THE PHYSIOLOGICAL AND NUTRITIONAL EFFECTS OF DIFFERENT TYPES OF MILK ON THE HEALTH OF INFANTS, CHILDREN, AND ADULTS

By

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Abstract

This literature review compares the physiological and nutritional benefits and detriments associated with different types of milks and their impacts on the health of infants, children, and adults. After the background presentation, the history of milk production, quality, and accessibility and their impacts of milk choices are reviewed. For infants, breastfeeding is commonly accepted as the best source of nutrition. In some situations, people choose alternative sources. Therefore, a section of the literature review analyzes factors that influence the process of breastfeeding and weaning. These factors include cultural norms, socioeconomics status, education, and health conditions. After covering the social aspects, the nutritional compositions of human breast milk and their physiological benefits are presented. The nutritional aspects of breastfeeding alternatives or formulas are also compared to determine the optimal source for infants. After weaning, humans rely on non-human milk sources. Therefore, the nutritional aspects of animal milks - cow, goat, and sheep and plant-based milks – soy and almond were compared. Finally, the impact of human modification of milk quality is analyzed to further understand the variety of milk choices present. Overall, both cultural and physiological conditions are considered to understand the benefits and detriments associated with each type of milk.
Background

Milk culture has flourished throughout human history. From the beginning of life, milk serves a source of nutrients. For most infants, breast milk is the only source of nutrition. After infancy, children rely only partially on milk for nutrition and parents may choose non-human milk sources. There are many different sources for people to choose from. The nutritional and physiological benefits associated with milk differ based on the source and production of milk. Some of the common types of milk include cow, goat, sheep, soy, and almond milk. The physiological and nutritional effects of different type of milk sources on the health of infants, children, and adults will be examined in this literature review.

History of Milk

History of Different Types of Milk Production

To understand the importance of milk in the human society, it is useful to review the history of milk production. Various types of milk production have been present throughout the human history. Some of these include small-scale productions, specialized milk production in large commercial diaries, dairy ranching, urban dairies, and pastoralism (Park et al 2013). Each of these strategies has its own positive and negative aspects. Economic conditions can impact the choice of milk production that prevails in a particular society. Small-scale productions excel in agricultural societies where both livestock and milk production are critical for economic success. On the other hand, large commercial diaries are more successful in industrialized countries “where optimal use of limited agricultural resources does not have to be considered” (Park et. Al 2013). This allows large commercial diaries to optimize milk output without
consideration for resource limitations. These large industries utilize all of their resources to optimize the quality of milk. Apart from the economic aspect, some production settings, such as dairy ranching, use milk production as a secondary resource (Park et. Al 2013). Dairy ranching focuses on raising young feeder stock. To accomplish their goal of raising livestock, dairy ranchers only sell cow’s milk if the amount of milk available exceeds the calf’s energy requirements (Park et. Al 2013). This limits the amount of milk used by people who rely on dairy ranching for their milk supply. Though the quantity is limited in dairy ranching, the quality of the milk is better because the cattle is well nourished resulting in better milk output (Park et. Al 2013).

**History of the Quality of Milk**

Apart from the origin of milk production, it is also important to analyze the history of infectious diseases that can originate from the production quality of non-human milks (Leedom 2006). Milk of non-human origin can contain infections due to the environment of milk production and the source of milk. Environmental infections arise through the use of contaminated milking equipments, unclean cleaning water, or contaminated milk storage containers (Leedom 2006). Some infections can also arise through animal’s conditions such as commensal or pathogenic flora of the udder, animal’s skin, or soiling of the udder through fecal contamination (Leedom 2006). To eliminate these infectious organisms from different milks, milk industries utilize improved water supplies, public health and hygiene, and pasteurization. Leedom (2006) highlights the difference between pasteurized and raw milk. Pasteurization of milk is “the most common method of decontamination”. Even though pasteurization does not completely sterilize milk, pasteurization is considered “a key safety factor” because it eliminates
most contamination by killing potential pathogens (Leedom 2006). The process of pasteurization involves heating milk at 63-66°C, depending on its fat content, for 30 minutes and then cooling milk through refrigeration to the temperature of 10°C (Leedom 2006). If pasteurization occurs in ultra-high temperature (138°C for 2s), then refrigeration is not needed because most of the temperature dependent bacteria have already been eliminated (Leedom 2006). The process of pasteurization varies based on state laws. Pasteurization is not always a guarantee of safety. For example, there was a listeriosis outbreak in 1983, which was due to the presence of *L. monocytogenes* in pasteurized milk. In addition, the refrigeration of pasteurized milk provides an ideal environment for the proliferation of *L. monocytogenes*, which correlated to the spread of listeriosis (Leedom 2006). Outbreaks can be prevented if the pasteurization temperature is higher than the minimum temperature leading to elimination of the contaminating organism.

Compared to pasteurized milk, raw milk causes more milkborne disease outbreaks. This is evident from a 1995 infection incident that took place in the 28 states where raw or unpasteurized milk sales were permitted (Leedom 2006). Unpasteurized milk consumption, specifically “milk of cows and goats”, promotes transmission of “tickborne encephalitis, a zoonotic arbovirus infection” (Leedom 2006). Leedom (2006) presents past outbreaks to highlight the importance of milk pasteurization. Infections proliferate due to the environmental conditions of milk production agencies that vary based on sanitation, natural climate, and availability of necessary equipment. If infections proliferate in various milk production settings, they can also be transferred to other dairy products such as butter and cheese. Even though pasteurization does not completely eliminate outbreaks, it is currently the best option present.
The quality of milk production also depends on the physical surroundings of the system (Park et. Al 2013). Urban dairies and pastoralist societies demonstrate this. Urban dairies located near the center of major cities tend to sell pure milk for the surrounding population because the dairies were initially established by traders to meet the local demand for clean fresh milk by keeping the milk safe from environmental infections (Park et. Al 2013). On the other hand, pastoralists’ production of milk depends on the location of pasture for their herd. If the herd grazes in a healthy pasture, the quality of production and amount of milk produced is enhanced. However, since pastoralism is practiced by nomads, the quality of the pasture does not stay constant (Park et. Al 2013).

