Effects of Intensive and Semi-Intensive Production on Sheep Milk Chemical Composition, Physicochemical Characteristics, Fatty Acid Profile, and Nutritional Indices

Eleni Kasapidou 1,*, Zoitsa Basdagianni 2, Vasileios Papadopoulos 1, Chrysoula Karaiskou 2, Anastasios Kesidis 1 and Arsenios Tsiotsias 1

Simple Summary: Intensive and semi-intensive sheep farming are the two farming systems usually employed in Greece. Several studies have been conducted on the effect of the farming system on sheep milk fatty acid composition. This study simultaneously examines milk basic composition, physicochemical characteristics, fatty acid composition, and nutritional value according to the production system. Bulk tank milk from farms using the intensive and semi-intensive production systems was analyzed. The results show that grazing can improve the fatty acid composition of milk. Thus, pasture-based feeding strategies could improve the fatty acid composition and the nutritional properties of sheep dairy products.

Abstract: Dairy sheep farming is a vital sector of the agricultural economy in Greece. Information on the effect of the farming system on sheep milk characteristics is critical for producing dairy products with improved nutritional value according to the current guidelines for healthy food consumption. This study aimed to investigate the basic composition, physicochemical characteristics, fatty acid composition, and nutritional indices of milk produced in intensive and semi-intensive sheep farms. Bulk tank milk samples from 20 intensive and 20 semi-intensive sheep farms were examined. Sheep in the intensive farms were kept indoors and were fed with roughage, silage, and concentrates. Sheep in the semi-intensive farms were kept indoors during the night and were moved to the pastures during the day. Sheep were fed with roughage, silage, and concentrates in combination with grazing. Milk composition and somatic cell count were determined with automatic analyzers. The physicochemical characteristics were determined with standard laboratory methods. The fatty acid composition was analyzed by gas chromatography. The farming system did not affect milk chemical composition and physicochemical characteristics. However, milk fatty acid composition and nutritional value were significantly improved in milk from farms using the semi-intensive production system, and this favorable effect was attributed to the inclusion of pasture in sheep diet.

Keywords: sheep milk; intensive production; semi-intensive; chemical composition; physicochemical characteristics; fatty acid composition; nutritional value

1. Introduction

Sheep breeding has a significant economic impact in the rural mountainous areas of Greece, and thus, there are 6.5 million dairy ewes [1] that produce approximately 650 million (tons) of milk annually [2]. The majority of sheep milk (90%) is converted into highly valued cheeses such as the well-known Feta cheese that is the most important export product of the Greek primary sector [3]. Sheep milk quality is primarily related to its processing performance, i.e., its capability to produce high yields of improved quality
dairy products [4]. In this respect, information on the composition, physicochemical properties, and nutritional value of sheep milk is critical for the dairy industry and the quality characteristics of the dairy products. On the other hand, there is growing consumer interest in dairy products’ nutritional and health aspects [5]. Furthermore, the quality characteristics of sheep milk are also crucial for the farmers, since Greek dairy factories qualitatively classify the produced milk and pay the farmers accordingly. The quality of sheep milk is affected by several factors such as genetics (breed and genotype), animal health, physiological (age and parity, lactation stage), environmental (season), and management (type of feed, farming system, milking techniques) aspects as well as their interactions [6–8].

With regard to the farming system, Hatziminaoglou et al. [9] classified the sheep production system in Greece as follows; (a) sedentary extensive, (b) transhumant, (c) semi-intensive, and (d) small intensive. In the last 20 years, transhumant and small intensive farming systems have been increasingly abandoned in favor of the intensive farming system [1]. However, the implementation of the intensive system results in higher feeding and structural expenses per ewe. Thus, a good alternative is a mixed feeding regime that combines grazing and a concentrate supplement [7,10]. Pasture feeding has a desirable effect on the flavor, antioxidant properties, and fatty acid profile of the produced dairy products [11–14]. According to Hadjigeorgiou [15], in Greece, more than 75% of the sheep farms are located in mountainous and less-favored areas where animal nutrition is still based on the use of the available rough grazing lands. Flocks graze natural pastures with native flora. According to the same author, the distribution of farms according to the farming system is 5% nomadic, 50% semi-extensive, 30% semi-intensive, and 15% home-fed. In the recent countrywide study of Lianou et al. [16] on milk hygiene from sheep flocks, the distribution of farms according to the production system was as follows: extensive 7%, semi-extensive 46%, semi-intensive 33%, and intensive 13%. As seen, the application of extensive and semi-extensive systems is declining, whereas the application of the semi-intensive system is increasing, and the application of the intensive system remains constant. Modern farmers prefer to keep their animals in facilities near their houses and feed them with either home-produced or commercial feeds while animals are allowed to graze in the nearby field. Finally, the semi-intensive farming system is popular in Greece because it allows farmers to lower the feeding costs.

The effect of the farming system on milk chemical composition, physicochemical characteristics, and fatty acid composition of commercially produced milk has not been extensively studied. Additionally, to our knowledge, no published data have simultaneously studied these groups of variables, enabling the production of milk with improved processing performance and a healthier lipid profile according to the current nutritional recommendations.

The objective of this study was to offer updated information on the chemical composition, physicochemical characteristics, fatty acid composition, and nutritional value of sheep milk produced in commercial farms using the intensive and semi-intensive farming system.

2. Materials and Methods

2.1. Sampling and Sample Processing

The study was carried out in dairy sheep farms located in the Regional Unit of Florina, Greece (40°46′58″ N 21°24′32″ E and altitude approximately 600 m) in the period from late May to late June 2019 and lasted 28 days. The Agricultural Veterinary Bureau of Aminteo supervised the farms. Farms were classified according to the European Food Safety Authority system [17]. Thus, animals in the intensive farms were kept in permanent housing with no access to pasture and were fed with roughage, silage, and concentrates. Animals in the semi-intensive farms were kept indoors during the night and some part of the day and were moved to the pastures during some period of the day. Sheep were fed with roughage, silage, and concentrates, in combination with grazing. The concentrates offered to the animals were either commercially produced, home-produced, or a combination of commercially and home-produced. Detailed information on the type of concentrate feed,
Animals 2021, 11, 2578

grazing species and duration of grazing was not recorded. Sheep in all farms, participating in the study, were crossbred animals.

