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Article #2 - The Anti-Allergy and Digestive Benefits of Goat Milk
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Introduction
Goat milk has certainly earned its place on the short list of whole foods with highly nutritious and health promoting properties. In the first article, Goat Milk from Perception to Perfection we discussed how the composition of goat milk attributes to its many health benefits. The second article delves deeper into the relationship between these nutritional characteristics and its digestive and allergy benefits in particular. For many years, anecdotal evidence demonstrating the enhanced digestibility and reduced allergenicity of goat milk compared to cow milk has captured the attention of people with health issues such as lactose intolerance, fat malabsorption and milk allergies. Recent scientific evidence has further elucidated the connection between the structural and functional characteristics of goat milk and its use in preventing and reducing these common dairy-associated health conditions. In more ways than one, goat milk can be considered an excellent dairy alternative with the potential to replace traditional dairy products and significantly enhance the health of people with dairy intolerances.

Milk Allergies and Lactose Intolerance
Before we discuss how goat milk can benefit people with milk allergies or intolerances, it is necessary to define these commonly used but often-misused terms. An allergy is defined as an altered or abnormal tissue reaction following exposure to a foreign antigen (McCullough 2003). The most common antigens in foods are proteins. Milk is considered one of the most common food allergens and is the most common sensitivity in young infants, with a 2 – 6% incidence (Lara-Villoslada et al. 2004). Allergies can be acute or chronic in nature, their symptoms ranging in severity from non-life threatening reactions such as eczema, rhinitis and digestive problems to very serious life threatening reactions including anaphylaxis, bronchospasm and urticaria (McCullough 2003).

Numerous studies and anecdotal evidence suggest that goat milk is a much less allergenic alternative to cow milk due to its differing protein structure, namely its casein micelle components (Park et al. 1994). Goat milk has demonstrated significant improvements in colic, minor digestive disorders, asthma and eczema over cow milk, as well as in infants and children with cow milk sensitivities (McCullough 2003). Haenlein et al. (2004) indicated that treatment with goat milk typically resolves between 30 and 40% of problem cases of childhood cow milk allergy, which can be higher in some cases (one study showed improvements in 49 out of 55 children treated with goat milk).

Milk Allergies and Lactose Intolerance continued

In contrast to an antigen-associated allergic reaction, lactose intolerance is caused by a deficiency in the lactase enzyme used to digest the milk sugar, lactose. In lactose intolerant individuals, unhydrolyzed lactose passes into the large intestine, where it is fermented by microbes that produce gases such as hydrogen, methane, carbon dioxide and short chain fatty acids leading to gastrointestinal disturbances such as flatulence, abdominal pain and diarrhea (Russell et al. 2011). Anecdotal evidence suggests that goat milk is easier to digest due to the softer curd formed in the stomach as a result of the much lower content of a particular type of casein, αs-1 casein (Robinson 2001). The implication is that the different casein composition of goat milk allows the digestive products (including lactose) to pass through the large intestine more quickly and helps prevent the symptoms of lactose intolerance (Robinson 2001). Other properties of goat milk such as its potential to stimulate the growth of probiotic bacteria also help to improve its lactose digestive properties.

Digestive and Anti-Allergy Nutritional Components

Several nutritional characteristics unique to goat milk lend to its enhanced tolerability in people with dairy digestive issues (ie. lactose intolerance or fat malabsorption) or allergies (Ceballos et al. 2009). Its distinct protein and fat structure are primarily responsible for these properties, with its significantly smaller fat globule size, fatty acid composition and different casein fraction from cow milk being the largest determinants (Silanikove et al. 2010). Other contributing factors include polyamines in the non-protein fraction, and its ability to stimulate the growth of probiotic bacteria (Bifidobacteria) in the intestine due to its oligosaccharide content (Raynal-Ljutovac et al. 2008).

Despite the relatively minute difference in lactose content of goat versus cow milk, together these nutritional components have a synergistic effect of helping to alleviate symptoms of lactose intolerance such as bloating, gas, diarrhea and intestinal distension. The differing casein micelle composition of goat milk compared to cow milk is the key factor contributing to its allergy benefits. In addition to improving lactose tolerance and allergenicity, goat milk fat is also more digestible largely due to its high content of medium-chain fatty acids, and is an excellent source of immediate energy for use in various metabolic processes (Ceballos et al. 2009). Below is an exploration of each of these factors and their link to improved tolerance in greater detail.

