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Perspective role of goat milk and products: A review

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Abstract
Goats play a vital role in livestock industries and socio-economic structure of rural people. South Asian countries are major producers of goat milk, whereas, European countries are the most developed dairy goat industries. Goat milk contains higher amount of vitamins, minerals and lower amount of lactose than cow milk, which is beneficial for lactose intolerance patients. It also contains trace elements, enzymes, protein and polyunsaturated fatty acids. The unique characteristics of goat milk have been fairly surveyed regarding nutritional value and some health benefits. Goat milk and its products thereof may be useful for fast brain development, curing dengue fever, lactose intolerance, digestive utilization of fat, anti-inflammatory, anti-carcinogenic properties, anti-microbial activity and less allergenic as an infant formula. Goat milk and goat milk based products are sold commercially, which purports numerous health benefits. Goat milk products other than cheeses are considered to be the dairy products with greatest marketing potential.

Keywords: Goat milk, Health benefits, Functional foods, Nutritional benefits, Dengue fever

Introduction
The importance of goats is as a contributor around the world of essential food in meat and dairy products. Goats also form an important component of livestock industry and play a vital role in the socio-economic structure of rural poor. Due to rapidly increasing human population, the demand for milk and milk products is on the rise in all developed and developing countries. The increased demand can be met by increasing ruminant livestock population as suggested by Devendra and McLeroy (1996) [1]. More than any other mammalian farm animal, the goat is a main supplier of dairy and meat products for rural people and developing countries and here the old saying of the "goat being the cow of the poor people" is quite appropriate. There are nearly 500 breeds of goats in the world; however, only a half dozen are generally raised for their milk purpose and about 600-700 million of dairy goats are present in the world (Kris, 2008) [2]. They are living in climates ranging from high altitude mountains to deserts (Bagley, 2006) [3]. More than 95% of the goat population is found in developing countries. Nondairy breeds of goats in the tropics have daily milk yield up to 0.5 liters while specialized dairy goat breeds, including the Nubian, Saanen, Alpine, LaMancha and Toggenburg, could give 2-4 liters per day (Peacock, 1996) [4]. The major species of dairy goats are Anglo-nubian, British Alpine, Toggenburg and Saanen. Toggenburg is the best breed that can produce two gallon (7.57 liters) milk per day (Galal, 2005) [5]. There are twenty well defined breeds of goats in India, although 70% population are non-descript and meat type. Some of the breeds such as Jamunapuri, Barbari, Beetal, Surti, Jakhrana produce fairly good amount of milk (Rashmi, *et al.,* 2013) [6].

Goat milk production
The role of goat milk to human nutrition is important in many developing countries. On the other hand the greater portion of goat milk still is not widely traded, but is consumed locally (Dubeuf *et al*. 2004) [7]. The evaluation of goat milk production during the period 1990-2014 is shown in different region Table1 and countries Table 2. Among the continents, Asia is constantly the larger producer of goat milk, followed by Africa, Europe and Americas. Oceania had a significant increase of goat milk production during the period 2000-2014 (+82.14%), followed by Asia (+58.75%), Africa (+47.13%) and America (+18.97%). In Europe, on the contrary, during the same period the goat milk production was decreased (+0.84%).

Table 1: Goat milk production (tonnes) in the World during the period 1990-2014

Year/ Region	1990	2000	2012	2014	% Change 2000-14	Contribution % in 2014
Asia	5485692	6948745	10410137	11031041	+58.75	60.15
Africa	2055653	2777245	4308399	4098032	+47.56	22.34
Oceania	25	28	48	51	+82.14	0.00027
Europe	2161678	2587928	2536773	2609704	+0.84	14.23
Americas	467190	505342	509761	601186	+18.97	3.28
World	9980102	12819288	17846118	18340016	+43.07	100.0

Source: Faostat, 2013; 2014 [66]

Table 2: Goat milk production (tonnes) in the different countries during the period 2012-14

Country	2012	2014	% Change 2012-14
Asia			
Bangladesh	2608000	2779086	+ 6.56
Pakistan	779000	822000	+5.52
China	291362	315802	+8.39
Turkey	369429	463270	+25.40
India	4949910	5180180	+4.65
Africa			
Kenya	267904	277684	+3.65
Mali	715000	420102	-41.24
Sudan	1088000	1116000	+2.57
Algeria	297201	313936	+5.63
Somalia	410000	399625	-2.53
America			
Mexico	155636	155497	-0.09
Jamaica	182000	185967	+2.18
Brazil	150000	153659	+2.44
Europe			
France	613711	604400	-1.52
Greece	347000	351209	+1.22
Spain	443625	477400	+7.62

Source: Faostat, 2013; 2014 [66]

In Asia, the largest producers of goat milk are India, followed by Bangladesh, Pakistan and Turkey. China, which poses the greatest number of goats in the world, has limited production in goat milk, because the larger number of goats in this country is farmed for meat production. Among the African countries, the largest amount of goat milk was produced by Sudan**,** followed by Mali, Somalia, Kenya and Algeria. In the American continent the leader countries in goat milk production are Jamaica, Mexico and Brazil, while in Europe the larger producers are France, Spain and Greece. The amount of goat milk production in different countries is given in Table 2.

Milk compositions

The average compositions of goat, cow and human milks are presented in Table 3. These compositions vary with breed, diet, parity, individuals, feeding, season, lactation period, environment conditions, farm management, locality and health status of animal. The Table 4 indicates variation in goat milk according to breed and country. Rashmi *et al.,* (2013) [6] have carried out a study to evaluate comparative aspect of goat and cow milk of Indian breads samples collected at Bikaner (Rajasthan). They reported that on an average, the cow and goat milk had 3.79% and 3.73% of fat, 2.98% and 3.02% of protein, 4.55% and 4.45% of lactose respectively and concluded that there was no significant difference between cow and goat milk composition. A different study shows that goat milk is still better and easily digestible because of size of its fat globule and type of amino acid present in its protein.