**History of Milk Accessibility**

Not everyone prefers or can benefit from pasteurized milk. Different cultural understanding and biases influence accessibility of milk. For example, Leedom (2006) includes a statement from the managing director of a cheese monger, which underlines the personal or cultural preferences present in some societies regarding the quality of raw milk. The statement states, “Good cheese can be made from pasteurized milk. Exceptional cheeses can be made only from raw milk” (Leedom 2006). This statement demonstrates the view of raw milk as the “exceptional choice”. Through many lay publications, it is evident that some people view raw milk with a higher standard than pasteurized milk (Leedom 2006).

Individual physiological issues such as lactose intolerance can affect accessibility of milk. To digest lactose, milk sugar, lactase enzymes must be present in the brush border of the small intestine enterocytes (Swagerty et al. 2002). Many people either lack or are deficient in the amount of lactase present in their body. Lactase enzyme production in the small intestine can
decrease with age. Lactose intolerant individuals suffer from many gastrointestinal symptoms such as abdominal pain, bloating, diarrhea, and excessive flatulence (Swagerty et al. 2002). On the other hand, in some subpopulations, individuals have a greater genetic capacity to maintain the expression of lactase enzymes even during later stages of life. The genes that enable this trait are called lactase persistence alleles (Enattah et al. 2008). Generally, the presence of the T\textsubscript{13910} variant allele in the lactase gene is used as an indicator of lactase persistence in a global population (Enattah et. al. 2008). The lactase gene also contains C\textsubscript{13910} allele, which works together with T\textsubscript{13910} to provide lactase persistence. C/T\textsubscript{13910} alleles are together referred to as a haplotype (Enattah et. al. 2008). A haplotype is a set of DNA variations that are inherited together and transferred throughout generations. Enattah (2008) analyzed the presence of two different types of lactase persistence alleles, C/T\textsubscript{13910} alleles and C/T\textsubscript{3712}. The history of these alleles and its correlation with the milk culture demonstrates how it impacts human physiology. The presence of different genes either promotes or limit lactose persistence in Euro-Asian and Saudi Arabian population. Many different milk cultures in these populations are used to explain the genetic variations present among them. A study on 124 Saudi Arabian subjects and 143 subjects from 12 different populations from around the world, determined that the Saudi Arabian population has two different genes that are responsible for promoting their lactose persistent characteristic (Enattah et al. 2008). The Saudi Arabian population has C/T\textsubscript{13910} haplotypes. This explains the lactase persistence observed in this society. The alleles differences between Euro-Asian and Saudi Arabian population may be due to the difference in their histories of animal domestication and dairy culture. The Saudi Arabian population allele variation correlates with the domestication of camels and the consumption of camel milk
10,000 years ago (Enattah 2008). Where as, the European allele mutation arises due to their domestication of cattle 5,000-10,000 years ago (Enattah 2008). The correlation between the allele age estimates and domestication of different animals in these population serves as evidence of the influence of various milk culture on human genetic makeup.

**Factors Influencing Breastfeeding and Weaning Process**

The process of breastfeeding provides bonding between mother and her infant (Liamputtong 2007). It can provide a natural form of birth spacing through lactational amenorrhea, which enables mother to recover her health after her energetically expensive pregnancy. The globally recommended scientific optimal duration for breastfeeding is about 4-6 months. Breastfeeding have many effects on infant “growth, iron status, morbidity, atopic disease, and motor development”. Furthermore, breastfeeding may influence the mother’s health by impacting her postpartum weight loss and, contributing to lactational amenorrhea (Kramer et. al. 2004). Breastfeeding for 6 months is, on average, more beneficial than 4 months for both mother and infant (Kramer et. al. 2004). This conclusion is based on research accumulated using two controlled trials and 17 observational studies performed in different geographic locations; including developing countries (Chile, Philippines, Peru, Honduras, Bangladesh, Senegal) and developed countries (Sweden, United States, Finland, Belarus, Australia) (Kramer et. al. 2004). While breastfeeding for 6 months is, generally, beneficial for both mother and child, exclusive breastfeeding can lead to iron and vitamin D deficiency, depending on the mother’s health. Therefore, iron and vitamin D supplements can counteract the hematologic complications that can occur due to deficiency of these nutrients (Kramer et.
al. 2004). In some countries, such as Belarus, exclusive breastfeeding resulted in reduction in risk of one or more episode of gastrointestinal infection in infants (Kramer et. al. 2004).

Since breastfeeding becomes less practical as infants age, the concept of weaning comes into play. Also, breast milk cannot satisfy all the nutritional needs for children, as they get older. The process of weaning is divided into two parts: introduction of non-breast milk food to the baby and complete termination of breastfeeding (Liamputtong 2007). Both breastfeeding and weaning process work together to influence children’s physiological development. Many factors have to be considered to determine the proper weaning time. Therefore, scientists consider the “weanling’s dilemma”, a debate over the optimal duration of exclusive breastfeeding before starting the weaning process (Kramer et al. 2004). This dilemma considers the pros and cons associated with exclusive breastfeeding to meet the nutritional requirements for infants after 4 months of age (Kramer et al. 2004). Even though breast milk has many protective qualities for infants, exclusive breastfeeding, from a scientific perspective, might not meet the micronutrient requirements of infants after 4-6 months of age (Kramer et. al. 2004). Apart from the scientific perspective, the timing of weaning is influenced by different circumstances such as cultural norms, socioeconomics statuses, and education.

