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Review Article

AN INSIGHT INTO THERAPEUTIC AND NUTRITIONAL PROFILE OF *AJA DUGDHA* (GOAT'S MILK): A REVIEW

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ABSTRACT

In many countries, goat (*Aja*) rearing is well organized and is an essential part of living in terms of contributing to the economic structure as well as nutrition. Goat milk (*Aja Dugdha*) is rich source of protein, vitamins, enzymes and mineral content and most of them are present in higher percentage than that of other commonly consumed milk. For instance, it contains 13% more calcium, 47% more vitamin A and 25% more vitamin B6 than cow's milk. It has better digestibility, alkalinity and buffer capacity than milk of other animals and also possesses numerous therapeutic properties viz. Anticancer, hepato-protective, cardio-protective and antihypertensive etc. Classical texts of Ayurveda also embrace its nutritive and therapeutic potential and indicated it in management of different diseases like *Atisara* (diarrhoea), *Jwara* (fever), *Rajyakshma* (tuberculosis), *Kshaya, Shosha* (atrophy/emaciation) etc. **Methodology:** Different scientific databases like Web of Science, Scopus etc. along with Ayurveda texts viz., *Charak Samhita, Kashyap Samhita* etc were searched in order to extract data pertaining to goat milk. Results: The present study revealed that in Ayurveda, goat milk has been indicated in the management of more than 20 disease conditions and conventional studies also reported more than 15 pharmacological properties of goat milk. **Discussion & Conclusion:** It has been found that the therapeutic and nutritive value of goat milk has been extensively studied in Ayurveda and conventional science as well. It's easy to digest and have a better composition of vitamins, fatty acids, protein and minerals than other available milks. Therefore, it can be a used a most appropriate alternative to human and cow milk but should with caution as it lacks sufficient quantity of iron, folate and vitamins C etc.

INTRODUCTION

The various species of goat have been one of the primary household animals for mankind to cater the need of food in the form of milk and meat as well as a financial asset since centuries.[1] Worldwide, *Aja Dugdha* (goat milk production has been reported to be around 18.66 million tons, where India contributed as a top producer with more than 6.16 million tons (27.14%) of goat milk, followed by Bangladesh (14.2%), Sudan (8.32%), Pakistan (4.35), France, Greece, Turkey, and Spain respectively.[2]

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There has been an increased interest in goat milk and its products worldwide because of its high nutritional value and health benefits.[3] Over 170 goat dairy products including 150 cheeses, milk, yogurt, ice cream etc. from 23 countries in 4 continents has been reported.[4] While defining the properties of goat milk, it is told to be light, astringent, appetizer *(Dipana*), and effective in diseases like dyspnoea, cough and haemoptysis.[5,6] Goat milk is also a great part of the infant diet as it deals with malnutrition.[7] Mahatma Gandhi even referred to goats as the "poor man's cow". In traditional system of medicine goat milk is being used in treatment of oral cavity ulcers and designated as Grandmother's drug. It is also reported that goat milk is effective in management of lesions formed in the infection of Herpes Simplex Virus type 1 (HSV-1).[8]

Various scientific studies have reported enormous benefits of goat milk and products derived from it. Ayurveda also described numerous health

benefits, indication in management of various disorders but its therapeutic and nutritive potential is still unexplored and poorly documented. Therefore, present study has been planned to review and reflect the therapeutic potential of goat's milk and its relevance in present era.

Methodology

Published literature on developments in research on goat milk, comprising original and review articles indexed in Web of Science, Scopus, PubMed and Cochrane library were searched using the key words like goat milk, *Aja Dugdha*, therapeutic potential and nutritive value etc. Google search has also been performed to explore the gray literature and studies published in non indexed journals regarding the same. Information has been extracted from a total of 33 published articles. Classical Ayurveda texts viz., *Charaka Samhita, Sushruta Samhita, Kashyapa Samhita, Ashtang Hridaya, Ashtang Hridaya* and *Bhavprakasha* have been reviewed to extract the therapeutic and nutritive indication of goat milk.