Table 3: Average composition of basic nutrients in goat, cow and human milk composition

Composition	Goat	Cow	Human
Fat (%)	3.8	3.6	4.0
Solids-non-fat (%)	8.9	9.0	8.9
Lactose (%)	4.1	4.7	6.9
Protein (%)	3.4	3.2	1.2
Casein (%)	2.4	2.6	0.4
Albumin, globulin (%)	0.6	0.6	0.7
Non-protein N (%)	0.4	0.2	0.5
Ash (%)	0.8	0.7	0.3
Calories/100 ml	70	69	68

Source: Filiz yangilar, 2013 [46]

Table 4: Composition of goat milk according to breed and country

Country	Breed	Total solids (%)	Fat (%)	Proteins (%)	Caseins (%)	Lactose (%)	Ash (%)
United Kingdom	British Saanen	11.6	3.48	2.61	2.30	4.30	0.8
United Kingdom	Nubian		4.94	3.60		4.51	
Francea	Alpine/Saanen		3.6	3.2			
Italy	Sardinian		5.1	3.9			0.71
Greece	Local	14.8	5.63	3.77	3.05	4.76	0.73
Cyprusb	Damascu	13.2	4.33	3.75	2.97		0.83
Spain	Murciano-Granadina			4.09	3.21		

Source: Pirisi *et al.,* (2007); Psathas (2005) [67, 68]

The average composition of goat's milk does not differ remarkably from cow milk. Goat milk differs from cow or human milk in having better digestibility, alkalinity, buffering capacity and certain therapeutic values in medicine and human nutrition (Coni *et al.,* 1999) [8]. The goat milk is better than cow milk for the reasons like the goat milk is less allergenic, naturally homogenized, easier to digest due to a smaller fat globules as well as higher levels of medium chain fatty acids and it matches with human milk better than cow milk (Cooke, 2010)[9]. However, the flavor of goat's milk is more intense in comparison to cow's milk, which restricts its acceptance by consumers (Gomes *et al.,* 2013) [10]. Goat milk has been recommended as an ideal substitute for cow and human milk (Zenebe *et al.,* 2014) [11]. Therefore, there is a need to provide an alternative means of feeding those infants who cannot have breast-feeding.

Fat of goat milk

A much overlooked component in goat milk is its fat or lipid component. Lipids are the most important component of milk in terms of cost, nutrition and physical and sensory characteristics that impart to dairy products (Park *et al.,* 2007) [12]. The biggest component, approx 97% of the lipid fraction of goat milk is triacylgiycerols (TAG), including large number of esterfied fatty acids (Cerbulis *et al.,* 1982) [13]. The average goat milk fat differs from average cow milk fat significantly in fatty acids (Jenness, 1980) [14]. Goat milk contain much higher amount of short chain and medium chain fatty acids, especially, butyric (C4:0), caproic (C6:0), caprylic (C8:0), capric (C10:0), lauric (C12:0), myristic (C14:0), palmitic (C16:0), linoleic (C18:2), and α-linolenic acids (Ceballos *et al.,* 2009) [15], but lower in stearic (C18:0) and oleic acid (C18:1). Goat milk exceeds cow milk in monounsaturated fatty acids (MUFA), saturated fatty acids (SUFA), medium chain triglycerides (MCT), polyunsaturated fatty acids (PUFA) (Table 5).

Table 5: Average fatty acid composition (g/100g milk) in lipids of goat and cow milk

Fatty acid	Goat milk	Cow milk
C4:0 butyric	0.13	0.11
C6:0 caproic	0.09	0.06
C8:0 caprylic	0.10	0.04
C10:0 capric	0.26	0.08
C12:0 lauric	0.12	0.09
C14:0 myristic	0.32	0.34
C16:0 palmitic	0.91	0.88
C18:0 stearic	0.44	0.40
C6-14 total MCT	0.89	0.61
C4-18 total SAFA	2.67	2.08
C16:1 palmitoleic	0.08	0.08
C18:1 oleic	0.98	0.84
C16:1-22:1 total MUFA	1.11	0.96
C18:2 linoleic	0.11	0.08
C18:3 linolenic	0.04	0.05
C18:2-18:3 total PUFA	0.15	0.12

Source: Ceballos *et al*., 2009 [15]

Three of fatty acids *viz.* caproic, caprylic and capric were named after goats because of their predominance in goat milk (Haenlein, 2004) [16]. Goat milk also has higher proportions of n-3 and n-6 polyunsaturated fatty acids (PUFA) as well as conjugated linoleic acid (CLA) (Ceballos *et al.,* 2009) [15]. The high content of PUFA, MUFA and MCT are beneficial for human health especially for cardio protection activities and CLA has been identified as a potent anti-carcinogen (Williams, 2000; Mir, *et al.,* 1999) [17, 18].

Capric, caprylic acids and MCT have become established medical treatments for an array of clinical disorders including malabsorption syndromes, chyluria, steatorrhea, hyper lipo-proteinemia, intestinal resection, premature infant feeding, non-thriftiness of children, infant malnutrition, epilepsy, cystic fibrosis, coronary by-pass, and gallstones, because of their unique metabolic ability to provide direct energy instead of being deposited in adipose tissues, and because of their actions of lowering serum cholesterol, inhibiting and limiting cholesterol deposition (Haenlein, 2004) [16]. In terms of cholesterol, goat's milk appears to offer a specific distinction in comparison to cow's milk, that contains about 14 to 17 mg cholesterol per 100 gram milk, while goat's milk is more usually recorded at 11 to 25 mg per 100 gram of milk (Garry *et al.,* 2000) [19].