**Cultural Norms**

Different cultural societies have different weaning practices based on their religious and societal structures. For example, women from Thailand and Pakistan believe that colostrum, milk produced immediately after birth to 5 days after birth, is beneficial for the development of their infants. On the other hand, people from the Republic of Buinea-Bissau in Africa view colostrum as “dirty”. Cultural influence can also be seen in the Malawi where there are many
mothers with HIV/AIDS. Because of their condition, HIV/AIDS infected women are advised to exclusively breastfeed their infants in the first 6 months because this period has lower risk for the transmission of the virus to the infant (Park et. al. 2013). Due to these different beliefs, children are introduced to breast milk during different stages of their lives (Liamputtong 2007). Termination or prolongation of breastfeeding also depends on cultural, socio-economical, and religious practices. A cross-cultural analysis of weaning practices can be used to promote creation of “culturally appropriate health services for immigrant communities in multicultural societies” (Liamputtong 2007).

**Socioeconomic Status**

Socioeconomic perspectives influence weaning practices. The influence of socioeconomic status is not only evident in weaning practices, but also in the health of the infants. Kalanda, Verhoeff, and Barbin (2006) analyzed the effects of breast-feeding on the growth, morbidity incidence, and risk factors for undernourished infants of low socioeconomic status in Malawi. The researchers compared these factors for infants, who received complementary feeding consisting of anything other than human breast milk, before 3 months of age, to those who received complementary feeding only after 3 months of age (Kalanda 2006). Complementary food consisted of “Phala”, local porridge. Infants who had early introduction to complementary food had more infections. Most of the mothers practicing early complementary feeding were illiterate. Kalanda, Verhoeff, and Barbin (2006) concluded that breast-feeding promotion programs should be introduced in these communities. Although the research is targeting a Malawian community, it may be applicable to other low-socioeconomic communities with lower educational status.
**Education**

The relationship between the impact of education and socioeconomics status on infant feeding practices was also the basis for a yearlong analysis of individuals using “focus group interviews” to “obtain data on the physical and food environments, culture and nutritional practices of communities” (Kruger and Gericke 2002). This research focused on mothers or caretakers from various educational backgrounds and their nutritional attitudes. Thus, their replies demonstrate the impact of education on people’s perspective towards choice of milk, feeding and weaning practices. Since the purpose of this research is to determine “baseline data on the nutritional practices of a rural community”, it maybe applicable on a larger scale (Kruger and Gericke 2002). The researchers interviewed focus groups using six different topics: general knowledge on infant feeding and health, breast-feeding, bottle-feeding, weaning, nutritional knowledge, and attitude towards nutrition. Interview responses were recorded under eight different categories: environment, health evaluation, subject-specific, types of feeding methods, feeding time, methods of feeding, volume fed, reasons and correctness of various feeding methods. The organization of the interview responses of six different focus groups allowed the researchers to determine that adhering to cultural taboos, due to the lack of proper nutritional knowledge, resulted in poor-quality feeding practices.

**Health Conditions**

There are many different types of formulas that can be utilized by mothers who cannot breastfeed their children. Working women in western societies wean their infants with milk formulas due to their busy schedules. In some cases, diseases and other health concerns found in mothers or infants can prompt the need for milk formulas. Chandra (1997) tested the effects
of breast milk, partial whey hydrolysate formula, cow’s milk formula, and soy formula on the prevalence of different atopic disease and allergies among 288 high-risk infants. Atopic diseases include a variety of allergic diseases such as eczema, asthma, and conjunctivitis. These infants were given breast milk or one of the formulas until 6 months of age. The mothers who chose to restrict their intake of common food antigens, such as dairy products, eggs, peanuts, and soy, during their pregnancy enhanced the prevention of allergic disease for the infants (Chandra 1997). This strategy of restriction works in favor for both formula fed and breastfed infants. Some high-risk infants with a family history of atopy were formula fed in an attempt to minimize the transfer or allergic diseases. Even with these interventions, atopic eczema and asthma can arise due to infant’s hyperallergic condition. Five years after this test was completed, a follow-up study was conducted to observe the impact of different formulas on the incidence of atopic diseases. Overall, the use of partial whey hydrosylate formula or exclusive breastfeeding is associated with a lower incidence of allergic manifestation for infants with a family history of atopic diseases (Chandra 1997).

From a proactive perspective, mothers who are themselves allergic to milk should consider using hypoallergenic milk themselves to avoid transferring their allergies to the infants. Frieri and Kettelhut (1999) report the impact that different foods have on the human immune system by analyzing pathogenic pathways. Allergens can be passed on to infants through intrauterine sensitization or breast milk. Intrauterine sensitization occurs when immunogenic fractions of food women consume during pregnancy gains access to the placental circulation. This results in sensitization of the fetus in utero. Sensitization in utero or through breast milk can lead to allergies towards milk or other substances (Frieri and Kettelhut 1999). If
sensitization does occur, parents can utilize hypoallergenic formulas such as soy formula or extensively hydrolyzed casein or partially hydrolyzed whey hydrolysate formulas.

