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Dietary White Grape Pomace Silage for Goats: Assessing the Impact of Inclusion Level on Milk Processing Attributes

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Abstract

Grape pomace is the principal by-product of the winemaking industry, with an estimated global production of 14 million tonnes annually. Traditional livestock systems often incorporate local agroindustrial by-products into ruminant diets, and grape pomace is particularly notable for its high concentrations of bioactive compounds. These grape-derived molecules may exert beneficial effects on animal oxidative balance, biochemical status and productive performance, offering an environmentally and economically sustainable alternative to conventional feed ingredients that may be incorporated into the milk produced. This study evaluated the impact of incorporating varying inclusion levels (0, 5, 10 and 15% DM) of ensiled white grape pomace (WGP) into isoenergetic and isoproteic diets on the nutritional and technological characteristics of goat milk. Eighty-eight Murciano-Granadina dairy goats were selected and allocated into eight homogeneous batches (n = 11 per batch) based on physiological traits. Following a pre-experimental sampling, each diet was randomly assigned to two batches, and the feeding trial lasted eight weeks. After a two-week dietary adaptation period, four biweekly samplings were conducted to obtain representative bulk tank milk samples from each batch. Milk samples were analysed for gross composition, pH, mineral profile, fatty acid composition, coagulation properties, colorimetric parameters and antioxidant capacity. WGP consumption significantly increased milk fat content, improved the lipid profile from a human health perspective, accelerated curd aggregation and elevated the yellowness index. Moreover, notable changes were observed in the antioxidant activity of the milk. Despite these effects, the overall composition of the milk remained largely unchanged, which is a key factor in preserving its technological properties. Nevertheless, the final product demonstrated enhanced biological quality, reinforcing its value as a functional food for human consumption.

Keywords: grape by-products; grape pomace; functional properties; fatty acids; health index; antioxidant

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1. Introduction

The global food production and processing industry is undergoing continuous expansion to meet the demands of a growing population and the evolving dietary habits of consumers [1,2]. Given that a substantial portion of livestock production relies on cultivated

cereals, legumes and forages, the sector is facing a marked decline in competitiveness [2]. Concurrently, from harvest to final product transformation, an estimated 1.3 billion tonnes of food are wasted annually, with fruits and vegetables accounting for approximately 60% of this loss [3]. The strategic use of agroindustrial by-products and alternative forages could provide locally sourced feed for livestock, thereby reducing dependence on imported feedstuffs. Moreover, their incorporation into animal diets contributes to minimizing waste generated by the food industry, lowering disposal costs and decreasing the land and other resources allocated to feed crop production—thus supporting the principles of a circular economy. However, the pronounced seasonality of harvests limits the year-round availability of these feed resources and their high moisture content results in a short shelf life. Previous studies have demonstrated that ensiling such by-products under controlled fermentative conditions effectively extends their preservation while maintaining the nutritional and hygienic standards required [4–6] for their inclusion in small ruminant diets [7–9].

Changes in milk composition—particularly in fat, protein and mineral content—can significantly influence its processing attributes and technological performance. For instance, variations in casein fractions and calcium levels affect coagulation kinetics and curd firmness, which are critical for cheese-making [10,11]. Similarly, shifts in fat content and fatty acid profile may alter heat stability and homogenization behaviour, impacting the quality of pasteurized and fermented products [12,13]. Therefore, compositional changes resulting from dietary interventions can have meaningful implications for the industrial suitability and nutritional value of milk [14,15]. Moreover, recent evidence indicates that, when diets are properly formulated to meet nutritional requirements, the inclusion of agroindustrial by-products neither compromises animal performance nor impairs product quality [16–18], and may even confer economic benefits [19,20].

An additional advantage of utilizing agroindustrial by-products is their frequent richness in bioactive compounds, whose intake has been associated with functional properties that benefit animal physiology and enhance the biological quality of their products [1]. One of the most significant by-products generated globally—estimated at 14 million tonnes annually—is grape pomace, a residue from grape processing for winemaking [21,22]. This by-product has attracted considerable interest in animal nutrition, as many of the grape's bioactive compounds remain in the pomace and are not transferred to the wine [23]. Grape pomace is a rich source of phytochemicals (including phenolics, flavonoids and tocopherols), antioxidants and polyunsaturated fatty acids [24–27]. Ruminants can tolerate higher inclusion levels of fibrous material and poorly digestible bioactive compounds—characteristic of plant-based by-products—than monogastric animals [28–30]. For this reason, ruminant livestock exhibits a remarkable ability to produce high-quality food from feedstuffs of limited biological value for human consumption.

Goat milk, characterized by its high total solids content and regarded as a complete and highly nutritious food, has gained recognition in developed countries as a functional food due to its multiple nutritional benefits, hypoallergenic properties and positive health effects—factors that have driven a sustained increase in its demand [31–33]. Currently, fresh goat milk ranks third in global consumption after cow and buffalo milk [34]. Europe accounts for 16% of global goat milk production, with Spain being the second-largest European producer, contributing 22% of the total (535.7 thousand tonnes) [35]. Although references in the literature regarding the effects of feeding silages derived from these by-products to sheep on milk quality, composition and animal health are scarce, they suggest the suitability of such practices for this purpose [36–39]. However, studies evaluating the effects of agroindustrial by-product consumption on the nutritional and technological properties of goat milk remain inconclusive and appear to be dose dependent. Muelas

et al. [40] reported no significant effects on the chemical composition or technological characteristics of milk from Murciano-Granadina goats fed up to 25% DM of artichoke by-products (plant and outer bracts). The same study noted a change in milk colorimetric parameters at this inclusion level, whereas a lower dose (12.5% DM) did not elicit this effect. Arco-Pérez et al. [41] evaluated the inclusion of 20% DM of ensiled tomato by-product and 20% DM of ensiled olive by-product, observing no impact on milk yield or gross composition in the same breed, although both by-products altered the fatty acid profile. Specifically, milk from goats fed these by-products showed increased levels of C18:1 trans-11, C20:2 and conjugated linoleic acid (CLA). However, prolonged consumption of ensiled tomato by-product increased saturated fatty acids (SFAs) while reducing monounsaturated fatty acids (MUFAs) and CLA. Monllor et al. [8] found that feeding 25% DM of ensiled artichoke plant improved the lipid and mineral profile of goat milk, and that a 40% DM inclusion of ensiled artichoke by-product increased polyunsaturated fatty acid (PUFA) and omega-6 fatty acid (n-6) content while reducing atherogenic (IA) and thrombogenic indices (TIs) [42]. In a full-lactation study, the same authors reported that feeding 40% DM of ensiled artichoke plant reduced the n-6/n-3 ratio in milk, whereas the same inclusion level of ensiled broccoli by-product appeared excessive, leading to selective feeding behaviour and reduced intake [43]. A concentrate mixture containing corn dried distillers' grains, dried citrus pulp and exhausted olive cake successfully replaced 44% of cereal grains in the concentrate for dairy goats, resulting in higher milk fat and protein yields and a more unsaturated milk fatty acid profile [44]. Huanca et al. [45] reported that milk and cheese from goats fed 19% DM of lemon tree leaves had higher fat and DM content, while medium-chain fatty acids and total free fatty acids were lower compared to a control diet.

