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Review article

Nutritional properties of small ruminant food products and their role on human health☆

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ABSTRACT

The genetic polymorphisms in ewe and goat milk protein are of great importance as they are associated to quantitative and qualitative parameters and also may be responsible for the generation of bioactive peptides. In goat milk genetic polymorphisms also play a role in eliciting different degrees of allergic reaction in patients affected by cow milk protein allergy. Feeding strategies in lactating goats have been directed to investigate the relationship between diet and genotype. In sheep breeding feeding techniques as pasture, probiotic, vegetable and marine oils supplementation enhance nutritional properties of fat in milk, cheese and meat products. Technological strategies for cheese production have been set up to improve the health benefits trough probiotic and prebiotic adjunct. Experimental model and clinical studies have been performed to evaluate the impact of dairy products on human health.

1. Introduction

Small ruminant food products are gaining major interest for their nutritional properties. Meat and milk and their processed products provide a more interesting nutritional regime for both children and adults and also supply the minor but essential nutrients, i.e. minerals and vitamins, as well as the major nutrients in the form of proteins, fats and carbohydrates.

Wide literature on small ruminant products offers an insight on management factors affecting milk, cheese, and meat composition; more recently, studies are focused on specific compounds able to exert a potentially positive effect on human health beyond basic nutrition.

The scientific interest on the nutritional properties of animal products is in contrast with public opinion regarding the impact of food from animal origin on human health. The association between animal fats and cardiovascular disease has been studied and recommendations range from totally excluding fats to a moderate consumption of fats due to their essential role in the body, and recently the emphasis has shifted from fat quantity to fat quality.

The objective of this review paper is to clarify the role of small ruminant food products on human health and also to give advanced updates on rearing systems, feeding and technological strategies useful to improve their content in healthy nutritional components.

2. Nutraceutical properties of goat caseins

Extensive investigation in goat milk revealed the presence of an high numbers of alleles at the four casein loci (Albenzio et al., 2009; Küpper et al., 2010; Moioli et al., 2007; Roncada et al., 2002; Sacchi et al., 2005). The casein polymorphism is associated with different casein synthesis levels (distinguishing strong, medium, weak, and null alleles) and different rate of phosphorylation of the peptide chain (Albenzio et al., 2009; Grosclaude et al., 1994; Martin 1993; Park et al., 2007). Goat milk from animals with strong alleles has been associated with higher cheeses yields and firmer curds than milk from animals carrying weak alleles (Albenzio et al., 2009; Clark and Sherbon, 2000; Tziboula-Clarke, 2003). Also κ-CN levels of glycosylation and phosphorylation affects the susceptibility of goat milk to clotting enzymes (Amigo et al., 2000) with important technological implication by influencing the coagulation stages of renneting and consequently the inclusion of nutrients in the curds. Albenzio et al. (2009) demonstrating that among casein genotype, SCC, and goat milk, the former was the factor that accounted for a significant percentage of the total variability for goat milk renneting

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(r, k20, a30). The study of goat casein loci permits to differentiate goat population on the basis of milk utilization: animals with weak or null casein alleles should be used in breeding programs aimed at producing milk with hypoallergenic properties and animals with strong alleles to improve quality and properties of milk and related products (Albenzio et al., 2009; Roncada et al., 2002; Sacchi et al., 2005).

The polymorphism of *CSN1S1* genotype affects milk characteristics at various level: dietary protein and high-energy diets utilization are more efficient in goats homozygous for strong alleles (in particular AA goats) which consequently achieve higher milk protein and fat concentration (Bonanno et al., 2013a). Goats displaying a strong genotype (AA goats) are also characterized by higher dimension of fat globules, better creaming ability of milk, and lower milk polar lipids (minute quantities of total lipids with high nutritional, physiological, and health value for the consumer) of fat globules than for goats that are deficient for the null genotype $CSN1S1^{*}0_1 0_1$ (Cebo et al., 2012). Moreover some fatty acids differ in concentration as a function of the *CSN1S1* genotype: milk of goats homozygous for strong alleles containing more short- and medium-chain FAs (SCFA and MCFA), largely synthesized *de novo* in the mammary gland, less branched chained FA (BCFA) mainly derived from rumen bacteria and less odd-chain FA (OCFA) partly derived from rumen bacteria and from partly mammary de novo synthesis from C3 precursors (Harfoot and Hazlewood, 1997). Also delta-9-desaturase activity is lower in goats with strong *CSN1S1* genotypes than in goats with low genotypes (Chilliard et al., 2013). Some differences in fatty acids (FA) composition were found also amongst strong alleles: goats with AA genotype are characterized by higher concentrations of some SCFA and MCFA than goats with BB genotype, which, in turn, had higher concentrations of most long chain fatty acids (LCFA), as reported by Balia et al. (2013). Mammary epithelial cells in goats carrying *CSN1S*1-defective alleles present a strongly reduced rate of transport of the other caseins, essential for the micelle formation, to the Golgi apparatus. As a consequence the other caseins accumulate in the rough endoplasmic reticulum, disturbing the whole secretion process, including that of lipids, with a negative feedback on the *de novo* synthesis of fatty acids (Ollier et al., 2008). Indeed, some genes involved in lipid synthesis, cell communication, and chromatin remodelling are down regulated in *CSN1S1*-defective alleles (Ollier et al., 2008). *CSN1S1* genotype seems also to influence the composition of milk oligosaccharides (OS), free complex carbohydrates. Besides lactose, all mammalian milk include sugars which are not degraded by human digestive enzymes but provide nourishment to commensal microbes, competitor of pathogenic microorganisms in gastrointestinal cells (Meyrand et al., 2013). Goat milk has a profile most comparable to human milk, since compared with cow and sheep it has the highest content of OS (250–300 mg/L, versus 60–90 mg/L and 30–45 mg/L, respectively), even if it is still much lower than human milk (12–13 g/L) (Urashima et al., 2013). Furthermore, goat milk exhibits a moderate number of OS with structural elements critical to human milk OS bioactivity. In particular, it showed the presence of fucosylated and sialylated OS, involved in protective activities in the gastro-intestinal tract, in the prevention of diarrhoea, which is one of the most common causes of infant mortality and in the promotion of infant brain growth (Meyrand et al., 2013). Two studies also showed that goat milk OS have anti-inflammatory effects and reduce intestinal inflammation in mice with induced colitis (Daddaoua et al., 2006; Lara-Villoslada et al., 2006). Although the concentration of OS in milks from $CSN1S1^{*}AA$ and $CSN1S1^{*}0_1 0_1$ genotypes was not different, milks of individuals with the two genotypes could be discriminated by the fucosylated OS, providing evidence of a genetic influence on specific OS biosynthesis (Meyrand et al., 2013). This is presumably connected with the above-mentioned obstruction of the rough endoplasmic reticulum in the mammary epithelial cells of goats carrying *CSN1S1*-defective alleles, since OS synthesis takes place there.

