J Food Sci Nutr Res 2019; 2 (1): 049-060 *DOI: 10.26502/jfsnr.2642-1100008*

Research Article

An Insight in Key Volatile Compounds in Goat Milk Based on their Odor Active Values

Rita de Cássia R Egypto Queiroga[1], Maria Terezinha Santos Leite Neta[2], Rafael Donizete Dutra Sandes[2], Narendra Narain[2*], Mércia de Sousa Galvão[1], Marta Suely Madruga[1], Roberto Germano Costa[3]

[1]Universidade Federal da Paraíba, Food Engineering Department, João Pessoa-PB, Brazil

[2]Universidade Federal de Sergipe, Laboratory of Flavor and Chromatographic Analysis, São Cristóvão-SE, Brazil

[3]Universidade Federal da Paraíba, Farming Department, Bananeiras-PB, Brazil

***Corresponding Author:** Narendra Narain, Universidade Federal de Sergipe, Laboratory of Flavor and Chromatographic Analysis, CEP: 49100-000, São Cristóvão-SE, Brazil, E-mail: narendra.narain@gmail.com

Received: 08 March 2019; **Accepted:** 18 March 2019; **Published:** 21 March 2019

Abstract

Goat milk is known to possess an off-flavor generally known as 'goaty flavor', which is not appreciated by consumers. Mostly the short-chain fatty acids are responsible for this undesirable sensory attribute. The objective of the present work was to identify the volatile compounds present in goat milk and to relate their impact on aroma characteristics. Volatile compounds from the milk were obtained by using a simultaneous distillation and extraction technique utilizing Likens and Nickerson's apparatus. Two hundred milliliter of milk was used and extraction was carried out at 55°C for 120 min by using a mixture of pentane-ethyl ether (2:1) solvent. The extracts were concentrated and analyzed for the identification of volatile compounds using a system of high resolution gas chromatograph coupled with mass spectrometer. Better separation was achieved in a non-polar capillary column. A total of 91 volatile compounds were positively identified and these represented mostly the classes of compounds belonging to esters, aldehydes, alcohols, fatty acids, ketones and aromatics. The main compounds and their concentrations were hexanol (9481.92 µg/L), pentanoic acid (3040.08 µg/L), 2-pentanone (1651.03 µg/L), methyl 9-octadecenoate (1613.88 µg/L), methyl hexadecanoate (1060.61 µg/L) and 2-pentanol (1683.28 µg/L), while the compounds with their OAVs of 5 and higher that contribute in goat milk aroma were decanal (88), (*E*)-2-hexenal (72), hexanol (47), octanal (40), ethyl hexanoate (35), pentanal (34), nonanal (30), 2-pentanone (24), heptanal (23), methyl hexanoate (20), γ-dodecalactone (11), 2-heptanone (10), heptanol (9), ethyl octanoate (9), 2-pentadecanone (9), β-ionone (8), α-pinene (5), 2-methylthiophene (5), octadecanal (5).

Keywords: Goat milk; Volatile Compounds; Aldehydes; Alcohols; Esters; Lactones; Carboxylic acids

1. Introduction

The main components of the milk, which contribute to the flavor and other sensory attributes, are proteins and fats. Goat milk has more nutritional qualities that are better for human consumption than cow's milk, such as less lactose levels, more quantity of vitamins and reduced lipids amount. Other characteristic of goat milk is its distinctive aroma and flavor, which are derived from their lipid fraction and it varies widely based on principal factors such as genetic diversity of breed, feeding practices, season of obtaining milk and lactation stage. Goat milk is different from cow's milk due to its "goaty" flavor and aroma classified in off-flavor attributes, which are not quite appreciated by consumers. Scientific knowledge on precursors leading to the formation of characteristic goat milk flavor is limited. Mostly the short-chain (C_6, C_8 and C_{10}) fatty acids are held responsible for this undesirable sensorial attribute [1]. Ha and Lindsay reported the triglyceride composition of goat, sheep and cow milks, attributing the presence of minor branched chain compounds in goat milk, including 4-methyl octanoic acid which has an extremely low odor threshold value. Moreover, the goat milk flavor is the result of the lipolytic action of the milk lipoprotein lipase, which in goat milk is largely bound to the fat [2].

