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Research Article

Goat Milk as a Healthy Dietary Source and Nutrition for Humanity

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ABSTRACT

Goat milk constitutes 2.4% of the total world milk production while more than 85% of the total global milk supply comes from cows and these are the most important dairy species for human consumption. Ironically an increasingly large number of people appear to consume goat milk and its products compared to other dairy species on a global scale. Among the developing countries with large population sizes and concomitant high rates of under nutrition and malnutrition, the populations of goats have increased in numbers with relatively higher growth rate than any other domestic dairy species. Therefore, like cow milk, goat milk seems to be an equally important and in fact a healthy alternative source of milk and milk products to meet the emerging challenges of malnutrition among developing countries with rising populations. If intensive management practices are followed, then goat farming, particularly of milk producing goat species, could be profitable regardless of the country. Goat farming and preference to goat milk have at least three important and valid reasons. They are: Goats are more adaptable to harsh climatic and geological conditions when compared to other domestic milk producing mammals. They are easier to rear and cost-effective to maintain particularly by women and children when compared to other milk producing mammals. Goat milk has superior health and nutritional attributes than milk from other dairy sources. Goat milk and its products including cheese and yoghurt are valued in entire dairy industry of the developed countries as they provide gourmet foods to connoisseur consumers. Goat milk and its products have high health relevance and can function as an alternate dietary dairy source for persons with milk allergies and other gastrointestinal disorders. The preferable nutritional composition and thus the therapeutic properties of the goat milk are not only due to the superior milk protein quality and mineral composition but are also due to the differences in its lipid and its fatty acid composition. Goat milk has higher proportions of short and medium chain fatty acids; beneficial bioactive peptides and the natural quantities and ratios of certain minerals such as calcium, magnesium and phosphorus; as well as polyamines, nucleoside and nucleotide and several metabolically functional components and minor compounds which are found to be beneficial for child growth, health maintenance and over all well-being of humans. Therefore, goat milk has made three important and historical contributions to the nutrition, economy and well-being of entire mankind in the form of (i) dietary source for human consumption, (ii) dairy food of specialty gourmet interest and (iii) medial and therapeutic applications.

Keywords: Dairy goats; Production; Contribution; Economy; Nutrition; Human health; Milk

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INTRODUCTION

Among domesticated animals, goats have been maligned historically and are still a stigma in many regions of the world particularly due to its occasional offensive odor particularly emanating from the buck. As the odor tend to float around the premises of goat rearing farms, it offends human beings especially in the milking facilities and can potentially affect the flavor of the doe's milk, if there is improper or insufficient ventilation, milking practices and cooling of the milk. However, this odor, emitted by the buck, also called as "buck effect" functions as an aphrodisiac enticing the libido for doe (female adult goat) and stimulates their sexual activity. Such stimulation is helpful for reproductive and thus in consequent milking capacity [1].

Historically speaking, bovine milk constituted a significant proportion of the dairy industry all across the world in terms of the milk production volume as well as the quantity of consumption by the mankind. Nevertheless, as far as the frequency or the number of people who drink milk is concerned, goat milk stand relatively higher as increasingly more number of people from all across the world are consuming goat milk than milk from any other single species. Goat milk serves more population around the world particularly in the underdeveloped and developing countries whose population depends on the goat milk for their subsistence, nutritional needs and survival. Therefore, the contribution of the goat milk to human economy, nutrition and overall well-being cannot be underestimated. Caprine milk can be easily digested, has distinct alkalinity, higher buffering capacity, as well as certain distinct therapeutic properties when compared to bovine or human milk and such properties can be potentially utilized for diet based therapy and nutrition.