**Nutritional Composition of Human Breast Milk**

Generally, breast-feeding is considered the best option for infants. Breastfeeding has both physiological and social benefits. Breast milk is composed of nutrients that provide protection against infections for infants while reducing the risk of postpartum hemorrhage for the mother (Liamputtong 2007). Human breast milk contains the highest concentration of carbohydrates compared to other commonly consumed animal milks such as cow, sheep, or goat milk (see Table 2). These high amounts of carbohydrates present in the milk provide infants with the necessary nutrients for growth. The protein composition of human milk is also significantly different from other animal milk. For example, human milk has a greater portion of whey protein compared to casein proteins that are more prominent in cow’s milk (“Infant Formula” 2004). For infants, whey protein has considerably higher physiological benefits than caseins because it is more easily digestible and thus results in higher nutrient absorption (“Infant Formula” 2004). Even though human breast milk contains more fat than other mammalian milks, it also contains lipases that compensate for the lack of pancreatic lipases in immature infants (“Infant Formula” 2004). This improves the rate of fat absorption in infants (“Infant Formula” 2004). These qualities make human breast milk more biologically active and thus more physiologically beneficial for infants.

Human breast milk is also composed of unique dietary nucleotides, which are nonprotein nitrogenous compounds. Singhal (2010) presented a controlled trial with infants
who were randomly assigned to either a formula fed group, dietary nucleotide-supplement formula fed group, or a breastfed group. Human dietary nucleotides were supplemented in the infant formula to test the impact of nucleotides on infant growth. Breastfed infants served as a reference group. To compare the growth of infants in the formula fed groups, researchers measured infant’s occipitofrontal head circumference, weight, and length at birth and then every eight weeks until the age of 20 weeks. Milk formulas supplemented with human dietary nucleotides promoted greater physiological development than formulas without these supplements. Infants fed dietary nucleotide supplemented formula milk had increased weight gain, length, and head growth compared to infants who were fed non-supplemented formulas. Breastfed infants had the best outcomes, further supporting the benefits of human breast milk over nucleotide-supplemented formula.

Human breast milk also contains human milk oligosaccharides (HMOs), which further distinguish human breast milk from other non-human milk. Human milk oligosaccharides are structurally diverse unconjugated glycans that are unique to human milk (Bode 2012). Other animals have oligosaccharides as well; however, their oligosaccharides are not as complex or structurally diverse as HMOs. Cows, goats, and sheep have oligosaccharides, but their concentration is 100-1000-fold lower than that in human milk (Bode 2012). HMOs are composed of five types of monosaccharaides- glucose, galactose, N-acetylglucosamine, fucose, and sialic acid (Bode 2012). HMO profiles vary for every woman (Bode 2012). Genetic, cultural, nutritional, and environmental variations influence the types of HMOs present in breast milk. (Bode 2012). HMOs are synthesized in the Golgi apparatus using the same process as lactose since every type of HMO can carry lactose at their reducing end (Bode 2012).
HMOs are soluble decoy receptors that prevent pathogen attachment to infant mucosal surfaces to lower the risk of viral, bacterial and protozoan parasite infections (Bode 2012). Due to their complexity, human milk oligosaccharides serve as bifidogenics, prebiotics, natural protectors against necrotizing enterocolitis (NEC), antiadhesive antimicrobials, immune modulators, and promoters of brain development. Bifidogenics promote growth of desired bacterial communities in the infant’s intestine. Prebiotics allow specific changes in composition and activity in the GI microflora that lead to benefits for both mothers and infants (Bode 2012). HMOs prevent infants from NEC, which is one of the most common fatal disorders for infants. Apart from being beneficial for infants, HMOs could also be considered beneficial for the breast-feeding mothers. HMOs can serve as antiadhesive antimicrobials and reduce microbial infections because HMOs mimic mucosal cell surface receptors, where pathogens invade and bind to infect the body. This reduces the risk of infections by preventing pathogen binding to the actual mucosal cell surface (Bode 2012). HMOs also operate as immune modulators in bacterial communities of milk in the mammary gland. HMOs can directly modulate immune responses in vitro by either acting locally on cells of the mucosa-associated lymphoid tissues or on a systemic level (Bode 2012). Both local and systemic interference enhance the immunity of the both the infant and the mother. HMOs can also be considered as nutrients for brain development. Sialylated HMOs contain Sia-containing gangliosides and poly-Sia containing glycoproteins (Bode 2012). The presence of these Sia nutrients promotes brain development during pre and post-natal stages (Bode 2012).
**Nutritional Composition of Different types of Milk Formulas**

Women who do not breastfeed may use different types of milk formulas. In this thesis, three types of milk formulas, whey hydrolysate, cow, and soy, are analyzed. Partial whey hydrolysate formulas are made of proteins that are partially broken down or hydrolyzed. These are given to hyperallergic infants who have trouble tolerating caseins in cow’s milk. Whey proteins are more easily digested since their composition mimics human milk (Owens et. al. 2013). Partial whey hydrolysate formulas typically consist of less protein than soy formula, but more than human breast milk and cow’s milk (See Table 1). Moreover, partial whey hydrolysate formula has almost the same amount of fat and carbohydrates as soy and cow’s milk formula. Breast milk and partial whey hydrolysate formula are better than cow’s milk and soy formulas at lowering incidences of atopic allergies (Chandra 1997).

Formula companies have started to supplement galactooligosaccharides (GOS) and fructooligosaccharides (FOS), types of HMOs substitutes, in various infant formulas. These oligosaccharides are synthesized using lactose and fructose. The combinations of these sources have some beneficial influence on the microbiota composition, as observed from infant’s feces.

**Nutrient Analysis of Non-Human Milk**

Breast milk is important and recommended for infants. However, after the age of infancy, children will rely on other types of milk sources. Parents may choose a particular type of milk based on a combination of nutritional, cultural and socioeconomical factors. Therefore, it is important to consider the content of different types of milk and their impact on physiological development. Milk composition varies depending on factors such as the type of
species, species’ health status, species’ environmental factors, and species’ stage of lactation (Park et. Al 2013).

