Short communication: Compositional characteristics and aromatic profile of caciotta cheese obtained from Friesian cows fed with a dietary supplementation of dried grape pomace

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ABSTRACT

The aim of the present work was to explore the chemical-sensorial characteristics and aromatic profile of caciotta cheese obtained from Friesian cows fed a diet enriched with grape pomace obtained from red grape (*Vitis vinifera* L.). Dietary enrichment with grape pomace influenced the production of caciotta cheeses in interesting ways from a compositional point of view, as cheese samples were rich in polyphenols, giving a high antioxidant potential. From a biochemical standpoint, we noted a slight decrease of proteolysis during ripening, whereas, according to the analysis of volatile compounds, lipolysis was the most relevant phenomenon in samples. The presence of bioactive compounds also modified the fatty acid profile of milk and cheese, leading to an increase in concentration of linoleic, vaccenic, and rumenic acids. No significant variations were found in the sensory profile. These results showed the potential of dietary grape pomace intake to influence the chemical-nutritional and nutraceutical properties of cow milk and cheeses, whose introduction to the market could be attractive to consumers, providing interesting implications for the dairy industry. Finally, our results identified a valid use of an agro-industrial by-product, grape pomace, whose disposal generally presents economic and environmental problems.

Key words: grape pomace, polyphenols, volatile compounds, caciotta cheese

Short Communication

Animal feeding is of great importance for cheese quality because of its ability to influence the chemical-nutritional composition and bacterial profile of milk (Benchaar et al., 2007; Nudda et al., 2015; Manso et al., 2016), which are of great importance consider-

ing increasing consumer interest in foods containing functional ingredients with beneficial effects on health and disease prevention. The characterization of plant extracts and their use in the production of functional foods for humans and animals is an area of considerable interest. Previous studies have examined enriching the diet of farm animals with agro-industrial by-products rich in polyphenols to improve the chemical-nutritional properties (Singh-Nee and Pandey, 2009). Grape pomace (**GP**) is the main solid by-product of wine making, representing a rich source of potent bioactive compounds, especially polyphenols (2–6.5%), such as phenolic acids, simple flavonoids, tannins, and proanthocyanidins, which are attributed with a wide range of biochemical activity and represent the principal antioxidants for humans. Dietary intake of these compounds has beneficial effects, especially in the treatment and prevention of several chronic diseases, including cancer and inflammatory diseases (Vauzour et al., 2010). We focused on the characterization of milk from Friesian cows fed with a dietary supplementation of dried grape pomace (**DGP**) and the caciotta cheese made from that milk.

Eighteen Friesian cows, homogeneous for age (43 ± 3 mo) and lactation days (80 ± 18 d), were used in our study. Animals were randomly divided into 2 groups of 9 cows each: a control group (**GP**–) and a treated group (**GP**+), whose diet was supplemented with DGP. The cows were housed for the entire trial period in 2 separate freestalls with bunks on straw, a drinking trough, and an access to an identical feeding area with width of 75 to 80 cm for each animal. The study was conducted for a period of 60 d, in which all animals received about 23 kg/head per day of DM of TMR, taking into account the information reported in the seventh edition of Nutrient Requirements of Dairy Cattle (NRC, 2001); diet composition is reported in Table 1. Samples of TMR were analyzed for DM (method 930.15), CP (method 954.01), ether extract (method 920.39), crude fiber (method 962.09), and ash (method 942.05) according to AOAC (1990); NDF, ADF, and

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Table 1. Ingredients and chemical composition (mean $\pm$ SD) of TMR¹