Proteins of goat milk

There are two distinct phases of milk proteins; an unstable micellar phase composed of casein and a soluble composed of whey proteins. The caseins constitute about 80% of the proteins and are classified as αs_1, αs_2, β and κ-caseins, while the major whey proteins are β-lactoglubulin and α-lactalbumin (Slacanac *et al.,* 2010) [20]. The αs_1-casein and β-lactoglobulin are important allergens in cow´s milk, and the differences in protein content and composition between cow and goat milk have emphasized that goat milk as an alternative to people suffering from cow´s milk allergy. Goat milk contains a smaller amount of αs_1-casein than cow milk, although appreciable quantitative variability exists, and the antigenicity of β-lactoglobulin can be partially eliminated by certain treatments (Tomotake *et al.,* 2006) [21]. However, many studies showed that people who are allergic to cow milk proteins often cross-react to proteins in goat milk. Goat milk as a substitute for people with cow milk allergy is further discussed under "Nutritional and therapeutic values of goat milk". Goat milk contains lower amounts of the αs-casein, higher amounts of the β-casein fractions and approximately equal amounts of the κ-casein fractions compared to cow milk. The major protein in cow milk is αs_1–casein, while in goat milk it is β-casein. Goat milk also contains some αs_1-casein, but the amount and genetic variants differ between goat populations (Park *et al.,* 2007) [12].

The casein micelles in goat milk differ from those in cow milk in having greater β-casein solubilization, more calcium and phosphorus and lower heat stability (Jenness, 1980) [14]. The curd is also weaker which directly influence the digestibility in the gastro-intestinal tract. The acidic environment in the gastro-intestinal tract causes the formation of smaller and less dense clusters in goat milk compared to cow milk (Slacanac *et al.,* 2010) [20]. There are not many studies performed on different genetic variants of goat whey protein. But two types of β-lactoglobulin have been identified in goat milk and three variants of α- lactalbumin (Moatsou *et al.,* 2005) [22]. Both the percentages of β-lactoglobulin and α-lactalbumin are lower in goat milk compared to cow milk (Park *et al*., 2007) [12]. The amounts of free amino acids are different between goat and cow milk. Six of 10 essential amino acids are reported to be higher in goat milk; threonine, lysine, isoleucine, cystine, tyrosine and valine (Haenlein, 2004) [16]. Average amino acid composition of goat and cow milk, as published in official USDA tables, shows higher levels of threonine, isoleucine, lysine, cystine, valine essential amino acids in goat milk (Table 6). Their metabolic effects have not been studied much in goat milk; however the higher content of cysteine (derived from cystine) has been shown to improve intestinal absorption of copper and iron in a rat model of malabsorption syndrome (Barrionuevo *et al*. 2002) [23]. Taurine is the most representative free amino acid in goat milk and the concentration is much higher than in cow milk (Tripaldi *et al.,* 1998; Belewu and Adewole, 2009; Sarwar *et al.,* 1998) [24, 25, 26]. Taurine is involved in many different roles in the human body, such as growth and brain development, formation of bile salts, modulation of calcium flux and the stabilization of membranes as an osmoregulator and/or by attenuating toxic substances. Taurine deficiency in human tissues may lead to cardiomyopathy, epilepsy, lack of growth among others (Huxtable, 1992) [27].

Table 6: Amino acid composition of goat and cow milk (µM/100 ml)

Amino acid	Goat milk	Cow milk
Tryptophan	2.50	1.98
Threonine	2.78	2.01
Leucine	2.04	1.98
Methionine	0.96	0.85
Histidine	1.94	1.32
Isoleucine	1.64	1.23
Lysine	3.75	2.65
Phenylalanine	1.21	1.08
Valine	4.95	3.50
Taurine	55.93	48.23
Aspartate	1.01	0.98
Glutamate	17.01	15.89
Alanine	8.68	5.78

Source: Harish *et al.,* 2016 [34]

Minerals of goat milk

Goat milk contains major and trace minerals including Ca, Mg, P, K and Zn, Se, Cu, Cl, I, Fe respectively. According to study of Kędzierska-Matysek, *et al.,* (2013) [28], Milk obtained from goats in stage I of lactation (winter feeding) was the richest source of Zn, Fe and Cu, while milk from stage II (summer feeding) was the highest in K, and milk from stage III (autumn-winter feeding) was the highest in Ca, Na, Mg and Mn. Concentrations of zinc, iron, and copper decreased over the course of lactation. It contains high level of calcium, potassium, iron, copper, selenium, and manganese than cow milk. Studies by other authors confirm this observation, having detected more magnesium and zinc than in cow milk (Soliman 2005; Park *et al.* 2007; Ceballos *et al.* 2009) [29, 12, 15]. Thus, goat milk can be an alternative source of calcium as well as other elements. The Table 7 shows minerals content (amount in per 100 g) of goat milk compared to cow milk and vital role necessary for human body and metabolism. Overall, goat milk has more Ca, P, K, Mg and Cl, and less Na and S contents than cow milk (Park and Chukwu, 1988; Chandan *et al.,* 1992) [30, 31].