Very few publications are available which deal with identification and quantification of volatile compounds present in goat milk [1, 3, 4, 5] and these relate mostly to the feeding systems and their effect on the composition and flavor quality of goat milk. Fedele et al. [3] reported the presence of β-caryophyllene and α-copaene as dominant terpenes in goat milk. Queiroga et al. [6] detected 174 volatile compounds from goat milk, such as phenols, acids, lactones, ketones, alcohols, esters and terpenes. The presence of terpenic compounds is related to the plant species utilized for the feeding systems. Yang et al. [1] identified the compounds responsible for the "goaty" flavor in goat milk as being short fatty acids (C6:0 to C9:0). Flavor of dairy products is a critical parameter affecting consumer acceptance, shelf life, and other attributes [7, 8]. Since goat milk has gained economic importance and is classified as a functional food, it participates in health maintenance and reduces disease. Of late, there is an increase in goat milk production due to its utilization in cheese making. In the Mediterranean and many eastern European countries, it is important to elucidate the aroma composition to help to avoid the development of products with off-flavor in order to increase its consumption [9-11]. Thus, the objective of the present work was to identify the volatile compounds present in goat milk and to acquire an in depth knowledge on key volatile compounds as related to their odor active values contributing to the milk's overall aroma characteristics.

2. Material and Methods

The goat milk was collected from 20 animals of Saanen breed, which were confined in the Sector of Caprinoculture of Federal University of Paraíba, located in city of Bananeiras. The animals were fed with a feed containing grass Tiffton mixed with a balanced diet.

2.1 Volatiles isolation

The volatile compounds were extracted by using Likens and Nickerson's [12] apparatus, which uses the simultaneous distillation and extraction technique. The extraction conditions were optimized by Queiroga et al. [6]

in which 200 mL of goat milk was diluted with 100 mL of distilled water and extraction was performed with 20 mL of pentane:ether (2:1) for 120 min. The extracts were concentrated to a final volume of 0.3 mL under the flow of nitrogen gas.

2.2 High resolution gas chromatography/mass spectrometry

A combined system of gas chromatograph (Shimadzu GC 17A) coupled with a mass spectrometer (GC/MS-QP5050A) was used. One microliter of the concentrated volatile extract was injected in the column in a splitless mode. Capillary GC investigations were carried out on non-polar capillary column HP-5MS (30 m × 0.25 mm; 0.25 µm). The carrier gas used was helium and column head pressure was maintained at 11.5 psi having a flow rate of 1 mL/min. The oven temperature was programmed: initiation at 30°C for 5 min, increased at 5°C/min to 80°C, maintained at 80°C for 30 min, increased at 5°C/min to 220°C, wherein maintained for 45 min. The temperatures of the injection port and the GC/MS interface were 200°C and 230°C, respectively. The mass spectrometer was operated in the electron ionization mode with an electrical energy of 70 eV and an ion source temperature of 250°C. The mass spectrum was scanned between 30 and 350 atomic mass units at 0.1 sec interval. The identification of compounds was done by using the linear retention index (LRI) values, determined on retention time data obtained by analyzing a series of normal alkanes (C_8-C_{21}). Volatile components were positively identified by matching their LRI values and mass spectra with those of standards, also run under identical chromatographic conditions in the laboratory.

2.3 Quantification of volatile compounds

The volatile compounds were quantified using the analytical curves prepared from the results obtained on chromatographic analysis of aroma compound standards of different classes of organic compounds such as esters, alcohols, ketones, aldehydes and terpenes, also performed under identical analytical conditions as that of the samples.

2.4 Statistical analysis

All chromatographic data were analyzed in triplicate and the results were expressed as mean ± standard deviation values.

3. Results and Discussion

3.1 Volatile profiles of goat milk

Table 1 lists the volatile compounds identified in goat milk. The data cites the retention indices and the concentration of the identified compounds, which are organized according to their organic classes. It was observed that some compounds have the superscript letter [a], which signifies that the compound was tentatively identified since there was no pure standard compound available, which could be run under the identical analytical conditions. Thus the identification was considered tentative when it was based mainly on matching an unknown mass spectrum with a spectrum available of NIST (National Institute of Standards and Technology, USA) mass spectral data system or the

literature [13, 14]. In a typical chromatogram analyzed for the volatile extracts obtained from goat milk, a total number of 91 components were separated out of which, 63 compounds were positively and 28 tentatively identified. The other constituents could not be identified. Among the identified components in the goat milk of Saanen breed, the largest number of compounds belonged to esters, being 29 compounds, followed by alcohols (13), aldehydes (12), terpenes (11), carboxylic acids (8), ketones (6), lactones (5), aromatics (5) and sulfur compounds (2).