Against this background, the present study aimed to evaluate the effects of including different proportions of white grape pomace (WGP) silage in the diets of lactating dairy goats on milk quality traits. Specifically, we assessed gross composition (including somatic cell count), mineral and fatty acid profiles, milk coagulation properties, colorimetric parameters and antioxidant activity. The ultimate goal was to identify the optimal inclusion level of WGP silage based on the nutritional and technological characteristics of the milk.

2. Materials and Methods

2.1. Animals and Facilities

The research was conducted using a dairy goat herd located at the teaching and experimental facilities of Miguel Hernández University in Spain. The trial extended from the end of April—when preliminary sampling was performed—until the close of June. This farm houses a herd of Murciano-Granadina goats, kept in straw-bedded pens under a free-stall housing system. Each goat was provided with 1.5 m^2 of individual space, 35 cm of linear access to the feeding area and unrestricted access to fresh water. Feeding was scheduled twice daily, at 9:00 a.m. and 3:00 p.m., and goats were milked once a day (Casse milking parlour, 2 × 12 × 12, GEA, Bönen, Germany), in accordance with standard practices in the region. This study was approved by the Office of Responsible Research at Miguel Hernández University (UMH.DTA.JDS.04.22).

2.2. Experimental Design

From an initial group of 120 goats at the five weeks postpartum stage of lactation, and fed a conventional diet, 88 animals were selected based on parity, body weight (37.70 ± 5.48 kg), milk yield (2.89 ± 0.84 kg/day) and somatic cell count (LSCC, 2.96 ± 3.30 10^3 cells/mL). The animals were distributed into 8 homogeneous batches (11 goats/batch), ensuring balance across the selection criteria. After a pre-experimental sampling, every diet was randomly assigned to 2 batches: Control (conventional diet without

by-products), 5_WGP (conventional diet including 5% WGP silage on a dry matter basis), 10_WGP (diet including 10% DM of WGP silage) and 15_WGP (diet including 15% DM of WGP silage). Following a two-week dietary adaptation period, four biweekly samplings were conducted to obtain representative bulk tank milk samples from each dietary group. Bulk tank milk was maintained at 4 °C under continuous agitation during sampling to ensure homogeneity. A representative volume was collected and immediately divided into uniform aliquots. Gross composition, somatic cell count (SCC), milk coagulation properties, pH and colorimetric parameters were determined immediately. The remaining aliquots were stored at −20 °C until analysis of mineral content, fatty acid profile and antioxidant capacity.

Milk sampling was carried out sequentially as lactation progressed across the scheduled sampling weeks. To disentangle the effects of lactation stage from those of dietary treatment, two complementary strategies were implemented: a control group receiving the conventional diet was maintained consistently throughout the trial, and the statistical interaction between sampling week and dietary treatment was explicitly tested. This dual approach enabled the identification of stage-dependent dietary effects while minimizing potential confounding associated with the temporal structure of the experimental design. The diets were the same as those previously used by Galvez-Lopez et al. [9]. Briefly, all diets were formulated according to the recommendations of Fernández et al. [46] for goats producing 2.5 kg of milk/day, ensuring isoenergetic and isoproteic rations tailored to their production level. Animals were fed fixed amounts twice daily, with no ad libitum access. Details regarding the ingredients, chemical composition and daily feed offered (Table 1) are presented below. The WGP silage used in the study was sourced from the quality and stability trials of this agroindustrial by-product conducted by Galvez-Lopez et al. [5].

Table 1. Ingredients and chemical composition of experimental diets containing different inclusions of red grape pomace by-product for dairy goat feeding.

Item	Diets			
	Control	WGP_5	WGP_10	WGP_15
Ingredients (g/kg DM)				
Pelleted grain mix	612.0	602.0	648.0	593.0
Alfalfa hay	368.0	348.0	252.0	277.0
Barley straw	20.0	-	-	20.0
WGP silage	-	50.0	100.0	150.0
kg DM offered/animal/day	2.20	2.22	2.21	2.25
Gross composition (g/kg DM)				
DM (g/kg FM)	890.38	856.70	825.72	786.30
OM	878.95	865.83	869.36	868.32
CP	176.00	175.00	177.00	178.00
EE	31.00	31.00	37.00	38.00
NDF	314.00	310.00	350.00	370.00
ADF	158.00	171.00	183.00	196.00
ADL	26.30	38.10	39.70	50.05
Starch	254.00	254.00	254.00	257.00
Total sugar	49.00	45.00	45.00	47.00
Total polyphenols (GAE eq.)	6.45	7.63	7.40	8.23
ME [1] (Mcal/kg DM)	2.85	2.81	2.78	2.74
Mineral content (g/kg DM)				
Ca	11.40	9.90	11.30	10.30
P	3.70	3.70	3.90	3.70
Na	4.80	4.40	4.30	3.90
K	13.60	12.90	12.70	12.40
Mg	3.20	3.00	3.10	2.90

Table 1. *Cont.*

Item	Diets			
	Control	WGP_5	WGP_10	WGP_15
Fatty acids profile [2]				
C4:0	0.28	0.26	0.28	0.10
C6:0	0.10	0.09	0.10	0.04
C12:0	0.23	0.17	0.17	0.12
C14:0	0.51	0.40	0.41	0.31
C16:0	18.89	17.40	17.17	15.95
C16:1c9	0.36	0.37	0.41	0.38
C18:0	2.84	2.80	2.73	3.01
C18:1c9	21.82	22.32	22.30	22.75
C18:1c11	0.91	0.93	0.95	1.03
C18:2n6	43.94	46.68	47.51	48.78
C18:3n3	7.18	5.68	5.46	5.07
C20:0	0.40	0.39	0.36	0.40
C20:1n9	0.22	0.23	0.23	0.24
C22:0	0.29	0.27	0.26	0.29
C24:0	0.32	0.30	0.25	0.26
SFA	24.96	23.04	22.57	21.18
MUFA	23.46	23.97	24.03	24.55
PUFA	51.57	52.99	53.39	54.25
UI	134.53	136.18	136.86	138.54

WGP: White grape pomace, WGP_5: diet with 5% of WGP, WGP_10: diet with 10% of WGP, WGP_15: diet with 15% of WGP. DM: dry matter; FM: fresh matter; OM: organic matter; CP: crude protein; EE: ether extract; CF: crude fibre; NDF: neutral detergent fibre; ADF: acid detergent fibre; ADL: acid detergent lignin; GAE eq.: gallic acid equivalent; ME: metabolic energy: [1] [47]; [2] percentages of the methylated fatty acid area in the fatty acid profile; SFA: saturated fatty acid; MUFA: monounsaturated fatty acid; PUFA: polyunsaturated fatty acid; UI: unsaturation index.