Table 7: Mineral contents of goat milk compared to cow milk with its vital functions

Mineral	Functional role and metabolism	Goat	Cow
Ca (mg)	Bone structure, muscle and nerve functions and blood coagulation	134	122
P (mg)	Bone structure, muscle and nerve functions and energy production	121	119
Mg (mg)	Bone structure, muscle and nerve functions and activation of enzymes vitally for cell functions	16	12
K (mg)	pH balance and function of nerves, muscles and kidneys	181	152
Na (mg)		41	58
Cl (mg)	pH balance, maintain blood volume and pressure, constituent of hydrochloric acid in gastric juice, affect liver function	150	100
S (mg)		28	32
Fe (mg)	Oxygen transport from lungs to blood, major component in hemoglobin and myoglobin	0.07	0.08
Cu (mg)	Enzymes involved in iron and oxygen metabolism and cell defense against free radicals	0.05	0.06
Mn (mg)	Reinforce bones and joints, contributes to metabolism of fatty acids, cholesterol and immune functions, regulate blood sugar level and antioxidant	0.032	0.020
Zn (mg)	Enzymes involved in CO_2 transport, gene formation, protein production and co-operate with insulin which regulate metabolism of carbohydrates	0.56	0.53
I (mg)	Thyroidal hormones involved in protein metabolism	0.022	0.021
Se (µg)	Cell protection against free radicals, affect white blood cells in the immune system and protect against heavy metals	1.33	0.96

Source: Park *et al.,* 2007 [12]

Carbohydrate of goat milk

Lactose is a major carbohydrate present in goat milk but content slightly low as compared to cow milk (Slacanac *et al.,*2010) [20]. Lactose is an important nutrient because it favors intestinal absorption of Ca, Mg, P and utilization of Vitamin D (Park *et al.,* 2007) [12]. Other carbohydrates found in goat milk are oligosaccharides, glycopeptides, glyco-proteins and nucleotides in small amounts. Goat milk is significantly rich in lactose-derived oligosaccharides compared to cow milk (Slacanac *et al.,* 2010) [20]. Milk oligosaccharides are thought to be beneficial to human nutrition because of their prebiotic and anti-infective properties (Kunz, C. *et al.,* 2000) [32].

Vitamins of goat milk

Milk is a good source of most known vitamins. Goat milk has higher amount of vitamin A and vitamin B contents than cow milk because goats convert all β-carotene to retinol from foods into vitamin A in the milk (Table 8) and that's conversion of β-carotene leads to whiter appearance of, goat milk than cow milk (Park *et al.,* 2007) [12]. Goat milk is deficient in folic acid and vitamin B12, which cause 'goat milk anemia' (Jenness, 1980; Park *et al.* 2007) [14, 12]. Folate is necessary for cell metabolism, the synthesis of red blood cells and it prevents neural tube defects in fetus. Both folate and vitamin B12 deficiency can cause megaloblastic anemia in infants. Several authors reported that goat milk is lower in vitamin B12, vitamin A, C &D than cow's milk. In contrast McCance and Widdowson (1978) [33] reported equal amounts of vitamin C in both goat and cow milk and lower amounts of vitamins A and D in goat milk. Goat milk contains excessive levels of vitamins B, Thiamin, riboflavin and pantothenate for a human infant, but infants fed solely on goat milk are overburdened with these vitamins (Harish *et al.,* 2016) [34].

Table 8: Vitamin contents (amount per 100 g of milk) of goat and cow milk as compared with human milk

Vitamin	Goat	Cow	Human
Vitamin A (IU)	185	126	190
Vitamin D (IU)	2.3	2.0	1.4
Thiamine (mg)	0.068	0.045	0.017
Riboflavin (mg)	0.21	0.16	0.02
Niacin (mg)	0.27	0.08	0.17
Pantothenic acid (mg)	0.31	0.32	0.20
Vitamin B6 (mg)	0.046	0.042	0.011
Folic acid (µg)	1.0	5.0	5.5
Biotin (µg)	1.5	2.0	0.4
Vitamin B12 (µg)	0.065	0.357	0.03
Vitamin C (mg)	1.29	0.94	5.00

Source: Park *et al.,* 2007 [12]

Nutritional and therapeutic values of goat milk

Digestibility and Micronutrient absorption

The most appearing property of goat milk is its rather superior digestibility and absorption of micronutrients. Digestibility of goat's milk is highly enhanced by nature of the proteins and the fat molecules. The digestibility of goat milk can be attributed to its casein curd which is both softer and smaller than that produced by cow milk. This makes it more easily accepted by the human digestive system (Park, 2007) [12]. The size of the fat globules also affects the digestibility since it provides a better dispersion and a more homogenous mixture of fat. The large total surface area of the globules makes it easier for enzymes to reach and get in contact with the lipids (Attaie, 2000) [35]. The high proportion of short and medium chain fatty acids in goat milk contributes to easier and faster digestion. Lipases attack ester linkages of such fatty acids more readily than those of longer chains. Medium chain triacylglycerols in goat milk are absorbed intact in the intestine and do not undergo degradation and re-esterfication processes. Micelle formation is not required for absorption, since the molecules are taken up directly into the portal vein (Aliaga, 2010) [36]. Finally, goat milk does not contain the protein agglutinin that promotes clustering of fat globules. The absence of clustering facilitates digestion and absorption (Farah, 1991) [37]. Aliaga *et al.* (2000) [38] compared the influence of goat and cow milk on digestion and utilization of calcium in rats. They found that goat milk enhanced calcium content of femur, sternum and Longissimus dorsi muscle better than cow milk. The increased digestibility of protein is of more importance to infants, invalids and convalescent diets. In terms of digestibility and nutrient absorption, it is a better substitute for breast feeding.

Lactose intolerance

Goat milk, as well as cow and human milk, contains lactose. Despite that, many people with lactose intolerance do tolerate to drink goat milk. It has been hypothesized that the reason is the superior digestibility of goat milk (Johansson, 2011) [39]. Goat milk is more completely and easily absorbed than cow milk, leaving less undigested residue behind in the colon to ferment and cause the uncomfortable symptoms of lactose intolerance (Haenlein, 2004; Aliaga, 2010) [16, 36].