This thesis will examine the nutritional compositions of five different types of non-human milks - cow, goat, sheep, soy, and almond. For these five different sources, the amount of calcium, vitamin D, lipids, proteins, and carbohydrates will be compared (See Table 2). Physiologically, each of these components works together to enhance the quality and the benefits of the type of milk. Calcium constitutes the mineral aspect of bone and teeth. It also influences blood pressure, muscle contraction, blood clotting, and cofactor of enzymatic system (Park et. al. 2013). For calcium to be physiologically beneficial in the human body, Vitamin D is essential. Vitamin D regulates the calcium availability in the whole body by stimulating calcium absorption in the small intestine, and stimulating calcium resorption in bone through osteoclastic activity or resorption in kidney (Park et. al. 2013). Lipids come in various forms. The smaller the micelles, the more easily it can be digested and absorbed. Micelles are spherical aggregates of lipids in fluid created due to their amphipathic nature. Proteins are polymers of different amino acids that perform various function in living organisms. The amount and type of protein a type of milk contains contributes to its physiological benefits. Different types of milk contain different amounts and types of carbohydrates. Lactose serves as the most dominant type of carbohydrate in most types of milks (Park et. al. 2013). All of the types of milks contain some amount of folate, a synthetic form of the vitamin, folic acid, which is needed for growth and development (Park et. al. 2013). Folate deficiency can lead to many different health issues for both the fetus and mother during pregnancy. Pregnant women who are folate-deficient are at increased risk of having children with prematurity, low birth weight,
neural tube defects with spina bifida, and occasionally anencephaly (Park et. al. 2013). Folate deficiency can cause megaloblastic anemia, which leads to “enlargement of erythrocytes and bone marrow cells due to reduction in DNA, RNA and protein synthesis” (Park et. al. 2013). Since folate influences homocysteine metabolism, folate deficiency is a risk factor for coronary heart disease because it increases plasma homocysteine concentration by limiting the segregation of methionine, an amino acid (Park et. al. 2013). The increasing concentration homocysteine aggregates and clogs blood vessels resulting in hypertension and other coronary hearth diseases. According to Dietary Reference Intakes, 400µg/day of folate is recommended for both men and women. This level increases to 600µg/day for pregnant women to meet the needs for fetus development (Park et. al. 2013).

Animal Milks

Cow’s Milk

In most parts of the world, cow’s milk serves as the primary source of milk post infancy. Cow’s milk provides about 113g/100g of calcium per cup (See Table 2). One cup of cow’s milk can provide about one-third to one-fourth of the Institute of Medicine’s Recommended Daily Allowance for calcium. Vitamin D is usually added to cow’s milk to increase the bioavailability of calcium. Cow’s milk contains 0.1 milligrams of vitamin D per 100 gram (See Table 2). Many advertisement companies emphasize presence of calcium in cow’s milk to promote cow’s milk as a source of “strong bones” (Wiley 2014). However, the location and condition of the farms in which cows are raised and milked can influence the quality of milk composition. This is one of the most important challenges that dairy industries face. Compared to other animal milks,
cow’s milk contains more long-chain fatty acids, which result in larger micelles during metabolism. This makes the digestion of cow’s milk harder than other animal milks. Furthermore, cow’s milk is primarily composed of α-s-1-caseins proteins, which can promote allergies. This may explain the high incidence of cow’s milk-based allergies present in human population (Haenlein 2004). Cow’s milk has the same amount of folate as human milk (See Table 2).

The prevalence and popularity of cow’s milk in United States and other countries is due to its reputation as a growth enhancer. Cow’s milk contains high amounts of lactose, a major carbohydrate that increases intestinal absorption of calcium, magnesium, phosphorus, and vitamin C (Park et al. 2013). This image of cow’s milk as a “strength and growth provider” is exploited by the advertisement without much scientific support. Now, this image has become universally acceptable. Also, the growth-enhancing concept is further propagated due through the creation of various “food taboos” due to cultural beliefs. Taboos are societal practices that might seem “silly” or “irrational” to outsiders, yet are adhered to by that particular community (Wiley 2014). “Food taboos” present in some societies restrict individuals from choosing other, more beneficial, milk sources. For example, in India, due to the prominence of Hinduism, which promotes veneration of cows, people tend to view cow’s milk as something “sacred” (Wiley 2014). This might have originated due to the culture of farming that served as the main source of economy. However, cow’s milk now serves as the main type of drinking milk in India due to the veneration of the sacred cow. This veneration is demonstrated through the “sacred cow complex” and the position of cow’s milk in Ayurveda, the ancient Indian medical system (Wiley 2014). According to Ayurveda, cow’s milk is considered the most digestible due to its dilute
characteristic (Wiley 2014). Due to the presence of large micelles resulting from cow milk’s long-chain fatty acids, physiologically, Ayurveda’s claim can be disproven. Yet, taboos prevail in the Indian society and promote its reliance on cow’s milk.

**Goat’s Milk**

Humans have consumed Goat’s milk since 8000BC in Mesopotamia. Currently, it is prominently utilized in the Middle East (Park et al. 2013). On a global scale, goat’s milk is used most by the rural societies, especially in arid and semi-arid farming lands (Park et. al. 2013). Goats prevail in these harsh environments because they can easily consume types of pasture and forage that cattle struggle with. According to Food and Agriculture Organization data for 2009, Goat milk production represents about 2.2 percent of total world milk production (Park et. al. 2013). Overall, goat milk’s unique characteristics deem it as physiologically more beneficial that cow’s milk.

