Meat and milk quality of sheep and goat fed with cactus pear

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ABSTRACT

Consumer demand for quality food products is increasing rapidly, motivating a similar interest in the production sectors. Meat and milk quality can be evaluated from the perspective of the producer, where high yields and profits are sought. From the consumer viewpoint, sensorial characteristics are the most important, although, nowadays, welfare and health are also imperative. This has increased the demand for better characteristics and fatty acid differentiation in products of animal origin. In general, sheep meat it is considered milder than goat meat, principally due to the higher lipid content, however, both types of meat are well appreciated by consumers. Goat milk is highly valued for its characteristics and is commonly used to feed children and adults with allergic and gastrointestinal problems. The lipid profile of meat and milk products depends on what the animal eats, consequently, the feed has an important role in improving the products. Cactus pear is an excellent feed for animals in semiarid regions. Cactus pear consumption has been shown to increment the linoleic, linolenic and conjugated linolenic acid fatty acids, without modifying the sensorial quality of goat and sheep products.

Keywords: Cactus pear, small ruminants, conjugated linolenic acid, linoleic acid, lipid profile.

INTRODUCTION

According to the Food and Agriculture Organization of the United Nations, the world herd was estimated at 1,006,785,752 million goats and 1,209,908,142 million sheep (FAO, 2014). However, with extensive systems of productions, mainly due to a deficit in the quantity and quality of the food has led to low yields (Nogueira *et al*. 2010). In recent years, goat and sheep farming has assumed an important role in agribusiness, from being a subsistence activity to becoming an endeavor of considerable socioeconomic importance (Souza *et al*. 2011).

One of the major constraints on livestock productions is food, which is responsible for 60–70% of the cost production and, thus, it is crucial to seek alternative feeding strategies to reduce this cost (Neto *et al*. 2011). In semiarid zones, it is particularly necessary to reduce the effects of the dry seasons on small ruminant production, with foods that supply adequate nutritional characteristics and are available in times of shortage of other foods.

The food most used in these circumstances is cactus pear, due to its capacity to resist dry seasons, and its high water retention and productivity in such hazardous environments. The cactus pear is used as both a water and energy source. Despite these characteristics, however, it has a low protein content and, therefore, must be complemented with other sources of protein (Andrade-Montemayor *et al*. 2011). In meat and milk production, qualitative and quantitative characteristics depend on factors associated with the environment and nutrition.

Meat consumers are looking for healthier foods, with nutritional and sensorial qualities and functional properties beneficial to human health (Costa *et al*. 2008). This scenario has stimulated the need to enhance the fatty acid content of meat, mainly the polyunsaturated fatty acids and omega-6:omega-3 ratio. Therefore, this work aims to review the literature pertaining to the diet of sheep and goats and its effects on the characteristics of meat and milk.

Cactus pear

The cactus pear is a succulent food that has a high dry matter (DM) digestibility coefficient (64%) and is rich in mucilage and soluble carbohydrates (29.1–59% DM basis). These values may vary depending on the age and cactus species. The chemical composition of cactus pear includes a high mineral content (15–25%) (Andrade-Montemayor *et al*. 2011), with low DM (7–16%) and crude protein (CP) (3–7%). These characteristics result in an increased production of volatile fatty acids (VFAs), allowing an increase in the availability of nutrients (Ben Salem *et al*. 1996; Cerrillo and Juarez, 2004; Nieva *et al*. 2006; Santos *et al*. 2006).

In livestock production, the cactus pear has been used for many years. In particular, *Opuntia* ssp. and *Nopalea* ssp. are used as forage and as substitutes of corn or energy-rich concentrates. Different levels of substitution have been evaluated, ranging from 20–100% of cactus pear in the diet, with favorable results for weight gain and milk production (Cavalcanti *et al*. 2008; Pinto *et al*. 2010). Ben Salem and Smith (2008) considered cacti as the “bank of life” for their contribution as a water resource for animals and humans. Various studies have shown that increasing the quantity of cactus in the diet of goats (Costa *et al.* 2009a; Andrade-Montemayor *et al*. 2011) and sheep (Gebremariam *et al*. 2006; Bispo *et al*. 2007), decreases their water intake. However, as the sole food, cactus results in low milk production, reduced fat amount, and the development of metabolic disturbances, mainly diarrhea, due to its low physically effective fiber content (Beltrão-Filho, 2008).