Bulk tank milk samples from 20 intensive and 20 semi-intensive sheep farms were collected. Dairy sheep farms were selected on a convenience basis, i.e., willingness of the farmers to collaborate in the study and to allow sample collection. Milk in the tanks was manually mixed with a plunger to achieve homogeneity before sampling. Samples (2 from each farm) were collected in 50 mL plastic screw-capped flasks, placed in isothermal containers with ice packs, and transported to the laboratory within 4 h following collection. Both samples were collected in the same day. Samples aimed for analyzing Somatic Cell Count (SCC), chemical composition, and physicochemical characteristics were kept at 4 °C and analyzed within 24 h following collection. Sodium azide (0.01 g/100 mL) was added as a preservative to the milk samples destined to determine Somatic Cell Count. Samples aimed for the determination of fatty acid composition were kept at −20 °C until analyzed.

2.2. Milk Chemical Composition and Somatic Cell Count

Milk composition (fat, protein, lactose, and total solids content) was determined by infrared analysis (FTIR interferometer), using a Milkoscan FT6000 Analyzer (Foss Electric, Hillerød, Denmark). Milk moisture content was calculated by deducting the total solids content from 100, and milk ash content was calculated by deducting fat, protein, and lactose contents from the total solids content. The ratio fat content/protein content was also determined. Somatic Cell Count (SCC) was determined with a Fossomatic 5000 instrument (Foss Electric, Hillerød, Denmark), and the obtained data were log-transformed to normalize the distribution.

2.3. Milk Physicochemical Properties

Before analysis, the samples were placed in a heated water bath to reach room temperature and, following that, they were thoroughly mixed by gentle inversion of the sample container multiple times without causing frothing. Milk pH was measured using a glass electrode with a built-in temperature sensor (5014T electrode, Crison, Barcelona, Spain) in a Crison GLP 21 pH-meter (Barcelona, Spain), which was calibrated with standard buffer solutions at pH 4.0 and 7.0 according to the manufacturer’s instructions. The electrical conductivity of the samples was measured by a GLP 31 conductometer (Crison Instruments, Barcelona, Spain) using a Sodium Ion-Selective Electrode 9650, calibrated with 147 µS/cm, 1413 µS/cm, and 12.88 mS/cm buffer solutions. Refractive index and Brix value were determined using a digital refractometer (DR6000-T, Krüss, Hamburg, Germany) set at 20 °C.

2.4. Milk Fatty Acid Composition

Fatty acid composition was determined by gas chromatography (GC) as described by Papaloukas et al. [18]. Briefly, lipids were extracted with a chloroform/methanol solution (1:2 v/v) that contained 0.01% (w/v) of t-butyl-hydroxytoluene (BHT) to prevent fatty acid oxidation during extraction, according to the Bligh and Dyer method [19]. Fatty acid methyl esters were prepared from the extracted lipids by base-catalyzed methanolysis of the glycerides using KOH in methanol, according to the method ISO-IDF 15884 [20] of the International Organization for Standardization. Fatty acid methyl ester analysis was performed on an Agilent Technologies 6890N GC equipped with a flame ionization detector (FID) and a 60 m × 0.25 mm i.d., 0.25 μm film thickness DB-23 (50% Cyanopropyl 50% dimethyl polysiloxane) capillary column (Model Number: Agilent 122 2362). The injector temperature was set at 250 °C. The oven temperature was programmed to increase from 110 °C (held for 6 min) to 165 °C at 1 °C/min (held for 13 min), to 195 °C at 15 °C/min (held for 22 min), and to 230 °C at 7 °C/min (held for 7 min). The carrier gas was helium at 0.7 mL/min, the injection volume was set at 3 μL, and the split ratio was 1:50. The injection was performed using an Agilent 7683 Series auto-sampler. Fatty acids were identified using three commercial standard mixtures: (a) 37-component FAME mix
Animals 2021, 11, 2578

(Supelco, 47885-U), (b) PUFA-2, Animal source (Supelco, 47015-U), and (c) a mixture of cis- and trans-9,11- and -10,12-octadecadienoic acid methyl esters (Sigma-Aldrich, O5632-250MG) as reference standards. Fatty acids were quantified by peak area measurement, and the results were expressed as percent (%) of the total peak areas for all quantified acids. Fatty acids were grouped as saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA), and unsaturated fatty acids (UFA).

2.5. Milk Lipid Quality Nutritional Indices

The milk fatty acid profile was used to calculate the following indices related to healthy fat consumption. In addition, all nutritional indices were used to assess the nutritional value of milk and other dairy products in various studies.

The hypocholesterolemic/hypercholesterolemic fatty acid ratio (h/H) ratio was calculated according to the formula reported by Chen and Liu [21]:

\[ h/H = \frac{(C18:1 \text{ cis} + \sum \text{PUFA})}{(C12:0 + C14:0 + C16:0)} \]

The atherogenicity (AI) and thrombogenicity (TI) indices were calculated according to the following formulae proposed by Ulbricht and Southgate [22]:

\[ AI = \frac{[C12:0 + (4 \times C14:0) + C16:0]}{\sum \text{UFA}} \]

\[ TI = \frac{(C14:0 + C16:0 + C18:0)/[0.5 \times \sum \text{MUFA} + (0.5 \times \sum \text{n-6 PUFA}) + (3 \times \sum \text{n-3 PUFA}) + (n-3/n-6)]}{(C12:0 + (4 \times C14:0) + C16:0)} \]

The health-promoting index (HPI), was proposed by Chen et al. [23], was calculated according to the formula:

\[ HPI = \frac{\sum \text{UFA}}{C12:0 + (4 \times C14:0) + C16:0} \]

The Desirable Fatty Acid (DFA) index was calculated according to the formula of Rhee [24] as follows:

\[ DFA = \sum \text{UFA} + C18:0 \]

2.6. Statistical Analysis

One-factor variance analysis was employed for the comparisons between the farming systems. Correlations between SCC and milk composition were calculated as Pearson’s correlations. SPSS software (version 26.0, SPSS Inc., Chicago, IL, USA) was used for data analysis. The results were considered to be significant when the \( p \)-values were <0.05.