Others authors like Sant'Ana et al. [16], Queiroga et al. [6] and Siefarth and Buettner reported the presence of 19, 174 and 54 compounds, respectively. The main compounds identified in this study, such as hexanol (9481.92 µg/L), pentanoic acid (3040.08 µg/L), 2-pentanone (1651.03 µg/L) were previously reported by these authors. However, in this paper we are reporting the presence of the following compounds in goat milk: Esters (isobutyl acetate, isopropyl butanoate, ethyl tridecanoate, butyl 10-undecenoate, isoamyl cinnamate, benzyl benzoate, butyl dodecanoate, isopropyl tetradecanoate, methyl (Z)-9-hexadecenoate, octadecanol acetate, butyl heptadecanoate), alcohols (2-methyl-1-hexanol, tridecanol, 1,2-dodecanediol, pentadecanol), terpenes (cumene, camphor, β-ionone, β-farnesene, cubenol, α-cadinol, farnesol), ketone (2,3-hexanedione), sulfur compounds (butanethiol, 2-methylthiophene). The prominent sulfur compound found in milk is dimethyl trisulfide that has been reported previously as a flavor compound in both yogurt and cow's milk [15]. However, in this work on goat's milk, the presence of 2-methylthiophene (23.46 µg/L) was detected and its presence was reported by Bendall [15] in cow milk and products like yogurt.

The volatile compounds identified which were in higher concentrations in goat milk were hexanol (9481.92 µg/L), pentanoic acid (3040.08 µg/L), 2-pentanone (1651.03 µg/L), methyl 9-octadecenoate (1613.88 µg/L), methyl hexadecanoate (1060.61 µg/L) and 2-pentanol (1683.28 µg/L). Fedele et al. [3] reported the dominant presence of terpenes such as β-caryophyllene and α-copaene. However in this work on goat's milk, these compounds were not found, although other terpenic compounds such as β-farnesene (80.16 µg/L), α-terpinene (31.28 µg/L), β-ionone (26.39 µg/L), δ-cadinene (23.46 µg/L), α-cadinol (20.53 µg/L) and α-pinene (12.71 µg/L) were found. The presence of terpenes in milk are related to the animal diet, since such compounds can pass from the plants to the milk and can be used as biomarkers in a feeding animal system (Sant'Ana et al., 2019). The goat milk from the breed Saanen grown in the Northeast region of Brazil had more presence of terpenes, which is related to animals feeding with a forage support of Tiffton hay.

Compounds	**$LRI_{exp.}$**	**$LRI_{lit.}$**	**Concentration in milk (µg/L)**	**Odor notes**
Carboxylic acids				
3-methylbutanoic acid	860	875	50.83 ± 10.24	cheesy, dairy
pentanoic acid	897	900	3040.08 ± 612.15	cheesy, milky
heptanoic acid	1088	1085	591.40 ± 80.11	cheesy, waxy
octanoic acid	1198	1197	493.65 ± 76.09	fatty, rancid
dodecanoic acid	1526	1529	11.73 ± 2.00	fatty, coconut