Fat Composition

In the Goat Milk from Perception to Perfection article, we discussed the major differences in the fat composition and distribution of goat milk compared to cow milk, which include the size of the fat globule and its high content of short and medium-chain fatty acids. Although the total fat content of goat and cow milk is quite similar, the average size of goat milk fat globules is about 2 µm, in comparison to 2.5 to 3.5 µm in cow milk (Haenlain et al. 2004; Silanikove et al. 2010). This allows for better dispersion and a more homogenous mixture of fat in goat milk and results in the softer texture of goat milk products, making it easier to digest (Raynal-Ljutovac et al. 2008; Haenlein et al. 2004). Furthermore, unlike cow's milk, goat milk does not contain agglutinin, a compound which causes aggregation of antigens. Consequently, the fat globules in goat milk do not cluster, further facilitating its improved digestion and absorption (Haenlain et al. 2004).

Fat Composition continued

Goat milk also contains more of the essential fatty acids (linoleic and arachidonic acids) and a higher proportion of short-chain and medium-chain fatty acids (MCFA) than cow milk (Raynal-Ljutovac et al. 2008). Specifically, goat milk is much higher in butyric (C4:0), caproic (C6:0), caprylic (C8:0), capric (C10:0), lauric (C12:0), myristic (C14:0), palmitic (C16:0) and the essential omega-3 linolenic (C18:2) (Haenlein et al. 2004; Tomotake et al. 2006). Table 1 below demonstrates the differences in fatty acid composition between cow and goat milk fat.

Table 1: Fatty Acid Composition of Bovine and Caprine Milk Fat

	Bovine	Caprine 1	Caprine 2
C4:0	0.2±0.1	1.2±0.3	0.4±0.1
C6:0	1.8±0.2	2.6±0.1	2.0±0.1
C8:0	1.1±0.1	3.3±0.2	2.5±0.1
C10:0	2.7±0.4	12.6±0.4	11.2±0.2
C12:0	3.2±0.5	5.6±0.6	4.3±0.1
C14:0	12.3±1.5	12.9±0.8	11.9±0.3
C16:0	45.7±3.6	28.4±2.0	32.7±0.6
C16:1	2.2±0.3	0.6±0.0	0.6±0.0
C18:0	7.7±0.7	10.3±1.1	11.0±0.2
C18:1	21.8±4.8	20.4±1.7	21.3±0.5
C18:2	1.3±0.2	2.2±0.1	2.3±0.1

(Tomotake et al. 2006)

This fat distribution makes goat milk be more readily digested and absorbed than cow milk because fat digesting enzymes called lipases are able to attack the ester linkages of fatty acids more readily than those of longer chains and be readily hydrolyzed in the digestive tract (Haenlain et al. 2004; Ceballos et al. 2009). This altered metabolism of MCFA also facilitates their ability to be absorbed without the need for reesterification (Ceballos et al. 2009). The fast absorption of MCFA is followed by equally fast oxidative metabolism, making MCFA excellent direct and immediate energy sources instead of being deposited into adipose tissue (Ceballos et al. 2009; Haenlain et al. 2004).

The combined effect of the high degree of digestibility combined with the immediately available energy of MCFA enables better utilization of protein, making MCFA useful in treating certain metabolic diseases (Ceballos et al. 2004). MCFA such as caprylic and capric are used clinically to treat a wide array of conditions including malabsorption syndromes, steatorrhea, intestinal resection, infant malnutrition, premature infant feeding, and non-thriftiness of children (Haenlain et al. 2004).

Protein Composition

A significant amount of research into the hypoallergenic properties of goat milk has been performed over the last two decades. The primary focus of this research has been in elucidating the link between particular casein proteins and the allergenic potential of milk. As mentioned above, goat milk contains a significantly lower level of αs-1 casein, a major allergen in bovine milk (Lara-Villoslada et al. 2004). Beta-lactoglobulin (β-lactoglobulin), alpha-lactoglobulin (α-lactoglobulin) and bovine serum albumin are also major allergens present in milk, however αs-1 casein appears to dominate the allergenic potential for reasons described below. Table 2 below demonstrates the differences in contents of the major proteins in cow and goat milk.