3. Results and Discussion

3.1. Milk Chemical Composition

Milk from the semi-intensive system had a higher but non significantly different \( (p \geq 0.05) \) ash, fat, and protein content and a lower lactose content compared to intensively produced milk (Table 1). De Renobales et al. [11] also reported that part-time grazing did not affect milk gross chemical composition in relation to milk from ewes kept indoors. However, in a similar study conducted in the same area, it was found that milk protein, fat, lactose, and ash contents were significantly lower in milk from intensive farms than in that from semi-intensive farms [25]. It is important to note that the average milk composition from both production systems has significantly lower values than the those reported by Wendorff and Haenlein [26] for milk from Greek sheep breeds (7.88% fat, 6.22% protein, 0.92% ash, and 19.43% total solids). In our study, the average lactose content was higher than the one reported in the latter study (4.42%). The average composition of milk from both production systems was within the range reported by Alichanidis et al. [27] (5.1–9% for fat, 2.5–5.1% for protein, 0.7–1% for ash, 3.7–5.5% for lactose, and 15.2–19.3% for total solids). According to data from the Hellenic Agricultural Organization [28], the average (May–June 2019) composition of milk produced in the Regional Unit of Florina where the study was conducted was as follows: 6.23% fat, 5.51% protein, 4.78% lactose, and 11.12% non-fat solids. Furthermore, countrywide, the gross composition of milk in the same period
was as follows: 6.47% fat, 5.55% protein, 4.75% lactose, and 11.08% non-fat solids. There were no significant differences \((p \geq 0.05)\) in the fat/protein ratio between milk samples from the two production systems. The ratio was similar (1.199) to the one calculated considering the fat and protein content of milk from dairy ewes in Greece [4]. The fat/protein ratio has been associated with cheese quality characteristics such as texture, smoothness, and fineness in goat cheeses [29]. Finally, it is critical to bear in mind that although part-time grazing was associated with a reduction of the amount of concentrates provided to the animals, there was no adverse effect on the gross composition of the produced milk. Thus, milk production from animals on the semi-intensive system may be better from a financial point of view.

Table 1. Effect of the production system on sheep milk chemical composition, fat/protein ratio, and somatic cell count.

| Variable                  | Production System          | SEM  | Significance |
|---------------------------|----------------------------|------|--------------|
|                           | Intensive                  | Semi-Intensive |             |              |
| Moisture (%)              | 82.71                      | 82.41 | 0.273        | NS           |
| Ash (%)                   | 0.81                       | 0.82  | 0.008        | NS           |
| Fat (%)                   | 6.40                       | 6.63  | 0.230        | NS           |
| Protein (%)               | 5.39                       | 5.53  | 0.097        | NS           |
| Lactose (%)               | 4.70                       | 4.62  | 0.062        | NS           |
| Total solids              | 17.30                      | 17.59 | 0.273        | NS           |
| Fat: Protein ratio        | 1.189                      | 1.199 | 0.039        | NS           |
| SCC (log_{10} cells/mL)   | 3.271                      | 3.288 | 0.100        | NS           |

NS = Non-significant.

Milk somatic cell count also did not differ \((p \geq 0.05)\) in relation to the two production systems. Bulk tank somatic cell count is the first and most important index used by farmers and the dairy industry to assess udder health in the flocks and milk hygiene because increased somatic cell counts affect milk production and cheese yield. Although the European Union (Regulation 853/2004) [30] has set a legal limit at 400,000 cells/mL for cow milk, there is no limit for somatic cell count in sheep milk. According to Sevi et al. [31], sheep milk’s satisfactory hygienic and technological quality is achieved at 70,000 cells/mL (6.85 log10 cells/mL). Gonzalo [32] proposed a somatic cell count lower than 500,000 (5.70 log10 cells/mL) for good-quality milk, whereas the somatic cell count for healthy sheep mammary gland should not exceed 250,000 cells/mL (5.39 log10 cells/mL). Lianou et al. [16] also reported no differences in the somatic cell count in bulk tank milk collected from farms using the intensive or the semi-intensive production system. In the previous study, the somatic cell count expressed as geometric mean was higher in the milk from intensive farms than in that from semi-intensive farms \((5.45 \times 10^5 \text{ vs. } 4.50 \times 10^5 \text{ cells/mL, respectively})\).

3.2. Milk Physicochemical Properties

The physicochemical properties of milk did not differ significantly \((p \geq 0.05)\) in relation to the two production systems, as expected (Table 2). Milk physicochemical properties are affected by milk chemical composition and somatic cell count. Therefore, the lack of effect of the production system on the previously reported parameters was also reflected in the physicochemical characteristics of the milk obtained from the production systems.

Milk from both production systems had pH values within the range (6.41–6.79) reported by Pappa et al. [33]. However, electrical conductivity, refractive index, and Brix values were higher than the values reported in the review study of Park et al. [34] (refractive index 1.3492–1.3497 and electrical conductivity 3.8 mS/cm) and the study of Gelasakis et al. [35], where samples collected from individual animals were used (electrical conductivity 4 mS/cm and Brix value 4).
Table 2. Effect of the production system on sheep milk physical properties.

| Variable                | Production System | SEM  | Significance |
|-------------------------|-------------------|------|--------------|
|                         | Intensive         | Semi-Intensive | SEM  | Significance |
| pH                      | 6.70              | 6.70 | 0.027        | NS              |
| Electrical Conductivity (mS/cm) | 4.42              | 4.47 | 0.065        | NS              |
| Refractive index         | 1.354             | 1.354 | 0.000        | NS              |
| Brix (°Bx)               | 13.69             | 13.73 | 0.161        | NS              |

NS = Non-significant.