Item	Diet		Dried grape pomace	<i>P</i> -value
	GP–	GP+		
Ingredient				
Maize silage, %	54.8	51.1		
First cut, alfalfa hay, %	11.2	7.7		
Straw, %	4.2	1.3		
Maize grain meal, %	8.7	11.7		
Soybean meal, %	7	7.2		
Fine bran, %	7.5	7.7		
Barley meal, %	5	6.6		
Vitamins and minerals, %	1.6	1.6		
Grape pomace flour, %		5.1		
Chemical composition (DM basis)				
DM, %	56.6	58.5	91.5	
CP, %	15.4	15.5	11.4	
Ether extract, %	2.9	2.8	3.9	
Ash, %	5.4	5.6	12.1	
NDF, %	34.1	32.5	37.5	
ADF, %	21.4	19.3	34.8	
ADL, %	4.2	4.7	20.3	
Starch, ² %	28.2	29.8		
UFL ³ /kg of DM	0.94	0.92		
Bulk milk composition				
Lactose, %	4.85 $\pm$ 0.51	4.71 $\pm$ 0.64		NS
Protein, %	3.36 $\pm$ 0.39	3.28 $\pm$ 0.35		NS
Fat, %	3.75 $\pm$ 0.45	3.91 $\pm$ 0.38		NS
Urea, mg/100 mL	23.40 $\pm$ 3.57	21.99 $\pm$ 2.72		NS
pH	6.5 $\pm$ 0.07	6.57 $\pm$ 0.05		NS
TPC, μ g of GAE ⁴ /mL	68.13 $\pm$ 1.07	91.14 $\pm$ 1.74		**
Antioxidant activity, TEAC ⁵ μ mol/mL	0.59 $\pm$ 0.02	0.73 $\pm$ 0.04		**
Milk yield, kg/d	31 $\pm$ 3.52	30.12 $\pm$ 4.05		NS

¹Nutritional composition, total phenolic compounds (TPC), antioxidant activity, and yield of milk obtained from standard feeding (GP–) and dietary enrichment with dried grape pomace (GP+).

²On a DM basis.

³UFL = unité fourragère lait.

⁴GAE = gallic acid equivalents.

⁵TEAC = Trolox equivalent antioxidant capacity.

***P* < 0.01.

ADL were determined by the detergent procedures of Van Soest et al. (1991). The GP– cows received a complete feed formulated taking into account the nutritional needs of cows in mid-lactation. The GP+ cows received the same complete feed, formulated according to the same requirements and prepared in the same way; however, we added 2 kg/head per day of DGP to the GP+ diet, calculated considering the parameters previously reported by Manso et al. (2016).

On d 60, the milk was collected separately for each group and manipulated in the same way as in cheesemaking, according to the following manufacturing protocol. Bulk milk was pasteurized at 75°C for 20 s, cooled to 36 $\pm$ 1°C, and transferred to a container, where starter bacteria was added (60 g/100 L) followed by acidification. We used DEM 6 and STA IDC 13 (CSL S.r.l., Lodi, Italy) starter cultures. Rennet (75% of chymosin and 25% of pepsin; 1:18,000 strength; Clerici, Cadorago, Italy) was added (15 g/100 kg) to

the milk and coagulation began after 30 min of incubation. The curd was broken into small pieces roughly the size of hazelnuts, portioned in aliquots of $\sim$ 1 kg, transferred into plastic molds, and kept at 50°C until the pH reached a value of 5.20 $\pm$ 0.1. After this, a 20% NaCl water solution was used to salt the cheese in brine (1 h/kg of cheese). Thereafter, the salted, fresh cheese was stored in the ripening room at a controlled temperature (10°C $\pm$ 0.5) and a relative humidity of 85%. To evaluate changes in the chemical composition and quality attributes due to ripening, sampling and analyses on caciotta cheese were carried out 1 d and 28 d after cheesemaking. Samples of 20 g each, collected in triplicate from 3 different cheesemakings, were partly immediately analyzed and partly packed under vacuum and frozen at –20°C until analysis.