Antimicrobial activity

Goat milk contains high levels of medium chain fatty acids, such as caprylic and capric acids (C8 & C10). These fatty acids are highly antimicrobial. Capric and caprylic acids are used in dietary supplements to inhibit the growth of *Candida albicans* and other yeast species (Mwenze, 2015) [40].

Alkalinizes the blood and the intestine

Goat milk helps to increase the pH of the blood stream. It is the only dairy product with the highest amount of the amino acid L-glutamine an alkalinizing amino acid. Acidic blood and low intestinal pH levels have been associated with fatigue, headaches, muscle aches and blood sugar imbalances (Mwenze, 2015) [40].

Less allergenic as an infant formula

In most developed countries the goat milk is specifically marketed for the infant formula. In the USA and Canada the department of pediatrics has recommended that cow's milk be avoided for children between 0-6 months due incidences of allergy (Playford *et al.* 2000) [41].

Brain development

Sialic acid present in colostrums and milk is regarded as an important biological component that plays a role in development of brain and increasing immunity in infants. Sialic acid profile of goat colostrums and milk is similar to human milk. Sialiloligosaccharides content of goat's milk was significantly higher than the milk of other ruminants (Harish *et al.,* 2016) [34].

Dengue fever

Dengue has become a major health problem in India. It is mainly transmitted to humans by *Aedes aegypti* mosquito, which constitutes the etiological agents of the disease. So, for treating this disease goat milk and milk products are mostly preferred. Deficiency of Selenium and decrease in platelet count are the main complications of dengue fever. Goat milk as well as its products is richest source of Selenium (Se) as comparison to cow and sheep milk & Goat milk also found to help the digestive and metabolic utilization of various minerals (Gunjan *et al.*, 2011) [42].

Inflammatory bowel disease (IBD)

IBD is an important health problem because of its effect on the patient´s quality of life and because of its high prevalence, which has increased in the past few years. IBD can often be treated pharmacologically, and sometimes also with prebiotics and/or probiotics. But additional treatments are much necessary. Two studies in Spain have evaluated the effect of oligosaccharides isolated from goat milk in rat models of induced colitis (Villoslada *et. al.,* 2006; Daddaoua *et. al.,*

2006) [43, 44]. Colitis could be compared with the intestinal inflammation that occurs in IBD. The oligosaccharides from goat milk are shown to have an anti-inflammatory effect.

Cancer

Goat milk has a high content of conjugated linoleic acid (CLA) (Ceballos *et al.,* 2009) [15]. Anti-carcinogenic properties of CLA have been reported against mammary and colon cancer in animal models, as well as *in vitro* models of human melanoma, colorectal and breast cancer (Johansson, 2011) [39].

Growth factors for infants

Goat's milk contains high levels of growth factors similar to those found in human milk making it an essential diet for the infants. The Transforming Growth Factors (TGF) has a physiological role in maintaining regular functionality of the infant. (Playford *et al*., 2000)[41].

Despite negative public perception of goat milk and its products, its consumption has significant health benefits. Goat's milk and its products play significant roles in human nutrition. Goats differ from cows in terms of their anatomy, physiology and product biochemistry. These differences support the contention that goat's milk offers many unique qualities for human nutrition. According to Harden and Hepburn, (2011) [45] four year survey of milk drinkers revealed that 66.8% of those consuming goat's milk did so for medical reasons; in particular to overcome intolerance to cow's milk and 71.3% of those who consumed goat's milk stated that they received significant health benefits from the product. These benefits included; improved digestion (in particular irritable bowel type symptoms), reduced catarrh, improved asthma and reduced eczema (Figure 1).

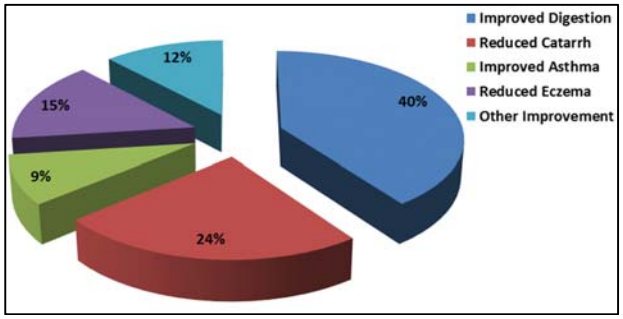

Fig 1: Reported health benefits with goat's milk.

Limitations of goat's milk

Low in folic acid

Goat's milk contains virtually no folic acid. To be adequate as an infant formula it has to be fortified. Lack of folic acid has been linked to congenital defects such as malformation of spinal cord associated with siemese twins (Mwenze, 2015) [40].

Goat's milk is an apocrine secretion

Apocrine is a type of glandular secretion where the secreting cell is released along with the milk. Cow secretion is alveolar merocrine secretion the cells remain undamaged during secretion. This type of secretion produces milk with high levels of cytoplasmic debris and epithelial cells. The milk has high levels of somatic cell counts which are not desirable (Mwenze, 2015) [40].

