Happy Days Dairies Ltd. Article Series

Article #4 - Goat Milk's Immune-Enhancing Properties

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Article 4 Goat Milk's Immune-Enhancing Properties

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Introduction

Goat milk has long been recommended as an ideal substitute for cow's milk, particularly for individuals suffering from cow milk allergies. Although this nutritional benefit of goat milk is widely accepted, its additional wide scope of immune-enhancing properties largely remains in the shadows of research. Along with its favorable macro- and micronutrient composition, goat milk is a natural source of many immunological substances that serve multiple functions in the body. In fact, the uncanny nutritional similarities between goat and human milk further this notion, with human milk being revered as the single best source of immune-strengthening nutrients for infants. In light of these nutrient properties and compositional similarities, goat milk certainly deserves its place amidst other well-known natural immune-enhancing substances.

The Immune System

Our immune system protects our bodies against infection, and the immune response consists of both our innate and adaptive immune systems. The innate immune system is an initial line of defense against foreign pathogens consisting of barriers including skin, mucosal linings and cell recognition that result in the elimination of invaders from the body. The adaptive immune system is the secondary defense mechanism that comes into play when the innate response is unsuccessful at preventing the invasion of pathogens. At this point, the immune system adapts its response during an infection in order to improve its recognition of the pathogen. This improved response is then retained once the pathogen has been eliminated, which allows the adaptive immune system to provide faster and stronger reactions the next time the same pathogen is present (O'Shea et al. 2004).

Many types of cells are involved in the innate and adaptive immune response, with T- lymphocytes (T-cells), Natural Killer (NK) cells and B-lymphocytes (B-cells) as the main players. T-cells, which are part of the adaptive immune response, mature in the thymus and perform important immunoregulatory functions via their secreted products and also act as effector cells, capable of killing other cells. T-cells are particularly useful in the defense against intracellular bacterial and protozoal pathogens, viruses and fungi. Natural killer (NK) cells, which are able to develop without the help of the thymus, are important components of both innate and adaptive immunity. These cells can kill target cells by using antibody-dependent mechanisms.

The Immune System continued

Similar to NK cells, B-cells are also independent of the thymus and complete their maturation in the bone marrow. When these cells are stimulated, they differentiate to form immunoglobulin (also known as antibody)-producing plasma cells. A single B-cell gives rise to many antibodies which are used to identify and eliminate pathogens. Although immunoglobulins (Ig) are similar in structure, minor differences within the main immunological classes (IgG, IgM, IgA, IgD and IgE) are associated with a variety of biological properties, and IgG and IgA account for the majority of serum immunoglobulins (O'Shea et al. 2004).

A number of factors influence our immune health, and nutrition in particular is a main determinant of the body's immune response. As discussed in my previous articles, macro- and micronutrients play a key role in almost all biological reactions and exert antioxidant and anti-inflammatory effects in the body. This is important as inflammation is the body's primary response to infection, and oxidation has been linked to the development of many diseases, including cancer. Furthermore, other factors such as the maintenance of a healthy intestinal microflora with the help of probiotics and prebiotics (also contained in goat milk) are essential for protecting against the negative effects of pathogenic infection.

The Role of Goat Milk in Immunity - Antioxidant and Anti-inflammatory Properties

Proteins and Bioactive Peptides in Goat Milk

Goat milk is a source of complete protein that contains all essential amino acids without the heavy fat content and mucus-producing components of cow milk (Atanasova and Ivanova 2010). As discussed in my previous article, it is the difference in casein protein composition between cow and goat milk that is a key contributor to the lower allergenicity of goat milk. However, both cow and goat milk have also been extensively studied for its antimicrobial and anti-inflammatory characteristics, which is attributed to components of the whey and casein milk proteins as well as their bioactive peptides and include immunoglobulins, lactoferrin, lactoperoxidase, folate binding protein, and more recently, α-lactalbumin and β-lactoglobulin (Atanasova and Ivanova 2010). Table 1 summarizes the biological functions of some of these proteins.

