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EXPLORING THE POTENTIAL OF GOAT MILK AS A SUBSTITUTE FOR PHYTOESTROGENIC ACTIVITY IN INFANT FORMULA

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ABSTRACT

Nutrition is the most vital life-sustaining component for everyone. The best way to ensure adequate nutrition in early childhood is through breastfeeding, which plays a pivotal role in healthy digestion, brain development, and immunity. Regardless of the cause, the cessation of breastfeeding affects an infant's health. The lack of proper nutrition in infant's places mothers in a vulnerable situation, often leading them to adopt formula feeding practices. However, the introduction of the isoflavone class of phytoestrogens in infant formula is considered an endocrine disruptor, with potential negative effects on health, as it acts as a weak estrogen mimic. Lifetime exposure to these estrogenic substances has been associated with malignancies and various reproductive system anomalies. In Ayurveda, clear guidelines exist for substituting breast milk when it is unavailable. *Acharya Sushruta* and *Vagbhata* recommend goat milk as an alternative, as it contains the same casein protein structure as human milk, making it homologous, less allergenic, and easier to digest due to its smaller fat globules and better absorption. Additionally, goat milk has a high calcium content, which is crucial for the growing bones of infants.

KEYWORDS: Breastfeeding, infant formula, phytoestrogens, goat milk.

INTRODUCTION

Breastfeeding is recognized by the WHO as the optimal method for feeding infants. The lack of exclusive breastfeeding during the first six months of life often leads to the adoption of formula feeding practices. The high utilization of infant formula in early life has been linked to adverse health outcomes in the future. A global evaluation of the impact of infant formula has revealed the presence of endocrine-disrupting chemicals (EDCs), a class of xenobiotic toxins. These toxins contribute to significantly high levels of phytoestrogens in the plasma of infants fed with soy-based formula. These formulas, made from soy protein isolates, contain substantial amounts of phytoestrogens from the isoflavone class. The continuous exposure to isoflavones in soy-fed infants results in plasma concentrations exceedingly early-life estradiol levels, potentially triggering a hormone-sensitive period that may lead to "precocious puberty," an emerging detrimental effect of phytoestrogens. In classical Ayurvedic texts, *Acharya Sushruta* and *Vagbhata* clearly recommend goat milk as a substitute when breast milk is unavailable. Beyond its nutritional benefits, goat milk contains essential components such as antibodies, glycoproteins, and oligosaccharides, which help protect infants by preventing pathogen infections and supporting the growth of intestinal epithelium. Given its multifaceted benefits, goat milk presents a significant alternative for non-breastfed infants, potentially mitigating the harmful effects of early exposure to phytoestrogens in the future.

METHODS

The literature search was conducted using Ayurvedic Samhitas, as well as databases such as Springer, PubMed, ScienceDirect, and Google Scholar.

RESULTS

Significance of optimal breastfeeding: Optimal breastfeeding for the first two years of life is the most effective intervention to prevent child deaths worldwide. It is also one of the most cost-effective strategies for improving child health. According to the WHO, exclusive breastfeeding is defined as feeding an infant only breast milk, without any additional food or drink, not even water. Breast milk plays a crucial role in the development of a diverse and balanced microbiota, which is essential for proper innate and adaptive immune responses during the first months of life. It continues to provide up to half or more of a child's nutritional needs in the second half of the first year and up to one-third during the second year of life. Ayurveda, the ancient science of life, emphasizes the importance of *sthanya* (breast milk) as *balajeevana*, meaning a substance that vitalizes and nourishes the child.

Acharya Bhela describes *sthanya* as *pranayatana*, signifying it as the baby's source of life-sustaining nectar. Ayurvedic texts place great importance on breastfeeding, detailing its proper formation, secretion, feeding methods, as well as its abnormalities and management.

Infant formula: Infant formula is designed as an alternative for infant feeding, aiming to closely replicate the nutritional composition of breast milk. The recently updated FDA regulations on current good manufacturing practices for infant formula mandate that it meets quality standards ensuring normal physical growth and providing sufficient biological quality of protein components.[1]

Three major forms of infant formula

Form	Description	Pros	Cons
Powder	The least expensive form of infant formula must be mixed with water before feeding	• Least expensive • A doctor can adjust concentration to increase calories as needed	Not sterile
Liquid	Concentrated liquid that must be mixed with an equal amount of water	• Easier to mix than powder • Packaged sterile	More expensive than powder
Ready-to-feed	The most expensive form of infant formula that requires no mixing	• No mixing • Packaged sterile	Most expensive choice

Four major classes of infant formula with indications

Types	Description	Indications
Hydrolyzed	Cow's milk proteins that are extensively or partially subjected to hydrolysis to reduce the allergenicity of the milk proteins	**Partially hydrolyzed 100% whey**: • Infants at considerable risk of allergy who are not exclusively breastfed. **Extensively hydrolyzed casein**: • Infants at considerable risk of allergy who are not exclusively breastfed.
Soy-protein based	Supports normal growth and development in the term infant	• Parental preference • Infants with hereditary lactase deficiency • Infants with galactosemia
Amino-acid based	Hypoallergenic infant formula made from the simplest forms of individual amino-acids	• Infants with cow's milk protein allergy and multiple food intolerances who cannot tolerate hydrolyzed protein formulas
Organic	Safe and acceptable but with no added health benefits	• Nil

