agriculture

MDPI

Article

Stubble Quality of Wheat Grown under No-Tillage and Conventional Tillage Systems, and Effects of Stubble on the Fermentation Profile of Grazing Ewes' Ruminal Fluid

Hajer Guesmi [1], Cyrine Darej [1], Piebiep Goufo [2,*], Salah Ben Youssef [3], Mohamed Chakroun [3], Hichem Ben Salem [3], Henrique Trindade [2] and Nizar Moujahed [1]

[1] Ecosystems and Aquatic Resources Research Unit Laboratory, Department of Animal Sciences, National Agronomic Institute of Tunisia (INAT), University of Carthage, 43 Ch. Nicolle Street, Tunis 1082, Tunisia; guessmihajer55@gmail.com (H.G.); cyrine.darej@gmail.com (C.D.); nizar.moujahed@yahoo.fr (N.M.)

[2] Center for the Research and Technology of Agro-Environmental and Biological Sciences (CITAB), Universidade de Tras-os-Montes e Alto Douro (UTAD), Quinta de Prados, 5000-801 Vila Real, Portugal; htrindad@utad.pt

[3] Laboratory of Animal Productions and Forages, National Institute of Agronomic Research of Tunisia (INRAT), Hédi Karray Street, Ariana 2049, Tunisia; benyoussef.salah@iresa.agrinet.tn (S.B.Y.); chakroun.mohamed@iresa.agrinet.tn (M.C.); bensalem.hichem@iresa.agrinet.tn (H.B.S.)

* Correspondence: pgoufo@utad.pt

Abstract: Conservation practices that involve leaving mulch on the soil are known to increase soil fertility. However, mulch is an important source of feed for ruminant livestock. Accordingly, the trade-offs between mulching and stubble uptake by livestock are currently hot topics in the research field. In this study, a comparison between the quality of stubbles of wheat grown in no-tillage and conventional tillage fields and the rumen fermentation characteristics of Barbarine ewes grazing in the two fields was carried out. Samples were collected four times after wheat grain harvesting. Immediately after harvest, stubble biomass was slightly higher under no-tillage than conventional tillage. The ewes displayed different grazing behavior, with feeding at a higher rate on the conservative stubble than the conventional stubble. This feeding behavior seemed to be an adaptive strategy to offset the decline in the nutritional quality of stubbles from no-tillage-grown wheat. Indeed, dry matter, protein, fiber, and ash contents were lower in stubbles from no-tillage than conventional tillage at the second sampling time. Consequently, the concentration of the volatile fatty acid, propionic acid, was lower in ewes grazing in the conservative plots. However, this feeding behavior did not cause any body weight impairment during the two-month experimental period. At the end of grazing, the no-tillage practice was found to be comparable to the conventional tillage system according to the amount of residue remaining on the soil surface. Therefore, no-tillage could not be used to solve the competition between crops and livestock for residues.

Keywords: livestock digestion; dryland ecosystem; forage allowance; stocking rate; rumen fermentation; volatile fatty acids; ammonia emissions; agricultural sustainability; rumen pH

Citation: Guesmi, H.; Darej, C.; Goufo, P.; Ben Youssef, S.; Chakroun, M.; Ben Salem, H.; Trindade, H.; Moujahed, N. Stubble Quality of Wheat Grown under No-Tillage and Conventional Tillage Systems, and Effects of Stubble on the Fermentation Profile of Grazing Ewes' Ruminal Fluid. *Agriculture* **2022**, *12*, 520. https://doi.org/10.3390/agriculture12040520

Academic Editors: Piotr Prus, Federico Infascelli and Vincenzo Tufarelli

Received: 21 February 2022
Accepted: 4 April 2022
Published: 6 April 2022

1. Introduction

The fragility of dryland ecosystems is induced by many factors, including the degradation of natural resources (i.e., soil and biodiversity loss), the increasing costs of agricultural inputs (e.g., energy, labor, pesticides, etc.), and climate change [1–3]. This is particularly true for countries of the Mediterranean basin which are characterized by semi-arid or arid environments [1,4,5], leading to low soil quality and water shortage [6]. Additionally, the increasing use of agricultural mechanization in soil preparation in these regions has been reported to increase the risk of erosion and soil degradation [2,3,7–9]. These factors are

currently threatening the sustainability of production systems in dryland areas [4], and solutions are needed to mitigate or adapt to these changes [5].