RESULTS

Classical Aspect

Various classical Ayurveda texts have numerous references of *Aja Dugdha* pertaining to its therapeutic properties and indications. These indications are summarized in Table 1 as below.

Table 1: Therapeutic properties and indications of *Aja Dugdha* mentioned in different Ayurveda Classics

S.No.	Ayurveda Classics	*Rasa*	*Virya*	*Vipaka*	Therapeutic Properties	Indications
1	*Charak Samhita*[9]	*Kashaya, Madhura*	*Shita*	-	*Grahi, Laghu*	*Kshaya, Kasa, Atisar, Rak- tapitta, Jwara*
2	*Sushruta Samhita*[10]	-	-	-	Properties similar to cow milk. *Dipaniya, Laghu, Sangrahi*	*Shosha, Kasa, Shwasa, Raktapitta*
3	*Ashtanga Hrudya*[11]	-	-	-	*Laghu*	*Shosha, Shwasa Jwara, Atisar, Raktapitta*
4	*Bhav Prakash*[12]	*Kashaya, Madhura*	*Shita*	*Katu*	*Grahi, Laghu*	*Kshaya atisar Kasa, Jwara, Raktapitta*
5	*Yoga Ratnakar* [13]	-	-	-	Properties similar to cow milk, *Vishesh dipana, Grahi, Laghu*	*Kshaya, Arsha, Jwara Atisara, Raktadosh, Bhrama*
6	*Kai. Ni.*[14]	*Madhur, Kashay*	*Shita*	-	Properties similar to cow milk, *Dipana, Laghu Sangrahi, Snigdha, Mri du, Balya Shukrala*	*Kshaya, Kasa Arsha, Jwara Shwasa, Atisara Trushna, Vatarakt Vatarakt, Raktapitt*
7	*Dha. Ni.*	*Kashay, Madhur*	*Shita*	-	*Grahitara, Laghu*	*Kshaya, Kasa Jwara, Atisar, Raktapitta.*
8	*Ni. Ra.*	*Kashay, Madhur*	*Shita*	-	*Grahi, Laghu*	*Kshaya, Kasa Jwara, Atisar, Raktapitta*
9	*Ra. Ni*[15]	-	-	-	More potent than cow milk, Diet for weak person	*Sarva Vyadhi hara*

Besides, consumption of goat milk has also been indicated in diseases like *Udara Roga*[16,17], *Raktapittahara yoga*[18], *Atisara*[19], *Stanyaabhava*[20,21], *Trishna*[22], *Pakwatisara*[23], *Rajyaskshma*[24] and *Matradugdha Abhava-Bala Roga*.[25] Moreover, it is also indicated as a food supplement in various disease conditions viz., *Pittaj Gulma*[26], *Arsha* [27,28], *Virechan Atiyoga*[29], *Jwaratisara*[30], *Grahani*[31], *Raktapitta*[32], *Vatarakta*[33], *Hikka-swasa*[34] and *Gulma roga*[35] etc.

Various Ayurveda texts have mentioned use of goat milk as a potentiating agent to enhance the therapeutic action of formulations indicated in different pathological conditions. It has been used as levigation media (*Bhawana dravya*) to potentiate the pharmacological effect of the drugs viz., *Grahani Kpata Rasa*[36], *Piyushavalli Rasa*[37], *Shrinripati Vallabh Rasa*[38], *Mahanripativallabh Rasa*[39], *Pranavallabha Rasa*[40], *Kshayakesari Rasa*[41], *Rasendra Gutika*[42], *Rajamriganko Rasa*[43], *Purandar Vati*[44], *Chandramrita Rasa*[45], *Swasachintamani Rasa*[46], *Swasakasachintamani Rasa*[47], *Talkeshwara Rasa*[48], *Somanatha Rasa* and *Rasendra Gutika*[49] etc.

Conventional Aspect

In present review study, it has been found that numerous studies have reported the comparative composition of goat milk with other common milk used for consumption and has been tabulated in Table 2.