Goat milk products and market potentials

Goat milk and goat milk base manufactured dairy products are considered as a niche product. Various dairy goat products, including fluid, fermented, frozen, condensed, and dehydrated milk products, are produced in many countries. Goats' milk products especially cheeses and yogurt are very popular in the Mediterranean peninsula, the Middle East, Southern Russia and the Indian subcontinent (Filiz Yangilar, 2013) [46]**.** Cheese is the most important goat dairy commodity, traded in large quantities among and within nations. Goat cheese was originated in Mesopotamia (Filiz Yangilar, 2013) [46]. U.S. Department of Agriculture describes over 400 varieties of goat cheese and lists over 800 names of cheeses, many of which are made from goat milk or combinations of goat with cow, ewe, or buffalo milk. Goat milk is the proprietary item for few varieties of soft, semi hard and hard cheese, which are being marketed as a premium cheese in European countries (Pal *et al.,* 2011) [47]. Some goat milk based cheeses and their composition with country of origin is showed in Table 9. In France, the production of goat's cheeses increased by 13% (in the same year) whereas that of cow's cheeses increased only 1% and the consumption of goat's cheeses expanded approx. 20% per year (Pape and LePape, 1997) [48]. There have also been suggestions that French cheeses have a more favorable smell and milder flavor, which is preferred by most consumers in the market. Greece and France have the pioneer in goat milk cheese production and In India; cheese prepared exclusively from goat milk is hardly available (Pal *et al.,* 2011) [47].

Table 9: Compositions and country origin of goat milk cheese varieties

Country of Origin	Cheese Variety	Consistency	% Fat (DMB min.)	% Moisture	Raw materials
France	Cortinde Chavignol	Semi-hard	45	53 max	Goat milk
	Chabichou	Soft	45	50 max	-
	Le-Mothe St-Herage	-	45	55 max	-
	St-Maure	-	45	55 max	-
	Valencay	-	45	55 max	-
	Selles sur Cher	-	45	4l max	-
	Pouligny St Pierre	-	45	40 max	-
	Picodon de la Drme	-	45	-	-
	Rocamadour	-	45	-	-
Greece	Feta	Soft	45	53	Sheep + 5-10% Goat milk
	Kaseri	Semi-hard	45	42 (average)	Goat + sheep milk
	Graviera of Crete	Hard	38	40 min	-
	Kopanisti	Soft	48	60 (average)	Cow/sheep/goat milk or mixtures
	Galotyri	Soft	47	71	Goat and/ or sheep milk
	Metsovone	Hard	44	42	-
	Ladotyri	-	47	34	-

	Formaella	-	50	33	-
Israe	Goat cheese	Soft	45	66	Goat milk
Spain	Valideteja	Hard	-	-	-
	Cabrales	Soft	31	-	Blend of cow/sheep/goat milk
	Iberico	Hard/oily		-	-
	Majoreo	Hard	50	-	Goat milk
Mexico	Anejo Enchilado	Hard	-	-	-

Source: Tziboula-Clarke (2003) [52]

There are around 20 goat milk processors in Australia. Demand for milder flavored goat cheese is slowly developing and may present a niche market opportunity for Australian cheese manufacturers. The primary production is cheese, but does also include yoghurt and ice cream. These manufacturers are scattered throughout Western Australia, South Australia, New South Wales, Victoria, Tasmania and Queensland. Victoria has the greatest number of specialist cheese manufacturers producing goat cheese **(**Kate Stoney and Julie Francis, 2001) [49].

In Japan, Goat cheese is mainly imported from France and sold through specialist cheese stores to cheese enthusiasts. Japanese consumers prefer cheeses such as feta to be made with cow milk, instead of goat or sheep milk, to suit their milder flavor preference (Kate Stoney and Julie Francis, 2001) [49]. Cheese consumption in Taiwan is much lower than in Japan. Goat cheese is classified as a high value cheese and is consumed only in five star hotels and high-end hotels in Taiwan.

Chemical and structural composition of goats milk is affected its rennetability (Calvo and Balcones 1998) [50]. It could be concluded that rennet clotting time of goat's milk is markedly shorter and the complete forming curd time is lower than cow's milk (Fatma *et al.,* 2014) [51]. A piquant and peppery sharp flavor observed in ripened goat milk cheese due to presence of greater proportion of short & medium chain fatty acids in goat milk fat (Tziboula-clarke, 2003) [52].

Attulla *et al.* (2014) [53] fortified goat cheese with caramel, cocoa and cocoa with walnuts are corresponding high quality protein ingredient for sweet spreadabled cheese and concluded that fortified sweet goat cheese with cocoa and walnut could be regards as Egyptian economic products and nourished for human consumption especially for children feeding.