Except in Antarctic, goats can be found in all continents providing milk for human consumption. Dairy cows (*Bos taurus*) are difficult to rear in desert and mountainous regions while Yaks (*Bos gruniens*) are milked only in the high altitude mountains of Tibet and Mongolia; camels are milked only in desert countries. Sheep are mainly farmed for their wool and meat production. Water buffaloes can neither be found nor milked outside of India, South-East Asia and Italy. Cattle milk production from Brahma-Zebu (*Bos indicus*) is limited to only Brazil and Central America. Horses and donkeys have been milked in Mongolia, Bulgaria and on specialty farms in Europe, Egypt and Chile. Moose were found to be milked on a resort farm in Northern Russia, whereas reindeer produce milk for human consumption in a few arctic regions of Siberia and Finland. South American camelids like llamas und Alpaca were never known to have been milked before the times of Columbus. It is indeed strange to know that Incas, Mayas, Aztecs who were known to be technologically advanced and very athletic did not have any milk or dairy products in their diets and is in fact quite contrary to the beliefs of western health authorities who recommend daily dietary calcium requirement of 1000 mg for adult humans, which is obtained at the best by drinking three glasses of milk [2].

MATERIALS AND METHODS

The number of goats have increased constantly all across the world and consequently the goat population reached one billion population size with a rate of more than 50% increase during the past 40 years, particularly in Africa and Asia (Table 1). However, their numbers have been quite stagnant in America and decreased slightly in Europe. In Mediterranean region, their population increased, which indicate that dairy goat numbers increased compared to the numbers from around the world, which is more of a dual or multi-purpose comprising of meat, brush and fiber goats. Goats have been substantial contributors of milk and dairy products to the human beings all across the world and are valued for their economical sustenance, subsistence as well as a source of health and nutritious alternative diary dairy source even though goats produce only 2.4% of the total global annual milk supply, The contribution of the goats to the well-being and nutrition of humanity is very important in many regions of the world notably in Meditteranean and in the Middle East. Therefore, the purpose of this article is to review the significance and importance of goat milk contributions to the well-being, nutrition and economic sustenance of humanity on a global perspective [3].

Global goat milk production

Goat milk production increased from 11 to 19 million tons or in other terms showed an increase of 62% from 1993 to 2013 with France, Spain, Turkey and Greece leading in tonnage, in that order. During the same period, the world population also increased from 5.5 to 7.2 billion. This suggests that goat rearing and its numbers have increased in Asia and Africa in order meet the diary milk consumption needs of the people and as a consequence more people are now exposed to goat milk than to any other milk producing species on a world-wide basis [4].

In the year 2013, the total goat milk production was 17,957,000 Metric Tons, accounting for 2.4 % of total global milk production of 747,707,000 MT from cows, buffaloes, goats, sheep and camel all taken together. In fact on percentage basis, the goat milk production has increased in Africa (94.7%), Asia (73.1%), Europe (67.96%), North America (19%) and South America (16.5%) in the recent 20 years indicating that more quantities of goat milk is being increasingly consumed by large number of people across the world than from any other milk producing species [5]. Goat milk is the main source of dairy food item for poor people, small-scale farmers and has the potential to prevent mal and under nutrition in developing countries. Goat milk has been proved to be beneficial for people with bovine milk allergies and gastrointestinal afflictions.

Properly milked and cooled goat milk is odor-free and is in fact very hard to distinguish from cow milk with respect to taste and odor. Thus, quality milk production from goats is now possible and goat milk production has made great progress over recent years in dismantling the misconception of milk consumers. Goat milk is sought after for infants with cow milk allergy and to those people who develop gastrointestinal disorders upon consumption of bovine milk.

In the Western countries, interest in goat milk has grown among cheese connoisseurs and among upscale markets and restaurants [6].

The interest for goat milk yogurt has also showed an increasing trend. Goat milk has different casein protein polymorphism in αs1 and αs2. Unlike cow milk, goat milk has higher proportion of αs 2 resulting in the formation of soft curd with lower cheese yield. The large-scale production of pure goat milk yogurt has had this technical hindrance and was overcome by blending goat milk with cow milk or sheep milk or by the use of certain additives to increase firmness.