Table 2: Protein fraction (g/100 g protein) of goat milk and cow milk

	Goat milk	Cow milk	R.S.D.[a]	Level of significance	Difference (%) for goat milk[b]
Casein (Cn)	82.70	82.65	0.76	NS[c]	
α_{S1}-Cn	18.92	30.80	1.71	***	−62.8
α_{S2}-Cn	8.52	7.50	1.83	NS	
β + κ-Cn	55.26	44.35	2.79	***	+19.7
Whey proteins	17.30	17.35	0.76	NS	

[a] R.S.D. = residual standard deviation.
[b] Difference (%) for goat milk = [(goat milk value − cow milk value)/goat milk value] × 100.
[c] NS = $P > 0.05$.
*** $P < 0.001$.

(Ceballos et al. 2009)

The lower content of αs-1 casein in goat milk improves digestibility and reduces allergenic responses for several reasons. First, it gives goat milk a softer, more easily broken down curd in the acidic conditions of the stomach, improving the ability of digestive protease enzymes (Ceballos et al. 2009, Silanokove et al. 2010). In vitro studies confirm a different pattern of digestion of goat milk proteins compared to cow milk proteins. For example, one study showed that 96% of goat casein was completely hydrolysed in vitro by trypsin compared with cow's casein with only 76–90% (Silanikove et al. 2010). After treatment with human gastric and duodenal juice, only a small amount (~23%) of goat β-lactoglobulin remained undigested in comparison to approximately 83% in cows (Silanikove et al. 2010). Second, αs-1 casein acts as a carrier for other allergens in cow milk such as β-lactoglobulin, which is tightly linked to the casein micelles and therefore more difficult to digest (Lara-Villoslada et al. 2004). The lower content of αs-1 casein in goat milk is believed to allow for better absorption of β-lactoglobulin and other allergens and is thus less allergenic than cow milk (Lara-Villoslada et al. 2004).

Of note here is the fact that genetic variations (called polymorphisms) in goat breeds influence the presence and levels of each protein fraction in goat milk, and thus influence its overall allergenic potential. Certain breeds of goat are more likely to have less αs-1 casein and are thus more effective in reducing milk allergies. This natural variation of αs-1 casein content also adds to the complexity of prescribing goat milk as a hypoallergenic alternative, and accounts for the variation seen in tolerance levels of different varieties of goat milk in allergic subjects (Albenzio et al. 2012; Ballabio et al. 2011). Thus although there is much evidence suggesting the benefits of goat milk for individuals with cow milk allergy, caution should still be exercised in highly sensitive populations (ie. infants, highly allergic individuals). Table 3 shows the variation in skin prick allergy tests in several samples of cow and goat milk.

Table 3: Skin prick tests with commercial cow milk, commercial goat milk and individual goat milk samples

Patient	Cow milk	Commercial goat milk	Goat milk sample 2	Goat milk sample 6
A	10	—	0	0
B	5	3	0	0
C	5	5	2	3
D	7	3	0	0
E	7	3	0	0
F	5	2	0	2

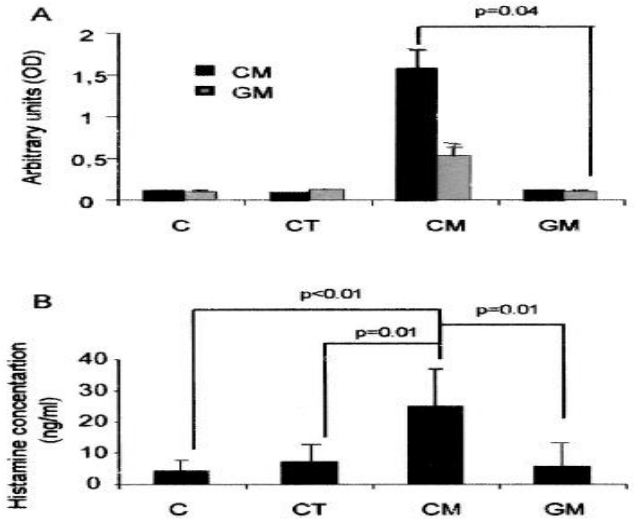
[1]Positive response: wheal diameter ≥3mm; — = not performed.