Though goat milk is not as prominent as cow’s milk in dairy, it has proven to be more beneficial in certain conditions. As with cow’s milk, the constituents of goat milk differ based on the condition in which goats are raised, age of lactation, feeding management, and reproduction (Park et. al 2013). Under high quality milk production, goat milk has 4.14g of fat content and 3.56g of protein in every 100g of milk (Park et. al 2013). In addition to having a higher fat amount than cow’s milk, goat milk has smaller fat micelles, which results in the softer texture of goat milk products. Furthermore, the small size of fat globules in goat milk allows better human digestion by lipases (Park et al 2013). Goat milk also varies in fatty acid profile compared to cow’s milk. Goat milk is composed of higher proportion of short-chain fatty acids and medium chain triglycerides (MCT). This component of goat milk fat is extremely beneficial
for humans as it promotes positive cardiovascular health (Haenlein 2004). In regards to the protein constituents, goat milk contains all of the main proteins found in most dairy sources. These include caseins, β- lactoglobulin, and α-lactalbumin (Park et al. 2013). However, compared to cow’s milk, goat milk has more α-s-2-casein instead of α-s-1-caseins. α-s-2-casein in goats promotes better digestibility and greater calcium solubility by affecting the shape of the micelles (Park et al. 2013). Goat milk also contains higher amount of calcium and vitamin D than cow’s milk. Goat milk can lead to better gastrointestinal development, infant development, immunological development, and greater antibiotic and probiotic actions (Heinlein 2004). These qualities make goat milk more nutritionally and therapeutically healthy for humans than cow’s milk.

**Sheep’s Milk**

Like goat milk, sheep milk is also used more prominently in Mediterranean and Middle Eastern countries. In these locations, climate does not favor cattle raising. People rarely drink plain sheep milk. Sheep milk is more commonly used for milk products such as cheese, yoghurt, or butter. Nutritionally, sheep milk contains more calcium, lactose, folic acid, fat, and protein components than cow’s milk and goat milk (See Table 2). Sheep milk is composed of smaller fat globules than cow’s milk and goat’s milk (Park et. al. 2013). As mentioned before, small fat globules are more easily digested. As a result, sheep milk is more easily digested than cow and goat milk because its fat globules are smaller. Unlike cow or goat milk, sheep milk contains K-CMP, a type of whey protein that is a good source of antithrombotic peptides (Park et al. 2013). Antithrombotic properties inhibit the aggregation of human platelets by hydroxylation of K-CMP with trypsin by thrombin and collagen (Park et. al. 2013). Also, the caseins found in sheep
milk have antioxidant activity. K-casein inhibits linoleic acid oxidation leading to antioxidant activity. Sheep milk also has higher concentration of vitamins, especially vitamin D, in comparison to cow’s milk and human milk (See Table 2). This characteristic enables sheep milk to hold more calcium in comparison to both cow and goat milk (Park et al. 2013). Sheep milk also contains more folate than human and cow’s milk, which makes it a better source for lowering the risk of coronary heart disease development (See Table 2).

**Plant-Based Milks**

**Soymilk**

Soymilk is a popular substitute milk source for lactose intolerant individuals (Endres 201). This type of milk has many benefits associated with it. One of the main benefits of soymilk is that it can lower the amount of low-density lipoprotein cholesterol, or the “bad” cholesterol, in humans (Bricerello et. al. 2004). Physiologically, low-density lipoprotein (LDL) has detrimental effects and its accumulation promotes cardiovascular disease and metabolic syndrome (Bricerello et. al. 2004). Furthermore, soymilk has many antioxidant properties because it contains isoflavones proteins instead of caseins, the proteins found in cow’s milk. Soymilk contains fewer overall proteins than sheep, cow, and goat milk, but it has more protein than human milk. Due to the presence of isoflavones, soymilk also leads to increase in high-density lipoprotein, which has beneficial effects for humans (Bricerello et. al. 2004).

In a study with sixty subjects diagnosed with hypercholesterolemia, the effects of soymilk were compared to non-fat cow milks. Soymilk reduced the concentration of low-density lipoprotein cholesterol in humans more than non-fat cow’s milk. Many mechanisms have been
proposed to explain the mechanism behind the beneficial effects of soy proteins. One mechanism suggests that casein protein found in cow’s milk reduces the number of LDL receptors found in the liver resulting in an increase in plasma cholesterol level (Khosla et al 1991). On the other hand, soy protein inhibits cholesterol absorption in the small intestine in order to reduce the low-density lipoprotein (Bricerello et. al. 2004). Also, soymilk has saponins, a steroid glycoside, which is found in many vegetables. Saponins interact with bile acids and result in creation of large mixed micelles, which limits the absorption of cholesterol. Therefore, soymilk limits the absorption of cholesterol from other sources and makes metabolism of cholesterol harder (Bricarello et al. 2004). Recently, another mechanism has been proposed to explain the influence of isoflavones on the reduction of LDL levels. Isoflavones may reduce LDL by increasing the expression of peroxisome proliferator-activated receptors (PPARs), which reduce the level of blood cholesterol. Many of these mechanisms of soy milk work together to lower the level of LDL cholesterol in the blood (Bricarello et al. 2004). Soymilk also contains double the amount of folate found in human milk, which further lowers the risk for developing coronary heart diseases (See Table 2).

