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Factors Affecting Sensory Quality of Goat Milk Cheeses: A Review

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Abstract

The combination of tastes and aromas associated with caprine milk lead to a range of unique flavors and sensory properties that are critical to overall quality of caprine milk and its processed products. Goat milk production has risen dramatically in the past two decades. Since numerous breeds of goats have been raised under different localities, environmental and management conditions in many parts of the world, no single factor can universally describe or identify sensory characteristics of a wide variety of goat cheeses produced and consumed around the world. Rather, there are many factors that influence the flavor and sensory qualities of goat milk cheeses. The flavor of cheese arises from a series of complex reactions involving microbial metabolism and enzymatic reactions which include proteolysis of proteins, lipolysis of fats, and fermentation of carbohydrates. Caprine milk reportedly has more fat, protein and ash, and less lactose than cow milk. The types of pasture fed to an animal not only affect the taste of cheese but the color of the products. Because of the amount of carotene present in large amounts in green forage and its contribution to the yellow color in cheese, cheeses made with spring milk are likely to be more yellowish color than those made with winter milk. Lipolysis of fat causes rancid flavor defect in milk, cheese, and other dairy products, while proteolysis provides a major impact on flavor, aroma, and textural characteristics of most cheese varieties. Much more research needs to be done on the sensory quality of goat milk cheese to show the factors directly causing sensory properties of different varieties of goat milk cheeses. Understanding the complexity of flavors embodied by goat milk and goat milk products further aids in the production of quality products that enhance the consumer acceptability of caprine milk cheese products. This paper explores the current up-to-date reports on various factors associated with sensory qualities of caprine milk cheese products.

Keywords: Goat cheese; Sensory quality; Flavor compounds; Lipolysis; Proteolysis

Introduction

The Agricultural Handbook No. 54 of the USDA [1] describes over 400 varieties of goat cheeses and lists over 800 names of cheeses, made from goat milk or combinations of goat with other species milk such as cow, ewe, or buffalo [2].

Milk of various non-bovine species including goats, sheep, buffalo, Zebu, mare, camel, reindeer, and yak are important for human nutrition and subsistence in many parts of the world. These milks are becoming increasingly profitable and popular as alternatives to bovine milk-based products due to their success in the market and growing consumer interests. The milk of non-bovine dairy species serves 3 types of markets in many parts of the world, such as (i) home consumption, (ii) specialty gourmet interests and (iii) medical needs [3], besides being the alternative milk nutrient source where dairy cattle do not survive for climatic or geological reasons, and where cow milk is too expensive.

Goat milk is often consumed by young children, the elderly, those who are ill, or have cow milk allergy and low tolerance to cow milk. The use of goat milk as a hypo-allergenic infant food or milk substitute in infants allergic to cow milk has been reported in much anecdotal literature [4,5]. In addition, some recent comparative human allergy and growth studies have been revealed that hypoallergenicity and growth rate of children were better in goat milk than those in cow milk [6,7].

The volume of goat milk production has been dramatically increased in the past two decades [4,8], and worldwide production of goat milk has been risen by approximately 60% between 1993 and 2013 [9]. The goat is the most versatile domesticated animal and was the first livestock domesticated and its milk was used for human consumption [10]. Certain chemical and nutritional compositions of goat milk, such as non-protein nitrogen and oligosaccharide contents are closer to human milk compared to those of the cow milk. However, large variations can occur in milk composition, depending on different factors such as breeds, diet, stage of lactation, environmental and management conditions in both species [2-4,11].

However, studies on the food quality and organoleptic properties of goat milk and its dairy products have not been sufficiently investigated to-date. The combination of tastes and aromas associated with caprine milk lead to a range of unique flavors that are critical to overall quality and properties of the milk and its processed products [12]. This paper reviews the factors associated with sensory quality of goat milk cheeses, including milk composition, genetics, somatic cells, feeds, stages of lactation and storage conditions, etc.

Composition of Caprine Milk

Goat milk differs from cow or human milk in higher digestibility, distinct alkalinity, higher buffering capacity, and certain therapeutic values in human medicine and nutrition [11,13-15].

Although there are certain species-specific differences in composition of milk, the basic nutrient composition of goat milk is similar to that of cow milk [5]. Caprine milk, on the average, contains

12.2% total solids, consisting of 3.8% fat, 3.5% protein, 4.1% lactose and 0.8% ash (Table 1), indicating that it has more fat, protein and ash, and less lactose than cow milk [4-5].