Chemical composition of milk (fat, protein, casein, lactose, and urea) was determined by MilkoScan FT 6000 (Foss Integrator IMT; Foss, Hillerød, Denmark),

Total phenolic compounds were determined according to the Folin-Ciocalteu method (Singleton and Rossi, 1965), whereas the evaluation of milk antioxidant activity was performed by using the 2,2'-azino-bis(3-ethylbenzothiazoline-6-sulphonic acid) method, following the procedure described by Chen et al. (2003). The determination of pH, DM, total proteins, lipids, and ash in cheese was performed as previously described by To-falo et al. (2015). The nitrogen fractions were evaluated to obtain information about proteolysis; water-soluble nitrogen and trichloroacetic acid-soluble nitrogen were determined according to Kuchroo and Fox (1982) and Polychroniadou et al. (1999), respectively. The evaluation of the amounts of phenolic compounds in caciotta cheese was performed according to Han et al. (2011), measuring the retention coefficient of polyphenols in the curd by subtracting the amount of residual total phenolic content in whey from the total phenolic content initially determined in bulk milk. Higher retention coefficients indicated a reduced loss of the functional ingredients. To further investigate the proteolytic profile in cheese, SDS-PAGE was performed according to the procedure reported by Laemmli (1970); protein samples for electrophoresis were prepared by the method of Shalabi and Fox (1987). Milk lipid fraction was extracted according to the AOAC International (2000); the extraction was performed as described by Domagała et al. (2010) using a mix of chloroform and methanol (2:1, vol/vol). Transmethylation of lipid extracts and separation of FAME was performed following the procedure reported by Castellani et al. (2017). Peak areas were quantified using ChromeCard software (Thermo Fisher Scientific, Waltham, MA), and the relative value of each individual fatty acid was expressed as a percentage of the total fatty acids. The value of each fatty acid was used to calculate the sum of SFA, MUFA, and PUFA. Extraction of volatile compounds (VOC) from milk and cheese samples was performed by solid-phase microextraction, and GC-MS analysis was performed with a gas chromatograph (Clarus 580; Perkin Elmer, Waltham, MA) coupled with a mass spectrometer (SQ8S; Perkin Elmer). The gas chromatograph was equipped with an Elite-5MS column (length $\times$ internal diameter: 30 $\times$ 0.25 mm; film thickness: 0.25 μ m; Perkin Elmer). For GC-MS, 5 g of grated cheese were mixed with 10 mL of saturated NaCl solution (360 g/L) and 10 μ L of internal standard solution (4-methyl-2-heptanone; 10 mg/kg in ethanol) was added. The vials were sealed with a polytetrafluoroethylene-silicone septum (Supelco, Bellefonte, PA) and stirred at 60°C; VOC were extracted from the headspace with a divinylbenzene-carboxen-polydimethylsiloxane solid-phase microextraction fiber (length: 1 cm; film thickness: 50/30 μ m; Supelco) with an exposition time of 60 min.

After adsorption, the extracted VOC were thermally desorbed into the GC injector splitless mode for 1 min at 250°C. For desorption, the oven temperature was held at 50°C for 1 min, increased at a rate of 3°C/min up to 200°C and held for 1 min, and then increased from 200°C to 250°C at 15°C/min and held for 15 min. Helium was used as a carrier gas at a flow rate of 1 mL/min. The mass spectrometer operated in electronic impact ionization mode at 70 eV and data were collected in full-scan mode with a scan time of 0.2 s over a mass range of 35 to 350. Source and interface temperature were held at 250°C. Volatile compounds were identified by comparison with mass spectra of a library database (NIST Mass Spectral library, Search Program version 2.0, National Institute of Standards and Technology, US Department of Commerce, Gaithersburg, MD) and by comparing the eluting order with Kovats indices. Sensory analysis of fresh (1 d after cheesemaking) and ripened cheese (28 d after cheesemaking) was carried out by using a qualitative descriptive analysis (Stone et al., 1974). The panel was made up of a minimum of 7 untrained panelists that were regular consumers of cheese, who judged the samples for a set of descriptors on an arbitrary 7-point scale from 0 (low) to 7 (high). For cheese, the following descriptors were considered: visual aspects (color, number of holes, holes irregularity), physical and textural properties (elasticity to the touch, hardness and graininess during mastication), aroma (olfactory intensity), and taste (bitter, sweet, salted, acid). Statistical data processing was performed by the procedure GLM (Nelder and Baker, 1972) of the statistical package SPSS 13.0 (SPSS Inc., Chicago, IL). When the variance analysis was significant ($P < 0.05$), the differences between the means were compared by the least significant difference test.