Genetic polymorphism in goat milk protein associated with different milk protein composition may be responsible for the generation of a wide spectrum of casein-derived peptides (Korhonen and Pihlanto, 2006; Meisel, 1997) therefore the study of potential bioactivity of peptide sequences liberated upon hydrolysis is of particular interest. Santillo et al. (2009) investigated the effects of indigenous proteolytic enzymes on the release of bioactive peptides from Garganica goat milk. The authors evidenced the principal role of serine proteinase, especially plasmin, in the liberation of several peptides with potential bioactivity deriving from β-CN and α_{s2}-CN. Almost 90% of the peptides identified shared structural homology with previously described bioactive peptides in caprine and bovine milk and dairy products: some of the peptides have been shown to exert ACE-inhibitory activity or displayed structural homology with peptides with antihypertensive or antioxidant activity.

Goat milk has gained importance in human nutrition as a significant segment in many populations of developed countries is afflicted with cow milk allergies (CMA) and gastro-intestinal disorders (Haenlein, 2004). In patients with CMA IgE-binding epitopes on α_{s1}-, α_{s2}-, κ-CNs, α-lactoalbumin, and β-lactoglobulin were recognized (Järvinen and Suomalainen, 2001; Natale et al., 2004). Genetic polymorphisms of goat milk protein influence the presence and level of synthesis of each protein fraction in milk playing an important role in eliciting different degrees of allergic reaction (Park, 1994; Saini and Gill, 1991). Low levels of α_{s1}-CN in goat milk means that its casein profile is closer to human milk than that of cow milk (Clark and Sherbon, 2000) as human milk lacks α_{s1}-CN. Indeed, milk from animals possessing mild alleles can be employed to produce milk for allergic subjects (Roncada et al., 2002) and considered as alternative to human milk in infant nutrition (Slačanac et al., 2010). As an example the high frequency of the weak allele F and the presence of null allele for *CSN1S1* and the high frequency of A0 genotype at *CSN1S2* locus in Garganica breed could be exploited for CMA subjects feeding (Albenzio et al., 2009). Albenzio et al. (2012) studied the inflammatory response to Garganica goat milk in infant with CMA evaluating cytokines production by peripheral blood mononuclear cells (PBMCs) stimulated with whole milk, casein and β-lactoglobulin from cow and Garganica goat milk. In this study goat milk proteins lowered the production of proinflammatory cytokines and enhanced the release of antinflammatory ones from PBMC (Table 1).

α-CN showing lower levels in goat's than in cow's milk, and a different casein profile, was associated with different TNF-α levels produced by PBMC; this cytokine displayed a lower level after stimulation with casein fractions isolated from goat than from cow milk in children with CMA. Results on TNF-α evidenced that it is important to test the immune reactivity against each protein fraction before considering goat's milk as a safe substitute for feeding infant with CMA. Secretion of the regulatory cytokine IL-10 after PBMC stimulation was influenced by milk protein source being higher in goat's than cow's milk. Within cow milk protein fractions, casein induced higher levels of regulatory cytokine than β-Lg and milk protein mixture. IL-10 is one of the major cytokines produced by regulatory T-cells and exerts inhibitory actions on monocytes and T-cells, partly suppressing the formation of pro-inflammatory cytokines like TNF-α in T-cells and monocytes (Reuss et al., 2002). Tiemessen (2003) investigated the role of IL-10 in T-cells reactivity of children with CMPA suggesting that activated allergen-specific T-cells might contribute to an active form of immune suppression in vivo through the production of IL-10 and thereby prevent aberrant reactions towards antigens such as cow's milk.