The growing popularity, interest and need of goat milk is focused on the sustenance of poor and rural farmers with small land holdings and has immense relevance in educating people regarding the value and acceptability of goat milk. Goat milk is considered as a super dairy food with special dietetic, nutritional medical, biological and immunological functionalities. These attributes of goat milk are reflected in the substantial rise in the total goat population size as well as goat milk production all around the world by about 59.7% in the recent 20 years and by 62.4% in the past 40 years. In fact, the rate of increase in the number of goats has superseded the population growth rate of humans which were 41.1% and 26.4% over the past 20 and 40 years, respectively. In Africa, goats have increased by 92.1% with total increase of goat milk production by 94.7% as compared to the increase in the number of people by about 63.1%. Similarly, in Asia, the increase has been 73.1% and 27.2%, respectively [7].

RESULTS

Economic contribution and profitability of goat milk production

The question of whether dairy goat farming is economical when compared to bovine dairy farming with respect to the quantity of milk produced per animal, which is comparatively large among bovine sources. Previous studies have reported profitability of goat farming in the context of feed costs involved and the type of management practices being followed. A study on the management of 108 US dairy goat herds in the year 1978 revealed profitability within the range of 503 to 1,115 kg milk/goat/year in terms of income over feed costs which ranged from$117 to $406/goat/year. A similar study in Greece reported that the net return per goat per year was $24.05 for the intensive management practice whereas $7.55 was obtained for the extensive type management. In a large-scale study in India, it was found that the net income per goat per year ranged from $1.80 to $10.00, when milk production per goat per year ranged from 178 kg to 595 kg, respectively.

At annual production level of 680 kg milk, the break-even producer price for goat milk was $0.52 per kg whereas it was$0.26 per kg milk at 1,161 kg of annual milk production level. In France, net returns per goat per year was comparatively higher at $112.00 when goat milk was processed into goat cheeses and then sold as value added products from the farm when compared to $74.93 that was obtained when only the milk was sold as such.

These findings were in confirmation of the results obtained from a similar previous study in Italy. Goat cheese gained popularity among gourmet consumers and this has great relevance and value to goat farming profitability. Goat farming profitability also comes from distinct advantages in region with harsh climatic and geological conditions such as deserts in Africa and Asian countries and in high altitude and mountainous countries like Greece and China. Several review studies have also emphasized on these advantages and profitability of goat farming [8].

During the past 40 years dairy goat has gained reputation as a valued member of the world dairy industry. This is proved by the FAO statistics which showed that goat milk makes up 55% of all milk in Bangladesh, 51% in Somalia, 24% in Iran and 16% in Sudan in the year 2001. This also demonstrates the nutritional value of goat milk in underdeveloped and developing countries facing the burden of high prevalence in under nutrition and malnutrition. Compared to European standards of 60 g of protein requirement from milk and meat, in Bangladesh, a person is supplied only 5 g protein per day from milk and meat, in Somalia 17 g, in Iran 16 g and in Sudan 22 g. Nevertheless, the milk productivity per goat in such countries needs adequate attention and improvement because not all goats are being milked. Production levels have been 40 kg/goat/year in Bangladesh, 31 kg in Somalia, 15 kg in Iran and 31 kg in Sudan, when compared to 121 kg in Spain and 400 kg in France.