Constituents	Goat	Cow	Human
Fat (g)	3.8	3.6	4
Protein (g)	3.5	3.3	1.2
Lactose (g)	4.1	4.6	6.9
Ash (g)	0.8	0.7	0.2
Total Solids (g)	12.2	12.3	12.3
Calories (cal)	70	69	68

Table 1: Basic composition of goat, cow and human milks (mean values per 100 g). Data from USDA [69], Jenness [4], and Haenlein and Caccese [11].

Significant variations in composition and yield of milk were observed during different seasons and stages of lactation of milking cows, where the same phenomena are expected to occur in goat milk. The fat, total solids, and protein contents of the milk are high in early lactation, fall rapidly and reach a minimum during the 2^{nd} to 3^{rd} months of lactation, and then increase towards the end of lactation [3,16]. This causes an inverse relationship between the yield of milk and percentage composition of these components [5,17].

Diameter	Goat	Cow	Buffalo	Sheep
(μm)	--------------------------------- (%) ------------------------------------			
1.5	28.4	10.7	7.9	28.7
3	34.7	32.6	16.6	39.7
4.5	19.7	22.1	16.4	17.3
6	11.7	17.9	20.3	12.1
7.5	4.4	12.2	20.9	2
9	1	3.1	10.5	0.2
10.5	0.2	1.4	1.7	...
12	...	0.1	2	0.1
13.5	...	...	0.4	...
15	...	...	0.3	...
16.5	...	...	...	...
18.5	...	...	0.1	...
Average	3.49	4.55	5.92	3.3

Table 2: Frequency distribution of average size fat globules in milk of goats, buffaloes, cows, and sheep. Adapted from Fahmi et al. [18]; Park [5].

One of the significant differences between goat and cow milk is found in the physico-chemical structure and composition of milk fats and proteins. The average fat globule size of goat milk is about 3.49 micrometers as compared to 4.55 micrometers for cow milk fat (Table 2) [11,18,19], indicating that goat fat globule size is significantly smaller than cow counterpart, which is related to the higher digestibility of the former than the latter. These differences in physicochemical characteristics would make differences in lipid and protein degradations in manufactured dairy products during aging processes. Goat milk contains five principle proteins: β-lactoglobulin (β-Lg), α-lactalbumin (α-La), κ-casein (κ-CN), β-casein (β-CN), and α_{s2}-casein (α_{s2}-CN) [4,5,20,21], where it generally contains significantly lower or minimal level of α_{s1}-casein (α_{s1}-CN). These proteins were named after their corresponding proteins of cow milk due to their homologous nature in composition and properties [22]. The casein composition in goat milk is influenced by genetic polymorphism on the casein loci [21,23], which can have significant impacts on proteolysis.

Sensory Characteristics of Caprine Milk Products

Cheese is the major dairy products produced from goat milk in most goat producing countries in the world especially in the Mediterranean region. Caprine milk cheese first began in Mesopotamia [24]. Goat milk cheese probably started off as soft cheese then turned into hard and ripened cheeses. Goat milk cheeses were developed later in other Mediterranean countries such as Turkey, Greece, Syria, Israel, Iraq, and Iran [10].

Goat cheeses contain 17-18% and 20-30% fat (wet basis) in soft and hard type, respectively, while cow Cheddar cheese contain about 30% fat in general, but lower than sheep or other non-bovine milk cheeses [5,25]. Average diameters of fat globules for goat, cow, buffalo and sheep milks were reported to be 3.49, 4.55, 5.92 and 3.30 μm, respectively (Table 2). Smaller fat globules make a better dispersion and more homogeneous mixture of fat in goat milk, which would provide lipases with a greater surface area of fat for enhanced digestive action. Goat milk has a higher proportion of fatty acids including capric, caprylic and caproic acids. The composition of these short chain fatty acids gives goat milk and its cheeses for their unique tangy flavor [24]. When goat milk cheese is aged, the tangy flavor may cause creamy and earthy cheese taste.

The sensory qualities of cheese are influenced by a number of factors including animal genetics, the milk production environment and processing technologies [26] and to the chemical and microbiological characteristics of the raw material used [27]. The quality and composition of raw milk are among the major factors determining yield and quality of cheese.