The dietary integration of DGP did not influence milk composition (Table 1), either in terms of nutritional quality (fat, proteins, casein, and lactose) or as regards the ureic content. Our findings on chemical composition are in agreement with previous studies that tested the effect of dietary supplementation of by-products of the winemaking industry (Nudda et al., 2015); however, other authors reported the reduction of protein content as a resulting effect of the action of polyphenols (Nielsen and Hansen, 2004). As expected, a significant ($P < 0.01$) increase of total phenolic compounds was observed in GP+ samples; probably as a direct consequence of this, even a significant increase in the antioxidant activity has been highlighted. In the cheese we studied, diet did not induce significant differences in chemical composition (Table 2). Particularly interesting is the data concerning the retention coefficient of polyphenols, as the value is almost identical (0.79 ± 0.04 and 0.76 ± 0.03 , respectively) in both the

GP– and GP+ samples, probably as a direct consequence of similar content in terms of proteins, which interfere with the phenolic compounds, trapping them in the cheese matrix. This finding shows the effects of the polyphenols in GP+ cheese samples and the consequent maintenance of the antioxidant properties previously found in milk.

The evaluation of the nitrogen fractions allowed us to obtain information about proteolysis during cheese ripening. As reported in Table 2, only slight variations were induced by the feeding strategy, probably related to microbial metabolic modification induced by DGP, which has the effect of reducing the expression and the activity of proteolytic enzymes able to hydrolyze casein-derived peptides to small peptides and free AA. These data were also confirmed by the SDS-PAGE (data not shown), which showed an almost identical protein profile, with the presence in cheese samples of high amounts of β -LG, a protein that is characterized by high resistance to hydrolysis (Santoro and Faccia, 1996). Extensive proteolysis would produce large quantities of free AA, which are the fundamental substrates of the decarboxylation process that lead to the biosynthesis of amines, which are not associated with high-quality cheese because of their potentially adverse health effects and poor flavor (Marino et al., 2013).

Regarding the fatty acid composition in milk (Table 3), an increase in the percentage of linoleic acid (C18:2n-6; $P < 0.01$), and *trans*-vaccenic acid (C18:1 *trans*; $P < 0.01$) was seen in samples obtained from GP+. By studying the acidic profile in cheese (1 and 28 d after cheesemaking; Table 3), we observed the same modifications already evident in milk with the addition of a significant increase in concentration of rumenic acid (CLA *cis*-9,*trans*-11; $P < 0.01$) in GP+ samples. These results are in agreement with several studies that tested the effect of GP or grape seeds on ruminants. In particular, Tsiplakou and Zervas (2008), highlighted that the increase of linoleic acid in the diet of both sheep and goats led to a significant increase in the concentration of fatty acids in milk, in particular *trans*-vaccenic, linoleic, and rumenic acids, which are of the greatest interest to humans. Similarly, Correddu et al. (2015) verified an increase in n-6 PUFA (in particular linoleic acid) in milk obtained from sheep receiving grape seed flour in the diet. The importance of vaccenic acid lies in the fact that this compound represents the substrate of the mammary gland Δ^9 -desaturase, which is responsible for the production of at least 90% of all rumenic acid, a compound with high biological value for humans (Whigham et al., 2000). It is therefore conceivable that the DGP we used conferred a high polyunsaturated component, probably correlated with the presence of grape seeds, which directly contributed

Table 2. Chemical composition and analysis of nitrogen fractions in cheese samples from GP– (standard feeding) and GP+ (dietary enrichment with dried grape pomace)¹