Studies on the lipid composition of cactus and its fruit have shown 0.70 $mg.mg^{-1}$ linoleic and linolenic acids (Vasta *et al*. 2008), 32.83 g/g^{-1} of total fatty acids (Abidi *et al*. 2009), and

67.7% of the total fatty acids as C18:2-n6 and C18:3-n3 in cladodes cactus. The fruit contain a respective 8.6 and 0.69%, γ- and α-linolenic acid of the total lipids present, and are major contributors to the neutral lipids and sterols. No exact ratio that should be consumed for optimal health has yet been established, studies demonstrate that a balance in the ratio of these fatty acids in the diet, is effective for the treatment of several diseases, such as cancer, cardiovascular disease, hypertriglyceridemia and rheumatoid arthritis (Garófolo and Petrilli, 2006; Simopoulos, 2008). The fatty acids composition of cactus pear (Table 1) as mentioned before, is rich in linoleic acid (C18:2), Liolenic acid (C18:3), this fatty acids has been accepted as precursor of arachidonic acid, and having hypocholesterolemic effect, and inhibitory properties against colon cancer (El-Mostafa et al. 2014).

Meat quality

The concept of meat quality is very difficult to define because it is a subjective term whose interpretation is implicitly affected by attributes important to the consumer (color, texture, succulence and taste). These attributes may vary among consumers, depending on their cultural and personal experience. Nonetheless, there are other parameters that are important for producers and sellers (Berian *et al*. 2000; Warris, 2000), chiefly the carcass yield and composition, which are generally evaluated in yield cuts and muscle, bone and fat proportions and determine how much of the product can be sold. Higher yields mean more product and potentially a higher profit.

Meat quality can be also evaluated from the physical and sensory perspective (color, water retention, palatability), being more imperative criteria for the consumer, who will finally judge whether the product is acceptable or not. Non-sensory attributes have also become increasingly important to consumers. Meat products should be free of dangerous diseases and chemicals, and offer elevated levels of proteins and fatty acids, such as EPA and DHA (Warris, 2000).

Physical characteristics of meat quality

The pH of meat is one of the main factors in the transformation of muscle to meat, with a decisive effect on the quality of fresh meat and its derived products. The final pH may vary, depending on the handling and pre-slaughter diet of the animals and other factors associated with the animal, such as age, temperament, species and gender. Studies with cactus pear have shown that the use of cactus had not influence on the pH of goat and sheep meat (Abidi *et al*. 2009; Mendoça Junior, 2009; Costa *et al*. 2012a).

The process of cooking the meat, including the time and type of heat transference, can alter the chemical composition and nutritional value of meat products, particularly, modifying the protein, fat, ash and DM levels, due to the loss of nutrients and water during the procedure. The cooking losses associated with meat yield are characteristics influenced by the water holding capacity (WHC) in meat structures (Monte *et al*. 2012). This capacity provides the sensation of succulence when chewing. A poor WHC results in high drip and purge loss, which can represent considerable losses in carcass yield and cut. Studies carried out with cactus on the feeding of goats (Table 2) and sheep (Table 3) have not observed any influence of the diet on the cooking losses (Abidi *et al*. 2009; Costa *et al*. 2012a).

Table 1. Lipid composition (g 100 g^{-1} of fatty acids) of cactus and other foods.

Fatty acids	Cactus pear (seed)	Cactus pear (fruit pulp)	Cactus pear (cladode)	Cactus pear (young cladode) 15 days	Cactus pear (mature cladode) 2 months	Corn silage[1]	Sugar cane[1]	Alfalfa hay	*Acacia farnesiana*	*Prosopis glandulosa*
Author	Ramadan & Mörsel, 2003	Ramadan & Mörsel, 2003	Abidi *et al.* 2009	Ortega-Pérez *et al.* 2010	Ortega-Pérez *et al.* 2010	Leão *et al.* 2011	Leão *et al.* 2011	Toyes-Vargas *et al.* 2013	Toyes-Vargas *et al.* 2013	Toyes-Vargas *et al.* 2013
C12:0	-	-	1.33	0.21	2.03	0.47	1.5	-	0.62	0.15
C14:0	-	0.89	1.96	0.59	3.49	0.62	1.72	1.80	1.15	0.40
C16:0	18.0	28.9	13.87	17.46	17.3	20.61	36.66	33.61	23.7	11.74
C17:0	-	-	-	0.46	1.21	-	-	0.84	1.16	0.60
C18:0	2.07	2.14	3.33	2.23	2.70	3.96	8.08	7.36	11.05	5.86
C16:1	2.01	1.92	0.24	0.14	0.16	4.18	-	4.63	1.01	1.33
C18:1-n9	19.3	10.2	-	7.70	5.93	27.52	24.24	4.55	6.16	1.81
C18:2-n6	56.1	45.9	34.87	26.53	16.32	38.89	19.07	17.70	19.03	8.45
C18:3-n3	2.52	9.60	32.83	36.30	38.62	7.93	4.55	30.74	21.32	24.44

[1]% fatty acids in natural matter.