pentadecanoic acid	1827	1842	145.65 ± 23.51	-
heptadecanoic acid	2058	2059	212.12 ± 12.72	-
octadecanoic acid[a]	2168	2164	139.78 ± 33.44	odorless, mild fatty
Esters				
butyl acetate	816	816	2.219 ± 0.17	fruity, banana
isobutyl acetate[a*]	823	782	171.07 ± 14.29	fruity, sweet, banana
isopropyl butanoate*	827	820	66.47 ± 5.78	fruity, pineapple
methyl hexanoate	911	911	201.37 ± 21.36	fruity, sweet
ethyl hexanoate	1000	1000	30.30 ± 2.99	fruity, sweet
butyl butanoate	1003	1002	91.89 ± 17.18	fruity, banana
ethyl octanoate	1193	1201	43.99 ± 9.35	fruity, waxy, sweet
methyl nonanoate	1266	1227	20.53 ± 2.97	fruity, sweet, pear
ethyl nonanoate	1297	1296	11.73 ± 1.62	fruity, sweet, waxy
ethyl tridecanoate*	1698	1695	66.47 ± 8.03	-
butyl 10-undecenoate[a]*	1663	1660	4.89 ± 0.51	fatty, buttery
methyl tetradecanoate	1721	1722	160.31 ± 21.21	fatty, balsamic
isoamyl cinnamate*	1732	1719	4.89 ± 0.82	floral, cocoa
benzyl benzoate*	1744	1757	110.46 ± 25.88	sweet balsamic oily
butyl dodecanoate*	1771	1772	99.71 ± 16.07	-
isopropyl tetradecanoate*	1797	1813	32.26 ± 2.18	-
ethyl tetradecanoate	1801	1803	274.68 ± 54.07	waxy, sweet
methyl (*Z*)-9-hexadecenoate[a]*	1891	1890	107.53 ± 34.62	-
methyl hexadecanoate	1925	1925	1060.61 ± 81.62	waxy, fatty, oily
butyl tetradecanoate	1979	1977	138.81 ± 20.73	oily, fatty
methyl heptadecanoate	2024	2028	311.83 ± 15.45	-
butyl pentadecanoate	2079	2080	409.58 ± 69.36	-
methyl 9-octadecenoate[a]	2098	2087	1613.88 ± 173.04	-
methyl octadecanoate	2122	2123	745.85 ± 53.85	oily, waxy
ethyl 9-octadecenoate	2158		907.14 ± 89.01	-
butyl hexadecanoate	2181	2174	186.71 ± 13.77	-
ethyl octadecanoate	2197	2197	443.79 ± 79.42	waxy
octadecanol acetate[a]*	2216	2209	115.35 ± 10.39	-
butyl heptadecanoate*	2285	2269	86.00 ± 27.01	-
Alcohols				
2-methyl-1-propanol[a]	643	647	7.82 ± 1.34	etheral, winey

butanol	656	655	575.76 ± 36.11	fermented, sweet
2-pentanol	700	700	1683.28 ± 242.48	fermented, sweet
hexanol	861	863	9481.92 ± 802.13	herbal, alcoholic
2-methyl-1-hexanol[a]*	886	886	24.44 ± 2.56	-
heptanol	931	946	28.35 ± 1.78	green, herbal
benzyl alcohol	1082	1082	86.00 ± 23.18	green, rose
tridecanol[a]*	1599	1586	79.18 ± 25.39	musty
1,2-dodecanediol[a]*	1753		52.79 ± 13.63	-
pentadecanol*	1786	1789	151.52 ± 32.2	-
hexadecanol	1844	1841	553.27 ± 75.03	waxy, floral
heptadecanol	1986	1982	267.84 ± 49.12	-
octadecanol	2089	2089	543.50 ± 67.42	-
Aldehydes				
pentanal	695	698	402.74 ± 54.15	fermented, fruity
hexanal	797	798	2.93 ± 0.73	green, fresh
(*E*)-2-hexenal	859	856	1231.67 ± 156.45	green, banana
heptanal	888	882	69.40 ± 6.90	green, fresh, fatty
octanal	987	983	56.70 ± 8.83	waxy, citrus
nonanal	1100	1103	30.30 ± 4.61	waxy, rose
decanal	1201	1202	8.80 ± 1.78	sweet, waxy
pentadecanal	1704	1701	37.15 ± 2.00	fresh, waxy
hexadecanal	1813	1815	85.04 ± 16.47	cardboard
heptadecanal	1908	1903	61.58 ± 9.01	-
9-octadecenal[a]	2004	1999	529.81 ± 35.35	fatty
octadecanal	2031	2024	409.56 ± 80.93	oily
Terpenes				
cumene[a]*	920	920	4.89 ± 1.09	-
α-pinene	933	931	12.71 ± 1.21	herbal
α-terpinene	1016	1017	31.28 ± 5.66	-
camphor[a]*	1141	1146	9.78 ± 3.17	campherous
β-ionone*	1450	1462	26.39 ± 6.12	floral, sweet
β-farnesene[a]*	1464	1462	80.16 ± 9.59	
γ-cadinene[a]	1543	1543	4.89 ± 0.43	
δ-cadinene[a]	1552	1522	23.46 ± 5.27	
cubenol*	1647	1642	4.03 ± 0.78	spicy, green, herbal