2.3. Variables Analysed

The composition of the diets (Table 1) was determined according to AOAC (1999) methods [48]: dry matter (DM, g/kg; method 930.5), organic matter (OM, g/kg DM; method 942.05), ether extract (EE, g/kg DM; method 920.39), crude protein (CP, g/kg DM; method 984.13) and total sugars (g/kg DM; method 974.06). Neutral detergent fibre (NDF, g/kg DM), acid detergent fibre (ADF, g/kg DM) and acid detergent lignin (ADL, g/kg DM) were analysed according to Van Soest et al. [49]. Starch content was determined using the polarimetric method of Ewers [50]. Total polyphenol content (PT, g GAE eq./kg DM) was analysed using the Folin–Ciocalteu method as described by Kim et al. [51]. The mineral content in the diets was determined using an Inductively Coupled Plasma Mass Spectrometer (ICP-MS; Agilent 7700x, Santa Clara, CA, USA) following acid digestion of the samples according to González Arrojo et al. [52]. The lipid profile determined by the separation of isomers of PUFAs was performed through direct methylation of the lyophilised sample, without prior fat extraction, according to Kramer et al. [53]. Identification of the methyl esters of fatty acids (FAMEs) was carried out using Shimadzu GC-2030 coupled with a flame ionization detector (FID) and an automatic injector AOC-20i (Shimadzu, Kyoto, Japan) equipped with a capillary column (CP Sil 88 100 m × 0.25 mm, 0.20 µm particle size, Agilent, Santa Clara, CA, USA). A mix of FAMEs (18912-1AMP; Sigma-Aldrich, Saint Louis, MO, USA) was used as a standard for identifying the peaks in the fatty acid profile of the sample. Results were calculated as a percentage of each fatty acid in total fatty acids profile.

Gross composition of bulk tank milk—including fat, CP, lactose, useful DM (UDM), non-fat dry matter (NFDM) and milk urea—was analysed using mid-infrared spectroscopy (CombiFossTM 7 DC, Foss, Hillerød, Denmark). Moreover, somatic cell count (LSCC, 10^3 cells/mL) was determined via flow cytometry (CombiFossTM 7 DC, Foss, Hillerød,

Denmark). Total cholesterol content was determined following saponification and methylation of milk samples. Quantification was performed using high-performance liquid chromatography (HPLC 1200, Agilent Technologies, Santa Clara, CA, USA) equipped with a diode array detector (DAD) set at 208 nm. The separation was carried out under isocratic conditions using a mobile phase of 2-propanol:hexane (2:98, *v*/*v*) at a flow rate of 1 mL/min, according to the method described by Domínguez et al. [54].

The mineral content in the diets was determined following acid digestion of the samples according to González Arrojo et al. [52]. Quantification was performed using an Inductively Coupled Plasma Mass Spectrometer (ICP-MS; Agilent 7700x, Santa Clara, CA, USA) equipped with an Octopole Reaction System (ORS). To account for potential physical and matrix interferences, an internal standard was employed throughout the analysis.

The milk fatty acid profile was determined following the fat extraction method described by Romeu-Nadal et al. [55] and fatty acid methylation was performed according to Nudda et al. [56]. Fatty acid methyl esters (FAMEs) were separated using the same equipment and column previously described for the diet's fatty acid profile. The fatty acids were individually identified by comparison with the relative retention times of a standard mix of external standards (37FAME mix, Supelco, Bellefonte, PA, USA). Results were calculated as percentage of each fatty acid in the total fatty acids profile. Nutritional and health-related indices of fatty acids were calculated following the methodology proposed by Chen and Liu [57].

To determine the milk coagulation properties, the samples were pre-conditioned at 32 °C for 15 min in a water bath. Recombinant chymosin (Larbus S.A., Madrid, Spain) was diluted 1:100 in distilled water. Ten mL of milk was placed in each well of the Optigraph (Ysebaert, Frépillon, Francia) and 100 µL of the diluted chymosin was added to start the test at 32 °C and follow the changes of optical properties for 50 min. Accordingly, the variables rennet coagulation time (RCT, min), aggregation rate (min) and curd firmness (mm) were determined using the Optigraph system under controlled conditions. pH measurements were performed using a pH meter (Model pH/Ion 510, Eutech Instruments Pte Ltd., Singapore).

Colour evaluation was performed using the CIE 1976 *L*a*b** (CIELab) coordinate system with a spectrophotocolorimeter (CM-700, Minolta Camera Co., Osaka, Japan), set to a 10° standard observer angle and D65 illuminant under SCI (Specular Component Included) mode. To minimize measurement interference, a low-reflectance glass cube (Minolta CR-A51/1829-752; Konica Minolta, Tokyo, Japan) was used as a measuring instrument. The measured CIELab parameters included lightness (*L**), red/green coordinate (*a**) and yellow/blue coordinate (*b**). Based on these values, the psychophysical attributes hue angle (*h**) (Equation (1)) and chroma (*C**) (Equation (2)) were calculated using the following equations [58]:

$$h^* = \tan^{-1}(b^*/a^*) \quad (1)$$

$$C^* = \sqrt{(a^{*2} + b^{*2})} \quad (2)$$

Moreover, whiteness (WI) (Equation (3)) and yellowness (YI) (Equation (4)) indices were determined according to the following equations [59]:

$$\mathrm{WI} = 100 - \sqrt{[(100 - L^*)^2 + a^{*2} + b^{*2}]} \quad (3)$$

$$\mathrm{YI} = 142.86 \times (b^*/L^*) \quad (4)$$

To evaluate the antioxidant activity, ABTS scavenging and FRAP reducing power were determined. For the ABTS analysis (reduction of the 2,2′-azino-bis(3-ethylbenzothiazoline-6-sulfonate) radical), the method described by Leite et al. [60] was followed. The FRAP analysis (Ferric Reducing Antioxidant Power, i.e., reduction of ferric ion to ferrous state) was conducted according to the protocol by Oyaizu (1986) [61]. The results of these reactions were measured

by spectrophotometry using a UV–visible spectrophotometer (Zuzi 4255/50, Auxilab, Arlegui, Navarra, Spain) at wavelengths of 734 and 593 nm for ABTS and FRAP, respectively. The antioxidant capacity value of the sample was expressed in mg Trolox eq/100 mL of milk.