**Almond Milk**

Recently, people have started to use almond milk substitute to counteract the negative symptoms associated with cow’s milk allergies or lactose intolerance. The process of preparing almond milk involves heating an aqueous dispersion of partially de-oiled almond powder up to 90°C. This solution is mixed with 0.1% of a stabilizing hydrocolloid and left alone to solubilize before proceeding with grinding. The mixture undergoes centrifugal clarification to remove large particles. To gain a safe product, almond milk is homogenized under ultra-high
temperature and then cooled with the pressure of 180,00 hectopascals before being packaged (Berger et al. 1997). Almond milk contains less carbohydrates, fat, and protein than cow, goat, sheep, and soymilk sources. Some almond milk powders supplement the product with additional nutrients, which include vitamins, sugar, lipids, and proteins. Almond supplementation benefits humans by lowering chances for cardiovascular diseases. An almond-based diet consists of high concentration of plasma α-tocopherol (a form of vitamin E) concentration (Jambazian 2005). Even though all forms of vitamin E from diet are absorbed in the small intestine and transported to the liver, only α-tocopherol is secreted into the circulation because of the presence of hepatic α-tocopherol selective transporter proteins (Jambazian 2005). Alpha-tocopherol is protective against conditions such as “cardiovascular disease, cancer, diabetes, hypertension, and cognitive decline” (Jambazian 2005). High levels of plasma lipids, which include cholesterol, low-density lipoproteins, and triglycerides, in the blood, are associated with increased occurrence of cardiovascular diseases (Jambazian 2005). Almonds lower the serum lipids level in our body by increasing α-tocopherol levels (Jambazian 2005). This results in lower rates of cardiovascular diseases (Jambazian 2005).

**Impacts of Human Modification of Milk Quality**

Human processing of natural milk can further modify the quality of the milk. This concept is demonstrated through the comparison of milks with different dietary fat content. People tend to assume that fat-free milk is the best source for achieving or maintaining one’s optimal weight and health. Since “fat” has many negative connotations and also considered as the main risk factor of many chronic diseases in present society, people try to limit their fat
consumption. Thus, the use of low-fat or skim milk proliferates in the society. We must look past the pre-established cultural biases in order to scientifically determine the milk of superlative quality for both males and females of different ages.

Both culture and media impact people’s choice of milk. This is evident from women and teenagers who drink reduced fat milk. Women and teenagers experience more energy deficit because they do not compensate by consuming fruits and other carbohydrates like men. Due to the lack of compensation, teenagers do not meet the 30% intake of energy from fat recommended by the Committer of Nutrition, American Academy of Pediatrics (Lee et. al. 1998). This results in inadequate amount of nutrition leading to “suboptimal growth and development” among teenagers (Lee et. al. 1998). This is promoted through the “dieting” fad that is present among teenagers and women. As people have learned the benefits of whole milk, they are beginning to use it more than fat free milk as they age (Lee et. al. 1998). The use of whole milk is more prominent among individuals from higher socioeconomics status due to higher education levels (Lee et al. 1998).

**Conclusion**

The different types of milks used by the human society serve as evidence of milk’s importance. The literature reviewed in this thesis presents evidence that breast milk is the optimal source of nutrition for infants. However, if the mother cannot breastfeed due to health related issues or other reasons, partial whey hydrolysate formula milk serves as the optimal nutritional replacement for infants. Post infancy, humans rely on different types of non-human milks. The literatures reviewed in this thesis compare the physiological and nutritional benefits
associated with human, cow, goat, sheep, soy, and almond milks for children’s health. After comparing these five different types of milks, it is evident that each type of milk has its own nutritional and physiological benefits and detriments. Due to its popularity and other cultural beliefs, cow’s milk is considered the best source for carbohydrates. However, cow’s milk has fewer carbohydrates than sheep’s milk. Overall, sheep milk contains the highest amount of fats, proteins, and carbohydrates in comparison to the other four types of milks reviewed. However, sheep’s milk’s accessibility limits its prevalence in most societies. For individuals with calcium deficiency, almond milk will be the most beneficial. Almond also has high amount of vitamin D, which physiologically aids in calcium absorption. Individuals who need vitamin D supplementation should consider either goat or almond milk. Since soymilk has the highest amount of folate, women should consider using it during pregnancy to ensure proper fetus development. Folate also reduces the risk of coronary heart diseases. Therefore, soymilk and sheep’s milk can both be used to reduce the risk of coronary heart diseases due their high folate content. Throughout history, the choice of milk has been based on types of productions, quality of milk, and accessibility to type of milks. Currently, the choice of milk is not only based on the nutritional compositions of milks, but also on the cultural, socioeconomical, and educational factors. Overall, both cultural and physiological conditions should be considered in order to determine the optimal type of milk for health benefits.
<table>
<thead>
<tr>
<th>Nutrients</th>
<th>Calcium mg/100g</th>
<th>Vitamins</th>
<th>Fat g/100g</th>
<th>Protein g/100g</th>
<th>Carbohydrate (g/100g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soy Formula</td>
<td>65</td>
<td>E- 1.3g</td>
<td>3.5</td>
<td>1.9g</td>
<td>7.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C-7.2mg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydrolyzed Whey Formula</td>
<td>51</td>
<td>E- 1.0g</td>
<td>3.5</td>
<td>1.6g</td>
<td>7.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C-7.8mg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cow’s Milk Formula</td>
<td>51</td>
<td>D-1.0μg</td>
<td>3.55</td>
<td>1.36</td>
<td>6.92</td>
</tr>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>A- 59μg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Human Milk</td>
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<td>D- 0.1μg</td>
<td>4.38</td>
<td>1.03</td>
<td>6.89</td>
</tr>
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</table>

Table 1: Nutritional Values of Human Milk and Different Types of Milk Formulas (USDA National Nutrient Database)
Table 2