Conservation agriculture (Conser-A) is a promising alternative to conventional agriculture (Conven-A), where minimum machinery intervention is employed, and soil fertility is improved with mulching [7,10]. Conser-A is based on three principles: (i) minimal soil disturbance, i.e., zero tillage, (ii) permanent soil cover with mulch, and (iii) crop rotation [10,11]. No-tillage is becoming increasingly attractive to farmers because it clearly reduces production costs relative to conventional tillage [7]. However, this "biological and ecological" paradigm represents a challenge to ensure agricultural sustainability, including pastures, arable and perennial crops, trees, and livestock [5].

The southern river of the Mediterranean basin is home to more than 75% of smallholder farming systems [1,4]. For decades, livestock has been the main component of farming systems in the Mediterranean basin [12,13]. Livestock systems in the region are seasonally integrated to use winter cereal pasture and warm season perennial grasses [14]. Indeed, crop residues represent a major resource for livestock feeding during the dry season [15]. Thus, crop–livestock integration might be incompatible with one of the principles of Conser-A, that being mulching by leaving a certain amount of crop residues on the soil surface [14,16].

Studies on trade-offs between mulching and stubble uptake by livestock and related to the allocation of biomass resources among competing objectives have yielded conflicting results. The results of a simulation in southern Africa suggested that the retention of most of the crop residue as mulch was unrealistic and undesirable in farming systems that rely on livestock for traction [17]. In the Moroccan drylands, El-Shater and Yigezu [18] found that residue retention is economically and biophysically beneficial even for owners of livestock; this is because the monetary value of the additional grain yield more than offsets the cost of purchasing an equivalent amount of feed from the market. Despite these two examples, assessments of the economics of residue retention, especially in drylands, is scant, mainly due to the lack of raw data for modelling studies. Crop–livestock integration under Conser-A requires good knowledge of the dynamics of biomass change in the field, as well as the response of animals to grazing conditions (e.g., stocking rate, grazing duration, etc.).

During the establishment of crop–livestock systems, the nutritional quality of crop residues for animals is often neglected. Current crop management strategies focus on grain quality [9,19,20], with little attention paid to stubble quality [21]. A viable livestock enterprise requires a constant supply of forage to reduce the cost of supplemental feed. The factor most strongly influencing crop yield, particularly grain yield, is soil fertility [7,9–11,19]. If Conser-A practices that increase soil quality also increase biomass quality, this could help offset the reduction in forage quantity that occurred when some stubble is used as mulch; this could also help in the creation of new strategies for reducing pasture grazing intensity. Solid data are needed that would enable such a possibility and improve the integration of crop and livestock under Conser-A.

Thus, the main objective of this study was to compare Conven-A and Conser-A with respect to the influence of the cropping system on stubble biomass and nutritional quality. Moreover, the body weight and digestion parameters of ewes grazing on wheat stubbles were evaluated.

2. Materials and Methods

2.1. Experimental Design

This experiment was carried out at the experimental station (36° 84′ 56″ N 10° 19′ 07″ E) of the National Institute of Agronomic Research of Tunisia (INRAT). The station is situated in Ariana, a coastal city in northeastern Tunisia. The climate at the station is semi-arid, with high spatial and temporal variability, average annual rainfall of 350 mm, annual average temperature of 17 °C, and maximum temperature reaching 36 °C in July. The study was part of a long-term experiment that began several years ago and involved a Conven-A and Conser-A comparison of agronomic, quality, and biomass characteristics of cereals. Conven-A involved the use of moldboard plowing to 30 cm depth as primary

tillage to prevent crust formation, followed by repeated secondary shallow tillage to remove weeds and prepare the seabed. In the study area, intensive tillage is widely used by farmers for continuous cereal production. Conser-A was defined as no-tillage, with the crop residue mulch retained on the soil surface; crop residues were cut and spread evenly with a combine-attached chopper. In recent years, the no-tillage system has experienced a substantial expansion in the area due to great incentives from the government.