Milk pH is used as an indirect index for the microbiological quality of milk, and thus, titratable acidity is usually determined. The other three variables, i.e., electrical conductivity, refractive index, and Brix value, are not frequently determined. Electrical conductivity is used as a rapid method for detecting subclinical mastitis in individual animals [36]. Refractive index and Brix value are used to measure milk total solids [37]. Therefore, determining the physiochemical properties of milk could be a convenient, rapid strategy for assessing milk chemical composition [35] and monitoring the health status of the animals [38] at the farm level. Furthermore, the convenient and portable equipment required for these analyses would enable farmers to manage their flocks efficiently, and thus, collecting these data should be encouraged and promoted by both veterinarians and the dairy industry.

3.3. Milk Fatty Acid Composition and Nutritional Value

Sheep milk fatty acid composition is presented in Table 3. Myristic (C14:0), palmitic (C16:0), and stearic (C18:0) were the major saturated fatty acids in milk from both production systems. Oleic (C18:1 cis-9) and linoleic (C18:2 n-6 cis) acids were the predominant fatty acids in the monounsaturated and polyunsaturated lipid classes, respectively. The levels of linolenic (C18:2 n-6) and α-linolenic (C18:3 n-3) acids did not differ statistically (p ≥ 0.05)(521,830),(540,841) in milk from the intensive and the semi-intensive system. Grass contains elevated levels of α-linolenic (C18:3 n-3) acid, and this can explain the elevated levels of α-linolenic acid and its biohydrogenation intermediates such as conjugated linoleic acid (CLA) (C18:2 cis-9 trans-11), vaccenic acid (C18:1 trans 11), and stearic acid (C18:0) in the milk from ewes raised using the semi-intensive system [5]. Milk from the semi-intensive production system had a higher (p < 0.001) content of CLA, which possesses anti-carcinogenic, anti-atherogenic, anti-obesity, and anti-diabetic properties [39]. Milk and dairy products are the main sources of CLA acid in the human diet, and increased levels of this acid have been found in milk from pasture-grazing or grass-fed animals [40,41]. With regard to the nutritionally important long-chain PUFA, milk from ewes on the semi-intensive production system had significantly higher (p < 0.001) levels of arachidonic acid (C20:4 n-6), whereas there were no differences in the levels of eicosatrienoic (C20:3 n-3), eicosapentenoic (C20:5 n-3, EPA), and docosapentenoic (C22:5 n-3) acids in the milk from both production systems. Sheep milk does not contain high levels of long-chain PUFA due to the extensive biohydrogenation of these acids in the rumen [42] in general. The higher PUFA content (Table 4) observed in the milk from ewes on the semi-intensive system is attributed to grazing in mountainous areas, and it has been reported by Bravo-Lamas et al. [43]. Forage feeding can modify the fatty acid composition of ruminant milk, as reported in the study of Elgersma et al. [41]. According to Chilliard et al. [44], pasture feeding decreases the content of SFA, particularly, of fatty acids such as capric (C10:0), lauric (C12:0), and myristic acids, and it increases the content of fatty acids favorable to human health such as oleic acid, α-linolenic acid (C18:3 n-3), and conjugated linoleic acid (CLA) (C18:2 cis-9 trans-11). Furthermore, green plants are the primary dietary sources of n-3 PUFA in ruminants, and increased dietary levels of n-3 PUFA can improve fatty acid composition in ruminant milk and meat [40]. Furthermore, according to Angeles-Hernandez et al. [45], the ratio of forage to concentrates in the animal diet can significantly affect milk fatty acid profile.
Table 3. Effect of the production system on sheep milk fatty acid composition (% of total identified fatty acids).

| Fatty Acid | Production System | SEM | Significance |
|------------|-------------------|-----|--------------|
|            | Intensive | Semi-Intensive |       |
| Saturated fatty acids |          |                |       |
| C4:0       | 1.60      | 1.58           | 0.045 | NS           |
| C6:0       | 1.84      | 1.78           | 0.063 | NS           |
| C8:0       | 6.89      | 6.27           | 0.282 | ***          |
| C10:0      | 4.65      | 4.06           | 0.213 | ***          |
| C12:0      | 2.58      | 2.57           | 0.124 | NS           |
| C14:0      | 12.50     | 11.44          | 0.304 | ***          |
| C15:0      | 1.12      | 1.08           | 0.040 | NS           |
| C16:0      | 29.55     | 26.57          | 0.628 | ***          |
| C17:0      | 0.70      | 0.80           | 0.033 | ***          |
| C18:0      | 8.73      | 11.09          | 0.579 | ***          |
| C20:0      | 0.32      | 0.36           | 0.040 | NS           |
| C21:0      | 0.18      | 0.17           | 0.014 | NS           |
| C22:0      | 0.03      | 0.04           | 0.008 | NS           |
| Monounsaturated fatty acids |          |                |       |
| C14:1      | 0.46      | 0.49           | 0.019 | NS           |
| C15:1      | 0.29      | 0.29           | 0.014 | NS           |
| C16:1      | 1.20      | 1.02           | 0.056 | ***          |
| C17:1      | 0.29      | 0.29           | 0.016 | NS           |
| C18:1 trans | 0.50      | 0.54           | 0.052 | NS           |
| C18:1 trans-11 (VA) | 1.59 | 1.78 | 0.221 | NS |
| C18:1 cis-9 | 20.19 | 22.47 | 0.669 | *** |
| C20:1      | 0.11      | 0.15           | 0.024 | NS           |
| Polyunsaturated fatty acids |          |                |       |
| C18:2 n-6 cis | 2.66 | 2.54 | 0.112 | NS |
| C18:2 n-6 trans | 0.82 | 1.13 | 0.084 | *** |
| C18:3 n-3 | 0.66      | 0.78           | 0.072 | NS           |
| C18:2 cis-9 trans-11 (CLA) | 0.30 | 0.42 | 0.054 | *** |
| C20:2      | 0.05      | 0.05           | 0.007 | NS           |
| C20:4 n-6 | 0.10      | 0.12           | 0.009 | ***          |
| C20:3 n-3 | 0.03      | 0.04           | 0.008 | NS           |
| C20:5 n-3 | 0.06      | 0.08           | 0.010 | NS           |
| C22:5 n-3 | 0.01      | 0.01           | 0.004 | NS           |