Fermented goat milk products played a significant role in securing food for rural communities of many developing countries. Fermented goat milk incorporating live probiotic cells represent a group of products with great prospects in future with regards to their nutritive and therapeutic properties (Slacanac *et al.,* 2010) [20]. The functional value of goats' milk may be further exploited through fermentation by selected microorganisms possessing specific features. A mixed starter comprising *Lactobacillus acidophilus*, *Bifidobacterium lactis* and *Streptococcus thermophilus* has been successfully used for fermentation of goats' milk and a high viability of probiotic strains in a fermented goats' milk stored at 4 ºC for 10 days has been reported (Filiz Yangilar, 2013) [46]. The viable lactic acid bacteria in fermented milk products have been associated with increased lactose intolerance, a well-balanced intestinal micro flora, antimicrobial activity, stimulation of the immune system and anti-tumoural, anti-cholesterolaemic and anti-oxidative properties in human subjects (Slacanac *et al.,* 2010) [20]. Beyond all nutritive features of goat milk, one of the major disadvantages is nonexistent of folic acid content. This disadvantage could be solved by using folate producing bacteria during fermentation by use in *streptococcus thermophilus* and *Lactobacillus delbrueckii subsp. bulgaricus* in goat milk results in yoghurt with significant quantity of folate and good sensory features (Sanna *et al.,* 2005) [54]. Goat milk yogurt was one of the traditional products from countries where fermented dairy foods originated. Goat milk yogurt can be made in a similar manner to the cow counterpart. Yoghurt manufacture with cows and with goats milk (100%, 75%, 50% and 25%) substitution blend with cow's milk revealed that goats milk yoghurt (100%) had the highest protein content (4.2%) fat (4.27%) and caproic (C6), caprylic (C8) capric (C10) and total solids (16.22%). Generally, goat's milk yoghurt samples (100%), (75%), (50%) were mostly significantly preferred to 25% goat's milk yoghurt sample at ($P > 0.05$) Ehirim and Onyeneke (2013) [55]. One of the main problems in manufacture of goat milk yogurt is weak and lack of consistency in curd tension or viscosity upon agitation compared with cow yogurt. Patel and Roy, (2016) [56] compared the quality of yoghurt using instrument texture analyzer and revealed that goat milk yoghurt was having lower firmness, consistency, cohesiveness and index of viscosity than cow milk yoghurt. Weak and lack of consistency in goat milk yoghurt is due to the difference in protein composition between the two milks, especially in casein contents (Park and Guo, 2006) [57]. On the other hand, there is a desire for alternatives to cow's milk due to problems relating to gastrointestinal intolerance and market demand for the formulation of novel dairy products. Goat's milk is reported to have higher digestibility and lower allergenic properties compared to cow's milk. In addition, these benefits may be further enhanced by using goat's milk as a vehicle for delivering probiotics and prebiotics. Paz, *et al.,* (2014) [58] showed the technological potential and adequacy of using goat milk to produce potentially symbiotic yogurt with good nutritional value with respect to protein, Ca/P, good sensory score and acceptability (95%) with good viability of lactic acid bacteria and probiotic culture. No flavors were associated to the goat milk, and satisfactory probiotic viability was maintained throughout the 21 days of refrigerated storage. Bano *et al.* (2011) [59] concluded that mixing 75% goat's milk and 25% sheep milk in manufacture of yoghurt improved color, flavor and texture scores of the resultant yoghurt.

Fermentation diminishes the "goaty" flavor, which is often perceived as distasteful to some consumers. This taste is attributed to the aroma compounds and acids produced by the yogurt starter cultures during fermentation. Damunupola *et al*. (2014) [60] suggested that the incorporation of beetroot extract could mask the goaty-flavor and goaty-odor of the yogurt made from goat milk. Four percent (4%) incorporation level of beetroot juice was preferred most by the panelists against 6% and 8%. Moreover, addition of beetroot juice did not change the pH and titratable acidity as compared to plain yogurt made from goat milk.

There are many other fermented goat milk products *viz.* buttermilk, acidophilus, sour dip and kefir being manufactured and consumed worldwide. The manufacturing procedures of these fermented goat milk products by use of different culture micro organisms are summarized in Table10.

Table 10: Manufacturing Conditions and Procedures of Cultured Goat Milk Products

Products	Type of milk	Culture Microorganism	Type of Inoculum	Rate of inculation (%)	Incubation Temperature (°C)	Incubation Time (Hr.)	Stop incubation at pH	Stop incubation at %TA
Buttermilk	Skim or low fat	*S. lactis* *S. cremoris* *L. citrovorum* *S. diacetilactis*	Bulk start or direct set	0.5-1.0 As directed	22 22	14-16 12-16	4.5 4.5	0.8 0.8
Acidophilus	Skim or low fat	*L. acidophilus*	Bulk start	0.5	37-44	18-24	3.8	1.0
Sour Dip	Half-n-half 11% fat	*S. lactis* *S. cremoris* *L. citrovorum* *S. diacetilactis*	Bulk start or direct set*	1.0	22	14-16	4.8*	0.7*
Kefir	Whole	*S. kefir* *T. kefir* *L. caucasicus* *S. lactis*	Kefir grains	As directed	22 followed by 10	12 24-72	4.5	0.8
Yogurt	Skim or low fat	*S. thermophilus* *L. bulgaricus*	Individual cultures or direct set	1.25 each or as directed	45.6	5-6	4.2	0.9

Source: Park and Guo (2006) [57]

Goat milk products other than cheese and yoghurt, pasteurized milk are considered to be the dairy products with greatest market potential. Therefore, several characteristics of goat milk are currently the focus of increase research interest. Goat milk should have a mild, neutral and appealing flavor. Park and Drake, (2005) [61] stated that the most important quality standard for goat milk is an acceptable, attractive odor and taste. According to Mowlem, (2005) [62] goats have had very bad publicity for many years and as a result considerable prejudice against goat products sold in the United Kingdom (UK). In Japan, dairy goat industry is extremely small as a result goat milk is currently unavailable in the market. Japanese consumers currently see goat milk as a poor alternative to cow milk with an adversely strong taste and flavor. It is stated that the milk would be described by almost everyone who was not a goat enthusiast as "strong, smelly, salty or sweet". With such a reputation it was almost impossible to persuade anyone to try goat milk, even if offered at no cost. Unfortunately, this is true in many regions around the world (Mowlem, 2005) [62]. Park and Drake, (2005) [61] added to this by stating that the two biggest barriers in marketing goat milk are negative public perception of "goat like" flavor and seasonal milk production. The origin of this misconception can be traced to the fact that goat milk is sometimes obtained in poor sanitary conditions and that goat milk products are poorly manufactured. In Singapore, UHT goat milk could also do well in the market if the product is readily available and the price is comparable with cow milk products. The leading newswire service 'India PRwire' release press on January 7, 2012; that Easily among the oldest know health foods and high up the list of easily digestible dairy products, Goat Milk makes a comeback in India. Launched by Nadur Goat Farms based in Udupi, Goat Milk is now available at several supermarkets across Bangalore and Mumbai in conveniently sized packs of 500 ml.