α-cadinol[a]*	1674	1676	20.53 ± 4.82	
farnesol*	1712	1710	9.77 ± 1.89	
Lactones				
δ-undecalactone[a]	1572	1579	156.40 ± 28.33	
γ-dodecalactone[a]	1657	1655	4.89 ± 1.02	lactone; fruity
δ-dodecalactone	1686	1677	20.53 ± 2.14	sweet, fruity
γ-hexadecalactone[a]	2147		61.58 ± 11.78	
δ-hexadecalactone[a]	2165	2154	254.15 ± 40.37	lactone; smooky
Ketones				
2-pentanone	682	684	1651.03 ± 309.21	fruity, sweet
2,3-hexanedione[a]*	794	781	24.44 ± 1.29	buttery, caramelic
2-heptanone	880	882	9.77 ± 0.11	cheesy, spicy, fruit
2-pentadecanone	1709	1702	61.58 ± 13.27	floral, jasmin, fatty
2-hexadecanone	1809	1809	123.17 ± 35.00	fruity
benzophenone[a]	1594	1590	9.78 ± 2.09	
Aromatics				
toluene[a]	760	760	120.23 ± 12.71	sweet
ethylbenzene[a]	857	857	78.20 ± 10.13	-
m-ethyltoluene[a]	956	957	9.78 ± 2.54	-
p-ethyltoluene[a]	963	963	1.96 ± 0.02	-
phenol[a]	979	979	1.95 ± 0.91	phenolic
Compostos Sulfurados				
butanethiol*	710	713	14.66 ± 3.15	sulfurous, roasted
2-methylthiophene*	775	773	23.46 ± 5.30	milk, cooked vegetables

LRI_{Exp}-Linear retention index experimental; LRI_{Lit}-Linear retention index literature; [a]-Tentatively identified compounds; *-Compounds reported for the first time in this work on goat milk aroma

Table 1: Volatile compounds identified in goat milk along with their characteristic odor notes.

There are various chemical and biochemical routes for generation of aroma compounds. The free fatty acids are formed due to the enzymatic processes involving lipase action which hydrolyzes and produces short chain fatty acids. A series of 2-ketones such as 2-pentanone, 2-pentadecanone, 2-heptanone and 2-hexadecanone have been found in fresh milk, which are produced from β-ketoacid glycerides by hydrolytic and decarboxylation mechanism. In this study a very high concentration of 2-pentanone (1651.03 µg/L) was found in milk. The oxidative flavor of milk fat is originated, primarily from linoleic and linolenic acids and gets substantiated by other polyunsaturated fatty acids. Twelve aldehydes (pentanal, hexanal , (*E*)-2-hexenal, heptanal, octanal, nonanal, decanal, pentadecanal, hexadecanal, heptadecanal and 9-octadecenal) were detected in goat milk. The main aldehyde concentration was that

of (*E*)-2-hexenal (1231,67 µg/L). However, Sant'Ana et al. [16] could not find any aldehyde when analyzing goat milk volatiles. In general, aldehydes are formed by oxidative processes involving microorganisms and enzymes like lipoxygenase [17].

3.2 Key volatile aroma compounds in goat milk

Table 2 lists the key volatile compounds which had odor activity values (OAV) higher than 1 and hence considered to contribute to the overall aroma in the goat milk matrix. The volatile compounds hexanol and (*E*)-2-hexenal are known to be associated with the formation of rancid odor while 2-pentanone contributes to a strong fatty odor. Methyl 9-octadecenoate and isopropyl tetradecanoate are known to be the principal compounds responsible for the odor of goat milk. According to OAV's the most important compounds contributing to goat milk aroma were decanal (88), (*E*)-2-hexenal (72), hexanol (47), octanal (40), ethyl hexanoate (35), pentanal (34), nonanal (30), 2-pentanone (24), heptanal (23), methyl hexanoate (20), γ-dodecalactone (11), 2-heptanone (10), heptanol (9), ethyl octanoate (9), 2-pentadecanone (9), β-ionone (8), α-pinene (5), 2-methylthiophene (5), octadecanal (5). In the sensorial analysis of goat milk, Sant'Ana et al. [16] reported the principal odor notes that characterized goat milk were "buttery" and "herbaceous". In this work hexanol, heptanol and α-pinene were detected which have high OAV's and their odor notes are characterized as "herbal". Other compounds with odor notes similar to "buttery" found in this work, and which also possessed a high OAV's were aldehydes like heptanal, decanal, octanal and nonanal that have odor notes classified as "fatty" and "waxy".