Table 2: Comparative Composition of different milks (mean values per 100g)[50]

Composition	Goat milk	Cow milk	Human milk
Energy (kcal)	**70**	69	68
Water (%)	87.5	**87.7**	86.7
Total solids (g)	12.2	**12.3**	**12.3**
Protein (%)	3.2	**3.3**	1.3
Fat (%)	**4.0-4.5**	3.8	4.1
Lactose (%)	4.6	4.7	**7.2**
Ash (g)	**0.8**	0.7	0.2

Goat milk is a complex oil-in-water emulsion form containing proteins, fats, carbohydrates (mainly lactose) as well as small amounts of minerals, enzymes, cells, hormones, immune globulins, and vitamins. The principal protein fractions in goat milk are about the same as in human, cow, and sheep milks. Milk protein fractions occur in two phases, caseins as suspended micelles and the soluble phase composed of whey proteins. The principal caseins in milk are known as αs1-casein, αs2-casein, β-casein, and κ-casein, and the major whey proteins are β-lactoglobulin and α-lactalbumin. Besides, lactoferrin, serum albumins and immunoglobulins along with other whey proteins are also reported to be present in smaller concentrations.[51]

Proteins and Amino acids

The protein portion has a fundamental role in the nutritional and technological value of milk. The total protein content in goat milk lies between 2.6 to 4.1g/l. Casein is composed of four compartments: αS1-casein, αS2-casein, β-casein, and κ-casein.[52] A study reported that higher concentration of six out of ten essential amino acids are detected in goat milk in comparison to that of cow milk.[53] These findings are depicted in Table 3.

Table 3: Amino acids Present in Goat milk

Essential amino acids	Goat milk	Cow milk
Thr	138.67	115.81
Ileu	160.54	128.04
Leu	341.01	266.23
Lys	342.86	252.59
Met	77.95	71.15
Cys	30.62	23.2
Phe	175.45	133.51
Tyr	162.51	159.99
Val	210.23	147.34
Total	**1639.84**	**1298.36**
Nonessential amino acids		
Arg	135.65	114.44
Hist	122.73	93.06
Asp	117.95	96.0.859
Ala	250.15	214.22
Glu	694.58	554.3
Gly	55.83	49.24
Pro	310.61	253.38
Ser	152.65	147
Total	**1840.15**	**1522.58**

Fats and Carbohydrates

Fat content can be varied according to season, breed, lactation stage, genotype, and feeding in terms of quantitatively and qualitatively.[54] Goat milk fat has higher physical properties such as surface tension, viscosity and specific gravity as compared to cow milk.[55] The comparative fatty acid composition of goat milk and other commonly consumed milk has been presented in Table 4.

Table 4: Comparative Fatty acid composition of commonly consumed milk (mg/100g milk)[56]

	Goat	Human	Cow	Sheep
Fatty Acids (g)				
Saturated (total)	2.67	2.01	2.08	4.6
4:0 (Butyric acid)	0.13	_	0.11	0.2
6:0 (Caproic acid)	0.09	_	0.06	0.14
8:0 (Caprylic acid)	0.1	_	0.04	0.14
10:0 (Capric acid)	0.26	0.06	0.08	0.4
12:0 (Lauric acid)	0.12	0.26	0.09	0.24
14:0 (Myristic acid)	0.32	0.32	0.34	0.66
16:0 (Palmitic acid)	0.91	0.92	0.88	1.62
18:0 (Stearic acid)	0.44	0.29	0.4	0.9
Monounsaturated (total)	1.11	1.66	0.96	1.72
16:1 (Palmitoleic acid)	0.08	0.13	0.08	0.13
18:1 (Vaccenic acid)	0.98	1.48	0.84	1.56
20:1 (Paullinic acid)	_	0.04	Trace	_
22:1 (Erucic acid)	_	Trace	Trace	_
Polyunsaturated (total)	0.15	0.5	0.12	0.31
18:2 (Linoleic acid)	0.11	0.37	0.08	0.18
18:3 (α-Linolenic acid)	0.04	0.05	0.05	_
18:4 (Stearidonic acid)	_	_	Trace	_
20:4 (Arachidonic acid)	_	0.03	Trace	_
20:5 (Eicosapentaenoic acid)	_	Trace	Trace	_
22:5 (Docosapentaenoic acid)	_	Trace	Trace	_
22:6 (Docosahexaenoic acid)	_	Trace	**Trace**	_
Cholesterol (mg)	11	14	14	21.7