Frozen products manufacturing process is used in some countries as a means of overcoming the seasonal nature of goat milk production (Haenlein 1998) [63]. Frozen dairy products like ice-cream, curd and frozen yoghurt are also manufactured from goat milk and combination with cow or buffalo milk in some countries. The ice cream was prepared from goat milk admixed with different levels of cow milk (25 and 50 %) and whole goat milk. It was concluded that up to 75% goat milk can be used to prepare ice cream without affecting the chemical and sensory qualities significantly and overrun in goat milk ice cream was more than the cow milk ice cream which adds in profit level (Lokhande, 2011) [64].

Paneer is an important nutritious and healthy indigenous dairy product, which occupies a prominent place among traditional dairy products and carries lot of market potential. It is a rich source of protein available at a relatively lower cost and forms an important source of animal protein for vegetarians. Viji *et al.* (2017) [65] prepared *paneer* by the admixture of goat and buffalo milk at different proportion and results of the study concluded that, good quality *paneer* prepared by admixture of goat milk at 25% level with buffalo milk had improved yield and obtained better overall sensory scores than all other treated *paneer* samples. The prepared *paneer* could be stored up to one week at refrigerated (4ºC) temperature and one day at room temperature (30 ºC) without any deterioration in quality.

Goat milk powder is regarded as a nutritional supplement in some countries. According to National Business Review (April, 2000), New Zealand's Dairy Goat Co-operative (DGC) is the world's largest producer of infant formula based on goat milk, and has increased its foreign exchange earnings from NZ$7 million to NZ$37 million between 1995 and 2000. New Zealand is the dominant supplier of value added canned goat milk powder to Taiwan. Canned powder and infant formula is generally aimed at children and sells mainly through drug stores or pharmacies. To develop a special formula that increases the value of goat milk powder, such as propolis goat milk or DHA goat milk, would be beneficial for the Goat milk processing industry. Korean market has very much potential for Goat milk powder as well as liquid goat milk and cheese products. Powdered milk, as a health/functional product, is viewed as the best opportunity for Australian goat milk in Japan. The Taiwanese market for other than goat milk powder is less developed. In Malaysian market, the main opportunities appear to be for goat milk powder, tablets and UHT goat milk with a shelf life of 28 days to 3 months.

Goat milk tablets are also becoming increasingly available on the Australian market. Goat milk tablets are the second most popular goat milk product in Taiwan. Currently, the majority of goat milk tablets in the market are made locally using goat milk powder and mixing it with other ingredients. The market potential for Australian goat milk tablets will be limited as the market for tablets has become very competitive.

Goat milk based butter, ghee and related products with their even higher contents of MCT, unsaturated fatty acids and CLA than the original milk has not been studied much nor produced commercially (Haenlein, 2004) [16].

Commercially available Goat milk products:

The different types of goat milk products have been prepared on large scale basis. These are in the form of fluid, fermented, frozen, condensed, dehydrated, tablets, powder and infant powder. A detail list of dairy goat milk processors and products commercially available worldwide is given in Table 11 along with website.

Table 11: Commercially available Dairy Goat's Processors and Products

Processor	Products	Location
Carmelis Alpine Goat Cheese Artisan Inc.	Goat Cheese	Kelowna,
The Farm House Natural Cheeses	Goat Cheese	Aggasiz,
McLennan Creek ;Goat pride Dairy	Goat Milk, Yogurt, Cheese (Organic)	Abbotsford
Oak Island Goat Dairy	Goat Milk	Isle de Chaines
Artisan Dairy	Goat milk kefir, cheese, yoghurt	Sonoma county, California
RanCher Acres	Goat Milk Yogurt, Goat Cheese	Ayleford
Hewitt's Dairy	Goat's Milk, Yogurt - Goat's Milk	Hagersville
Olympus	Goat Cheese	Trikala, Greece
Silani Sweet Cheese	Goat cheese and verity of cheeses	Schomberg
Salerno Dairy Products Ltd.	Goat cheese and verity of cheeses	Hamilton
Les Produits de maque Liberté	Fluid Milk, Goat Milk, Yogurt	St-Hubert, QC
Skotidakis Goat Farm	Goat's Milk, Cheese, Yogurt	St. Euguene
Hongcheon Stock Breeding Co-op	Alpine Goat Milk, Alpine Apple Goat Yoghurt	Korea
Kerr France Dairy Products	Goat milk, cheese, frozen curd, powder, cream, butter	Rue Auguste Blanqui
Caprobiotech	Goat Milk	Korea
The original chevre	Goat cheeses	France
Korea medi-R	Goat Milk	Korea
Dairy goat Co-operative (DGC)	Goat milk infant powder	Hamilton
Meyenberg	Goat milk, goat powder, butter and cheese	Turlock, CA
Laclare Farm™	Goat milk, yoghurt and cheese	Malone, WI
Oak Knoll Dairy, Inc.	Goat milk, Goat yoghurt	Windsor,Vermont
Nadur goat farm	Goat milk	Udipi, Karnataka
AVH Dairy,	Goat milk, goat powders (WPC, DM whey powder), Curd and cheese	Bergen, Netherlands
Delamere Dairy Ltd.	Goat milk, yoghurt, butter and cheese	Cheshire
Ontario dairy goat co-operative inc	Goat milk	Teeswater, Canada
St Helen's Farm	Goat milk, yoghurt, Ice-cream, butter and cheese	Seaton Ross, York

(**Source:** Canadian Food Inspection Agency: http://www.inspection.gc.ca/ ;)

Conclusions

Goat's milk and its products play a vital role in human nutrition. Due to highly nutritious in nature and possessing health benefits goat milk & its dairy products *viz*. cheeses, yoghurt, powder, and tablets etc. will have greater demand in near future as the consumers are not only of nutrition but also health conscious.

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