2.4. Statistical Analysis

The SCC values were transformed into base ten logarithms for statistical analysis.

The statistical evaluation of the measured variables was performed using a general linear model (PROC GLM, SAS v9.4, 2022), considering the fixed effects of diet, sampling time and their interaction, according to the following Equation (5):

$$Y = \mu + D_i + T_k + (D_i \times T_k) + e \quad (5)$$

where Y is the dependent variable, μ is the intercept, D_i represents the fixed effect of diet (i = Control, 5-WGP, 10-WGP, 15-WGP), T_k is the fixed effect of sampling (k = 0, 1, 2, 3, 4), $D_i \times T_k$ represents the interaction between both effects (8 levels) and e is the residual error.

Least squares means were calculated to interpret differences between levels of the fixed effects. The null hypothesis was rejected at $p < 0.05$, indicating statistically significant differences between levels.

3. Results

3.1. Gross Composition

The inclusion of white grape pomace (WGP) in the diet significantly influenced fat and CP content, NFDM, UDM and milk urea, as can be observed in Table 2. Fat content increased progressively with higher levels of WGP, reaching its peak in the WGP_15 milk (4.422%), which was significantly higher than both the control (4.061%) and the other WGP milks ($p = 0.001$). Similarly, CP content showed a positive trend, with WGP_5 exhibiting the highest value (3.395%), though differences with the other milks were not considered relevant. The NFDM content was significantly greater ($p < 0.0024$) in milk from the control and WGP_5 groups (8.8%) than in milk from WGP_10 and WGP_15 groups (8.6%). The UDM increased significantly in WGP_15 (7.716%) compared to the control (7.443%), indicating an overall enhancement in milk solids ($p < 0.0001$). Milk urea was also influenced by dietary treatment, with WGP_15 milk showing the lowest concentration (608.400 mg/L). All WGP milks presented significantly lower urea levels than control milk (638.600 mg/L) ($p = 0.0008$), although no consistent dose-dependent pattern was observed. Lactose, cholesterol content and LSCC remained unaffected across treatments ($p > 0.05$).

Table 2. Results of statistical analysis (F- and *p*-values) and least square means (±SEM) comparison for gross milk composition and total cholesterol content of milk across dietary treatments.

Item	Diet				SEM	*F-/p-Value*		
	Control	WGP_5	WGP_10	WGP_15		Diet	Sampling	Diet × Sampling
Fat (%)	4.061 ^{c}	4.237 ^{b}	4.183 ^{bc}	4.422 ^{a}	0.053	8.13 $_{0.001}$	41.99 $_{<0.0001}$	1.39 $_{ns}$
Protein (%)	3.382 ^{ab}	3.395 ^{a}	3.264 ^{c}	3.294 ^{bc}	0.030	4.54 $_{0.0139}$	8.51 $_{0.0004}$	0.15 $_{ns}$
Lactose (%)	4.644	4.622	4.641	4.622	0.020	0.37 $_{ns}$	20.64 $_{<0.0001}$	0.19 $_{ns}$
NFDM (%)	8.758 ^{a}	8.773 ^{a}	8.646 ^{b}	8.689 ^{b}	0.023	6.80 $_{0.0024}$	36.68 $_{<0.0001}$	0.35 $_{ns}$
UDM (%)	7.443 ^{b}	7.632 ^{ab}	7.447 ^{b}	7.716 ^{a}	0.066	4.32 $_{0.0168}$	36.75 $_{<0.0001}$	0.70 $_{ns}$
Urea (mg/L)	638.600 ^{a}	607.400 ^{b}	601.000 ^{b}	608.400 ^{b}	6.251	7.24 $_{0.0018}$	7.39 $_{0.0008}$	0.65 $_{ns}$
LSCC (10^3 cells/mL)	2.777	2.846	2.779	2.858	0.103	0.18 $_{ns}$	1.21 $_{ns}$	0.28 $_{ns}$
CHOL (mg/100 g)	18.304	18.120	18.113	18.431	0.221	0.48 $_{ns}$	6.39 $_{0.0002}$	1.89 $_{ns}$

WGP: white grape pomace, WGP_5: diet with 5% of WGP, WGP_10: diet with 10% of WGP, WGP_15: diet with 15% of WGP; SEM: standard error of the mean; NFDM: non-fat dry matter; UDM: useful dry matter (% fat + % protein); LSCC: Log10 somatic cell count; CHOL: total cholesterol content. a–c: Different letters in the same row indicate significant difference between diets; ns: non-significant ($p > 0.05$). F- and *p*-values are reported for the significant effects.

3.2. Mineral Profile

Regarding the mineral profile, only minor differences were found in the K milk content (Table 3), which was higher in WGP_10 (0.163 g/100 g) and WGP_15 (0.153 g/100 g) ($p = 0.0065$). The other minerals analysed did not show significant differences between WGP silage levels.

Table 3. Results of statistical analysis (F- and *p*-values) and least square means (±SEM) comparison for mineral profile of milk across dietary treatments.

Item	Diet				SEM	*F-/p-Value*		
	Control	WGP_5	WGP_10	WGP_15		Diet	Sampling	Diet × Sampling
Ca (g/100 g)	0.176	0.179	0.205	0.189	0.009	2.40 $_{ns}$	3.59 $_{0.011}$	5.69 $_{<0.0001}$
P (g/100 g)	0.151	0.156	0.167	0.155	0.008	0.77 $_{ns}$	1.12 $_{ns}$	2.39 $_{0.003}$
K (g/100 g)	0.137 ^{a}	0.141 ^{ab}	0.163 ^{c}	0.153 ^{bc}	0.006	4.50 $_{0.0065}$	5.42 $_{0.0009}$	6.09 $_{<0.0001}$
Na (g/100 g)	0.040	0.046	0.046	0.086	0.022	0.95 $_{ns}$	0.88 $_{ns}$	1.03 $_{ns}$
Mg (g/100 g)	0.015	0.016	0.017	0.033	0.008	1.00 $_{ns}$	0.9 $_{ns}$	1.04 $_{ns}$

WGP: white grape pomace, WGP_5: diet with 5% of WGP, WGP_10: diet with 10% of WGP, WGP_15: diet with 15% of WGP. SEM: Standard Error of the Mean. a–c: Different letters in the same row indicate significant difference between diets; ns: non-significant ($p > 0.05$). F- and *p*-values are reported for the significant effects.