In reference to carbohydrates, lactose is the major carbohydrate present in milk and quantity present has been reported about 44% in goat milk and 49% in sheep milk.

Minerals

Goat milk is distinguished and preferred for its high chloride and potassium content.[57] Concentration of various minerals present in goat milk has been shown in Table 5.

Table 5: Minerals concentrations in Goat & Sheep milk

Minerals	Goat (per L)	Sheep (per L)
Calcium (mg)	1260	1950–2000
Phosphorus (mg)	970	1240–1580
Potassium (mg)	1900	1360–1400
Sodium (mg)	380	440–580
Chloride (mg)	1600	1100–1120
Magnesium (mg)	130	180–210
Ca/P (mg)	1.3	1.4
Zinc (µg)	3400	5200–7470
Iron(µg)	550	720–1222
Copper (µg)	300	400–680
Iodine (µg)	80	53–90
Selenium (µg)	20	31

Vitamins

Goat milk is known to be a rich source of vitamin A, vitamin B1, vitamin B2 and vitamin B3. However, it has lower levels of folates, as well as vitamin B12, vitamin E, vitamin C, and vitamin D. As compared to cow milk, goat milk has lesser amounts of vitamin E, folic acid, and vitamin B12. Vitamins composition of goat and cow milk has been presented in Table 6.

Table 6: Vitamins in Goat & Cow Milk

Fat soluble vitamins	Goat milk	Cow milk
Retinol (mg)	0.04	0.04
Beta-carotene (mg)	0	0.02
D (µg)	0.06	0.08
Tocopherol (mg)	0.04	0.11
Water soluble vitamins		
B1 Thaimin (mg)	0.05	0.04
B2 Riboflavin (mg)	0.14	0.17
B3 Niacin (PP) (mg)	0.2	0.09
B5 Pantothenic acid (mg)	0.31	0.34
B6 Piridoxin (mg)	0.05	0.04
B8 Biotin (µg)	2	2
B9 Folic acid (µg)	1	5.3
B12 Cobalamin (µg)	0.06	0.35
C Ascorbic acid (mg)	1.3	1

It has been found that numerous conventional studies have been conducted to explore and analyse the therapeutic potential of goat milk and myriad therapeutic properties have been reported. Some of them are mentioned below.

Anti-inflammatory and Anti-mucosal Properties[58]: It has been reported that goat milk do not cause irritation in the gut and prevent mucous formation due to its smaller size of the fat globules which one ninth the size of fat globules present in cow milk.

Innate and Adaptive Immunities[59]: In a study, it has been found that goat milk fed mice exhibited enhanced immune response, antibody production (IgA, IgM, and IgG subclasses) and phagocytosis activity promotion.

Probiotic Supplement [60]: Goat milk has higher level of the oligosaccharides then the other milks. Oligosaccharides act as prebiotics in gut and improve the gut health. The isolates showed negative test for haemolytic and gelatinase activities and hence were considered safe. The lactic acid bacteria i.e., E. faecium GMB24 and E. hirae SMB16 isolated from goat milk have reported to exhibit significant pro-biotic potential and immune-stimulant activities. [61]

Anti-carcinogenic[62'63]: The risk of occurrence of cancer, carcinogenic toxicity and tumour suppression are prevented by Lactic Acid Bacteria (LAB) present in goat milk. The study of different strains of LAB in goat milk can strengthen the cancer prevention.[64]