Nutritional benefits and advantages of goat milk over bovine milk

The nutritional composition of goat and cow milk differs to a great extent at least in two major nutrients of proteins and lipids (Table 1). Same type of milk proteins are present in both goat and cow milk, however, their relative amounts differ to a great extent influencing the digestibility and milk processing. For example, αs1 casein is present in cow milk in higher proportion whereas its content in goat milk is either very low or not present altogether. In contrast, goat milk contains polymorphic variant of αs2 casein in higher proportions due to which the curd consistency is very soft. Soft curd enables better and easy human digestion but, lowers the cheese yield. The nature of kappa casein also is very different in goat milk primarily because of differential amino acid substitutions. Goat milk is rich in at least six amino acids (cysteine, tyrosine, lysine, valine, threonine and isoleucine) of the ten essential amino acids when compared to cow milk. These differences in the composition of goat and cow milk, also induce differences in certain physico-chemical properties such as size and form of casein micelle, extent of solubilization and heat stability. Certain metabolically important milk constituents of goat milk such as non-protein nitrogen, immoglobulins and lysozymes also significantly differ from those in cow milk (Table 2).

Table 1: Trends of populations of goats and people during the last 40 years.

		Million head			Change %	
		1973	1993	2013	1993-1973	2013-1993
Goats						
	World	385	611	976	58.70%	59.70%
	Africa	114	181	348	59.00%	92.10%
	N.C. America	11	13	12	19.70%	-10.30%
	S. America	20	22	21	10.20%	-3.80%
	Asia	221	370	571	67.60%	54.20%
	Europe	17	19	16	12.20%	-15.00%
	Medit. Region 1	44	39	43	-11.40%	10.70%
	Oceania	0.3	3	4	764.30%	44.10%
People						
	World	3,991	5,579	7,162	41.10%	28.40%
	Africa	396	681	1111	72.00%	63.10%
	N.C. America	316	414	523	31.10%	26.50%
	S. America	205	312	407	51.90%	30.50%
	Asia	2,236	3,380	4,299	51.10%	27.20%
	Europe	718	728	742	1.40%	1.90%
	Medit. region 1	352	447	539	26.90%	20.50%
	Oceania	21	28	38	34.40%	35.70%

Table 2: Caseins, minor proteins and enzyme contents of goat milk in comparison with those of cow and human milks.

Proteins	Goat	Cow	Human
Protein (%)	3.5	3.3	1.2
Total casein (g/100 ml)	2.11	2.7	0.4
α_{s1} (% of total casein)	5.6	38	-
α_{s2} (% of total casein)	19.2	12	-
β (% of total casein)	54.8	36	60-70.0
κ (% of total casein)	20.4	14	7
Whey protein (%) (albumin and globulin)	0.6	0.6	0.7

Nonprotein N (%)	0.4	0.2	0.5
Lactoferrin (µg/ml)	20-200	20-200	<2000
Transferrin (µg/ml)	20-200	20-200	50<
Prolactin (µg/ml)	44	50	40-160
Folate-binding protein (µg/ml)	12	8	-
Immunoglobulin			
IgA (milk:µg/ml)	30-80	140	1000
IgA (colostrum:mg/ml)	0.9-2.4	3.9	17.35
IgM (milk:µg/ml)	Oct-40	50	100
IgM (colostrum:mg/ml)	1.6-5.2	4.2	1.59
IgG (milk:µg/ml)	100-400	590	40
IgG (colostrum:mg/ml)	50-60	47.6	0.43
Lysozyme (µg/100ml)	25	10-35	4-40
Ribonuclease (µg/100ml)	425	1000-2000	10-20
Xanthine oxidase (µl O_2/h/ml)	19-113	120	-

The lipid content in the goat and cow milk can vary depending upon the extent of grazing and feeding management practices as well as their inherent genetic differences. Nevertheless, goat milk has specific nutritional advantage over cow milk in term of fatty acid composition of the lipids. The higher proportion of medium chain fatty acids (MCT), monounsaturated, polyunsaturated fatty acids and Conjugated Linoleic Acid (CLA) in goat milk is important for cardiovascular health of humans. The smaller size of the fat globules in goat milk renders it the properties of naturally homogenized milk and enables easier digestibility when compared to cow milk [9].