The Warner–Bratzler shear force (SF) is a method used to evaluate the softness of meat, which is defined as the ease with which the meat can be chewed. Several factors may influence the SF, for example, pre-slaughter management, the speed of *rigor mortis*, *post-mortem* pH, pre-slaughter temperature, glucose concentration in the muscle, the muscle used to determine the SF and method used to measure SF, among others (Monte *et al*. 2012). Studies have shown that for goat meat an SF of 7.42 kg.cm^{-2} is necessary (Sen *et al*. 2004, Santos *et al*. 2008), whereas 3.74 kg.cm^{-2} is considered necessary for sheep meat (Freire *et al*. 2010; Costa *et al*. 2012a). This difference is probably due to the higher amount of fat present in sheep meat than in goat meat. As observed in Table 2 and 3 the use of cactus in diets had no effect on meat WHC, cook loos, SF, moisture, fat and protein contents of goats and sheep

Chemical meat quality

The meat protein of sheep and goat is similar to beef meat. It has all the essential amino acids. Goat and sheep meat have around 20–25% protein, and in most instances, this amount is not influenced by the diet as showed in 2 and 3 , where little differences can be observed between both goats and sheeps feed with cactus or other feeds (Sen *et al*. 2004; Atti *et al*. 2006; Abidi *et al*. 2009; Mendoça Junior, 2009).

The meat quality is related to the proper fat distribution, called intramuscular and inter-extracellular fat, according to its location. The fat distribution influences the texture, succulence and flavor of the meat. In general, the fat distribution in young animals is barely traced, leaving a meat with softer texture and aroma than the meat of older animals, becoming more attractive to consumers (Monte *et al*. 2012).

The chemical characteristics of fat (fat profile) can be modified by factors such as age, gender, type of diet, live weight at slaughter, the location of fat, species and breed (Pérez *et al*. 2002; Bonagurio *et al*. 2004; Cruz *et al*. 2011). The influence of the type of feed on the fat accumulation is presented in Tables 2 and 3.The data shows that the meat of goats and sheep fed with cactus, has low fat, the total yield of fat, and subcutaneous and intramuscular fat (Santos *et al*. 2011; Costa *et al*. 2012b, Mahouachi *et al*. 2012).

Fatty acids of meat

Differences in lipid composition in the meat of small ruminants are related to the type of diet (Tables 4 and 5). In general, large amounts of saturated fatty acids are found in meat. When animals are fed with forages, the saturated fatty acids tend to increase, considering that the fiber stimulates the ruminal activity and with this the biohydrogenation. Nevertheless, the meat has higher amounts of polyunsaturated fatty acids and less fat deposition in the meat and depending on the type of forage, may contain higher linoleic acid (omega-3 precursor) levels (Costa *et al*. 2008; Leão *et al*. 2011). Animals fed diets based on concentrate (rapidly degradable carbohydrates) present higher amounts of unsaturated fatty acids due to their short duration in the rumen and, therefore, have less time to act in the biohydrogenation process (Costa *et al*. 2008; Costa *et al*. 2012b). Jambrenghi *et al*. (2007) did not observe any difference in the conjugated linoleic acid (CLA) content of goat meat for animals fed grass or concentrate. This was attributed to a year when the grass quality was low. An example of these modifications was observed by Santos *et al*. (2008) in young goat and sheep, observing that goat carcasses presented higher muscle mass and lower fat percentage.

In goat and sheep meat, the palmitic (C16:0) and stearic (C18:0) fatty acids contribute strongly to the total saturated fatty acids (Atti *et al*. 2006; Madruga *et al*. 2006; Arruda *et al*. 2012). Madruga *et al*. (2006) evaluated the effects of gender and breed on meat quality and observed that gender did not influence the saturated, monounsaturated and polyunsaturated fatty acid concentrations. In contrast, the breed had a significant influence on the monounsaturated and polyunsaturated fatty acid concentrations. In Santa Inês sheep, Cruz *et al*. (2011) noted an increase in total lipids and fatty acids of 10%, mainly in linolenic acids (C18:2) and CLA, when compared to the castrated animals.