Yang et al. [1] reported that "goaty" aroma in goat milk is due to presence of straight-chain fatty acids like C6:0 to C9:0 and some branched-chain C9:0 and C10:0 and that its participation in aroma depend mainly on their concentrations. In this study on aroma profile of goat milk, the compounds which had OAV>1 were octanoic acid (C8:0) (3), pentanoic acid (C5:0) (3), heptanoic acid (C7:0) (1) characterizing with odor notes of "cheesy", "fatty", "rancid" and "milky". In other publications, hexanoic acid (C6:0) is described as having pungent, goaty, sweaty, and blue cheese flavor notes; octanoic acid has waxy, soapy, goaty, musty, rancid, and fruity notes; and decanoic acid (C10:0) is described as soapy, bitter, goaty and rancid notes.

In this study, lactones which could contribute to the characteristic aroma of goat milk were γ-dodecalactone (11), δ-dodecalactone (4), δ-hexadecalactone (1). For goat milk, Sienfart and Buettner [18] reported the presence of γ-octalactone, γ-nonalactone, δ-nonalactone, δ-decalactone, γ-undecalactone and γ-dodecalactone as potent odor participants in goat milk aroma. Bendall, [15] also described these compounds as responsible for fruity and sweet characteristics in cow milk aroma. According to Chilliard [2], the compounds which contribute to milk flavor formation could be classified according to their origin: compounds originated from animal metabolism and/or feed forage, compounds produced by chemical reactions, enzymatic activity or from microbial flora before its processing, compounds generated by thermal treatment or the ones developed during storage. Although interpreting the characteristic aroma of foods is an extremely complex matter, the initial step is to identify the odor-impact compounds and then to evaluate the concentration of the major compounds present in the matrix.

Compounds	**Concentration in milk (µg/L)**	**Odor Threshold (µg/L in Water)**	**OAV**	**Odor notes**
decanal	8.80 ± 1.78	0.1[a]	88	sweet, waxy
(*E*)-2-hexenal	1231.67 ± 156.45	17[a]	72	green, banana
hexanol	9481.92 ± 802.13	200[b]	47	herbal, alcoholic
octanal	56.70 ± 8.83	1.4[b]	40	waxy, citrus
ethyl hexanoate	30.30 ± 2.99	0.87[c]	35	fruity, sweet
pentanal	402.74 ± 54.15	12[a]	34	fermented, fruity
nonanal	30.30 ± 4.61	1[a]	30	waxy, rose
2-pentanone	1651.03 ± 309.21	70[b]	24	fruity, sweet
heptanal	69.40 ± 6.90	3[a]	23	green, fresh, fatty
methyl hexanoate	201.37 ± 21.36	10[b]	20	fruity, sweet
γ-dodecalactone	4.89 ± 1.02	0.43[d]	11	-
2-heptanone	9.77 ± 0.11	1[b]	10	cheesy, spicy, fruit
heptanol	28.35 ± 1.78	3[b]	9	green, herbal
ethyl octanoate	43.99 ± 9.35	5[e]	9	fruity, sweet
2-pentadecanone	61.58 ± 13.27	7[b]	9	jasmin, fatty
β-ionone	26.39 ± 6.12	3.5[d]	8	floral, sweet
α-pinene	12.71 ± 1.21	2.5[b]	5	herbal
2-methylthiophene	23.46 ± 5.30	5[f]	5	-
octadecanal	409.56 ± 80.93	83.1[c]	5	oily
δ-dodecalactone	20.53 ± 2.14	4.6[g]	4	-
3-methylbutanoic acid	11.73 ± 2.00	12[h]	4	cheesy, dairy
isobutyl acetate	171.07 ± 14.29	58[c]	3	fruity, banana
octanoic acid	591.40 ± 80.11	190[i]	3	fatty, rancid
pentanoic acid	50.83 ± 10.24	1207[g]	3	cheesy, milky,
isopropyl butanoate	66.47 ± 5.78	43[b]	2	fruity, pineapple
hexanal	2.93 ± 0.73	2.4[d]	1	green, fresh
hexadecanal	85.04 ± 16.47	62[c]	1	cardboard
butyl butanoate	91.89 ± 17.18	87[b]	1	fruity, banana
δ-undecalactone	156.40 ± 28.33	150[b]	1	-
butanol	575.76 ± 36.11	405[c]	1	fermented, sweet