Additionally, got milk has better gastrointestinal digestibility, nutritional absorption, nutrient bioavailability. Such properties lead to better growth and make the goat milk a physiologically better alternate dairy food source for children and sick people. In a feeding trial comprising of 38 children aged between 6 and 13 years fed with equal volumes of either goat or cow milk per day for a period of 5 months, it was revealed that group of children consuming goat milk displayed better weight gain, statue, skeletal mineralization, bone density, blood plasma vitamin A, thiamin, riboflavin, niacin, hemoglobin and calcium concentrations. The statistical differences in blood hemoglobin, as well as biochemical and structural measurements between the groups consuming goat and cow milk were minimal.

Even though goat milk has superior biochemical composition and great nutritional as well as therapeutic potential, it has not been successfully used in marketing and promotion. In Madagascar, a study on the effect of goat and cow milk consumption among 30 hospitalized children revealed that goat milk consuming children outgained the group consuming cow milk by 9%. Another study in Spain reported that goat milk helped reduce the total cholesterol and LDL fraction due to its higher content of medium chain fatty acids MCT. Among Algerian children with malabsorption syndromes, consumption of goat milk was found to enable significantly higher rates of fat absorption in the intestines.

In animal model study comprising of rats fed with either cow or goat milk, it was revealed that intake of goat milk caused significantly higher liver weight, greater hemoglobin iron gain and higher iron absorption. In another study comprising of guinea pigs, it was found that alpha-s-1 casein intake developed allergic reactions and feeding with alpha-s-2 casein did not elicit such adverse reaction. Probably such findings can explain the cow milk allergy since cow milk contains higher proportion of alpha-s-1 casein. Goat milk lacks alpha-s-1 casein and predominantly contains alpha-s-2 casein indicating the reason behind its potential to cure cow milk allergy.

However, in case of clinical allergy it would be difficult to analyze which type is responsible due to wide genetic diversity of the milk proteins [10].

DISCUSSION

Goat milk as hypoallergenic dairy food

The use of goat milk as hypo-allergenic infant food or as milk substitute for infants with cow milk allergy has been reported in several anecdotal observations and recent literature. It is also reportedly used for cow milk allergy patients suffering from eczema, asthma, chronic catarrh, migraine, colitis, hay fever, stomach ulcer, epigastric distress and abdominal pain. It was observed that children who were sensitive to bovine milk allergy but not to goat milk, also showed similar allergenic reaction to bovine milk cheese but not to goat milk cheese. Administration of goat milk to infants with eosinophilia and gastrointestinal allergy led to improvement in the condition. In a separate case study, it was observed that chronic enteropathy among infants caused due to feeding of the cow milk formula was cured by replacing with goat milk. Similarly, other reports also demonstrated successful management of bovine milk allergy by substituting with goat milk formula.

Based on previous reports on the beneficial effects of goat milk, the evaporated form of goat milk or the goat milk powder has been recommended for infant formula. During milk processing the high heat treatment removes the sensitizing properties of the milk and thus reduces the allergenic properties. The inconsistency in cross allergenicity among milk sourced from different species could be either due to qualitative or quantitative reasons. Nevertheless some proteins of bovine milk were found to show higher incidence of positive skin test reactions than goat milk. Clinical research findings showing unsuitability of goat milk are scarce. Goat milk was found not suitable for 40% of cow milk allergy patients due to immunological cross reactivity between the two milk proteins [11].

Bioactive components in goat milk and their therapeutic effects

Lipids in goat milk are composed of medium and short chain fatty acids which are easily digestible in human gastrointestinal tract as the enzyme lipase cleaves the ester linkages of short and medium chains fatty acids in a much easier manner that in longer chains. Medium chain fatty acids in goat milk inhibit cholesterol deposition and facilitate its dissolution in gall stones, thus proving to be beneficial as hypocholesterolemic agent. Goat milk containing large proportion of MCT has potential to treat malabsorption among patients suffering from steatorrhea, chyluria, hyperlipoproteinemia and in case of intestinal resection, coronary bypass, childhood epilepsy, premature infant feeding, cystic fibrosis and gallstones. Goat milk also contains a relatively higher number of BCFA than cow milk, in particular trans-C18:1, which may be beneficial in countering the incidence of coronary heart disease.