Cheese flavor arises from a series of complex reactions which involves microbial metabolism and enzymatic reactions, including proteolysis of proteins, lipolysis of fats, and fermentation of carbohydrates [28]. The products of these microbiological and enzymatic activities result in a vast array of flavor compounds [29,30]. These reactions take place throughout the cheese making process, and are concentrated in the ripening phase [31]. Most of these reactions occur due to both endogenous and microbial-produced enzymes [32,33]. Proteases and lipases mediate many of the most important flavor-generating reaction s in goat cheese by the processes of lipolysis and proteolysis [28,34].

Flavors and their occurrence in cheeses often require deeper understanding on: (a) identification of specific flavor compounds, and (b) isolation of the specific reaction or metabolic pathways that produce flavor compounds [35]. Flavors of dairy products are directly affected during their maturation. Cheese maturation during storage is

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affected by the interplay of several factors, such as proteolytic and lipolytic enzymes, storage temperature and period, salting, pH of the curd, and humidity [28,36]. The specific catabolic compounds are generated in the cheese during ripening processes, which will influence the characteristic flavors of specific goat cheeses.

Aside from cheese, goat milk is used to make many different dairy products. Some of these include: dehydrated milk powder, fermented beverages (e.g. kefir), yogurts, frozen desserts (e.g. frozen yogurt, ice cream), confections, butters, and whey powders [25,37,38]. In the United States, the production of goat milk products especially in cheese products have been tremendously increased in recent two to three decades [25,38]. Research relating to the sensory properties of these specialty products is scarce due to their recent emergence in the mainstream marketplace. The flavor characteristics of the milk, influence the final flavor of these products, which are much in the same way with cheeses [25,38].

McGhee et al. [39] studied the effect of three levels of fat content, storage temperature and storage periods on the sensory properties of low-fat goat milk ice creams. Flavors identified included: cooked, freshness, rancid, sweetness, whey, acid, and oxidized, which were based on flavor characteristics of goat milk cheese lexicon as shown in Table 2. Storage time had significant effects on cooked, sweet, oxidized, rancid, and whey flavors. Fat content did not show significant effects on flavor perception, where all three types of the ice creams were formulated with low fat contents. However, fat is the major component in cheeses, where significant amounts of flavor compounds were generated in the aged goat milk cheeses by concomitant effects of storage temperature and time during 6 months storage [28,34].

Factors Influencing Organoleptic Quality of Caprine Milk Cheeses

Somatic cell count (SSC) on goat cheese sensory quality

Grade A goat milk is needed to produce all manufactured dairy goat products. Production of high quality raw milk is essential for successful production and marketing of dairy goat products [5]. Dairy goat products must be safe to consume, which must be free of pathogenic bacteria, antibiotic, insecticide and herbicide compounds [3,5]. The products should have good and no objectionable flavor, free of spoilage bacteria, and contain legal minimum limits of all nutrients [5,40].

Because SCC in raw milk has major impact on cheese quality, the FDA and each state health departments strictly enforce the regulations on the standards of Grade A raw milk. The raw milk shall be cooled to 45°F within two hours after milking, shall not exceed 100,000 per ml of bacteria, shall not have any antibiotics detectable with the *Bacillus subtilies* method, and shall not have a SCC over 1,500,000 per mL. Grade A pasteurized milk shall be cooled to 45°F and maintained at that temperature, shall not have bacteria over 20,000 per ml, shall not have coliform over 10 per ml, shall not contain phosphatase more than 1 microgram per ml when the Scharer Rapid Method is performed, and shall have no antibodies detectable by the *Sarcina lutea* Cylinder Plate Method [5].

Goat milk has a higher SCC than cow or sheep milk, because dairy goats have the apocrine secretory process in milk secretion system, while cows have mainly merocrine secretory system [5,13,41]. Milks with high SCC coagulate slowly and drip-dry poorly, lead to low cheese yield, due to higher protein and fat losses in whey.

Moisture content of goat milk cheese is higher than cow cheese, causing higher proteolysis and modification in proteolytic pattern of goat cheese [42]. It was also observed that increase in SCC induced decrease in firmness and elasticity and increase in stickiness in the cheese made with goat milk having SCC between 200 000 and 2200 000 cells/mL [27]. High SCC was also associated with taste descriptors such as “rancid” and “oxidized”, which is related to lipolysis, or “bitter” which is linked to proteolysis [43]. In addition, evidence has shown that goaty flavor and lipolysis are correlated with α_{s1}-casein genotype. Goat milk with little or no α_{s1}-casein has a lower fat content and higher lipolysis levels, and thereby shows a more intense goaty flavor [25]. Based on these characteristics of goat milk, the increase of α_{s1}-casein content in caprine milk by genetic selection scheme succeeded in improving both the coagulation behavior of cheesemilk and sensory properties of the goat milk cheeses [25].

