides additional protection against intestinal and respiratory infections in infants. Mothers should therefore be encouraged to breastfeed their babies because this is an important strategy for prevention newborn infections.

Recently, attention has been focused on the environmental damage associated with routine industrial and agricultural practices. A developing ecology movement has stimulated scientific concern about these problems and focused attention on the possible association between breastfeeding and the environment.

Contaminants can influence the quality of human milk. Studies have reported the presence of persistent organic pollutants in particular dioxins and furans (Krausmann, 2004). These organic pollutants are created and released into the environment through industrial chemical processes, and they have been described as highly toxic substances capable of contaminating water, air, and soil. When these pollutants enter the food chain, they become a serious public health problem (Lederman et al., 1996).

Due to their high liposolubility, these organic pollutants accumulate in the fatty tissues of living organisms and deposit on the surface of plants, fruits, and vegetables, which are then ingested by humans and animals. The pollutants accumulate in fatty tissues and subsequently enter the breast milk. These pollutants can be transferred to the child through breastfeeding and have serious implications, including potentially carcinogenic effects.

Concerns about breast milk contamination have contributed to declining rates of breastfeeding. This reduction in breastfeeding has engendered an increase in the use of human milk substitutes. The increased use of Formula-fed has been associated with deforestation, erosion, pollution, climate change and waste materials. Promoting premature weaning contributes to the destruction of natural resources.

The process of industrial modernization is characterized by fundamental changes in the interaction between socioeconomic systems and their natural environments (Ferrari, 2007).

The use of products such as industrially produced baby food has increased the environmental impact.
Breastfed children and formula-fed children experience different rates of morbidity and mortality. There is evidence of short- and long-term benefits of breastfeeding. Artificially fed infants have significantly higher rates of acute otitis media, nonspecific gastroenteritis, severe lower respiratory tract infections, atopic dermatitis, asthma, sudden infant death syndrome (SIDS), and necrotizing enterocolitis than breastfed infants.
Breastfeeding also contributes to a decrease in the use of industrialized milk, bottles and other products that damage the environment. Breastfeeding is an ecological act because it contributes to the environment by promoting an environment for current and future generations that enhances their quality of life and lowers their risk of malnutrition and infection.
The importance of breastfeeding to child development necessitates the development of new public health policies to support decreased levels of environmental contaminants for mothers living in high-risk areas and to ensure high-quality breast milk for their children.

6. Conclusion

Although both rates of breastfeeding and the composition and quality of human milk are influenced by cultural, behavioral, pathophysiological, intrinsic, immunological and environmental aspects, women should be strongly encouraged to breastfeed their children. In addition to being an excellent food source for newborns, breast milk decreases the high rates of maternal and infant complications. In addition, the growth rate of breastfed infants is related to the total amount of milk they consume rather than the concentration of fat, proteins or carbohydrates in the milk because breast milk is the most ecologically sound source of nutrition.
Breastfeeding is an ecological act because it supports an environment for current and future generations that enhances their quality of life and lowers their risk of malnutrition and infection.

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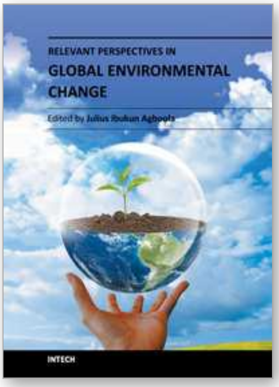

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Over the years, environmental change has sharpened significant dynamic evolution and knowledge in organizational structures of organisms, from cellular/molecular to macro-organism level including our society. Changes in social and ecological systems due to environmental change will hopefully result in a shift towards sustainability, with legislative and government entities responding to diverse policy and management issues concerning the building, management and restoration of social-ecological systems on a regional and global scale. Solutions are particularly needed at the regional level, where physical features of the landscape, biological systems and human institutions interact. The purpose of this book is to disseminate both theoretical and applied studies on interactions between human and natural systems from multidisciplinary research perspectives on global environmental change. It combines interdisciplinary approaches, long-term research and a practical solution to the increasing intensity of problems related to environmental change, and is intended for a broad target audience ranging from students to specialists.

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