3.3. Fatty Acids Profile

The major milk fatty acids quantified in this experiment are listed in Table 4. C12:0, C:14, C16:0, C18:3n3, SFA, IA, TI, HFA, OLESTE and CLAVACC significantly decreased ($p < 0.0001$) as the proportion of WGP in the diet increased. Conversely, MUFA, n6/n3, LA/ALA, UI, HH and HPI significantly increased ($p < 0.0001$) with higher dietary inclusion of WGP. C18:2n6 ($p < 0.0001$) and PUFA ($p = 0.0265$) were consistently higher in WGP milks compared to the control. Moreover, C4:0, C18:0, C18:1c9 and C18:1t11 were significantly higher ($p < 0.0001$) in WGP_15 milk, while C16:1c9 ($p < 0.0001$) and C24:0 ($p = 0.0195$) were significantly lower in WGP_15 milk.

Table 4. Results of statistical analysis (F- and *p*-values) and least square means (±SEM) comparison for fatty acids profile (percentages of the methylated fatty acid area in the fatty acid profile) and nutritional and health-related indices of milk across dietary treatments.

Item	Diet				SEM	*F-/p-Value*		
	Control	WGP_5	WGP_10	WGP_15		Diet	Sampling	Diet × Sampling
C4:0	1.110 ^{a}	1.067 ^{a}	1.059 ^{a}	1.172 ^{b}	0.025	4.31 $_{0.0081}$	2.66 $_{0.041}$	1.01 $_{ns}$
C6:0	1.903	1.777	1.816	1.905	0.040	2.53 $_{ns}$	1.06 $_{ns}$	1.45 $_{ns}$
C12:0	5.302 ^{a}	4.932 ^{b}	4.861 ^{b}	4.485 ^{c}	0.072	21.84 $_{<0.0001}$	2.15 $_{ns}$	1.68 $_{ns}$
C14:0	9.867 ^{a}	9.534 ^{b}	9.393 ^{bc}	9.258 ^{c}	0.062	17.61 $_{<0.0001}$	3.57 $_{0.0111}$	2.95 $_{0.0028}$
C16:0	28.857 ^{a}	27.778 ^{b}	27.682 ^{b}	26.930 ^{c}	0.132	36.36 $_{<0.0001}$	11.80 $_{<0.0001}$	4.95 $_{<0.0001}$
C16:1c9	0.557 ^{a}	0.580 ^{b}	0.555 ^{a}	0.492 ^{c}	0.007	26.00 $_{<0.0001}$	3.33 $_{0.0165}$	3.51 $_{0.0006}$
C18:0	7.023 ^{a}	7.982 ^{b}	7.961 ^{b}	9.089 ^{c}	0.123	47.42 $_{<0.0001}$	8.06 $_{<0.0001}$	4.31 $_{<0.0001}$
C18:1c9	12.713 ^{a}	13.559 ^{b}	13.239 ^{b}	14.072 ^{c}	0.139	16.82 $_{<0.0001}$	8.36 $_{<0.0001}$	1.91 $_{ns}$
C18:1c11	0.508	0.551	0.545	0.573	0.014	1.95 $_{ns}$	4.25 $_{0.0043}$	0.96 $_{ns}$
C18:2n6	3.295 ^{a}	3.431 ^{b}	3.602 ^{c}	3.563 ^{c}	0.033	17.99 $_{<0.0001}$	9.84 $_{<0.0001}$	1.50 $_{ns}$
C18:3n3	0.331 ^{a}	0.313 ^{b}	0.270 ^{c}	0.257 ^{d}	0.004	78.49 $_{<0.0001}$	45.67 $_{<0.0001}$	7.57 $_{<0.0001}$
C18:1 t11	2.373 ^{a}	2.716 ^{b}	2.528 ^{b}	2.946 ^{c}	0.064	24.04 $_{<0.0001}$	13.72 $_{<0.0001}$	3.05 $_{0.0021}$
CLA c9 t11	0.942 ^{a}	1.021 ^{b}	0.966 ^{a}	0.984 ^{ab}	0.023	8.71 $_{<0.0001}$	20.16 $_{<0.0001}$	1.90 $_{ns}$
C20:0	0.138	0.151	0.140	0.152	0.005	1.98 $_{ns}$	5.28 $_{0.0010}$	0.46 $_{ns}$
C20:1n9	0.054	0.060	0.061	0.059	0.003	1.49 $_{ns}$	0.91 $_{ns}$	1.00 $_{ns}$

Table 4. *Cont.*

Item	Diet				SEM	*F-/p-Value*		
	Control	WGP_5	WGP_10	WGP_15		Diet	Sampling	Diet × Sampling
C22:0	0.031	0.039	0.038	0.036	0.003	1.75 $_{ns}$	6.86 $_{0.0001}$	2.52 $_{0.0094}$
C24:0	0.016 ^{a}	0.019 ^{a}	0.017 ^{a}	0.013 ^{b}	0.002	3.56 $_{0.0195}$	13.53 $_{<0.0001}$	3.48 $_{0.0006}$
SFA	72.165 ^{a}	70.049 ^{b}	69.749 ^{b}	69.472 ^{b}	0.285	18.56 $_{<0.0001}$	2.31 $_{ns}$	1.69 $_{ns}$
MUFA	21.694 ^{a}	23.607 ^{b}	23.959 ^{b}	24.253 ^{b}	0.263	19.19 $_{<0.0001}$	2.51 $_{ns}$	1.45 $_{ns}$
PUFA	5.478 ^{a}	5.733 ^{b}	5.676 ^{b}	5.705 ^{b}	0.064	3.29 $_{0.0265}$	13.15 $_{<0.0001}$	1.52 $_{ns}$
n6n3	10.656 ^{a}	11.738 ^{b}	14.363 ^{c}	15.017 ^{d}	0.154	182.45 $_{<0.0001}$	92.70 $_{<0.0001}$	11.31 $_{<0.0001}$
LA/ALA	10.085 ^{a}	11.086 ^{b}	13.578 ^{c}	14.234 ^{d}	0.147	181.68 $_{<0.0001}$	90.66 $_{<0.0001}$	11.83 $_{<0.0001}$
UI	31.319 ^{a}	33.512 ^{b}	34.067 ^{b}	34.180 ^{b}	0.382	12.20 $_{<0.0001}$	3.02 $_{0.0246}$	1.06 $_{ns}$
IA	2.728 ^{a}	2.4162 ^{b}	2.378 ^{bc}	2.292 ^{c}	0.041	21.89 $_{<0.0001}$	2.33 $_{0.066}$	1.64 $_{ns}$
TI	3.359 ^{a}	3.094 ^{b}	3.063 ^{b}	3.057 ^{b}	0.041	12.58 $_{<0.0001}$	4.06 $_{0.0056}$	1.47 $_{ns}$
HFA	44.026 ^{a}	42.246 ^{b}	41.937 ^{b}	40.674 ^{c}	0.142	93.18 $_{<0.0001}$	3.58 $_{0.011}$	8.33 $_{<0.0001}$
HH	0.437 ^{a}	0.485 ^{b}	0.478 ^{b}	0.515 ^{c}	0.006	31.05 $_{<0.0001}$	8.48 $_{<0.0001}$	2.63 $_{0.0069}$
HPI	0.370 ^{a}	0.414 ^{b}	0.423 ^{bc}	0.439 ^{c}	0.006	26.35 $_{<0.0001}$	2.78 $_{0.0347}$	2.24 $_{0.0204}$
OLESTE	1.825 ^{a}	1.712 ^{b}	1.680 ^{b}	1.557 ^{c}	0.026	18.01 $_{<0.0001}$	22.24 $_{<0.0001}$	2.36 $_{0.0145}$
CLAVACC	0.436 ^{a}	0.413 ^{a}	0.418 ^{a}	0.360 ^{b}	0.008	15.43 $_{<0.0001}$	18.80 $_{<0.0001}$	1.28 $_{ns}$
OBCFA	3.567 ^{a}	3.352 ^{b}	3.276 ^{b}	2.966 ^{c}	0.027	82.59 $_{<0.0001}$	19.25 $_{<0.0001}$	4.33 $_{<0.0001}$