NS = Non-significant; *** = p < 0.001.

Table 4. Effect of the production system on sheep milk nutritional indices.

| Index | Production System | SEM | Significance |
|-------|-------------------|-----|--------------|
|        | Intensive | Semi-Intensive |       |
| SFA 1 | 70.69      | 67.81          | 0.772 | ***          |
| MUFA 2 | 24.64      | 27.02          | 0.728 | ***          |
| PUFA 3 | 4.68       | 5.17           | 0.237 | ***          |
| Medium chain triglycerides (C6:0–C14:0) | 27.86 | 26.94 | 0.919 | NS |
| h/H 4 | 0.560      | 0.688          | 0.027 | ***          |
| AI 5  | 2.825      | 2.355          | 0.115 | ***          |
| TI 6  | 2.915      | 2.513          | 0.100 | ***          |
| HPI 7 | 0.359      | 0.435          | 0.018 | ***          |
| DPA 8 | 38.038     | 43.279         | 1.215 | ***          |

1 = Saturated fatty acids; 2 = Monounsaturated fatty acids; 3 = Polyunsaturated fatty acids; 4 = Hypercholesterolic/Hypercholesterolemic index; 5 = Atherogenicity index; 6 = Thrombogenicity index; 7 = Heath promoting index; 8 = Desirable fatty acids; *** p < 0.001; NS = Non-significant.
The pattern of the fatty acid profile for milk from the intensive production system was similar to the one reported by De Renobales et al. [11] for dairy ewes on a concentrate-based diet. On the other hand, the pattern of fatty acid composition for milk from the semi-intensive production system was similar to the one reported by Bravo-Lamas et al. [43] for milk from ewes that grazed on valley grasslands close to the farm and were fed a small amount of concentrate. In general, ewes on the semi-intensive system produced milk with a better fatty acid profile. This is in agreement with the findings of De Renobales et al. [11] that reported improved fatty acid composition in milk from animals that were allowed to graze while receiving a concentrate supplement.

The effect of the production system on the lipid quality of milk is presented in Table 4. The content of SFA was significantly higher \((p < 0.001)\) in the milk from the intensive system, whereas the contents of MUFA and PUFA were significantly higher \((p < 0.001)\) in the milk from ewes on the semi-intensive system. However, there were no differences \((p \geq 0.05)\) in the medium-chain triglycerides (MCT) content in relation to the two production systems. Sheep milk is rich in MCT, which are important from a therapeutic point of view since they are easily absorbed and can be used in cases of nutrient malabsorption or undernourishment [46]. The h/H ratio was significantly higher \((p < 0.001)\) in the milk from farms using the semi-intensive system. Chen and Liu [21] reported h/H ratio values of 0.50–1.29 for ewe milk. The h/H ratio is used to assess the effect of fatty acid composition on cholesterol and the risk of cardiovascular disease because it is linked to the functional activity of fatty acids in lipoprotein metabolism for the transport of plasma cholesterol. Higher values of the h/H ratio are desirable [47]. AI was significantly lower \((p < 0.001)\) in milk from the semi-intensive production system than in milk from the intensive production system. In a recent review by Chen and Liu [21], it was reported that the AI for ewe milk ranges between 1.42 and 3.39. Similarly, the TI was also significantly lower \((p < 0.001)\) in the milk from the semi-intensive system. The reported range for TI was 1.00–2.72 [21]. Both AI and TI were within the reported range for sheep milk proposed by Sinanoglou et al. [48] and lower than 3 for milk from both production systems. AI indicates the relationship between the sum of the major saturated fatty acids and that of the main classes of unsaturated fatty acids. In contrast, TI describes the thrombogenic potential of fatty acids, indicating their tendency to form clots in blood vessels [49]. Lower values of both indices are beneficial for human health. Pietrzak-Fiecko and Kamelska-Sadowska [50] reported higher values for AI and TI and a lower h/H ratio for sheep milk compared to milk from other mammalian species. HPI was also significantly higher \((p < 0.001)\) in the milk from ewes in the semi-intensive farms. Bonano et al. [51] reported HPI values in the range of 0.16–0.28. Higher values of this index are desirable, since it is the reverse of TI [20]. Finally, the content of DFA was significantly higher \((p < 0.001)\) in the milk from the semi-intensive production system. Atti et al. [52] also reported that pasture-based diets significantly improved the DFA value of sheep milk. DFA is the sum of unsaturated fatty acids and stearic acid, all considered anti-atherogenic since they reduce plasma cholesterol and triacylglycerols [21,53].

4. Conclusions

The data obtained in this study showed no effect of the farming system on the basic composition and physicochemical characteristics of commercially produced milk in farms using the intensive or the semi-intensive production system. However, milk from the semi-intensive production system had significantly improved fatty acid composition and lipid quality nutritional indices in relation to milk produced in the intensive farms. Differences in the composition of fatty acids and in the lipid quality indices were attributed to the inclusion of pasture in sheep diet. This nutritional information could add value to the produced dairy products and create product differentiation.