heptanoic acid	3040.08 ± 612.15	500[g]	1	cheesy, waxy
methyl hexadecanoate	1060.61 ± 81.62	852[c]	1	waxy, fatty, oily

[a]Buttery et al. [19]; [b]Burdock [20]; [c]Pino and Quijano [21]; [d]Czerny et al. [22]; [e]Saberi et al. [23]; [f]Puvipirom and Chaiseri [24]; [g]Karagul-Yuceer et al. [25]; [g]Ong and Acree [26]; [i]Wagner et al. [27].

Table 2: Key volatile compounds (OAV>1) present in goat milk along with their characteristic odor notes.

Sieffart and Buettner [18] reported that six compounds were associated with goat-like odor characteristics accompanied by the attributes stable-like, fecal, or leather-like, and these were saturated acids like nonanoic acid, decanoic acid, dodecanoic acid. Although these compounds were found in the volatile profile of goat milk analyzed in this study, but they characterized for lower aroma impact as these compounds had their OAV's less than 1. Sieffart and Buettner [18] classified 3-methylbutanoic acid as a potent odorant in goat milk with notes as "sweety" and "cheesy"; in this study the same compound was found having OAV of 4, and hence corroborates with authors previously published work.

4. Conclusion

This work reports the presence of main volatile compounds identified in milk obtained from Saanen breed of goat, grown in the northeast region of Brazil. A total of 91 volatile compounds were identified and a majority of them belonged to esters, alcohols, aldehydes and terpenes. The work also reports the most promising odorous compounds viz. decanal (88), (*E*)-2-hexenal (72), hexanol (47), octanal (40), ethyl hexanoate (35), pentanal (34), nonanal (30), 2-pentanone (24), heptanal (23), methyl hexanoate (20), γ-dodecalactone (11), 2-heptanone (10), heptanol (9), ethyl octanoate (9), 2-pentadecanone (9), β-ionone (8), α-pinene (5), 2-methylthiophene (5), octadecanal (5), which could be responsible for goat milk aroma and its over-all flavor.

Acknowledgements

Authors (MTSLN) gratefully acknowledges the financial support in the form of a post-doc fellowship received from CAPES (Ministry of Education, Brazil).

Notes

The authors declare that there is no conflict of interest.

References

1. Yang CJ Ding W, Ma LJ, et al. Discrimination and characterization of different intensities of goaty flavor in goat milk by means of an electronic nose. Journal of Dairy Science 98 (2015): 55-67.
2. Chilliard Y, Ferlay A, Rouel J, et al. A review of nutrition and physiological factors affecting goat milk lipid synthesis and lipolysis. Journal Dairy Science 86 (2003): 1751-1770.
3. Fedele V, Claps S, Rubino R, et al. Variation in terpene content and profile in milk in relation to the dominant plants in the diet of grazing goats. South African Journal of Animal Science 34 (2004): 145-147.