Table 1: Biological Functions of Proteins Found in Goat Milk

Protein	Biological Function
B-Lactoglobulin	Carrier of retinol, fatty acids and triglycerides; Transfer of passive immunity; Immunomodulatory activity; Anti-carcinogenic activity
α-Lactalbumin	Lactose synthesis; Treatment of chronic stress-induced diseases; Anti-carcinogenic activity
Serum albumin	Synthesis of lipids; Antioxidant activity; Anti-carcinogenic activity
Lactoferrin	Antimicrobial activity; Antifungal activity; Anti-proliferative activity; Antiviral activity; Immunomodulatory activity; Anti-thrombotic activity
Immunoglobulins	Immunomodulatory activity; Growth and development

(Hernandez-Ledesma et al. 2011)

Milk whey proteins participate in a number of biological reactions that influence digestion, metabolic responses to absorbed nutrients, growth and development of certain organs, and disease resistance. Moreover, the breakdown of these proteins by enzymes during digestion can release bioactive peptides that exert specific biological activities, such as antihypertensive, antimicrobial, opioid, antioxidant, immunomodulant, or mineral binding. Recently, β-lactoglobulin, the major whey protein found in ruminant milk has been linked to mediating immune response through its role in developing passive immunity with IgG. Furthermore, this major whey protein is rich in the essential amino acid cysteine, which stimulates anticarcinogenic peptides thereby protecting against intestinal tumors (Hernandez-Ledesma et al. 2011).

Similarly, another whey protein, α-lactalbumin has been studied for its role in killing tumor cells in patients with skin and bladder cancers. In addition, studies have found that serum albumin, a whey protein present in milk following its passive transfer from the blood, has an inhibitory effect against the growth and development of breast cancer cells.

Finally, peptides derived from lactoferrin, an iron binding protein found in greater amounts in goat milk than cow milk, have been recognized for having antimicrobial and antifungal properties against a wide range of gram-positive and gram-negative bacteria. Lactoferrin is able to prevent the entry of pathogens into the host cell by blocking cellular receptors or by directly binding to the pathogen.

Proteins and Bioactive Peptides in Goat Milk continued

Furthermore, lactoferrin also exerts antioxidant properties as it scavenges free iron in the body, thereby limiting its availability to participate in oxidative reactions (Hernandez-Ledesma et al., 2011).

Peptides derived from casein also exert antihypertensive, antioxidant and antimicrobial effects. Antihypertensive and immuo-stimulating peptides can be generated from caprine β-caseins. Angiotensin-I converting enzyme (ACE) is a multifunctional enzyme located in various tissues such as plasma, lung, kidney, muscle, arteries and brain, and plays an important role in regulating blood pressure as well as the immune system. As ACE functions to increase blood pressure, individuals suffering from hypertension are normally given ACE inhibitory drugs. However, goat milk has been found to provide a good source of ACE-inhibitory peptides following the hydrolysis of goat milk caseins, and animal and human studies have shown their beneficial effects on blood pressure regulation (Nandhini et al. 2012). Proteolytic enzymes also release antioxidant peptides from caseins, and peptides derived from α-casein scavenge tissue damaging free radicals and inhibit lipid peroxidation in the body. Additionally, fragments of goat milk α-caseins have also been found to be a source of antimicrobial peptides, showing strong activity against Gram-negative bacteria (Park 2009).

On top of whey and casein proteins, goat milk contains minor proteins such as immunoglobulins (Igs), transferrin, lactoferrin, prolactin and folate-binding protein (Table 2). As previously mentioned, immunoglobulins produced by B-lymphocytes offer gastrointestinal protection against pathogenic microorganisms. They function as antibodies in the immune response, and are important for the immunity of the newborn young (Park 2009). Similarly, lactoferrin is known for its ability to improve and modulate the host immune system.

Table 2: Some Minor Protein Contents in Goat, Cow and Human Milk

Proteins	**Goat**	**Cow**	**Human**
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: μg/mL)	0.9-2.4	3.9	17.35
IgM (milk: μg/mL)	10-40	50	100
IgM (colostrum: μg/mL)	1.6-5.2	4.2	1.59
IgG (milk: μg/mL)	100-400	590	40
IgG (colostrum: μg/mL)	50-60	47.6	0.43
Nonprotein N (%)	0.4	0.2	0.5

(Park 2009)