Soy-based infant formulas have been in use for over 30 years. These formulas are composed of 95% soy protein isolates and contain significant amounts of phytates, aluminium and

phytoestrogens of the isoflavone class, which may cause unanticipated effects. Over the past decades, their utilization rates have consistently been higher than expected.[2] Although no overt toxicity has been directly linked to their consumption, in vitro and in vivo studies have raised concerns about the potential adverse effects of soy-based formulas on sexual development, reproductive function, neurobehavioral development, immune function, and thyroid function.

Phytoestrogens: Plant-derived compounds that are structurally and functionally similar to estrogens found in many foods. They are defined as substances that promote estrogenic activity in mammals and share a structural resemblance to mammalian 17β-estradiol. Phytoestrogens are classified into flavonoids, including isoflavones and coumestans, and non-flavonoids such as lignans. Among these, isoflavones are the most well-known phytoestrogens. The isoflavone composition of commercially available soy-based formulas is both qualitatively and quantitatively consistent with that of soy protein isolates.[3] The total isoflavone concentration in soy-based infant formulas ranges from 32 to 47 mg/L, whereas the isoflavone concentration in human breast milk is only 5.6 ± 4.4 µg/L. As a result, infants consuming soy-based formulas are exposed to 22–45 mg of isoflavones per day, whereas the intake of these phytoestrogens from human milk is negligible. Continuous daily exposure to isoflavones in soy-based formula leads to circulating concentrations that are 13,000–22,000 times higher than plasma estradiol levels in infants. Early-life exposure to such high levels of phytoestrogens may contribute to the development of long-term hormone-dependent diseases.[4]

Mechanism of Phyto estrogenic activity: Phytoestrogens can disrupt reproductive processes at various regulatory levels. A decline in fertility may also be attributed to the direct effects of phytoestrogens on the reproductive tract. These compounds can inhibit endogenous estrogen production in the ovaries, leading to disturbances in immune system regulation, follicle development, and estrogen synthesis.

Phytoestrogens may exert their biological activity through the following mechanisms:

- Mimicking the action of endogenous estrogens
- Acting as estrogen antagonists
- Altering the synthesis and metabolism of endogenous hormones
- Modifying hormone receptor levels

Additionally, phytoestrogens can modulate signaling molecules by.

- Blocking nuclear and membrane estrogen receptors
- Interfering with growth factor receptors
- Inhibiting G-protein coupled receptors in estrogen receptor-deficient cells
- Inducing apoptosis and counteracting anti-apoptotic signals.[5]

Thus, phytoestrogens exert multiple effects on circulating estrogen-regulated endocrine systems, which play a crucial role in mammalian reproduction.

Toxic effect of Phyto estrogenic activity in the reproductive system: Isoflavones, a class of phytoestrogens, exert both estrogenic and anti-estrogenic effects on the brain-pituitary-gonad axis - a key endocrine system regulating reproduction, as well as on peripheral reproductive organs in the mammalian reproductive system.[6]

Toxic effects of Isoflavones on Phyto estrogenic activity in experimental models[7]

Author	Experimental model	Type of exposure	Effects found
J.D. Sherrill et.al	Wistar Unilever rats	food	• Increased Leydig cells • Decreased testosterone production by Leydig cells
F. Eustache et.al	Long-Evans rats	Soy diet	• Decreased testosterone and serum estradiol
B. T Akingbemi et.al	Long-Evans rats	diet	• Increased body weight, testicle weight and serum androsterone
C. R Cederroth et.al	CD=1 Mice	diet	• Decreased size of seminal vesicle • Decreased reproductive performance
V. Romero et.al	Wistar rats	diet	• Early puberty • Irregularity in the estrous cycle • Prolongation of the estrous phase

Precocious puberty - a detrimental effect of Phyto estrogenic activity: In precocious puberty, pubertal changes occur earlier than expected, including the premature development of secondary sex characteristics such as breast development, pubic hair growth, and early onset of menarche and thelarche. More specifically, if thelarche occurs before 8 years of age or menarche before 9 years of age, the condition is classified as precocious puberty. Early puberty leads to physiological changes, preparing the body for sexual maturity and childbearing. However, since pubertal girls are often psychologically immature, they may be more vulnerable to making impulsive decisions, which could have negative societal implications.