Treatments were arranged in a completely randomized design on a 1.0-ha plot of clay-loam soil grown conventionally with common vetch for the past three years. The plot was divided into six electrically fenced subplots (three subplots for Conser-A and three subplots for Conven-A) covering 1665 m^2. In each subplot, durum wheat (*Triticum turgidum* subsp. *Durum* 'Karim') was sowed on November 25 at a density of 160 kg ha^{-1}. Conser-A subplots were seeded with a common planter, while Conser-A subplots were seeded with a no-till seed drill. All subplots were surface broadcasted with ammonium nitrate (150 kg ha^{-1}) and diammonium phosphate (100 kg ha^{-1}) at a rate of 1/3 before sowing and 2/3 at the beginning of wheat tillering. Before sowing, Conser-A subplots were treated with the herbicide glyphosate at a rate of 180 g a.i., equivalent to 3 L of commercial product per ha. In all subplots, weeds were controlled twice during the growing season with the application of 2,4-dichlorophenoxyacetic acid (2.5 L ha^{-1}). Wheat was harvested mechanically on June 12 of the following year at a cutting height of c.a. 25 cm, and grain yield was determined at 13% moisture content. The total grain yield was on average 1.32 and 1.58 t ha^{-1} ($p < 0.05$) for Conven-A and Conser-A subplots, respectively.

2.2. Animal Grazing

After wheat grain harvesting, female sheep were grazed on stubbles for two months at a stocking rate of five ewes per subplot. All animals were handled as described in the Guide for the Care and Use of Agricultural Animals in Research and Teaching [22] and under the approval of the Management Committee of "Bourbiaa" Experimental Farm of INRAT. A total of 30 Barbarine ewes were selected from the sheep flock of INRAT. These ewes had the following average features: age, 5 years; body weight (BW), 41.0 $\pm$ 2.2 kg; and gestational age, 2 months. Before the start of the experiment, the ewes were vaccinated against enterotoxemia using Coglavax (Ceva, France) and administered anthelmintic albendazole (Dalben 1.9, Ceva, France). All ewes were housed together and identified using different colors of painting for each subplot. Each day, ewes of the same color were placed in their respective subplots and granted access to clean water three times per day. The animals were allowed to graze twice per day, in the morning (5 AM to 8 AM) and afternoon (4 PM to 6 PM), with a total grazing duration of 5 h per day.

2.3. Stubble Measurements: Biomass, Dry Matter, Ash, Protein, and Fiber Contents

A quadrat sampling technique was used to estimate stubble biomass (BM) and to identify the stubble parts consumed by the ewes. In each subplot, four quadrats of 1 m^2 each were established. Representative stubble samples were collected at a cutting height of 5 cm from the soil at the beginning of the experiment and at 15-day intervals. Stubbles were separated into heads, leaves, stems, and vegetation (grasses and weeds) around the plants. Each stubble part was weighed immediately in the field using a balance, and the proportions of heads, leaves, stems, and vegetations were estimated and converted into ha basis (fresh weight = fw). Thereafter, the samples were taken to the laboratory for chemical analysis. All chemical reagents were obtained from Merck Chimie SAS (Fontenay-sous-Bois, France), unless otherwise stated.

Stubble samples were oven-dried at 70 °C to a constant weight to obtain the dry weights (dw) and dry matter (DM). Dried samples were ground to pass through a 1 mm screen, and the ash content (AC) was determined following AOAC Official Method^{SM} 942.05. For protein determination, the samples were digested in a Tecator 2040 (Foss NA, Hillerød, Denmark), distilled with a Kjeltec System 1026, and titrated with a Metrohm 655 Dosimat (VELP Scientific, Usmate, Italy). Thus, the total N content was determined

and multiplied by 6.25 to obtain the crude protein content (CP) [23]. The samples were analyzed by the sequential extraction of neutral detergent fiber (NDF) using the method described by Van Soest et al. [24].

2.4. Animal Measurements: Ewes' Body Weight and Rumen Fermentation Parameters

The BW of each ewe was determined before the start of the experiment and three times thereafter (every 15 days). At each sampling period, the animals were weighed early in the morning (5 AM) before the start of grazing. The forage-to-animal relationship was estimated using forage allowance. Forage allowance was expressed as the ratio of pregraze biomass (kg dw) to animal live weight (kg) per unit area (weight × 30 animals per ha) at every 15-day sampling period [25].