WGP: white grape pomace, WGP_5: diet with 5% of WGP, WGP_10: diet with 10% of WGP, WGP_15: diet with 15% of WGP; SEM: Standard Error of the Mean. CLA: conjugated linoleic acid; SFA: saturated fatty acid; MUFA: monounsaturated fatty acid; PUFA: polyunsaturated fatty acid; n6n3: ω-6/ω-3 fatty acid ratio; LAALA: linoleic acid/α-linolenic acid ratio; UI: unsaturation index; IA: Index of Atherogenicity; IT: Index of Thrombogenicity; HFA: Hypercholesterolemic Index; HH: hypocholesterolemic/hypercholesterolemic ratio; HPI: health-promoting index; OLESTE: oleic to stearic acid ratio; CLAVACC: conjugated linoleic acid to vaccenic acid ratio; OBCFAs: odd- and branched-chain fatty acids. SEM: Standard Error of the Mean. a–d: Different letters in the same row indicate significant difference between diets; ns: non-significant ($p > 0.05$). F- and *p*-values are reported for the significant effects.

3.4. Milk Coagulation Properties

As shown in Table 5, the aggregation rate was significantly lower in WGP_10 (1.359 mm/min) and WGP_15 (1.383 mm/min), without significant differences to the control (1.404 mm/min), while WGP_5 exhibited the highest aggregation rate ($p = 0.0127$). No significant differences ($p < 0.05$) were obtained between dietary treatments in rennet coagulation time nor in curd firmness.

Table 5. Results of statistical analysis (F- and *p*-values) and least square means (±SEM) comparison for milk coagulation properties and pH across dietary treatments.

Item	Diet				SEM	*F-/p-Value*		
	Control	WGP_5	WGP_10	WGP_15		Diet	Sampling	Diet × Sampling
Rennet coagulation time (min)	8.66	8.78	8.97	8.77	0.443	0.54 $_{ns}$	46.33 $_{<0.0001}$	0.63 $_{ns}$
Curd firmness (mm)	9.548	10.375	9.702	9.363	0.099	1.12 $_{ns}$	12.24 $_{<0.0001}$	0.26 $_{ns}$
Aggregation rate (mm/min)	1.404 ^{a}	1.591 ^{b}	1.359 ^{a}	1.383 ^{a}	0.305	3.76 $_{0.0127}$	52.74 $_{<0.0001}$	0.25 $_{ns}$
pH	6.749 ^{a}	6.697 ^{c}	6.723 ^{b}	6.730 ^{b}	0.007	9.55 $_{<0.0001}$	8.48 $_{<0.0001}$	2.36 $_{0.0148}$

WGP: white grape pomace, WGP_5: diet with 5% of WGP, WGP_10: diet with 10% of WGP, WGP_15: diet with 15% of WGP. SEM: Standard Error of the Mean. a–c: Different letters in the same row indicate significant difference between diets; ns: non-significant ($p > 0.05$). F- and *p*-values are reported for the significant effects.

Table 5 also presents milk pH values, with control milk showing the highest pH (6.749), and WGP_5 milk presenting the lowest pH values (6.697) ($p < 0.0001$).

3.5. Colorimetric Parameters

Colorimetric parameters are presented in Table 6. The inclusion of WGP in the diet significantly affected milk colour, as reflected in the a, b, h*, C* coordinates and YI. Values for a*, b* and C* decreased significantly in all WGP milks compared to the control ($p < 0.0001$), while h* was significantly higher in all WGP treatments ($p < 0.0001$). The YI showed a dose-dependent response, decreasing significantly with increasing dietary WGP levels ($p < 0.0001$). Control milk exhibited the highest YI compared to all WGP milks ($p < 0.0001$).

Table 6. Results of statistical analysis (F- and *p*-values) and least square means (±SEM) comparison for colorimetric parameters across dietary treatments.

Item	Diet				SEM	*F-/p-Value*		
	Control	WGP_5	WGP_10	WGP_15		Diet	Sampling	Diet × Sampling
L*	86.033	86.158	86.104	85.958	0.079	1.20 $_{ns}$	8.97 $_{<0.0001}$	1.31 $_{ns}$
a*	−1.309 ^{a}	−1.347 ^{b}	−1.356 ^{b}	−1.417 ^{c}	0.013	10.94 $_{<0.0001}$	39.84 $_{<0.0001}$	2.47 $_{0.01}$
b*	5.107 ^{a}	4.699 ^{b}	4.988 ^{c}	4.831 ^{d}	0.038	21.98 $_{<0.0001}$	19.75 $_{<0.0001}$	2.98 $_{0.001}$
h*	104.425 ^{a}	106.094 ^{b}	105.292 ^{c}	106.387 ^{b}	0.218	16.37 $_{<0.0001}$	31.06 $_{<0.0001}$	2.86 $_{0.0015}$
C*	5.274 ^{a}	4.890 ^{b}	5.173 ^{c}	5.037 ^{d}	0.036	21.77 $_{<0.0001}$	19.31 $_{<0.0001}$	3.02 $_{0.0009}$
WI	85.07	85.32	85.17	85.08	0.072	2.57 $_{ns}$	10.48 $_{<0.0001}$	1.14 $_{ns}$
YI	8.480 ^{a}	8.390 ^{b}	8.275 ^{c}	8.029 ^{d}	0.061	23.70 $_{<0.0001}$	21.19 $_{<0.0001}$	2.93 $_{0.0012}$