The fatty acid composition of the diet has a great influence on the fatty acids in meat. Unsaturated fatty acids in food are biohydrogenated in the rumen, whereas long chain fatty acids (polyunsaturated, omega-3) are less likely to be biohydrogenated, allowing them to be absorbed unmodified or as omega-6 and omega-3 precursors, which are deposited in the tissues of the animal (Costa *et al*. 2008). Najafi *et al*. (2012) evaluated the effect of soybean oil, fish oil and palm oil, which are rich in fatty acids (omega-6, omega-3 and saturated fatty acids, respectively), in the Mahabadi breed in semiarid conditions and discovered that animals fed fish oil had higher concentrations of C20:5 omega-3 (EPA) and C22:6 omega-3 (DHA) . Furthermore, the use of these oils resulted in a higher proportion of linolenic acid. Costa *et al*. (2012a) did not find any differences in the fatty acid composition of meat of Santa Inês sheep fed soybean hulls, however, a higher CLA content, with variations ranging from 3–4 $g.kg^{-1}$ were reported

In general, the fatty acid composition of cactus-fed animals shows increases in saturated fatty acids, CLA and polyunsaturated fatty acids. Palmitic (C16:1) and stearic (C18:0) acids are the main contributors to the concentration of saturated fatty acids in meat. Palmitic acid increases blood cholesterol levels, whereas oleic acid (C18:1) decreases it. Consequently, the relation between these fatty acids describes the beneficial effects of the different lipids found in red meat (Madruga *et al*. 2005). These results are attributed to the levels of linoleic and linolenic acid (70 mg.100 mg) present in cactus (Vasta *et al*. 2008). In studies with goats and sheep fed cactus, Abidi *et al*. (2009) revealed an increase in C18:1-trans and a higher percentage of saturated fatty acids and C20:2-n3, C20:4-n6 and C20:5-n3 in goat meat. Sheep meat also showed improvements in its composition, with higher CLA amounts than goat meat. . Costa *et al*. (2017) observed that using spineless cactus in sheep, the lipid profile increased the monounsaturated and polyunsaturated fatty acids when fed spineless cactus.

Sensorial quality

The sensorial analysis of meat is an important tool for the sensorial evaluation, and it serves as a quality control of the product, attending to the consumer exigencies relative to the attributes perceived by the senses. The principal characteristics evaluated are the appearance, constituted by color, brightness, size and shape. These characteristics are intrinsically linked to the synesthetic attributes, such as consistency and viscosity, as

Table 2. Physical and centesimal composition of goat meat.

Author/Muscle	**Feed**	**Breed**	**pH**	**WHC**	**Cook loos (%)**	**Shear force value (kg cm^{-2})**	**Moisture (%)**	**Fat (%)**	**Protein (%)**
Sen *et al*. 2004.	Zyzyphusnumulária + concentrate	-	5.9	57.0	22.6	7.4	74.2	3.1	20.4
Atti *et al*. 2006. *Longissimus dorsi*	Cactus pear + Oat hay	-	6.2		16.7	-	74.9	2.76	20.75
Atti *et al*. 2006. *Longissimus dorsi*	Cactus pear + Soya bean	-	6.2		14.1	-	74.4	2.35	21.73
Santos *et al*. 2008.	*Lolium perenne*	Portuguesa	5.8		11.1	7.7	76.4	1.0	-
Najafi *et al*. 2012. *Longissimus lumborum*	Palm oil	Mahabdi	5.7		27.1	4.3	74.8	3.1	20.8
Najafi *et al*. 2012. *Longissimus lumborum*	Soybean oil	Mahabdi	5.8		26.3	4.3	73.6	3.3	19.6
Najafi *et al*. 2012. *Longissimus lumborum*	Fish oil	Mahabdi	5.7		27.2	4.6	74.1	3.2	20.7

Table 3. Physical and centesimal composition of sheep meat.

Author	Feed	Breed	pH	WHC	Cook loos (%)	Shear force value (kg cm^{-2})	Moisture (%)	Fat (%)	Protein (%)
Sen *et al*. 2004	Zyzyphusnumulária+ concentrate	-	5.93	59.5	20.74	3.74	68.85	8.4	21.0
Santos *et al*. 2008	*Lolium perenne*	Portuguese	5.6		14.3	9.0	75.7	2.1	
Abidi *et al*. 2009	Cactus pear + oat hay	-	5.8	_	16.6	_	_	_	_
Mendoça Junior-2009	Cactus pear +Tifton hay	Santa Inês	5.7	_	32.71	3.58	74.19	1.8	25.34
Mendoça Junior-2009	Cactus pear + soybean hull	Santa Inês	5.6	_	33.49	3.42	73.93	2.2	24.55
Mendoça Junior-2009	Cactus pear + cotton seed	Santa Inês	5.6	_	32.97	3.37	74.02	2.6	24.89
Freire *et al*. 2010	-	Texel/S.Inês		_		3.3	74.6	3.5	22.0
Freire *et al*. 2010	-	Dorper/ S.Inês		_	_	2.3	75.8	3.0	20.5
Aguilar, 2010	Cactus pear dehydrated	Creole	5.8	30.5	_	_	75.93	5.1	20.01
Aguilar, 2010.	Cactus pear	Creole	5.8	32.1	_	_	76.58	5.3	18.7
Costa *et al*. 2012a.	Corn	Santa Inês	5.6	-	27.70	2.54	75.49	2.8	20.7
Costa *et al*. 2012ª	Cactus pear	Santa Inês	5.6	-	29.19	2.85	75.83	2.28	21.0