Sample	Ripening days	DM, %	Protein ²	Fat ²	Ash ²	pH	Water-soluble nitrogen, % N	12% Trichloroacetic acid-soluble N, % N
GP–	1	50.63 ± 1.88	12.76 ± 0.93	32.89 ± 2.55	3.84 ± 1.52	6.12 ± 0.05	3.77 ± 0.21	1.47 ± 0.11
	28	53.44 ± 1.35	18.02 ± 1.99	23.77 ± 4.95	6.63 ± 1.31	5.39 ± 0.03	9.04 ± 0.45	5.35 ± 0.51 ^a
GP+	1	49.54 ± 4.41	12.34 ± 1.55	31.63 ± 3.92	4.21 ± 0.87	6.27 ± 0.04	3.28 ± 0.27	1.19 ± 0.14
	28	53.61 ± 4.32	17.29 ± 1.05	25.28 ± 3.26	5.74 ± 1.90	5.20 ± 0.03	9.81 ± 0.75	3.89 ± 0.22 ^b

^{a,b}Values with different superscript letters differ significantly ($P < 0.01$).

¹Data are expressed as mean ± SD.

²Values expressed as % of DM.

Table 3. Acidic composition of bulk milk and cheese samples after 1 and 28 d of ripening with standard feeding (GP–) or enriched with grape pomace (GP+)

Item	Bulk milk				Cheese			
	d 1		d 28		d 1		d 28	
	GP–	GP+	P-value		GP–	GP+	P-value	
C4:0	2.59 ± 0.38	2.49 ± 0.35	NS		2.47 ± 0.60	2.44 ± 0.07	NS	2.35 ± 0.52
C6:0	2.02 ± 0.24	2.00 ± 0.19	NS		1.74 ± 0.21	1.81 ± 0.28	NS	1.81 ± 0.25
C8:0	1.39 ± 0.21	1.35 ± 0.06	NS		1.18 ± 0.13	1.21 ± 0.14	NS	1.19 ± 0.13
C10:0	3.41 ± 0.37	3.39 ± 0.26	NS		2.91 ± 0.34	2.93 ± 0.37	NS	2.92 ± 0.35
C12:0	4.15 ± 0.39	4.17 ± 0.37	NS		3.28 ± 0.38	3.60 ± 0.42	NS	3.26 ± 0.45
C14:0	12.52 ± 1.39	12.71 ± 1.23	NS		11.70 ± 1.29	11.94 ± 1.48	NS	11.95 ± 1.45
C14:1	1.08 ± 0.08	1.13 ± 0.10	NS		1.06 ± 0.13	1.05 ± 0.17	NS	1.02 ± 0.14
C15:0	1.06 ± 0.11	1.17 ± 0.12	NS		1.13 ± 0.16	1.17 ± 0.14	NS	1.05 ± 0.15
C16:0	34.15 ± 3.85	33.31 ± 3.90	NS		35.34 ± 4.22	34.48 ± 3.73	NS	34.67 ± 4.16
C16:1	1.01 ± 0.08	1.13 ± 0.17	NS		1.08 ± 0.15	1.03 ± 0.14	NS	1.04 ± 0.13
C18:0	10.73 ± 0.58	10.81 ± 0.48	NS		11.89 ± 1.62	11.73 ± 1.88	NS	12.16 ± 1.32
C18:1 <i>trans</i>	0.64 ± 0.08	0.98 ± 0.11	**		0.72 ± 0.09	0.95 ± 0.12	**	0.68 ± 0.08
C18:1 <i>cis</i> -9	17.20 ± 1.95	17.26 ± 2.18	NS		17.42 ± 2.19	17.51 ± 2.36	NS	17.83 ± 2.10
C18:1 <i>trans</i> -11	0.43 ± 0.04	0.40 ± 0.06	NS		0.40 ± 0.05	0.42 ± 0.04	NS	0.43 ± 0.06
C18:2	2.28 ± 0.23	2.60 ± 0.31	**		2.42 ± 0.26	2.65 ± 0.34	**	2.44 ± 0.08
C18:3	0.46 ± 0.06	0.47 ± 0.07	NS		0.40 ± 0.05	0.43 ± 0.06	NS	0.40 ± 0.02
Rumenic acid	0.44 ± 0.03	0.38 ± 0.06	NS		0.18 ± 0.02	0.23 ± 0.02	**	0.12 ± 0.01
Other	3.88 ± 0.32	4.33 ± 0.41	*		4.14 ± 0.56	3.91 ± 0.45	NS	4.31 ± 0.51

* $P < 0.05$; ** $P < 0.01$.