WGP: white grape pomace, WGP_5: diet with 5% of WGP, WGP_10: diet with 10% of WGP, WGP_15: diet with 15% of WGP; SEM: Standard Error of the Mean; L*: lightness; a*: red/green coordinate; b*: yellow/blue coordinate; h*: angle; C*: chroma; WIs: whiteness indices; YIs: yellowness indices. SEM: Standard Error of the Mean. a–d: Different letters in the same row indicate significant difference between diets; ns: non-significant ($p > 0.05$). F- and *p*-values are reported for the significant effects.

3.6. Antioxidant Activity

The ABTS radical scavenging potential was significantly higher ($p < 0.0001$) in WGP_10 milk (6.557 mg Trolox eq/100 mL) and WGP_15 milk (6.318 mg Trolox eq/100 mL) compared to control milk (6.041 mg Trolox eq/100 mL). In contrast, WGP_5 milk exhibited the lowest ABTS antioxidant capacity (5.721 mg Trolox eq/100 mL) ($p < 0.0001$). A similar trend was observed for the FRAP analysis, as shown in Table 7. FRAP values were significantly higher ($p < 0.0001$) in WGP_10 (5.175 mg Trolox eq/100 mL) and WGP_15 (5.416 mg Trolox eq/100 mL) milks compared to the control (5.057 mg Trolox eq/100 mL) and WGP_5, which again showed the lowest FRAP potential (4.984 mg Trolox eq/100 mL).

Table 7. Results of statistical analysis (F- and *p*-values) and least square means (±SEM) comparison for antioxidant activity of milk across dietary treatments expressed in mg Trolox eq/100 mL.

Item	Diet				SEM	*F-/p-Value*		
	Control	WGP_5	WGP_10	WGP_15		Diet	Sampling	Diet × Sampling
ABTS	6.041 ^{a}	5.721 ^{b}	6.557 ^{c}	6.318 ^{c}	0.115	10.1 $_{<0.0001}$	38.67 $_{<0.0001}$	2.19 $_{0.0153}$
FRAP	5.057 ^{a}	4.984 ^{b}	5.175 ^{c}	5.416 ^{d}	0.020	216.61 $_{<0.0001}$	41.08 $_{<0.0001}$	25.25 $_{<0.0001}$

WGP: white grape pomace, WGP_5: diet with 5% of WGP, WGP_10: diet with 10% of WGP, WGP_15: diet with 15% of WGP; a–d: Different letters in the same row indicate significant difference between diets. SEM: Standard Error of the Mean.

The sampling-related significant differences observed in milk parameters may be attributed to the physiological progression of lactation, which is known to influence milk composition and physical properties independently of dietary treatment.

4. Discussion

Regarding milk chemical composition, slight numerical improvements were observed following increased intake of WGP. It is well established that enhancing dietary fibre content promotes milk fat synthesis [62], and in the present study, WGP inclusion effectively increased the fibre content of the diets. This effect was further reinforced by the concomitant rise in dietary fat content associated with higher WGP inclusion levels, a factor directly correlated with milk fat concentration [63]. As a result, milk from WGP-fed animals exhibited a higher fat content. Variations in UDM were directly linked to the changes observed in milk fat content. Nevertheless, the observed differences were minor, as their magnitude was limited and they had no detectable influence on the technological properties of the milk. In this study, WGP silage inclusion was strictly regulated (up to 15%), and although significant differences were detected, further research is warranted to evaluate the effects of higher inclusion rates and to better characterize the potential of WGP to enhance gross composition and especially milk fat yield.

The scientific literature reports heterogeneous findings regarding the effects of incorporating various agricultural by-products into dairy goat diets on milk composition. Studies involving non-ensiled by-products—such as tomato fruits, citrus pulp, brewer's grain and yeast—have documented significant differences in milk composition, including increased levels of protein, casein and total solids compared to milk from goats fed conventional diets, upon replacement of 47% of the cereal-based concentrate [64]. Previously, the same authors [65] had only observed changes in lactose content when tomato and cucumber by-products were included in the diet, replacing 35% of the cereal-based concentrate. Monllor et al. [17] reported that milk from goats fed diets containing 40% ensiled artichoke by-product exhibited similar average values for fat, CP, UDM, NFDM, total solids (TS), casein and lactose compared to control milk. Although the literature on grape pomace inclusion and its effects on milk quality and composition remains inconclusive, most studies support its suitability for this purpose. Antunovic et al. [66] observed increased protein and fat content in milk from goats fed diets supplemented with up to 10% grape seed cake; however, as in the present study, these differences were not considered technologically relevant. This finding is consistent with Nudda et al. [67] and Manso et al. [68], who reported no increase in milk fat content when 300 g/day of grape seeds and up to 100 g/kg of grape pomace were incorporated, respectively. In contrast, Badiee Baghsiyah et al. [69] documented a reduction in milk fat and protein percentages in Saanen goats fed diets containing 10% dried grape pomace.

The milk mineral profiles observed across all dietary treatments were consistent with those previously reported by Guo [70] for goat milk. Accordingly, the inclusion of ensiled white grape pomace (WGP) had no discernible impact on the mineral composition of the milk, mirroring the findings of Monllor et al. [42], who reported similar outcomes when incorporating silages derived from other agroindustrial by-products also into the diets of Murciano-Granadina dairy goats.

Lower milk urea concentrations observed in the WGP-fed groups represent a relevant physiological response, which may be primarily attributed to enhanced nitrogen utilization—likely resulting from improved synchrony between rumen-degradable protein and fermentable carbohydrates. However, multiple factors may contribute to this outcome. The main determinants of milk urea formation are CP intake and the dietary protein-to-energy ratio [71]. In the present study, both diets were formulated to be isoenergetic and isoproteic, thereby minimizing confounding effects from these variables. Another factor influencing milk urea concentration is the dietary content of NDF, which was higher in diets with greater WGP inclusion [72]. According to Bonanno et al. [73], NDF and milk urea levels are negatively correlated—under isoproteic conditions—, which may explain

the lower urea values observed in the WGP_15 group. Additionally, WGP is rich in tannins [24,27], which bind to proteins in the rumen, forming complexes that hinder ruminal protein degradation [29,30]. This interaction reduces ruminal ammonia (NH_3) production, which is subsequently metabolised in the liver, with urea as the primary excretory product of this pathway [28].