Author Contributions: Conceptualization, E.K.; methodology, E.K.; formal analysis, Z.B.; investigation, C.K., V.P. and A.K.; writing—Original draft preparation, E.K.; writing—Review and editing, E.K. and Z.B.; supervision, E.K.; project administration, A.T.; funding acquisition, A.T. All authors have read and agreed to the published version of the manuscript.
Funding: This research was funded by the Research Committee of the University of Western Macedonia.

Institutional Review Board Statement: Not applicable.

Data Availability Statement: The data presented in this study are contained within the article.

Acknowledgments: The authors are grateful to Georgios Ragkos (DVM) and Konstantinos Rossios (Animal Technician) from the Veterinary Bureau of Aminteo and to Maria-Anastasia Karatzia (Agriculturist) from the Hellenic Agricultural Organisation Demeter for help with sample collection and sample analysis.

Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

| Abbreviation | Description |
|--------------|-------------|
| AI           | Atherogenicity index |
| CLA          | Conjugated fatty acids |
| DFA          | Desirable fatty acids |
| EFSA         | European Food Safety Authority |
| h/H          | Hypocholesterolemic/hypercholesterolemic ratio |
| HPI          | Health-promoting index |
| MCT          | Medium chain triglycerides |
| MUFA         | Monounsaturated fatty acids |
| PUFA         | Polyunsaturated fatty acids |
| SFA          | Saturated fatty acids |
| TI           | Thrombogenicity index |
| VA           | V vaccenic acid |

References

1. Gelasakis, A.I.; Valergakis, G.E.; Arsenos, G.; Banos, G. Description and typology of intensive Chios dairy sheep farms in Greece. *J. Dairy Sci.* 2012, 95, 3070–3079. [CrossRef] [PubMed]
2. Hellenic Agricultural Organisation. Available online: https://www.elgo.gr/images/ELOGAK_files/Statistics/2021/Milk21/2.%CE%95%CE%9B%CE%93%CE%9F_STATS_%CE%9C%CE%97%CE%9D%CE%99%CE%91%CE%9A%0%CE%9F%CE%A3%CE%9C%CE%97%CE%A4%CE%99%CE%9C%CE%97_%CE%90%CE%A1%CE%9F%CE%92%CE%95%CE%99%CE%9F%CE%A5%CE%93%CE%99%CE%94%CE%99%CE%9D%CE%9F%CE%A5_2020.pdf (accessed on 30 July 2021).
3. Pulina, G.; Milán, M.J.; Lavín, M.P.; Theodoridis, A.; Morin, E.; Capote, J.; Thomas, D.L.; Francesconi, A.H.D.; Caja, G. Invited review: Current production trends, farm structures, and economics of the dairy sheep and goat sectors. *J. Dairy Sci.* 2018, 101, 6715–6729. [CrossRef] [PubMed]
4. Bencini, R.; Pulina, G. The quality of sheep milk: A review. *Aust. J. Exp. Agric.* 1997, 37, 485–504. [CrossRef]
5. Nudda, A.; Battacone, G.; Boaventura Neto, O.; Cannas, A.; Francesconi, A.H.D.; Atzori, A.S.; Pulina, G. Feeding strategies to design the fatty acid profile of sheep milk and cheese. *Rev. Bras. Zootec.* 2014, 43, 445–456. [CrossRef]
6. De La Fuente, L.F.; Barbosa, E.; Carriedo, J.A.; Gonzalo, C.; Arenas, R.; Fresno, J.M.; San Primitivo, F. Factors influencing variation of fatty acid content in ovine milk. *J. Dairy Sci.* 2009, 92, 3791–3799. [CrossRef]
7. Bencini, R.; Stanislao Atzori, A.; Nudda, A.; Battacone, G.; Pulina, G. Improving the quality and safety of sheep milk. In *Improving the Safety and Quality of Milk*; Griffiths, M.W., Ed.; Woodhead Publishing Ltd.: Cambridge, UK, 2010; Volume 2, pp. 347–401. [CrossRef]
8. Silanikove, N.; Leitner, G.; Merin, U. Influence of animal health, breed, and diet on non-cow milk composition. In *Non-Bovine Milk and Milk Products*, 1st ed.; Tsakalidou, E., Papadimitriou, K., Eds.; Elsevier Academic Press: London, UK, 2016; pp. 61–79. [CrossRef]
9. Hatziminaoglou, I.; Polyzos, N.; Magoulias, I.; Boyazoglou, I. Législation, utilisation et perspectives: Cas de la Grèce. In *Terres Collectives en Méditerranée: Histoire, Législation, Usages et Modes D’utilisation par les Animaux*; Bourbouze, A., Rubino, R., Eds.; Ars Grafica: Rome, Italy, 1992; pp. 91–116.
10. Cosentino, C.; Colonna, M.A.; Musto, M.; Dimotta, A.; Freschi, P.; Tarricone, S.; Ragni, M.; Paolino, R. Effects of dietary supplementation with extruded linseed and oregano in autochthonous goat breeds on the fatty acid profile of milk and quality of Padraccio cheese. *J. Dairy Sci.* 2021, 104, 1445–1453. [CrossRef]
11. deRenobales, M.; Amores, G.; Arranz, J.; Virto, M.; Barrón, L.J.R.; Bustamante, M.A.; Ruiz De Gordoa, J.C.; Nájera, A.I.; Valdivielso, I.; Abilleira, E.; et al. Part-time grazing improves sheep milk production and its nutritional characteristics. *Food Chem.* 2012, 130, 90–96. [CrossRef]
12. Basdagianni, Z.; Papaloukas, L.; Kyriakou, G.; Karaiskou, C.; Parissi, Z.; Sinapis, E.; Kasapidou, E. A comparative study of the fatty acid and terpene profiles of ovine and caprine milk from Greek mountain sheep breeds and a local goat breed raised under a semi-extensive production system. Food Chem. 2019, 278, 625–629. [CrossRef]

13. Caroprese, M.; Ciliberti, M.G.; Albenzio, M.; Marino, R.; Santillo, A.; Sevi, A. Role of antioxidant molecules in milk of sheep. Small Rum. Res. 2019, 170, 102–108. [CrossRef]

14. Nudda, A.; Cannas, A.; Correddu, F.; Atzori, A.S.; Lunesu, M.F.; Battacone, G.; Pulina, G. Sheep and Goats Respond Differently to Feeding Strategies Directed to Improve the Fatty Acid Profile of Milk Fat. Animals 2020, 10, 1290. [CrossRef]

15. Hadjigeorgiou, I. Sheep and goat farming and rural development in Greece. In Proceedings of the International Conference Celebrating Pastoral Life Heritage and Economic Development, Athens, Greece, 11–12 September 2014.