4. Jaubert G, Bondin JP, Jaubert A. Flavour of goat farm bulk milk. In: MORAND-FEHR, P. (Ed.) Recent advances in goat research. Zaragoza: Ciheam-iamz (1997): 89-93.
5. Mariaca R, Berger T, Gauch R, et al. Occurrence of volatile mono-and sesquiterpenoids in highland and lowland plant species as possible precursors for flavour compounds in milk and dairy products. Journal Agricultural and Food Chemistry 45 (1997): 4423-4434.
6. Queiroga RCRE, Madruga MS, Galvao MS, et al. Extraction enhancement of volatile compounds from goat milk using the simultaneous extraction and concentration techniques. Revista do Instituto Adolfo Lutz 64 (2005): 97-103.
7. Kühn J, Considine T, Singh H. Interactions of milk proteins and volatile flavor compounds: implications in the development of protein foods. Journal of Food Science 71 (2006): 72-82.
8. Drake MA. Sensory analysis of dairy foods. Journal Dairy Science 90 (2007): 4925-4937.
9. Haenlein GFW. Goat Milk in Human Nutrition. Small Ruminant Research 51 (2004): 155-163.
10. Chye SJ, Ahmad R, Noor Aziah AA. Studies on the physicochemical and sensory characteristics of goat's milk dadih incorporated with tropical- fruit purees. International Food Research Journal 19 (2012): 1387-1392.
11. Kondyli E, Pappa EC, Svarnas C. Ripening changes of the chemical composition, proteolysis, volatile fraction and organoleptic characteristics of a white-brined goat milk cheese. Small Ruminant Research 145 (2016): 1-6.
12. Likens ST, Nickerson GB. Detection of certain hop oil constituents in brewing products. Proceedings of the American Brewing Chemists 5 (1964): 5-13.
13. Jennings W, Shibamoto T. Qualitative Analysis of Flavor and Fragrance Volatiles by Glass Capillary Gas Chromatography. Academic Press. New York (1980).
14. Kondjoyan N, Berdagué JL. A Compilation of Relative Retention Indeces for Analysis of Aromatic Compounds. Laboratóire Flaveur, Champanelle (1996).
15. Bendall JG. Aroma Compounds of Fresh Milk from New Zealand Cows Fed Different Diets. Journal Agricultural and Food Chemistry 49 (2001): 4825-4832.
16. Sant'Ana AMS, Bessa RJB, Alves SP, et al. Fatty acid, volatile and sensory profiles of milk and cheese from goats raised on native semiarid pasture or in confinement, International Dairy Journal 91 (2019): 147-154.
17. Hammond EG. Flavor Chemistry of Lipid Foods. Blackie Academic, London (1998).
18. Siefarth C, Buettner A. The aroma of goat milk: seasonal effects and changes through heat treatment. Journal Agricultural and Food Chemistry 62 (2014): 11805-11817.
19. Buttery RG, Guadagni DG, Ling LC. Volatile aroma components of cooked artichoke. Journal of Agricultural and Food Chemistry 26 (1978): 791-793.
20. Burdock GA. Fenaroli's Handbook of Flavor Ingredients (6th Edn.). Boca Raton: CRC Press (2010).
21. Pino JA, Quijano CE. Study of the volatile compounds from plum (Prunus domestica L. cv. Horvin) and estimation of their contribution to the fruit aroma. Food Science and Technology 32 (2012): 76-83.
22. Czerny M, Christlbauer M, Christlbauer M, et al. Re-investigation on odour thresholds of key food aroma

compounds and development of an aroma language based on odour qualities of defined aqueous odorant solutions. European Food Research and Technology 228 (2008): 265-273.

23. Saberi S, Cliff MA, van Vuuren HJJ. Impact of mixed S. cerevisiae strains on the production of volatiles and estimated sensory profiles of Chardonnay wines. Food Research International 48 (2012): 725-735.
24. Puvipirom J, Chaiseri S. Contribution of roasted grains and seeds in aroma of oleang (Thai coffee drink). International Food Research Journal 19 (2012): 583-588.
25. Karagül-Yüceer Y, Vlahovich KN, Drake M, et al. Characteristic Aroma Components of Rennet Casein. Journal of Agricultural and Food Chemistry 51 (2003): 6797-6801.
26. Ong PKC, Acree TE. Similarities in the Aroma Chemistry of Gewürztraminer Variety Wines and Lychee (Litchi chinesis Sonn.) Fruit. Journal of Agricultural and Food Chemistry 47 (1999): 665-670.
27. Wagner J, Granvogl M, Schieberle P. Characterization of the Key Aroma Compounds in Raw Licorice (Glycyrrhiza glabra L) by Means of Molecular Sensory Science. Journal of Agricultural and Food Chemistry 64 (2016): 8388-8396.

Citation: Rita de Cássia R Egypto Queiroga, Maria Terezinha Santos Leite Neta, Rafael Donizete Dutra Sandes, Narendra Narain, Mércia de Sousa Galvão, Marta Suely Madruga, Roberto Germano Costa. An Insight in Key Volatile Compounds in Goat Milk Based on their Odor Active Values. Journal of Food Science and Nutrition Research 2 (2019): 049-060.