(Ballabio et al. 2011)

Hypoallergenic Effects of Goat Milk

A study comparing the allergenicity of goat milk and cow milk in mice demonstrates the immunologic benefits of goat milk on reducing specific markers involved in the allergic response (Lara-Villoslada et al. 2004). Compared to goat milk, cow milk significantly increased markers of inflammation including cytokine interleukin-4 (IL-4) and antigen-specific immunoglobulin G1 (IgG1), key markers in hypersensitivity reactions. IgG1 binds to mast cells and promotes degranulation (the initiation of an allergic response), causing an increase in histamine levels and the resulting allergic symptoms. This reaction to cow milk was in contrast to goat milk, which did not induce an allergic response. Table 4 (A and B) below demonstrate the differences in IgG1 (A) and histamine (B) production in response to cow milk versus goat milk administration.

Table 4: Serum levels of IgG1 and Histamine following Cow Milk (CM) and Goat Milk (GM)



(Lara-Villoslada et al. 2004)

Hypoallergenic Effects of Goat Milk continued

A similar trial in children with cow milk protein allergies also demonstrated anti-allergy benefits with drinking goat milk (Albenzio et al. 2012). Subjects drinking cow milk had significantly higher levels of the inflammatory marker tumor necrosis factor-α (TNF-α) than those who consumed goat milk. TNF-α is a primary mediator of adverse reactions to cow milk protein including gastrointestinal distress, respiratory and cutaneous symptoms such as eczema (Albenzio et al. 2012). In addition to the lack of inflammatory effects with goat milk consumption, subjects who drank goat milk also had higher levels of the anti-inflammatory cytokine IL-10. IL-10 which suppresses the formation of pro-inflammatory cytokines such as TNF-α and is thought to contribute to immune suppression and thus prevent reactions to antigens in cow milk (Albenzio et al. 2012). Table 5 below shows the effect of cow milk compared to goat milk on these allergenic markers.

Table 5: Cytokine levels (pg/ml) in lymphocytes of children stimulated against protein fractions of cow and goat milk

Cytokine levels (pg/ml) in cultured supernatants of lymphocytes of children stimulated against protein fractions of cow's and goat's milk.

	Species	Milk protein fraction			SEM	Effects, *P*		
		Protein mixture[a]	Casein	β-Lg		Species	Protein fraction	Interaction
TNF-α	Cow	833.67A	1362.38bA	2401.81bB				
	Goat	651.02	380.37a	366.45a	220	*	*	NS
IL-10	Cow	236.82aA	482.17B	242.49A				
	Goat	460.94bB	448.81AB	441.94AB	70	*	***	**
IL-12	Cow	164.66	106.64	210.21				
	Goat	130.61	74.05	173.3	52	NS	NS	NS

Mean followed by different letters differ for $P<0.05$; a and b for species effect; A and B for milk fraction effect. NS, not significant.

[a] Protein mixture = casein: whey protein (80:20 w/w).

* $P<0.05$.

** $P<0.01$.

*** $P<0.001$.

(Albenzio et al. 2012)

Probiotic Benefits

Goat milk contains a significant level of carbohydrates called oligosaccharides which possess "prebiotic" properties, meaning they promote the growth of beneficial bacteria *Bifidobacteria* in the intestine (Raynal-Ljutovac et al. 2008). *Bifidobacteria* exert a wide range of health benefits including immunostimulation, prevention of pathogenic infections, anti-carcinogenic activity and cholesterol-lowering activity in addition to improving lactose maldigestion (Russell et al. 2011). With proper intestinal colonization with anaerobic bacteria such as *Bifidobacteria,* undigested carbohydrates such as oligosaccharides as well as lactose are able to be broken down into their monosaccharide components, which are then further metabolized to intermediates of the hexose fermentation pathway and converted to energy sources such as short chain fatty acids and other organic compounds (Russell et al. 2011). The ability of Bifidobacteria to metabolize lactose in the large intestine prevents the gastrointestinal symptoms associated with lactose intolerance.

Digestible Nutrition

The highly digestible and anti-allergy properties of goat milk serve as further testament to its well-deserved place at the top of the functional food chain. Considering the prevalence of cow milk-associated tolerance issues, the potential of goat milk to alleviate uncomfortable and in some cases, life-threatening symptoms of cow milk allergy certainly warrants the attention of both at risk populations as well as health conscious consumers desiring a highly digestible, less inflammatory dairy option. Goat milk's natural ability to address a wide range of dairy tolerance issues makes it an ideal dairy alternative for individuals with specific health needs and desires.

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