The fatty acid profile of milk from goats reported in this experiment was comparable to that reported by Stergiadis et al. [74] for typical goat milk. Moreover, the fatty acid composition observed in WGP-derived milk was closely linked to the lipid profile of the corresponding WGP-based diets, as previously described by Nudda et al. [75] and Correddu et al. [76]. The inclusion of WGP in the diet increased the concentration of vaccenic acid (C18:1 t11) in milk, primarily due to the higher oleic acid content in the feed, which serves as a precursor for Δ9-C18-desaturase activity involved in vaccenic acid synthesis [77]. This increase represents an improvement in the milk's lipid profile, which became more pronounced with higher levels of WGP inclusion. The elevated concentration of total polyphenols in WGP diets also contributed to increased levels of vaccenic acid and polyunsaturated fatty acids (PUFAs), likely due to their inhibitory effect on ruminal fatty acid biohydrogenation [78]. Additionally, the higher concentrations of other fatty acids in milk, such as linoleic acid (C18:2n6), were directly associated with their increased presence in the WGP-based diets [77]. These findings support the notion that the lipid profile of WGP exerts a direct influence on milk fatty acid composition.

Considering that WGP milk exhibited lower values for AI, TI, HFA and HH, alongside higher levels of UI, HH and HPI, it is noteworthy that WGP consumption improved milk quality in terms of cardiovascular and metabolic health potential [79–81]. The lower saturated fatty acid and higher unsaturated fatty acid content in WGP milk compared to the control further support this improvement [57,82,83]. These effects were dose dependent, becoming more pronounced with increasing levels of WGP inclusion in the diet. These results agree with other studies incorporating grape pomace into animal diets that have also reported a positive trend in the lipid profile of milk, with implications for human nutrition and health [68,84–87].

Regarding milk coagulation properties, the following differences were observed: milk from goats fed the WGP-5 diet exhibited a lower pH and a faster curd aggregation rate compared to other treatments. This behaviour is consistent with the enhanced enzymatic efficiency under acidic conditions, which reduces electrostatic repulsion between casein micelles and promotes κ-casein hydrolysis by chymosin [88,89]. Given the micellar structure of goat milk—more sensitive to pH shifts than bovine milk—, this effect may be further amplified [90].

Milk colour is influenced by factors such as the dispersion state of milk fat globules [91] and the concentration of natural milk pigments [92]. Moreover, the dispersion state of milk fat directly affects the physicochemical properties of dairy products [91]. The L* coordinate is primarily determined by the physical structure of milk, including the dispersion of casein micelles and fat globules [93]; therefore, WGP consumption did not appear to alter milk luminosity. The a* and b* coordinates are associated with the concentration of natural pigments in goat milk. The main pigments include riboflavin (green hue), β-carotene (yellow colouration), and, to a lesser extent, lutein [93]. In goat and sheep milk, the characteristic white colour results from the complete conversion of β-carotene into retinol [91]. Differences in a*, b* and chroma (C*) values between diets may be attributed to slight variations in pigment concentration. Notably, the yellow coordinate (b*) and colour saturation (C*) decreased in WGP milk, contributing to the lower YI observed in these samples. These findings suggest that replacing conventional feed ingredients with WGP may influence expected milk pigmentation. However, it is important to note that

such differences (>0.5 units) are imperceptible to the human eye and therefore considered irrelevant from an organoleptic standpoint.

Milk from goats fed higher levels of white grape pomace (WGP) exhibited slightly enhanced ABTS radical scavenging activity and FRAP. These effects can be directly attributed to the increased total polyphenol content of the WGP diets, resulting from the naturally high concentration of these compounds in grape pomace [23,24,26]. These bioactive compounds are well known for their strong antioxidant properties [25–27], which, as previously suggested, may be transferred to animal-derived products through dietary intake [29–31]. Similar findings were reported by Muelas et al. [94], who observed improved ABTS radical scavenging capacity in raw milk from the same goat breed when animals were fed diets containing 40% agroindustrial by-products silage. Despite their relevance, antioxidant assays have not been widely applied to fresh goat milk samples.

Most studies report only minor or negligible alterations in commercial milk composition, with outcomes largely influenced by the extent of dietary replacement with agroindustrial by-products. In cases where compositional shifts are minimal, the technological properties of milk are generally preserved.

5. Conclusions

White grape pomace silage can be successfully incorporated into balanced diets for dairy goats, replacing up to 15% of conventional ingredients without inducing significant changes in milk composition or its technological properties. The negligible alterations observed in overall milk composition are the primary factor contributing to the preservation of its processing characteristics. Meanwhile, the milk fatty acid profile was positively influenced by the inclusion of WGP silage, resulting in improved health-related indexes, particularly due to the higher degree of unsaturation in its fatty acid composition. Further research is needed to investigate higher inclusion levels of WGP silage and its long-term effects, to establish solid evidence on its impact on milk and dairy product production for human consumption.

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Abbreviations

ABTS	2.2′-azino-bis(3-ethylbenzothiazoline-6-sulfonate)
ADF	Acid detergent fibre
ADL	Acid detergent lignin
AOAC	Association of Official Analytical Chemists
CHOL	Cholesterol
CLA	Conjugated linoleic acid
CLAVACC	CLA/Vaccenic acid
CP	Crude protein
DM	Dry matter
EE	Ether extract
FRAP	Ferric Reducing Antioxidant Power
HFA	Hypercholesterolemic fatty acids
HH	Hypocholesterolemic/Hypercholesterolemic ratio
HPI	Health-promoting index
IA	Atherogenic index
ISO	International Standardization Organization
LA/ALA	Linoleic/Alpha-linolenic ratio
LSCC	Log10 somatic cell count
MUFA	Monounsaturated fatty acids
NDF	Neutral detergent fibre
NFDM	Non-fat dry matter
OBCFA	Odd- and branched-chain fatty acids
OM	Organic matter
OLESTE	Oleic acid/stearic acid
PUFA	Polyunsaturated fatty acids
SCC	Somatic cell count
SEM	Standard Error of the Mean
SFA	Saturated fatty acids
TI	Thrombogenic index
TS	Total solids
UDM	Useful dry matter
UI	Unsaturation index
VFAs	Volatile fatty acids
WGP	White grape pomace
WI	Whiteness index
YI	Yellowness index

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