<table>
<thead>
<tr>
<th>Nutrients:</th>
<th>Calcium mg/100g</th>
<th>Vitamin D μg/100g</th>
<th>Fat g/100g</th>
<th>Protein g/100g</th>
<th>Carbohydrates g/100g</th>
<th>Folate μg/100g</th>
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</thead>
<tbody>
<tr>
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<td>3.15</td>
<td>4.78</td>
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<td>1.65</td>
<td>2.88</td>
<td>3.29</td>
<td>10</td>
</tr>
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<td>Almond</td>
<td>197</td>
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<td>1.10</td>
<td>0.59</td>
<td>0.58</td>
<td>1</td>
</tr>
<tr>
<td>Goat</td>
<td>134</td>
<td>1.3</td>
<td>4.14</td>
<td>3.56</td>
<td>4.45</td>
<td>1</td>
</tr>
<tr>
<td>Sheep</td>
<td>193</td>
<td>0.18</td>
<td>7</td>
<td>5.98</td>
<td>5.36</td>
<td>7</td>
</tr>
<tr>
<td>Human</td>
<td>32</td>
<td>0.1</td>
<td>4.38</td>
<td>1.03</td>
<td>6.89</td>
<td>5</td>
</tr>
</tbody>
</table>

Table 2: Nutritional Values of Different Types of Milks (USDA National Nutrient Database)
Physiological and Nutritional Impacts on The Health of Infants, Children, and Adults

Women who cannot breastfeed utilize different types of milk supplements. Three types of popular formulas include partial whey hydrosylate, soy, and cow’s milk formulas. Partial whey hydrosylate formulas are the most beneficial for infants because their protein composition mimics human milk. Human milk also has higher concentration of whey protein than casein proteins. Whey proteins are easily digestible resulting in higher nutrients absorption that promotes growth.

Benefits of Breastfeeding

Human breast milk consists of dietary nucleotides and human milk oligosaccharides (HMOs), which are unique to breast milk and promote infant growth and development. Breast milk reduces microbial infections for infants by preventing pathogen binding to mucosal cell surface in the stomach. It contains Sialylated HMOs, which promote higher brain development during pre and post-natal stages. The process of breastfeeding provides bonding between mother and her infant. It can provide a natural form of birth spacing through lactational amenorrhea, which enables mother to develop her health after her energetically expensive pregnancy.
Non-Human Milks

Animal Milks

Cow’s Milk

Cow’s milk is the most accessible type of milk in our society. Milk companies falsely promote cow’s milk as the best source for calcium. Yet, in comparison to goat and sheep’s milks, cow’s milk has the least amount of calcium. Therefore, cow’s milk with additional nutrients supplements will be nutritionally more beneficial than raw cow’s milks.

Goat’s Milk

Goat milk contains higher amount of calcium, fat, vitamin D, and proteins, than cow’s milk. Also, goat milk is easily digestible because of its protein composition. Since goat’s milk is easily accessible in the United States, it serves us a better nutritional source than cow’s milk.

Sheep’s Milk

Due to the lack of accessibility to sheep’s milk, Americans do not rely heavily on it. Nutritionally, sheep’s milk contains the highest amount of fat, proteins, and carbohydrates. Sheep’s milk is easily digestible in comparison to both cow’s and goat’s milk. Sheep milk has high amount of folate, which aids in proper fetus development. So, it is beneficial for pregnant women.

Plants-Derived Milks

Soy Milk

Soy milk has high amounts of folate, which serves as a protective factor against cardiovascular diseases. Soy milk is composed of isoflavones, a type of protein, which aids in reduction of bad cholesterol (LDLs) and development of good cholesterol (HDLs). Like sheep’s milk, soymilk will be extremely beneficial for pregnant women because of the high folate concentration.

Almond’s Milk

Almond milk contains the highest amount of calcium, which will aid in bone growth and development. Like most plant-derived milks, almond milk is composed of lower amount of fats, proteins, and carbohydrates. In comparison to soymilk, almond milk has lower levels of folate. Therefore, it is not as beneficial for pregnant women and their fetus.

Nutritional Values of Human Milk and Different Types of Milk Formulas (USDA National Nutrient Database)

<table>
<thead>
<tr>
<th>Nutrients</th>
<th>Calcium mg/100g</th>
<th>Protein g/100g</th>
<th>Carbohydrate g/100g</th>
<th>Folate (µg/100g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cow</td>
<td>113</td>
<td>3.27</td>
<td>4.78</td>
<td>5</td>
</tr>
<tr>
<td>Soy</td>
<td>125</td>
<td>2.88</td>
<td>3.29</td>
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<td>197</td>
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<td>1</td>
</tr>
<tr>
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<td>4.45</td>
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<tr>
<td>Sheep</td>
<td>193</td>
<td>5.98</td>
<td>5.96</td>
<td>7</td>
</tr>
<tr>
<td>Human</td>
<td>32</td>
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</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nutrients</th>
<th>Calcium mg/100g</th>
<th>Vitamins</th>
<th>Fat g/100g</th>
<th>Protein g/100g</th>
<th>Carbohydrate g/100g</th>
<th>Folate (µg/100g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soy</td>
<td>65</td>
<td>E: 1.3g</td>
<td>3.5</td>
<td>1.9</td>
<td>7.6</td>
<td></td>
</tr>
<tr>
<td>Hydrolyzed</td>
<td>51</td>
<td>E: 1.6g</td>
<td>3.5</td>
<td>1.4</td>
<td>7.3</td>
<td></td>
</tr>
<tr>
<td>Whey</td>
<td>51</td>
<td>E: 1.6g</td>
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<td>1.4</td>
<td>7.3</td>
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<tr>
<td>Cow’s Milk</td>
<td>51</td>
<td>D: 1.0µg</td>
<td>3.55</td>
<td>1.36</td>
<td>6.92</td>
<td></td>
</tr>
<tr>
<td>Human Milk</td>
<td>32</td>
<td>D: 0.1µg</td>
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<td>1.03</td>
<td>6.89</td>
<td></td>
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</table>
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Bibliography