Stage of lactation on sensory quality of goat cheese

The composition of original milk would significantly affect the composition and organoleptic quality of the manufactured dairy products. In a study on the effect of stage of lactation on the yield of goat milk cheese, Fekadua et al. [26] found that total solids, fat, and protein contents of milk for hard and semi-hard cheeses were higher at early and late stages of lactation than they were during in mid-lactation (Table 3). They concluded that the actual cheese yield in hard cheese was higher at early (May) and late (September and October) stages of lactation compared to the mid-lactation (July and August) [26], which is attributed to the differences in total solid, fat and protein contents of the corresponding milk that were used for manufacture of the hard and semi-hard types of cheeses (Table 3). During mid-lactation (summer months), the animals are fed fresh pastures and forages which contain less solids, while actual milk yield is considerably increased [5,17].

%	May	June	July	August	Septembe r	October
Total						
Solids	10.7^{a}	9.98_{b}	9.78^{b}	9.83^{b}	$10.26^{a,b}$	10.67^{a}
Hard	$10.83^{a,b}$	$10.26^{a,b,c}$	$9.93^{b,c}$	9.72^{c}	9.74^{c}	11.2^{a}
Semi-Hard	-	-	-	-	-	-
Fat						
Hard	$2.96^{a,b}$	2.65^{c}	2.64^{c}	2.59^{c}	$2.78^{b,c}$	3.03^{a}
Semi-Hard	2.80^{b}	2.74^{b}	2.63^{b}	2.52^{b}	2.59^{b}	3.28^{a}
Protein						
Hard	$2.82^{b,c}$	2.73^{c}	$2.82^{b,c}$	$2.88^{b,c}$	2.91^{b}	3.16^{a}
Semi-Hard	3.28^{a}	2.89^{b}	2.88^{c}	2.87^{b}	2.80^{b}	3.00^{a}
a,b,c: Means with different superscript within a same column are significantly (P<0.05) different.						

Table 3: Gross Composition of Goat Milk used for Hard and Semi-Hard cheese making during 6 months of Lactation. Adapted from Fekadua et al. [26].

There is an inverse relationship between milk yield and cheese yield [5,17,21], which are directly related to the changes in fat, protein and total solids contents of the original milk used for the cheese manufacture. In Fekadua et al. [26] study, semi-hard cheese only had a higher cheese yield during the last month of lactation.

Coulon et al. [44] observed that cheeses made with early lactation milk were more yellowish and exhibited a lower fat in dry matter than others. Cheeses made with late lactation milk were stickier, more melting, less firm and less granulose than those made in early or mid-lactation. The taste of this cheese was more intense, persisting, acid and bitter, and the overall acceptability score was globally rated lower than others.

Effect of feeds fed milking goats on sensory quality of cheese

Sensory quality of caprine milk cheeses can be highly influenced by the types of feeds fed to the lactating animals. Off-flavor in goat milk can be attributed to the feeds, weeds, forages, chemicals, building materials, colostrum, estrus, mastitic milk, filthy utensils and strainer, unclean milking equipment, slow cooling, odors from bucks, barn and/or milk room. Feeding odorous feeds at least two hours before feeding is not recommended [25].

Coulon et al. [27] postulated that the type of feed fed to a lactating animal has an influence on the nutrient input and the main milk components (proteins and fat), which in turn have highly consequential effects on cheese-making performance, sensory characteristics, and texture. The type of pasture fed to lactating goats induces a modification of milk fatty acid composition, which affects cheese texture. Pasture fed diets led to more "animal" and less "bitter" and less "sour" odors [45].

Some cheesemakers have reported differences in the sensory characteristics of cheeses according to the type of forage fed to animals. These reports have been proved by scientific studies aimed at analyzing the sensory characteristic diversity of a given type of cheese and paralleling that diversity with the conditions under which the milk and cheeses were produced [27]. Martin [46] found that differences in sensory characteristics of cheeses could be associated with differences in forage types (hay or pasture) (Table 4).