Anti-hypercholesterol- In a study, goat's milk yoghurt was given to mice after hypercholesterolemic diet for 14 days. The results demonstrated that three types of bioactive peptides present in goat milk have shown anti-hypercholestrol activity in mice models. Furthermore, it has been found that goat milk yoghurt reduces the MDA level and prevents the accumulation of fats in liver. Moreover, on liver histopathology, it has been found that it also reduced the extent of cell damage in liver. [65]

Preventing and Inhibiting Osteoporosis[66]: In a study, patients were treated with 250ml/day of fresh goat's milk in the morning for 110 days and fasting serum calcium and CTX levels (samples collected in morning hours) were evaluated prior and post to administration fresh goat milk. The study suggested that regular intake of goat milk increases serum calcium levels and decreases CTX levels.

Anti-hypertensive:[67,68] It has been found that casein and whey proteins present in goat milk stimulates the ACE-inhibitory peptides. This study found one peptide from whey β-lactoglobulin, PEQSLACQCL and two peptides from caseins, ARHPHPHLSFM, and QSLVYPFTGPI that displayed ACE-inhibitory activity comparable to standard anti-hypertensive drugs having ACE-inhibitory action.

Antimicrobial:[69] In this study, antimicrobial activity of CSN1S2 protein present in Ethawah breed goat milk and yoghurt against pathogenic Gram-positive bacteria (Listeria monocytogenes, Staphylococcus aureus, and Bacillus cereus) and Gram-negative bacteria (Escherichia coli, Salmonella typhi, and Shigella flexneri) has been reported. Short chain fatty acids (SCFA), Medium Chain Triglycerides (MCT), capric,

caproic and caprylic acids found in goat milk also have been proved to possess antimicrobial activity.[70]

Antioxident:[71] It has been reported that goat milk fermented with *Lactobacillus plantarum* had potent radical scavenging and lipid peroxidation inhibition activity.

Cells Proliferation:[72] In-Vitro assays demonstrated that goat milk can counteract the effects of EAEC on cell renewal and repair the intestinal cell barrier function as goat milk contains higher concentrations of lysozyme hence offers additional protection.

Memory-enhancing effects:[73] It has been observed that addition goat milk in the diet enhances the both long and short term memory performances along with spatial memory performance. It also prevents memory decline in the D-galactose plus goat milk treated group as compared to the control group where only D-galactose was administered.

Anti-allergic:[74] The major therapeutic effect of goat milk proteins has been observed as their anti allergic and healing effect in the cases of cow milk allergy. In addition, the β-casein/α_{s1}-casein ratio (70%/30%) of goat milk proteins is similar to human milk, which results in more digestibilities compared to the cow milk in relation to higher sensitivity of β-casein to the protease enzymes.

Anti-atherosclerotic[75]: Goat milk provide 498.7mg of K and 121.5mg of Na that is sufficient in preventing high blood pressure and protecting against atherosclerosis.[76] It has also shown inhibitory activities against PAF (platelet-activating factor)-induced platelet activation.[77]

Modulate healthy human peripheral blood lymphomonocyte and polymorphonuclear cell function [78]: Goat milk has been found to stimulate pro-inflammatory (TNF-α and IL-6) and anti-inflammatory (IL-10) cytokines in the immuno-compromised host, reflecting its potential to stabilize immune homeostasis.

Antiviral properties[79]: The goat milk has exhibited significant (41%±11%) viral inhibition in mice model and administration of goat milk and goat milk yogurt can increase the superoxide dismutase (SOD) enzyme levels in the mice infected with malaria parasite.[80]

Hepatoprotective[81]: Goat milk prevented the antitubercular drug-induced hepatotoxicity and act as an effective hepatoprotective agent.

Iron Deficiency Anaemia[82]: Treatment with goat milk have shown increased serum level of iron, ferritin and hepcidin were found along with improved iron stores in bone marrow, spleen and liver. It is reported that goat milk consumption increases the uptake of Iron and Copper in digestive tract.[83]

Cardio-protective[84]: Goat milk reduces the probability of CVDs by virtue of its rich concentration of carnitine content that enhances the rate of ß-oxidation in mitochondria.