Table 4. Fatty acid composition of goat meat (%).

Author	Feed	16:0	16:1	18:0	18:1	18:2 n-6	18:3 n-3	CLA Cis-9, Trans-11	20:4	EPA 20:5 n-3	DPA 22:5 n-3	SFA	MUFA	PUFA	PUFA /SFA	MUFA /SFA	PUFA/ MUFA	n6: n3
Mahouachi, *et al*. 2012	Oat hay + concentrate	18.8	2.7	14.0	54.7	2.2	0.15	0,15	8.1	0.3	0.17	36.6	58.8	37.2	0.1	1.6	0.06	11.5
Mahouachi, *et al*. 2012	Cactus pear	19.6	2.3	17.5	50.4	2.3	0.18	0,22	10.2	0.9	1.7	40.0	53.9	44.4	0.1	1.34	0.08	0.9
Qwele *et al*. 2013	Hay	23.6	1.6	5.2	9.2	23.4	18.5	0.15	5.4	3.1	3.2	47.9	36.6	18.9	0.4	0.8	0.52	1.5
Qwele *et al*. 2013	*Moringa oleífera*	8.93	1.8	3.7	63.4	11.8	2.64	0.12	3.5	2.7	2.2	44.4	44.7	13.4	0.3	1.13	0.3	1.5
Abidi *et a*l. 2009	Cactus pear	17.8	1.0	10.9	28.4	11.9	1.02	0.59	14.3	3.2	3.7	32.0	312	36.7	1.1	0.82	0.96	8.5
Abidi *et al*. 2009	Barley	17.9	0.9	11.0	29.1	10.8	0.8	0.54	15.8	2.7	3.5	32.0	31.7	36.2	1.1	0.99	1.14	1.4
Atti *et al*. 2006	Cactus pear + oat hay	23.6	1.9	17.7	46.9	-	0.20	0.22	-	-	-	44.4	52.6	3.2	0.07	1.19	0.06	-
Atti *et al*. 2006	Cactus pear + soybean hull	23.2	1.5	19.7	44.7	-	0.20	0.32	-	-	-	43.4	51.6	4.5	0.10	1.12	0.08	-

SFA: Saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids.

Table 5. Fatty acid composition of sheep meat (%).

Author	Feed	16:0	16:1	18:0	18:1	18:2 n-6	18:3 n-3	CLA Cis-9, Trans-11	20:4	EPA 20:5 n-3	DPA 22:5 n-3	SFA	MUFA	PUFA	PUFA /SFA	MUFA/ SFA	PUFA/ MUFA
Abidi *et al*. 2009	Cactus pear	20.3	0.9	13.0	29.6	13.4	2.03	0.91	7.84	1.63	62	37.7	32.1	30.8	0.81	0.85	0.95
Abidi *et al*. 2009	Barley	19.2	0.8	11.6	25.1	15.7	2.19	0.82	8.82	2.52	3.38	34.6	30.1	35.2	1.01	0.87	1.168
Arruda *et al*. 2012	Tifton hay + corn meal + soybean bran	22.7	1.3	19.9	39.2	3.5	-	-	-	-	-	45.4	41.2	6.2	0.13	0.90	0.15
Costa *et al*. 2012b	Soybean hull	25.1	2.9	17.9	-	-	0.39	0.4	-	-	-	48.3	46.8	4.9	0.10	0.96	0.10
Mattos, 2009	Cactus pear 50 % + *Atriplex numulária*	26.2	1.9	15.2	45.5	0.02	0.02	-	-	-	-	44.3	51.5	4.1	0.09	1.16	0.08
Perez *et al*. 2002	-	23.1	2.4	14.7	40.7	4.5	0.28	-	1.77	-	0.32	40.2	42.9	7.07	0.17	1.06	1.41
Perez *et al*. 2002	-	23.1	2.4	14.5	43.3	5.0	0.28	-	1.70	-	0.35	40.0	45.6	7.6	0.18	1.12	0.16
Cruz *et al*. 2011	Green fodder	24.0	1.8	23.0	24.4	-	0.61	1.05	-	0.24	0.07	57.4	34.9	4.1	0.07	0.60	0.12
Madruga *et al*. 2006	hay, corn, soybean	20.6	1.5	16.0	32.0	10.7	0.99	-	-	-	-	44.4	43.1	12.3	0.28	0.97	0.28
Aguilar, 2010	Cactus pear	22.9	1.8	15.1	46.4	-	0.15	0.38	2.57	0.17		41.1	50.2	6.2	015	1.22	0.12
Leão *et al*. 2011	Sugar cane	25.9	2.0	16.8	37.9	3.6	0.25	-	4.17	-	-	50.86	39.9	9.1	0.18	0.77	0.22