Table 4. Volatile compounds of caciotta cheese samples after 1 and 28 d of ripening with standard feeding (GP –) or enriched with grape pomace (GP +)

Item	Volatile compound	d 1			d 28		
		GP –	GP +	P-value	GP –	GP +	P-value
Acids	Acetic acid	0.83 ± 0.03	0.35 ± 0.01	**	1.70 ± 0.08	1.45 ± 0.02	*
	Butanoic acid	0.34 ± 0.04	0.20 ± 0.01	**	1.73 ± 0.03	0.43 ± 0.03	**
	Pentanoic acid	0.12 ± 0.01	0.03 ± 0.00	**	0.11 ± 0.01	0.02 ± 0.00	*
	Hexanoic acid	0.13 ± 0.02	2.59 ± 0.19	**	3.59 ± 0.25	1.37 ± 0.17	*
	Heptanoic acid	0.44 ± 0.03	0.10 ± 0.01	*	3.77 ± 0.08	4.37 ± 0.40	NS
	Octanoic acid	58.14 ± 0.59	56.22 ± 0.67	NS	57.08 ± 4.44	59.51 ± 1.17	NS
	Nonanoic acid	0.50 ± 0.02	0.62 ± 0.08	NS	0.40 ± 0.05	0.46 ± 0.04	NS
	Decanoic acid	19.11 ± 1.15	19.54 ± 1.31	NS	0.45 ± 0.04	0.49 ± 0.06	NS
	Dodecanoic acid	0.55 ± 0.05	0.65 ± 0.07	NS	1.13 ± 0.14	1.66 ± 0.09	*
	2-Pentanol	ND ¹	ND	NS	0.06 ± 0.01	0.04 ± 0.00	NS
Alcohols	1-Butanol, 3-methyl	0.55 ± 0.06	0.74 ± 0.12	*	0.20 ± 0.01	0.30 ± 0.02	*
	1-Heptanol	0.13 ± 0.01	0.19 ± 0.02	NS	ND	ND	NS
Aldehydes	Heptanal	0.31 ± 0.02	0.23 ± 0.03	*	0.10 ± 0.02	0.13 ± 0.01	NS
	Nonanal	0.88 ± 0.16	0.47 ± 0.03	**	0.60 ± 0.07	0.70 ± 0.07	NS
	2-Nonenal	ND	ND	NS	0.06 ± 0.00	0.07 ± 0.01	NS
	Butanal, 3-hydroxy	0.03 ± 0.00	0.02 ± 0.00	NS	ND	ND	NS
Alkane	Hexane	3.47 ± 0.18	2.02 ± 0.11	**	ND	ND	NS
Ketones	2-Heptanone	2.73 ± 0.21	2.21 ± 0.06	*	ND	ND	NS
	Δ-Nonalactone	0.07 ± 0.01	0.14 ± 0.01	NS	0.16 ± 0.05	0.15 ± 0.04	NS
Lactones	Δ-Decalactone	0.54 ± 0.07	0.66 ± 0.07	NS	0.68 ± 0.08	0.76 ± 0.08	NS
	Δ-Dodecalactone	0.07 ± 0.01	0.09 ± 0.01	NS	0.15 ± 0.02	0.13 ± 0.02	NS
Esters	Ethyl butyrate	2.04 ± 0.18	3.28 ± 0.04	**	3.80 ± 0.29	3.41 ± 0.31	NS
	Ethyl hexanoate	1.30 ± 0.06	1.99 ± 0.24	*	13.06 ± 1.25	13.61 ± 1.15	NS
	Ethyl heptanoate	ND	ND	NS	0.15 ± 0.02	0.21 ± 0.03	NS
	Ethyl octanoate	ND	ND	NS	7.03 ± 0.58	5.76 ± 0.22	**
	Ethyl nonanoate	ND	ND	NS	0.18 ± 0.01	0.15 ± 0.02	NS
	Ethyl decanoate	0.08 ± 0.01	0.20 ± 0.07	**	4.13 ± 0.34	3.54 ± 0.29	*
Aromatic hydrocarbons	Ethyl dodecanoate	ND	ND	NS	0.27 ± 0.04	0.35 ± 0.04	NS
	Methyl hexanoate	0.30 ± 0.02	0.26 ± 0.01	NS	ND	ND	NS
	Ethylbenzene	2.60 ± 0.15	2.38 ± 0.20	NS	ND	0.67 ± 0.07	*
	p-Xylene	0.38 ± 0.04	0.62 ± 0.07	**	0.54 ± 0.04	0.69 ± 0.08	*