Lipids

Bioactive lipids in goat milk also influence the immune system. First, conjugated linoleic acid (CLA) has many beneficial and bioactive functions on human health including anti-carcinogenic, anti-atherogenic, immune-stimulating, growth promoting and body fat-reducing activities. CLA is a general term for all isomers of linoleic acid, with *cis*-9, *trans*-11 (*c*9, *t*11) and *trans*10, *cis12* (*t*10,*c*12) as the two most common forms. CLA is naturally found in ruminant milk and meat, and is an important bioactive component in goat milk. In terms of immune response stimulation, CLA has been found to modify mediators of immunity such as cytokines, eicosanoids, prostaglandins and immunoglobulins. Furthermore, CLA has the ability to reduce the allergy-related immunoglobulin IgE in humans, suggesting the anti-allergic potential of the lipid. CLA has also been shown to exert anti-inflammatory effects by decreasing the production of pro-inflammatory cytokines associated with irritable bowel disease, atherosclerosis, cancer and other immunopathologies in the body (Park 2009).

Goat milk is also rich in medium chain triglycerides (MCTs), which is one of the primary reasons that it facilitates improved nutrient absorption and energy production in the body. In addition, the medium chain triglycerides capric, caproic and caprylic acids, the most abundant forms found in goat milk, have been shown to possess antimicrobial activity. Numerous studies have shown the antibacterial activity of short chain fatty acids (SCFA). Recently however, MCTs appear to have a greater benefit than SCFAs for preventing bacterial infection of gram-positive and gram-negative bacteria, as well as *Salmonella*. A study investigating the effect of capric, caproic and caprylic acids on the pathogenicity of *Salmonella* infections in chickens found these MCTs to reduce bacterial invasion in the intestinal epithelium by decreasing the expression of a key regulatory gene related to the invasive capacity of *Salmonella* (Van Immerseel et al. 2004).

Finally, as with proteins, milk contains minor lipids including gangliosides, glycolipids, glycosphingolipids and cerebrosides, among others. These minor lipids are also considered bioactive components. Although the majority of studies on the functions of these lipids have been conducted on human and bovine milk, because these bioactive components are present in mammalian tissues, it is believed that these components in goat milk exert similar effects to that of cow and human milk. These functions include cell-to-cell interaction, immune recognition, and receptor functions for protein hormones and bacterial toxins such as enterotoxin and cholera toxin (Park 2009).

Carbohydrates

It is well known that human milk provides the best protection against infectious agents in infants in comparison to man-made formulas. This is partly attributed to the carbohydrate content, mainly oligosaccharides in human milk due to their ability to stimulate the growth of probiotic *Bifidobacteria* in the gastrointestinal tract which protect against pathogens. As a result, oligosaccharides are considered a source of prebiotics as they benefit the host by selectively stimulating the growth of desirable bacteria in the digestive tract. Due to these properties, human milk oligosaccharides have been recognized to have anti-inflammatory benefits, promoting a balance towards beneficial microflora, and are a proposed treatment option for inflammatory diseases such as inflammatory bowel disease (IBS).

Carbohydrates continued

Oligosaccharides are among the most abundant components in human milk after lactose and fat. Although goat milk contains a lower concentration of oligosaccharides in comparison to human milk, it is greater than in bovine and ovine (sheep) milks, and the oligosaccharide structures identified in goat milk are most similar to that of human milk. This is particularly significant for infant nutrition as human milk oligosaccharides are greatly beneficial for the infant due to their prebiotic and anti-infective properties.

The mechanisms behind their inflammation-fighting effects include increased production of butyrate, and the reduction of pro-inflammatory bacterial species by inhibiting their adhesion to the epithelial membrane, reducing bacterial translocation and promoting selective growth of beneficial *Lactobacillus* and *Bifidobacteria* species (Daddaoua et al. 2006; Hernandez-Ledesma et al. 2011). A Spanish study investigating the effect of goat milk oligosaccharides on rats with colitis found them to have anti-inflammatory effects, thereby proving to be potentially useful in the management of inflammatory bowel disease (IBD) (Daddaoua et al. 2006). Another Spanish study also found that rats with colitis fed goat milk oligosaccharides exhibited less severe lesions in the colon and a more favorable gut microbiota, demonstrating that goat milk oligosaccharides helps reduce inflammation and promotes recovery of damaged colonic mucosa (Park 2009).