16. Lianou, D.T.; Michael, C.K.; Vasileiou, N.G.C.; Petinaki, E.; Cripps, P.J.; Tsiilipoundiakí, K.; Katsafadou, A.I.; Politis, A.P.; Kordalis, N.G.; Ioannidi, K.S.; et al. Extensive countrywide field investigation of somatic cell counts and total bacterial counts in bulk-tank raw milk in sheep flocks in Greece. Foods 2021, 10, 268. [CrossRef]

17. European Food Safety Authority. Scientific opinion on the welfare risks related to the farming of sheep for wool, meat and milk production. EFSA J. 2014, 12, 3933–4060. [CrossRef]

18. Papaloukas, L.; Sinapis, E.; Arsenos, G.; Kyriakou, G.; Basdagianni, Z. Effect of season on fatty acid and terpene profiles of milk from Greek sheep raised under a semi-extensive production system. J. Dairy Res. 2016, 83, 375–382. [CrossRef]

19. Bligh, E.G.; Dyer, W.J. A rapid method of total lipid extraction and purification. Can. J. Biochem. Physiol. 1959, 37, 911–917. [CrossRef] [PubMed]

20. International Organization for Standardization (ISO). Milk Fat-Preparation of Fatty Acid Methyl Esters; ISO Publications: Geneva, Switzerland, 2002; Volume ISO 15884.

21. Chen, J.; Liu, H.-B. Nutritional Indices for Assessing Fatty Acids: A Mini-Review. Int. J. Mol. Sci. 2020, 21, 5695. [CrossRef]

22. Ulbricht, T.L.V.; Southgate, D.A.T. Coronary heart disease: Seven dietary factors. Lancet 1991, 338, 985–992. [CrossRef]

23. Chen, S.; Bobe, G.; Zimmerman, S.; Hammond, E.G.; Luhman, C.M.; Boylston, T.D.; Freeman, A.E.; Beitz, D.C. Physical and sensory properties of dairy products from cows with various milk fatty acid compositions. J. Agric. Food Chem. 2004, 52, 3422–3428. [CrossRef] [PubMed]

24. Rhee, K.S. Fatty acids in meats and meat products. In Fatty Acids in Foods and Their Health Implications; Chow, C.K., Ed.; Marcel Dekker: New York, NY, USA, 1992; pp. 65–93.

25. Ragkos, G.; Kasapidou, E.; Papadopoulos, V.; Mitilianga, P.; Parissi, T.; Gelasakis, A.I. Investigation on the Effect of Farming System on the Quantity and Quality Characteristics of Sheep Milk in Farms Located in the Region of Aminteo. In Proceedings of the of the 14th Hellenic Veterinary Congress, Thessaloniki, Greece, 11–13 May 2018. E-Abstracts.

26. Wendorff, W.L.; Haenlein, G.F.W. Sheep Milk–Composition and Nutrition. In Handbook of Milk of Non-Bovine Mammal; Park, Y.W., Min, D., Haenlein, G.F.W., Eds.; John Wiley & Sons: Hoboken, NJ, USA, 2017; pp. 210–221. [CrossRef]

27. Alicandris, E.; Moatsou, G.; Polychroniadou, A. Composition and Properties of Non-cow Milk and Products. In Non-Bovine Milk and Milk Products; Tsakalidou, E., Papadimitriou, K., Eds.; Elsevier Academic Press: London, UK, 2016; pp. 81–116. [CrossRef]

28. Hellenic Agricultural Organisation. Available online: https://www.elgo.gr/images/ELOGAK_files/POIOTHTA/QUALITY_LOCATION_%CE%9C%CE%9F%CE%9D%CE%A4%CE%97_2019.pdf (accessed on 30 July 2021).

29. Morand-Fehr, P.; Fedele, V.; Decandia, M.; Le Frileux, Y. Influence of farming and feeding systems on composition and quality of goat and sheep milk. Small Rumin. Res. 2007, 68, 20–34. [CrossRef]

30. FAO. Regulation (EC) No 853/2004 of the European Parliament and of the Council of 29 April 2004 on laying down specific hygiene rules for on the hygiene of foodstuffs. Off. J. Eur. Union 2004, L 139, 55.

31. Sevi, A.; Albenzio, M.; Taibi, L.; Dantone, D.; Massa, S.; Annichiarico, G. Changes of somatic cell count through lactation and a semi-extensive production system. J. Goat Sci. 2016, 1290. [CrossRef]

32. Gonzalo, C.; Tardáguila, A.; Ariznabarreta, A.; Romeo, M.; Montoro, V.; Pérez-Guzmán, M.D.; Marco, J.C. Somatic cell counts in dairy livestock and control strategies: Situation in Spain. In Mastitis and Milk Quality; Contreras, A., Sánchez, A., Romero, J.C., Eds.; Diego-Marin Publ.: Murcia, Spain, 2000; pp. 145–151.