Phytoestrogens, natural plant compounds abundantly found in soy and soy products, behave as weak estrogen mimics or as antiestrogens. The structural similarities between the phenolic ring of phytoestrogens and estrogen enable phytoestrogens to bind to estrogen receptors. Thus, they affect the timing of puberty, which can disrupt the ability to produce viable fertile offspring, sex-specific behavior, and fertility in animals.[8]

Another hormone that is of importance is progesterone. Progesterone is important for the differentiation of the mammary gland. The mammary gland is rudimentary at birth and progresses with puberty with the influx of estrogen and progesterone. It has been speculated that phytoestrogens block progesterone action in a significant manner. The effect of phytoestrogens on mammary gland development could involve blocking of the progesterone receptor or the combined effect of estrogen and progesterone. So, early exposure to this kind of endocrine disruptor chemical (EDC), which is one among the class of xenobiotic toxins, can lead infants into a deleterious situation that may negatively influence society.

Goat milk in infant nutrition: In Ayurveda, there are clear-cut descriptions of substitute for the non-availability of breast milk. Acharya Sushruta and Vagbhata advised that when the mother is unable to feed for any reason, goat milk is advised. According to *Charaka Samhitha*, it is *kashaya, madhura, sheeta, laghu, malasangrahaka.* It cures *rakthapitta, atisara, kshaya, kasa, jwara* and according to *Sushrutha Samhitha*, it is *agni deepaka, laghu, sangrahi, shwasahara, kasanashaka.*

Goat milk has higher amounts of conjugated linoleic acids playing a significant role in immune stimulation, growth promotion, and disease prevention. Studies suggest that human lysozyme (hLZ) milk from transgenic goats of the Artemis line could provide a safe, sustainable, and direct source of lysozyme-rich milk for communities facing high rates of childhood diarrhea. Goat milk is a reliable source of vitamin A, niacin, thiamin, riboflavin, and pantothenic acid. Also, it has a considerable amount of conjugated linoleic acid (CLA) which is reported against mammary and colon cancer.[9]

Comparative nutritional value of breast milk and goat milk

Parameters	Human milk	Goat milk
Total solids %	10.7-12.9	11.9-16.30
Proteins%	0.9-1.9	3.0-5.2
Casein/ whey ratio	0.4-0.5	4.6
Fat%	2.1-4.0	3.0-7.2

Lactose%	6.3-7.0	3.2-5.0
Ash%	0.2-0.3	0.7-0.9
Energy (kJ1-1)	2843	2802-2894

One of the important contributions of goat milk to human nutrition is calcium (1.2g) and phosphate(1g) per liter absorbed by the human infant. The use of goat milk is the source of proteins, short and medium-chain fatty acids, SN-2 palmitic acid, and milk fat globule membrane (MFGM). These features supply similarities to the complex human milk fat globules.[11]

Medicinal superiority of goat milk[10]

Attributes of Goat milk	Reason
Goat milk is naturally homogenized	• Consists of smaller fat globules & lacks agglutinin allowing milk to stay homogenous
Goat milk resembles human milk	• The oligosaccharide profile of goat milk is most like human milk
Goat milk is less allergenic	• Contains low levels of αS21 casein and elevated levels of αS2 casein, which is non-allergic
Goat milk is rapidly digested & absorbed	• Consisting of short chain fatty acids and medium chain fatty acids makes digestion better • Holds excessive amount of ATP used in the cellular reaction of the body • Holds taurine, glycine, and glutamic acid played a vital role in bile salt formation, osmoregulation, antioxidation and ca transport and in CNS
Alkaline powerhouse	• It has excellent buffering action and reduces acid production • Oligosaccharides from goat milk are likely to play a significant role in intestinal protection and repair • Helps to prevent ferropenic anemia (iron deficiency) and bone demineralization
Lactose intolerance	• Supplies osmotic balance in intestinal flora

DISCUSSION

Mother's milk is the ideal source of infant nutrition and is widely recognized as a biological fluid essential for optimal infant growth and development. However, in cases where breastfeeding is discontinued for any reason, mothers often turn to infant formula as an alternative. While soy-based formulas provide nutritional benefits, their widespread use has raised concerns due to the presence of phytoestrogens, which may have toxic effects on both early and late child development. Isoflavones, a class of phytoestrogens, mimic 17β-estradiol by binding to hormone receptors, acting as endocrine disruptors throughout infancy and pre-puberty, potentially affecting the development of the reproductive system.

In alignment with Ayurveda, goat milk is regarded as a natural substitute when breast milk is unavailable. According to the *Journal of American Medicine*, goat milk is one of the most nutritionally complete foods, offering both medicinal and dietary benefits.[12] Given its superior digestibility, rich nutrient profile, and reduced allergenic potential, goat milk presents a viable alternative to conventional formula feeding practices, making it an excellent option for infant nutrition.

CONCLUSION

It can be concluded that despite the beneficial therapeutic effects in the face of pathologies, the unknown consumption of isoflavones in food can damage the development and reproduction of infants. So, greater control over the insertion of formula fed targeted at pediatric consumers should be implemented with the ayurvedic substitute Goat milk; universally recognized as the *poor man's cow*. Hence, Goats must be fully exploited to get maximum benefits, particularly milk having medicinal and dietary significance. This could be the greatest boon for infant formula industrialization thereby reducing the detrimental effect of phytoestrogens in the future. So, goat milk could be considered a significant choice for milk consumption in infants.

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