Vitamins & Minerals

Discussed in detail in previous articles, vitamins and minerals play important roles in physiological, biochemical and metabolic reactions in the body. Goat milk contains several micronutrients important for maintaining immunity such as vitamin A, vitamin D and vitamin C, as well as calcium, zinc and selenium (Table 3).

Table 3: Mineral and Vitamin Contents (per 100g) of Goat, Sheep, Cow and Human Milk

Constituents	Goat	Sheep	Cow	Human
Mineral				
Ca (mg)	134	193	122	33
P (mg)	121	158	119	43
Mg (mg)	16	18	12	4
K (mg)	181	136	152	55
Na (mg)	41	44	58	15
Cl (mg)	150	160	100	60
S (mg)	28	29	32	14
Fe (mg)	0.07	0.08	0.08	0.20
Cu (mg)	0.05	0.04	0.06	0.06
Mn (mg)	0.032	0.007	0.02	0.07
Zn (mg)	0.56	0.57	0.53	0.38
I (mg)	0.022	0.020	0.021	0.007
Se (μg)	1.33	1.00	0.96	1.52
Al (mg)	n.a.	0.05–0.18	n.a.	0.06
Vitamin				
Vitamin A (IU)	185	146	126	190
Vitamin D (IU)	2.3	0.18 μg	2.0	1.4
Thiamine (mg)	0.068	0.08	0.045	0.017
Riboflavin (mg)	0.21	0.376	0.16	0.02
Niacin (mg)	0.27	0.416	0.08	0.17
Pantothenic acid (mg)	0.31	0.408	0.32	0.20
Vitamin B_6 (mg)	0.046	0.08	0.042	0.011
Folic acid (μg)	1.0	5.0	5.0	5.5
Biotin (μg)	1.5	0.93	2.0	0.4
Vitamin B_{12} (μg)	0.065	0.712	0.357	0.03
Vitamin C (mg)	1.29	4.16	0.94	5.00

(Park et al. 2007)

Vitamins & Minerals continued

Goat milk contains a similar amount of vitamin A as human milk. Vitamin A is important for both innate and adaptive immune responses, including cell-mediated immunity and antibody responses. A deficiency in this vitamin has been shown to lead to increased susceptibility to ocular, respiratory, gastrointestinal inflammatory and diarrheal diseases, as well as a decreased innate immunity affecting NK cell function and phagocytic activity. Similarly, vitamin D plays an important role in the immune system and may help prevent infections, autoimmune diseases, cancer and diabetes, in addition to its role in bone health maintenance. Vitamin D deficiencies seem to interfere with NK cell function, resulting in increased infections. Finally, vitamin C is a well-known water-soluble antioxidant that is found in greater amounts in goat milk than in cow milk. This vitamin has been shown to affect many aspects of the immune system including the regulation of immunity via antiviral and anti-oxidant properties (Geissler and Powers 2011).

In addition to vitamins, key minerals in goat milk that are important for health maintenance and immunity. Along with its well-known effects on skeletal health, calcium also plays a role in protecting against the development of colon cancer, and is thought to contribute to the binding and removal of carcinogenic agents in the gastrointestinal tract. Furthermore, a recent study found the resistance to infections to be linked to calcium intake (Park 2009). Goat milk also contains a larger amount of zinc compared to human milk. Zinc is an important mineral for the maintenance of healthy skin, wound healing and is directly involved in both innate and adaptive immunity. Zinc also has antioxidant activity and helps eliminate reactive oxygen species through its role as a cofactor for the antioxidant enzyme, superoxide dismutase (SOD). Similarly, selenium is a key mineral offering immune benefits as it also affects innate and adaptive immunity. Selenium acts as a key cofactor for the functioning of the antioxidant enzyme glutathione peroxidase (GPX), which is important for scavenging harmful free radicals in the body, as well as for macrophage activation (Geissler and Powers 2011).

Conclusion

In addition to its highly nutritional and anti-allergenic benefits, goat milk also serves as an important source of immune-enhancing proteins, lipids, carbohydrates, vitamins and minerals necessary for maintaining optimal health. This impressive property only serves to add to the superior reputation of goat milk as a functional dairy product.

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