The proteolytic digestion of goat milk and fermentation by lactic acid bacteria releases bioactive peptides which are physiologically active.

Such bioactive peptides of goat milk were found to have antimicrobial, antihypertensive, antithrombotic, antioxidative, cytomodulatory and immunomodulatory properties. Goat milk also have opioid-like acting peptides. The role of bioactive peptides from milk and milk food product were well researched for their effects of disease prevention, health improvement and therapeutic applications. Additionally, goat milk also has pH buffering capacity and was found to be ideal for treating stomach ulcers while its proteins mainly casein and phosphates contribute to its Buffering Capacity (BC) [12].

Polyamines in goat milk

Goat milk has several types of casein proteins, whey proteins (α-lactalbumin, β-lactoglobulin, lactoferrin, immunoglobulins, glycomacropeptide); enzymes (lactoperoxidase, lysozyme); lipids (Conjugated Linoleic Acid (CLA), phospholipids, cholesterol and minor lipids), bioactive peptides, bioactive carbohydrates (lactose, lactose derivatives, oligosaccharides), as well as other important milk constituents including growth factors, cytokines, milk hormones, enzymes, organic acids, minerals and vitamins. In addition to these, there are biologically and physiologically active components such as polyamines, nucleosides and nucleotides.

Polyamines, such as putrescine, spermidine and spermine, occur naturally in goat milk and they show a wide range of biological functionality and potential therapeutic effects. Spermidine and spermine and their diamine precursor putrescine play an important role in cell differentiation and growth. Polyamines stabilize the negative charge on the DNA and of the chromatin and regulate several transcriptional factors and protein synthesis.

Polyamines also regulate inflammation, digestion, immunological functions and immunoallergic responses by mediating the action of known hormones and growth factors. The polyamine reserves in human body need support of exogenous supply from dietary sources to facilitate rapid cell proliferation and growth in neonates or even during the process of recovery from an injury. The organs and the systems with high cell turnover rate are particularly dependent on the exogenous supply of dietary polyamines.

Nucleotides and nucleosides in goat milk

Nucleotides and nucleosides are minor non-protein constituents of the milk and they function as therapeutic agents and anti-carcinogens against the malignant cells. Nucleotides have great biological relevance for pre-term and gestational age infants. They serve as monomeric building blocks or subunits for nucleic acids such as DNA and RNA. The nucleotides are composed of a nitrogenous base, a five-carbon sugar (ribose or deoxyribose) and at least one phosphate group indicating that a nucleotide is made up of a nucleoside plus a phosphate group. However, the biological functions of these nucleosides and nucleotides in caprine and bovine milk needs further investigation [13].

CONCLUSION

Milk consumers in western cow milk producing countries may tend to overlook the importance, relevance, benefits and

contribution of goat milk to the well-being and welfare of humanity around the world. Goat milk currently serves more number of humans than ever before when compared to bovine milk or for that matter compared to any other dairy species. This implies that goat milk production and consumption has substantial role to play in global diary industry and it is necessary for economy, nutrition, subsistence and basic survival of ever increasing population of human beings in several countries.

Goat milk and its processed products constitute a significant portion of the agricultural production and the National economy particularly in underdeveloped and developing countries. In developed countries, goat milk forms an important segment of dairy industry, provides gourmet foods to connoisseur consumers and plays the role of therapeutic agent for people with cow milk allergy, other medical problems and gastro intestinal disorders associated with bovine milk consumption. Moreover, caprine milk has several nutritional and therapeutic advantages over cow milk due to fundamental differences in its composition of protein, lipid, mineral content as well as bioactive and physiologically important components that are beneficial for child growth, health maintenance and overall well-being of mankind.

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