¹ND = not detectable.
P* < 0.05; *P* < 0.01.

to the ruminal production of *trans*-vaccenic acid and in its transformation in rumenic acid.

The evaluation of the VOC profile in cheeses ripened for 1 and 28 d led to the identification of different classes of compounds (Table 4). The most abundant compound was represented by carboxylic acids, indicating that the main process during cheese ripening was lipolysis. Dietary enrichment of DGP had interesting effects on butanoic and hexanoic acids, which are present at lower concentrations in the GP+ samples at d 1 ($P < 0.05$) and, in a more marked way, 28 after cheesemaking ($P < 0.01$). Butanoic and hexanoic acids are considered to be mainly involved in the determination of cheese flavor, responsible for strong odors defined as cheesy, rancid, and sweaty. The lower production of these compounds probably depends on the reduction of lipolysis of the triglycerides by microbial and endogenous milk enzymes, resulting in a minor release of free fatty acids (Bertuzzi et al., 2018). Acetic acid, generally associated with pungent, vinegary, and acidic notes, tended to shrink in GP+ samples both at d 1 ($P < 0.01$) and 28 after cheesemaking ($P < 0.05$); this compound can derive from propionic fermentation and catabolism of residual lactose and citrate (Beuvier and Buchin, 2004). The ethyl esters represent the second group in order of abundance and seem to increase markedly during the ripening, passing from 4% at d 1 to 28% at d 28 after cheesemaking. Ethyl esters compounds are characterized by a low odor threshold and are generally associated with the sweet, fruity, and floral notes of surface-ripened cheese flavor. Finally, ketones were present at lower concentrations in cheeses at d 28 after cheesemaking without significant differences between GP– and GP+ samples. The release of methyl ketones is mainly attributed to mold metabolism, providing the typical flavor of surface mold-ripened and blue-veined cheeses (Collins et al., 2003). The overall reduction of these compounds was probably due to a reduction of the enzymatic activities responsible for their biosynthesis, which involve the free fatty acid oxidation to β -ketoacids and decarboxylation (Kilcawley, 2017).

From a sensory point of view, 12 parameters were considered for evaluation. The only significant differences were found in the samples from 1 d after cheesemaking, with the GP+ cheese characterized by a slightly darker coloring ($P < 0.05$), a harder consistency ($P < 0.05$), and a less sweet taste ($P < 0.01$). After 28 d of ripening, all the analyzed caciotta cheeses samples were similar without significant changes in terms of appearance, consistency, and taste.

In conclusion, we characterized a specific type of cheese produced using milk from cows fed differently enriched diets. Dietary enrichment with DGP seems to have improved all the analyzed chemical-nutritional

parameters, giving rise to a product rich in antioxidant compounds, with a higher concentration of fatty acids of interest to humans (*trans*-vaccenic, linoleic, and rumenic acids), less prone to proteolysis during ripening, and without significant alterations of the sensory profile.

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