33. Pappa, E.; Kondyli, E.; Sotirakoglou, K.; Bosnea, L.; Mataragas, M.; Albuclou, L.; Tsiplakou, E.; Pappas, A. Farmers profile and characterization of sheep and goat dairy chain in northwestern Greece. Sustainability 2021, 13, 833. [CrossRef]

34. Park, Y.W.; Juárez, M.; Ramos, M.; Haenlein, G.F.W. Physico-chemical characteristics of goat and sheep milk. Small Rumin. Res. 2007, 68, 88–113. [CrossRef]

35. Gelasakis, A.I.; Giannakou, R.; Valergakis, G.E.; Fortomaris, P.; Kominakis, A.; Arsenos, G. Prediction of sheep milk chemical composition using milk yield, pH, electrical conductivity and refractive index. J. Dairy Res. 2018, 85, 78–82. [CrossRef]

36. Fox, P.F.; Uniacke-Lowe, T.; McSweeney, P.L.H.; O’Mahony, J.A. (Eds.) Physical Properties of Milk. In Dairy Chemistry and Biochemistry; Springer International Publishing: Cham, Switzerland, 2015; pp. 321–343. [CrossRef]

37. Moore, D.A.; Taylor, J.; Hartman, M.L.; Sischo, W.M. Quality assessments of waste milk at a calf ranch. J. Dairy Sci. 2009, 92, 3503–3509. [CrossRef]

38. Caria, M.; Chessa, G.; Murga, L.; Todde, G.; Pazzona, A. Development and test of a portable device to monitor the health status of Sarda breed sheep by the measurement of the milk electrical conductivity. Ital. J. Anim. Sci. 2016, 15, 275–282. [CrossRef]

39. McGuire, M.A.; McGuire, M.K. Conjugated linoleic acid (CLA): A ruminant fatty acid with beneficial effects on human health. J. Anim. Sci. 2000, 77, 1–8. [CrossRef]
40. Cabiddu, A.; Decandia, M.; Addis, M.; Piredda, G.; Pirisi, A.; Molle, G. Managing Mediterranean pastures in order to enhance the level of beneficial fatty acids in sheep milk. *Small Rumin. Res.* 2005, 59, 169–180. [CrossRef]

41. Elgersma, A.; Tamminga, S.; Ellen, G. Modifying milk composition through forage. *Anim. Feed Sci. Technol.* 2006, 131, 207–225. [CrossRef]

42. Wachira, A.M.; Sinclair, L.A.; Wilkinson, R.G.; Hallett, K.; Enser, M.; Wood, J.D. Rumen biohydrogenation of n-3 polyunsaturated fatty acids and their effects on microbial efficiency and nutrient digestibility in sheep. *J. Agric. Sci.* 2000, 135, 419–428. [CrossRef]

43. Bravo-Lamas, L.; Aldai, N.; Kramer, J.K.; Barron, L.J.R. Case study using commercial dairy sheep flocks: Comparison of the fat nutritional quality of milk produced in mountain and valley farms. *LWT-Food Sci. Technol.* 2018, 89, 374–380. [CrossRef]

44. Chilliard, Y.; Glasser, F.; Ferlay, A.; Bernard, L.; Rouel, J.; Doreau, M. Diet, rumen biohydrogenation and nutritional quality of cow and goat milk fat. *Eur. J. Lipid Sci. Technol.* 2007, 109, 828–855. [CrossRef]

45. Angeles-Hernandez, J.C.; Vieyra Alberto, R.; Kebreab, E.; Appuhamy, J.A.D.; Dougherty, H.C.; Castelan-Ortega, O.; Gonzalez-Ronquillo, M. Effect of forage to concentrate ratio and fat supplementation on milk composition in dairy sheep: A meta-analysis. *Livest. Sci.* 2020, 238, 104069. [CrossRef]

46. Sanz Sampelayo, M.R.; Chilliard, Y.; Schmidely, P.; Boza, J. Influence of type of diet on the fat constituents of goat and sheep milk. *Small Rumin. Res.* 2007, 68, 42–63. [CrossRef]

47. Santos-Silva, J.; Bessa, R.; Santos-Silva, F. Effect of genotype, feeding system and slaughter weight on the quality of light lambs: II. Fatty acid composition of meat. *Livest. Prod. Sci.* 2002, 77, 187–194. [CrossRef]

48. Sinanoglou, V.J.; Koutsouli, P.; Fotakis, C.; Sotiropoulou, G.; Cavouras, D.; Bizelis, I. Assessment of lactation stage and breed effect on sheep milk fatty acid profile and lipid quality indices. *Dairy Sci. Technol.* 2015, 95, 509–531. [CrossRef]

49. Paszczuk, B.; Luczynska, J. The Comparison of Fatty Acid Composition and Lipid Quality Indices in Hard Cow, Sheep, and Goat Cheeses. *Foods* 2020, 9, 1667. [CrossRef]

50. Pietrzak-Fiećko, R.; Kamelska-Sadowska, A.M. The Comparison of Nutritional Value of Human Milk with Other Mammals’ Milk. *Nutrients* 2020, 12, 1404. [CrossRef]

51. Bonanno, A.; Di Grigoli, A.; Vitale, F.; Alabiso, M.; Giosuè, C.; Mazza, F.; Todaro, M. Legume grain-based supplements in dairy sheep diet: Effects on milk yield, composition and fatty acid profile. *Anim. Prod. Sci.* 2016, 56, 130–140. [CrossRef]

52. Atti, N.; Rouissi, H.; Othmane, M. Milk production, milk fatty acid composition and conjugated linoleic acid (CLA) content in dairy ewes raised on feedlot or grazing pasture. *Livest. Sci.* 2006, 104, 121–127. [CrossRef]

53. Mensink, R.P.; Zock, P.L.; Kester, A.D.; Katan, M.B. Effects of dietary fatty acids and carbohydrates on the ratio of serum total to HDL cholesterol and on serum lipids and apolipoproteins: A meta-analysis of 60 controlled trials. *Am. J. Clin. Nutr.* 2003, 77, 1146–1155. [CrossRef]