SFA: Saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids.

Table 6. Sensory acceptance of sheep and goat meat on a scale from 1 (bad) to 9 (excellent).

Specie	Author	Feed	Breed	Color	Odor	Tenderness	Juiciness	Palatability
Caprine[1]	Sen *et al*. 2004	Zyzyphus numulária + concentrate	-	4.5	4.0	3.37	3.87	3.87
Caprine[2]	Najafi *et al*. 2012	Palm oil	Mahabdi	-	5.6	4.9	5.6	5.7
Caprine	Najafi *et al*. 2012.	Soybean oil	Mahabdi	-	5.9	5.1	5.4	5.3
Caprine	Najafi *et al*. 2012.	Fish oil	Mahabdi	-	5.9	4.7	5.2	5.0
Ovine	Sen *et al*. 2004.	Zyzyphus numulária + concentrate		3.8	3.8	4.5	3.87	3.75
Ovine	Mendoça Junior, 2009	Cactus pear +Tifton hay	Santa Inês	3.6	4.0	3.5	3.94	3.90
Ovine	Mendoça Junior, 2009	Cactus + Soybean hull	Santa Inês	3.9	4.2	2.8	4.07	4.12
Ovine	Mendoça Junior, 2009	Cactus + Cotton seed	Santa Inês	3.9	4.0	3.0	4.12	4.12
Ovine	Freire *et al*. 2010	-	Texel/S.Inês	-	5.5	6.7	6.74	6.02
Ovine	Freire *et al*. 2010	-	Dorper/S.Inês	-	52	6.1	6.22	5.45
Ovine	Freire *et al*. 2010	-	S. Inês 30kg	-	5.9	6.7	6.71	6.50
Ovine	Freire *et al*. 2010	-	S. Inês 45kg	-	6.3	6.8	6.96	6.99
Ovine	Costa *et al*. 2012a	Corn	Santa Inês	-	-	3.3	5.14	4.03
Ovine	Costa *et al*. 2012a	Cactus pear	Santa Inês	-	-	3.3	4.93	4.22

consequences of oral perception, which also interact with the smell and taste in the constitution of the taste (Queiroz and Treptow, 2001). As observed in Table 6, the goat meat has no studies about the sensory acceptance when fed cactus and the most studied was the sheep meat. In terms of acceptance on a scale from 1 (bad) to 9 (excellent), the goat and sheep meat are considered in the middle of the scale and the kind of feed has no influence in these characteristics.

Goat milk

More than any other productive animal, goats are the main suppliers of meat and milk for the rural population. The main demand for goat milk is for its consumption, and interest in its derivates (cheese and yoghurt) are also popular in developed countries where it is sold at high prices. It also offers an alternative for particular allergies and other gastrointestinal conditions associated with bovine milk. Goat milk is less allergenic and has more digestible protein than bovine milk and a higher content of essential amino acids, such as threonine, isoleucine, lysine, cystine, tyrosine and valine (Kumar *et al*. 2012.)

Literature studies evaluating goat milk production (Table 7) have mentioned that there is no influence of the diet on the milk production ($kg.d^{-1}$). This is because the diets are calculated to reach the nutritional requirements for the production (Araújo *et al*. 2009). As a food rich in energy, cactus is used in association with a range of fodder sources, and several studies, mainly with cows, have shown that cactus has no influence on dairy production (Araújo *et al*. 2004; Silva *et al*. 2007).