Anti-dementia[85]: Studies have shown that both myristin and olein helps the body maintain the structure of nerves and brain cells, which may have a positive effect on dementia and Alzheimer's disease.

Galactagogue activity: Goat milk is found to be effective in increasing the milk production and protein content in lactating mothers.[86]

DISCUSSION

Scientific studies have reported that the tolerance of goat milk is better in some individuals due to its 7% less lactose content as compared to cow milk. In fact, our body can digest goat's milk within 20 minutes while it takes 2-3 hours to digest cow's milk.[87] On the basis of above studies it can be inferred that administration of goat milk in infants can prevents the episodes of gastrointestinal disturbances and diseases like diarrhoea, constipation and vomiting. It also found to be significantly effective in the management of respiratory disorders as it is well tolerated by the infants. It has been reported that beta casein comprises the largest fraction of total goat milk casein. The αS1 content present in cow milk is reported to higher than both the αS1 and αS2-casein content found in goat milk collectively. This variation of protein content is possibly the reason behind better digestibility, soft curd-forming properties and very mild or no allergic reactions in children.[88] Therefore, fermented goat milk forms a softer curd as compared to cow's milk and hence easily digested and absorbed. Daily and judicial consumption of goat milk significantly improves the mineralization of skeleton, raises the haemoglobin and vitamin level in the blood.[89] These activities are possibly due to the significant differences between physico-chemical structure and composition of goat and cow milk fats. The average diameter fat globules present in goat milk are reported to be about 3.5 micro meters as compared to 4.5 micro meters in cow milk. Average diameters of fat globules for goat, cow, buffalo, and sheep milks were reported to be 3.49, 4.55, 5.92, and 3.30 micro meters, respectively. Smaller fat globules make a better dispersion and more homogeneous mixture of fat in goat milk, which would provide lipases with a greater surface area of fat for enhanced digestive action. From a human health standpoint, natural homogenization of goat milk is be better for digestion than the mechanically homogenized cow milk products. The fat globules range between 1 and 10μm in both goat and cow milk, but the ratio of fat globules smaller than 5μm is ~60% in cow milk whereas it is more than 80% in goat milk.[90] It was established that the consumption of raw milk reduces total cholesterol level because of the higher presence of MCT (36% in goat milk & 21% in cow milk), which decreases the synthesis of

endogenous cholesterol. It also helps to boost the immune system. Goat's milk alkalizes the digestive system and helps to increase the pH level in the blood stream also, which in turn prevents gastric ulcer.[91]

Viral inhibition by antibodies found in goat milk. This assumption has been ruled out through Immunofluorescence Assays (IFA) for detecting anti HSV-1 antibodies in goat milk which were all negative. The possibility that antiviral activity of goat milk is caused by high concentration of chloride ions has been ruled out based on our finding of a lower chloride concentration. Reduced viral infectivity of HSV-1 might have been caused by surface blockade of HSV-1 by goat milk active components.

CONCLUSION

On reviewing the studies reported in goat milk it has been found that the diverse usage of goat milk is mentioned in ancient classical texts of Ayurveda and recent advanced research also support the facts. Goats' milk products play an important in human health because of their nutritive and therapeutic values. It is reported to have higher nutritional values in comparison to other commonly consumed milk such as cows, buffalo etc. Goat milk is not just a part of food, it possess numerous medicinal properties too. It has higher content of bioactive compounds, beneficial fatty acids and proteins. Its beneficial effects range from malabsorption disorders and inflammatory bowel diseases to reduce the risk of cardiovascular disease due to its ant-oxidative properties. It's high time to switch to goats milk because of its enormous health benefits and similarity with human milk but consumed with a fact in mind that it contains inadequate quantities of iron, folate, vitamins C and D, thiamine, niacin, vitamin B6 and pantothenic acid to meet nutritional needs.

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