	Trail 1	Trail 1	Trail 2	Trail 2
Cheese	Grass Silage	Pasture	Grass Silage	Hay
Dry Matter %	52.6	52.7	54.6	54.8
Yellow Index	24.7**	30.5	32.9**	29.9
Firm Texture	4.3**	3.4	4.6	4.5
Sticky Texture	4.1*	3.5	3.1	3.3
Taste Intensity	5.0**	5.6	5.4	5.3
Odor Intensity	4.6	4.4	5.2	5.2
Bitter Taste	1.5*	1.9	3.5	3.2

Table 4: Effect of Forage Conservation on Sensory Characteristics of Cheese. Adapted from Martin [46].

In the similar line of a study at the Comté region of France, Monnet et al. [47] found the evidence of associations between the floristic typology of pastures and the sensory typology of cheeses. Gaborit et al. [48] also observed that goats fed alfalfa hay resulted in producing cheeses with much more intense flavors than those lactating goats fed maize silage. Urbach [49] observed that cheeses made of the milk from animals fed on low quality silage caused certain deficiencies, especially in hard-cooked cheeses. Such deficiencies were revealed as the presence of butyric spores in silage and milk, including delayed swelling, unpleasant taste and odor. These problems appeared far less frequent in animals fed on high quality silage.

Cheese color may also be dependent on forage composition. Milk contains variable amounts of pigments including carotene. Carotene is present in significant amounts in green forage and contributes to yellow coloration of dairy products. Carotene is highly sensitive to ultraviolet light, and it is destroyed during forage drying and preservation [50]. The type of diet fed to goats has a marked effect on carotene levels in milk, and on the color of cheese [27]. It has been discovered that cheeses made with spring milk are more yellowish in color than those made with winter milk. Cheeses made with winter milk from dairy goats fed grass silage are more yellowish than those made with milk from animals fed hay. Maize silage, containing very little carotene, produces very whitish cheeses [45]. When forage is conserved well, the conservation method has little influence on the sensory characteristics of cheese, except on color.

Effect of genetics on sensory quality of goat cheese

In Norwegian studies, it was demonstrated that the preferred "goat" cheese flavor sought by consumers in Northern European cheeses was attributed to a hereditary feature of goat populations, and such characteristic flavor was also linked to the animal breed [27]. In other studies, cheeses made with Norwegian breed goats' milk were confirmed to have a stronger "goaty" taste than those made with Saanen goats' milk [27].

For the last few decades, caprine breed genotyping has revealed the existence of a wide polymorphism on the αs1-casein locus which led to reduced proteosynthesis, and a stronger "goaty" flavor in the milk and cheese [23,51]. Genetic polymorphism also has been shown to affect sensory quality of goat and sheep milk, and their products [51]. Tsartsianidou et al. [51] also demonstrated the nucleotide polymorphisms within the goat κ-casein gene of Greek indigenous breeds, which alter the isoelectric point of the *para*-κ-casein peptide, and lead to false positive results by official German method. Previous DNA analysis of the goat κ-casein gene has shown high levels of polymorphism.

Effects of storage on sensory quality of caprine cheeses

Sensory and organoleptic properties of different species milk cheeses can be greatly influenced by chemical and biochemical changes that occur during storage of the cheeses. Proteolysis and lipolysis have been regarded as two major biochemical processes in the multifaceted phenomenon of cheese aging. These two biochemical aging processes involve a variety of chemical, physical, and microbiological changes under controlled environmental conditions in bovine cheeses [28,32,52].

With respect to caprine milk cheese products, numerous biochemical and physical changes also can occur in different types of cheeses during manufacturing, distribution and storage processes, as observed in bovine milk cheeses, due to ripening and degradation of nutrients in the products. During aging processes under different environmental conditions, lipolysis and proteolysis take place in the cheeses, resulting in a variety of chemical, physical, microbiological, textural, and rheological changes in the goat cheese products [34,52-54].

Several extensive reviews have been reported on the rate, extent, and nature of protein and fat degradation of bovine and caprine milk cheeses during aging [28,52, 53]. It has been demonstrated that sensory qualities of cheeses are greatly affected by levels of peptides, amino acids, and free fatty acids resulting from proteolysis and lipolysis during storage [55,56].

Lipolysis on sensory quality of goat cheeses: Lipolysis and the resulting free fatty acids are closely associated with characteristic flavors of goat milk cheeses. Goat cheese flavors and lexicon are described in Table 5 as the major flavor descriptions: goaty/animal, sour/citrus, soapy, whey, diacetyl, and others [57-59]. Flavor deterioration caused by lipolysis of dairy products creates serious problem in products quality and their storage stability [60,61].