Several studies have confirmed the lack of influence of cactus in the diet of goats on the milk composition (Table 8). According to Costa *et al*. (2010), the chemical composition of milk was not affected in goats fed cactus as a substitute for ground corn. The amounts of protein, lactose, DM, ash, density and acidity were not affected by the substitution levels. However, the fat was reduced 22% when substitution of ground corn was 100% (276 g cactus kg^{-1} of DM experimental diet). Increases in lactose amounts and an average reduction of 11.5% in the fat amount were observed in the milk of goats fed diets with 46% cactus (Oliveira, 2014). In this instance, the changes may be associated with the amounts of lipids and fiber in the diet (Morand-Fehr *et al*. 2007) and an increase in propionate production in the rumen (Neiva *et al*. 2006).

Fatty acids in milk

Milk fat is formed from glucose, acetate and β-hydroxybutyrate, although some dietary or metabolic and intestinal fatty acids can also be incorporated into the mammary gland from the bloodstream. Approximately 25% of the milk fatty acids are derived from the diet, and the other 50% originate from the blood plasma. The remaining 25% are made in the mammary gland from precursors, such as acetate (Peres, 2001; Chilliard and Ferlay, 2004). Modifications of fatty acids through the diet are influenced by the quantity and quality of fiber and lipids. Foods rich in non-structural carbohydrates as small fiber particles, generally increase the propionate production, decreasing, in proportion, the acetate and butyrate formation.

Lipid supplementation for lactating animals is used as an energy resource to meet the nutritional requirements at the beginning of lactation and as a strategy to modify the milk lipid composition (Costa *et al*. 2009b). Goats supplemented with vegetable oils have shown

Table 7. Production and centesimal composition of goat milk according to various food sources.

Author	Food	Food inclusion (%)	Milk yield (kg d^{-1})	Fat (%)	Protein (%)	Lactose (%)	Solid total (%)	Solid-not-fat (%)	Ash (%)
Araújo *et al*. 2009	*Manihot glaziovii* /ground corn, soybean, wheat	30	1.4	4.11	3.62	4.50	13.03	8.92	-
Araújo *et al*. 2009	*Manihot glaziovii* /ground corn, soybean, wheat	50	1.33	3.98	3.69	4.47	12.94	8.96	-
Fernandes *et al*. 2008	Corn-soybean/ *Pennisetum purpureum*	15/60	1.09	3.89	3.23	4.20	12.71	-	0.69
Fernandes *et al*. 2008	Corn-soybean / Pennisetum purpureum + Cotton seed oil	3	1,03	4.72	3.28	4.24	13.16	-	0.71
Fernandes *et al*. 2008	Corn-soybean / Pennisetum purpureum + sunflower oil	5	1.00	4.16	3.34	4.33	13.05	-	0.70
Ollier *et al*. 2009	Alfalfa hay/ concentrate	60/40	4.26	3.27	3.19	4.57	-	-	-
Ollier *et al*. 2009	Alfalfa hay/ concentrate	40/60	4.21	3.21	3.22	4.63	-	-	-
Delgado-Pertiñez *et al*. 2013	Shrubs and leaves of trees	*Ad libitum*	1.11	4.90	3.75	4.09	13.55	8.53	-

Table 8. Production and centesimal composition of goat milk from animals supplemented with cactus pear.

Author	Food	Food inclusion (%)	Milk yield (kg d^{-1})	Fat (%)	Protein (%)	Lactose (%)	Solid total (%)	Solid-not-fat (%)	Ash (%)
Costa *et al*. 2009b	Cactus pear/ground corn	0	1.50	3.8	3.11	3.85	11.98	8.04	0.81
Costa *et al*. 2009b	Cactus pear/ground corn	14	1.63	3.7	3.05	3,.61	11.78	8.04	0.81
Costa *et al*. 2009b	Cactus pear/ground corn	28	1.54	2.9	3.06	3.54	11.33	7.79	0.78
Lima, 2014/Oliveira, 2014	Tifton hay/concentrate	0	2.219	3.4	3.84	3.92	11.19	7.5	-
Lima, 2014/Oliveira, 2014	*Opuntia stricta*	46	2.68	2.9	3.82	4.33	10.43	7.52	-
Lima, 2014/Oliveira, 2014	*Nopalea sp*	46	2.574	3.1	3.76	4.08	10.72	7.59	-
Lima, 2014/Oliveira, 2014	*Nopalea cochenillifera*	46	2.692	3.0	3.82	4.17	10.54	7.65	-
Mahouachi *et al*. 2012	Pasture/oat hay/ concentrate	*Ad libitum*	0.500	3.9	2.8	-	-	-	-
Mahouachi *et al*. 2012	Cactus pear /oat hay/ concentrate	*Ad libitum*	0.415	3.7	2.8	-	-	-	-
Atti, *et al*. 2010	Cactus pear /oat hay/ concentrate/ soybean cake	*Ad libitum*	0.423	3.1	2.67	-	-	-	-

Table 9. Fatty acid composition of milk from animals fed cactus pear (%).