Term	Definition	References
cooked/ milky	aromatics associated with cooked milk	skim milk heated to 85 °C for 30 min
whey	aromatics associated with Cheddar cheese whey	fresh Cheddar whey
diacetyl	aromatics associated with diacetyl	diacetyl
milkfat/ lactone	aromatics associates with milkfat	fresh coconut meat, heavy cream, d-dodecalactone
waxy/ animal	waxy/crayon-like aromatic primarily associated with cheeses made from goat or sheep's milk	4-methyl octanoic acid and 4-ethyl octanoic acid 100 ppb of each in MeOH in a sniffing jar
brothy	aromatics associated with boiled meat or vegetable stock	Knorr beef broth cubes, Knorr vegetables broth cubes, canned potatoes
sweet	fundamental taste sensation elicited by sugars	sucrose (5% in water)
salty	fundamental taste sensation elicited by salts	sodium chloride (0.5% in water)

Table 5: Goat cheese lexicon and references. Adapted from Carunchia Whetstine et al. [57].

Goat milk contains higher concentrations of short- and medium-chain fatty acids (MCT) than cow milk does [3-5]. The higher levels of short-chain free fatty acids in goat milk appear to be associated with the development of goaty flavor in its products. Hydrolysis of fat catalyzed by lipase enzymes has shown to be a major problem in the dairy industry because it causes organoleptic defect of rancid flavor in milk, cheese, and other dairy products [5,28,55,62].

Lipolysis is a major factor deteriorating sensory quality and consumer acceptability of different species dairy products, including cow, goat and sheep milk cheeses. There are three different types of lipolysis in dairy products, which are induced lipolysis, spontaneous lipolysis, and microbial lipolysis [28]. Lipolysis can be induced by processing factors such as agitation and homogenization, temperature during transportation, storage and processing, farm factors such as milking machines, pipelines, pumping and bulk tank, and dairy plant factors, such as mixing, separation and poor refrigeration [28,55]. Spontaneous lipolysis occurs during milk processing factors, such as cooling, mixing and separation that disrupts milk fat globule membranes, and milking animal factors such as stage of lactation, feed season, breed, mastitis, milk and fat yield, and physiological factors such as estrous cycle [28]. Microbial lipolysis can occur because many microorganisms that contaminate dairy products are lipolytic, produce lipase, and also causes the development of rancid flavor [28]. Bacterial lipases are different from milk lipases, are not destroyed by pasteurization, and can attack milk fat globule membranes. These lipases cause lipolysis and eventually have significant negative impact on sensory quality of final cheese products [28,55].

Studies have shown that aging time and temperature significantly elevated levels of volatile FFA in goat Cheddar cheese, and also increased storage time and temperature synergistically increased proteolysis and lipolysis of goat cheeses in general [34]. The 4-ethyloctanoic acid was reported to be principal compound responsible for the characteristic goaty-type aromatic flavor noted in goat milk cheese [63]. The existence of notable amounts of other volatile branched-chain and n-chain fatty acids provided a blended heavy, goat-muttony flavors in both caprine and ovine milk cheeses [63]. Although n-fatty acids occur abundance, certain minor volatile branched fatty acids exhibited characteristic flavors at low concentrations [64].

Proteolysis on sensory quality of goat cheeses: Goat milk has lower casein content than cow milk. Goat's casein micelles have a different composition, size and hydration in caprine milk compared to cattle milk [5,65]. Goat milk also has different proportions of the four major caseins (αs1, αs2, Β, κ) compared to cow milk which influence the cheese making process [5,21,65]. This different composition of different caseins have shown different coagulation properties and proteolytic patterns, which can affect texture and catabolism of cheese matrix, resulting in different sensory characteristics and consumer acceptability [5,21].

Levels of peptides and amino acids resulting from proteolysis are attributable to a major impact on flavor, aroma, and texture of most cheese varieties [28,52]. The firmness of cheese curd is strongly correlated with α_{S1}-CN content of milk [4,5,21]. The protein degradation rate is strongly related to the accessibility of proteolytic enzymes to the cheese substrates, which is controlled by the structure and configuration of the cheese protein matrix [5,21].

Milk proteins undergo enzymatic coagulation during cheese manufacture. Rennet is a mixture of chymosin, pepsin and other enzymes from calf stomach [5]. Rennet coagulation of milk proteins of cow and goats causes proteolysis by the formation of para-κ-CN and NPN [5,21,28].