Specie	Goat	Goat	Goat	Goat	Cow	Cow
Author	Costa *et al*. 2010	Costa *et al*. 2010	Costa *et al*. 2010	Hilario *et al*. 2010	Oliveira *et al*. 2007	Oliveira *et al*. 2007
Food	Cactus/ corn	Cactus/ corn	Cactus/ Corn	Shrub/ cactus	Cactus/ corn	Cactus/ Corn
Cactus inclusion (%)	0	14	28		0	51
C10:00	7.95	8.34	10.87	6.4	1.98	1.99
C11:00	0.04	0.03	0.18	0.04	-	-
C12:00	3.15	3.43	5.25	2.7	3.3	3.26
C13:00	0.05	0.11	0.18	0.07	-	-
C14:00	8.56	9.35	11.16	9.2	14.0	13.46
C14:1	0.07	0.08	0.16	-		-
C15:00	0.61	0.72	1.49	1.2		-
C 16:0	22.66	24.48	31.93	30.1	40.14	53.54
C16:1	0.52	0.42	0.55	1.7	2.06	3.41
C18:0	15.33	13.72	5.37	9.7	13.65	6.25
C18:1 cis 9	25.43	22.92	14.74	23.0	19.59	15.08
C18:2 n-6	2.03	2.34	2.13	2.4	1.5	2.11
C18:3n-3	0.49	0.53	0.14	0.9	-	-
C18:3n-6	0.08	0.19	0.32	0.02	-	-
C20:4	-	-	-	1.4	-	-
SFA	62.8	64.59	71.93	62.71	73.07	78.5
MUFA	26.73	23.92	16.11	24.7	21.65	18.49
PUFA	2.77	3.29	2.95	4.72	1.5	2.11
PUFA/SFA	0.04	0.05	0.04	0.08	0.02	0.03
MUFA/SFA	0.47	0.42	0.26	0.39	0.30	0.24
PUFA/MUFA	0.1	0.13	0.18	0.19	0.07	0.11
N6: n3	4.01	4.17	9.13	2.69	-	-
DFA	44.8	40.93	24.44	39.12	36.8	26.85

SFA: Saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids; DFA: Desirable fatty acids (unsaturated + C18:00).

increases in the concentration of unsaturated fatty acids (29.25% control diet vs. 38.02% with 3% sunflower oil in the diet, Fernandes *et al*. 2008), oleic (19.1% control vs. 27.4% with lupine seeds), linoleic (2.2% control vs. 3.4% sunflower oil) and CLA (0.56% control vs. 2.28% sunflower oil) (Chilliard and Ferlay, 2004).

Studies with cactus as food for goats have shown improvements in the amounts of CLA and polyunsaturated fatty acids present in the meat (Abidi *et al*. 2009; Nefzaoui *et al*. 2010; Mahouachi *et al*. 2012). Regarding milk production, there are a few studies evaluating the fatty acid composition of goats fed cactus as observed in Table 9. Costa *et al*. (2010) observed that goats fed cactus showed increased saturated fatty acid concentrations in the milk (62.80–71.93%), mainly C10:0 (capric acid), C12:0 (lauric acid) and C14:0 (myristic acid). The use of cactus in ruminant diets has shown a tendency to decrease the monounsaturated fatty acid concentrations, probably due to the low amount of this type of fatty acids present in the cactus (Oliveira *et al*. 2007; Costa *et al.* 2010). The polyunsaturated fatty acids amount in milk was not modified by the use of cactus. Other studies on the lipid profile of milk, however, have shown that in goats fed grass and cactus, modifications in fatty acids cannot be attributed specifically to the cactus inclusion (Hilario *et al*. 2010).

CONCLUSIONS

Animal products of goat and sheep origin have physical, chemical and sensorial attributes of quality that are greatly appreciated by consumers. However, particular care has to be taken in the animal feeding, because the food is a determinant factor in the quantity and type of fatty acids.

The use of cactus pear as an alternative feed source for the production of meat and milk improves the contents of fatty acids considered as healthier (CLA, linoleic and linolenic acids), which allows it to stand out in the markets where the sale of these products is valued.

The inclusion of cactus in diets for small ruminants is a good alternative, as it reduces the feed cost without diminishing the production and quality of meat and milk, facilitating profitable production. In addition to the feed, other factors need to be considered to obtain meat and milk quality, ranging from animal selection (gender, age, breed) to type of production (intensive or extensive), and the rest of the chain productive process.

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