Many changes occur in the body and flavor of goat milk cheese during aging after manufacture. These changes are attributed to the

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fact that amino acids, fatty acids, and methyl ketones of different carbon lengths, Iactones, and many other organic compounds are becoming free in the cheese matrix [5,28]. Proteolysis affects cheese ripening by displaying changes in texture through degradation of the protein network along with an increase in pH and higher water binding capacity [28,53].

Proteolysis is also directly and/or indirectly related to the sensory quality of cultured dairy products including cheeses and yogurts. Proteolysis is responsible for the development of flavor components in bovine and caprine cheeses, such as amino acids and peptides [28,66], changes in pH by the formation of NH_3, and increased release of sapid compounds during mastication [28]. It has been reported that there are five proteolytic agents involved in the aging of cheeses, which include: (i) indigenous enzymes in raw and/or pasteurized milks, (ii) coagulating enzymes, rennet or its substitute such as chymosin, pepsin or microbial proteinases, (iii) starter culture bacteria and their enzymes after the cells are lysed, (iv) enzymes from secondary starters, such as propionic acid bacteria, and yeasts and molds, and (v) nonstarter bacteria that opportunistically entered during cheese making [28,52].

Undesirable organisms causing defects of ripened bovine and non-bovine dairy species cheeses, which include heterofermentative lactobacilli, yeasts and molds and citrate- and spore-forming bacteria [5]. These undesirable microbes are introduced adventitiously with starter culture, where some of them can survive during pasteurization of milk or gain access to cheese milk or curds that are in contact with processing equipment and utensils during cheese manufacture, especially in small scale farm dairy facilities with dairy goat production [28,67].

Recent storage studies on sensory quality of goat cheeses: A study was conducted to evaluate the feasibility of five years long term frozen storage and its effect on sensory quality of Monterey Jack goat milk cheeses [59]. The sensory profiling by the trained panel revealed that the long-term frozen storage significantly (P<0.05) reduced cooked/milk, sweet and milk fat flavors, while no changes occurred in diacetyl, whey, sour, salty, brothy and waxy flavors (Figure 1). There was a noticeable grainy/pasty texture detected in the 5-year frozen-stored cheeses. However, flavor characteristics of the goat cheeses were not significantly changed, indicating that the long-term 5 years frozen storage of goat milk cheese appeared to be feasible and applicable for later consumption and marketing with still acceptable sensory quality scores (Figure 1).

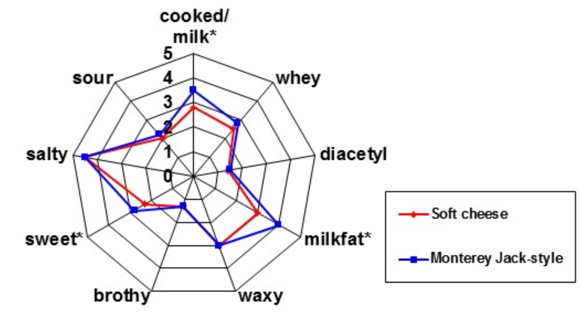

Figure 1: Sensory flavor profiles of fresh soft and 5 years frozen Monterey Jack-style caprine milk cheeses. Sensory attributes were scored on a 15 point universal intensity scale [68-70], where 1=very low and 15=highest possible intensity. Attributes followed by an asterisk (*) are different between the timepoints. Values are the means of duplicate sensory panel sessions.

NOTE: Texture profiling was not conducted and there was a noticeable grainy/pasty texture in the frozen cheese that was not present in the non-frozen cheese. Adapted from Park [59].

Effects of refrigerated and frozen storage on organic acid composition of commercial plain soft (PS) and Monterey Jack (MJ) goat cheeses were studied [36]. Differences (P<0.05) were found in tartaric, formic, and uric acid contents of PS cheese between fresh and frozen-thawed treatments (Table 6). Freezing caused increases (P<0.05) in formic and uric acids, while decreases in tartaric acid in the PS cheese. However, Califano and Bevilacqua [68] found no significant effect of freeze-cycle on the variations in organic acid contents in their cow milk Mozzarella cheese. Effects of aging (refrigerated storage at 4oC for 28 days) on changes in organic acids in PS cheese showed that only 3 acids (orotic, malic and butyric) were affected and all other acids were not influenced by the refrigerated aging (Table 6).

Organic Acids	Unfrozen			Frozen-Thaw		
	0d	14d	28d	0d	14d	28d
Plain soft goat cheese						
Tartaric acid[1,2]	1.72[a]	1.70[a]	1.70[a]	1.53[b]	1.45[b]	1.48[b]
Formic acid[1,2]	0.79[b]	0.85[b]	0.83[b]	1.28[a]	1.22[a]	1.21[a]
Orotic acid[2]	0.042[a]	0.011[b]	0.011[b]	0.043[a]	0.014[b]	0.013[b]
Malic acid[2]	1.87[b]	1.99[ab]	2.10[a]	1.82[b]	2.05[a]	1.87[b]
Lactic acid	10.72	10.83	10.98	9.58	10.77	10.45
Acetic acid[2]	5.9	6.96	7.1	7.5	6.79	6.46

Citric acid	0.52	0.67	0.72	0.71	0.73	0.65
Uric acid[1,2]	0.017[b]	0.02[b]	0.015[b]	0.029[a]	0.038[a]	0.034[a]
Propionic acid[2]	0.71	0.79	0.69	1.28	0.6	0.83
Butyric acid[2]	0.65[b]	0.81[b]	0.94[a]	0.01[c]	0.83[b]	1.24[a]
Monterey Jack goat cheese						
Formic acid[2]	2.66	2.66	2.62	2.7	2.2	2.44
Pyruvic acid[1]	1.89[b]	1.29[bc]	1.11[c]	2.04[a]	1.29[bc]	1.11[c]
Malic acid[1,2]	1.13[b]	1.00[b]	1.38[b]	1.50[ab]	1.82[ab]	2.34[a]
Lactic acid	10.45	9.56	9.16	9.28	10	10.24
Acetic acid[1,2]	1.78 [b]	1.86[b]	2.43[a]	1.96[b]	2.19[b]	2.82[a]
Orotic acid[2]	0.009	0.008	0.011	0.006	0.011	0.015
Citric acid[1]	1.17[ab]	0.85[b]	0.77[b]	0.91[ab]	1.31[a]	1.32[a]
Uric acid[2]	0.062	0.072	0.064	0.064	0.056	0.054
Propionic acid[1,2]	3.23[c]	3.36[c]	5.96[b]	5.43[b]	5.53[b]	7.16[a]
Butyric acid[1,2]	10.56[b]	10.58[b]	11.94[a]	10.50[b]	13.04[a]	14.04[a]
[1]Mean difference between unfrozen and frozen thaw groups is significant ($P<0.05$).						
[2]Differences between soft and Monterey Jack cheeses are different ($P<0.05$ or 0.01).						
[a,b,c]Means with different superscript within same row are significant ($P<0.05$).						

Table 6: Comparison of mean organic acid contents (mg/g cheese) of unfrozen (fresh) and frozen-thawed plain soft with Monterey Jack goat milk cheeses aged at 4°C for 4 weeks. Adapted from Park and Lee [36].

On the other hand, frozen and thawed MJ cheese had higher ($P<0.05$) acetic, butyric, citric, malic, propionic and pyruvic acids compared to the unfrozen control cheese (Table 6). Pyruvic acid was found only in MJ cheese and its initial content was highest and gradually decreased with refrigerated aging. However, acetic, butyric, malic, and orotic acids contents were elevated by aging time and highest at 28 d among the 3 different refrigerated storage periods. Pyruvic and butyric acids were two distinct and solid organic acids in MJ cheese [36]. The changes in these organic acids during storage would make differences in sensory properties of the plain soft and Monterey Jack goat cheeses.

Conclusions

Numerous types of goat milk cheeses are produced around the world. Findings scientific information from one particular dairy production setting may not always be applicable to others. It has been discovered that certain main factors seem to have common effects on sensory and consumer acceptability of dairy goat products. Goat milk has been reported to have higher total solids, fat, and protein for hard and semi-hard cheeses at early and late stages of lactation. Late lactation milk has been reported to produce the cheese stickier, more melting, less firm and less granulose than cheeses made during early or mid-lactation. The types of pasture fed to dairy animals not only affect the flavors of cheese, but also the color of the products. Goats that were fed alfalfa hay produced goat milk cheeses with much more intense flavor than goats fed maize silage. Because of the high amounts of carotene present in green forage and its contribution to the yellow color in cheeses, it has been discovered that cheeses manufactured with spring milk are likely to show more yellowish color than those made with winter milk. More researches are necessary to determine factors associated with the sensory quality of goat milk cheeses with respect to milk production, processing and storage of manufactured products, in order to pinpoint the exact causes-effect relationships in sensory and organoleptic properties in goat milk cheese products.

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