Rumen sampling was performed three times at the end of the experiment (August 8, 9, and 10). Rumen fluid was collected three times per day (1 h before grazing, H0, and 2 and 4 h after grazing, H2 and H4) using the oral stomach tubing method [26] with the Ruminator sampling device (Profs Products, Wittibreut, Germany). The device consisted of a rubber tube (length: 3 m; internal diameter: 18 mm) connected to a vacuum pump and a stainless-steel probe head. One person restrained the ewe and held its nose at a 90° angle to avoid movement, while another held the ewe's mouth and passed the probe head over the tongue, past the epiglottis, through the esophagus. Once the probe head reached the rumen, a suction pump (suction velocity = 7 m^3 h^{-1}) was applied and continued until the rumen fluid visibly flowed through the tube. The first 20 mL of the sample was discarded to minimize contamination with saliva. Approximately 40 mL of rumen fluid was collected in a 50-mL centrifuge tube. Between the animals, the tube was washed thoroughly with warm water. The rumen fluid was strained through four layers of cheesecloth, and the pH was immediately determined using a digital pH meter, before being frozen at −18 °C until further analysis.

The samples collected each day for each hour were pooled and used to determine volatile fatty acid (VFA) concentrations using a modified method of Erwin et al. [27]. Samples of 1.5-mL rumen fluid were centrifuged at 10,000× *g* for 15 min at 4 °C. Aliquots of the supernatant (1.0 mL) were added with 100 µL of pivalic acid solution as internal standard. The solutions were vortexed and mixed with 252.5 µL of 25% phosphoric acid. After centrifugation at 10,000× *g* for 15 min at 4 °C, VFA concentrations in the supernatants were measured using a gas chromatograph (GC-2010 Plus, Shimadzu, Kyoto, Japan) coupled with a flame ionization detector (FID-2010 Plus, Shimadzu, Kyoto, Japan). A total of 0.2 µL of supernatant was loaded with inlet temperature set to 210 °C at a split ratio of 200, running a constant flow (pressure of 70 kPa) of helium carrier gas set to 0.5 mL min^{-1}. The DB-225MS capillary column (0.25 µm, 30 m × 0.25 mm i.d., Agilent Technologies, Wilmington, DE, USA) temperature was maintained for 5 min at 135 °C. The FID temperature was set to 180 °C. A solution composed of acetic (66.6 mmol L^{-1}), propionic (27.0 mmol L^{-1}), isobutyric (2.8 mmol L^{-1}), butyric (17.0 mmol L^{-1}), isovaleric (4.9 mmol L^{-1}), valeric (4.8 mmol L^{-1}), caproic (4.3 mmol L^{-1}), and caprylic (4.3 mmol L^{-1}) acids was used as external standard solution. The standard solution (1.0 mL) was also mixed with pivalic acid and 25% phosphoric acid and injected into the GC-FID. VFAs were identified by comparing the retention times with the external standards. Lab Solution software 5.71 (Shimadzu, Kyoto, Japan) was used to integrate the area under the curves for each VFA peak and quantification was achieved by adjusting peak areas to the area of pivalic acid and calibration with external standards. The concentrations are expressed in mmol L^{-1}. The total VFA concentration was defined as the sum of all identified VFAs.

A modification of the microdiffusion technique of Conway and O'Malley [28] was employed to estimate the ammonia (NH_3-N) concentration in the rumen fluid. Two mL of 2% boric acid was added to Tashiro's reagent (0.1% ethylene blue and 0.03% methyl red in ethanol) as a pH indicator and placed in the inner chamber of the microdiffusion cell. In the outer chamber, 1 mL of saturated sodium carbonate solution was placed on one side, and 1 mL of rumen fluid was placed on the opposite side. The cells were then

incubated at 38 °C for one hour. NH_3-N released following the mixing of components in the outer chamber was trapped by boric acid, and the content in the inner chamber was titrated against 0.01 N H_2SO_4 to determine the concentration of NH_3-N in mg L^{-1}.

2.5. Statistical Analysis

Data generated from this experiment were subjected to analysis of variance according to the GLM procedure of SAS/STAT 15.1 (SAS Institute, Cary, NC, USA) using the "Repeated Measure" model. The GLM Repeated Measure provides analysis of variance when the same measurement is performed several times on each subject or case. In this study, the model included the cropping system (Conven-A and Conser-A), the sampling period, and their interactions as independent variables. The animal was considered as a co-variable. Accordingly, all data were subjected to an LSMEAN test. The least square means obtained were linear combinations (sum) of the estimated effects (means) from the model. The model was described using the following equation: $Y_{ijk} = \mu + A_i + B_j + (AB)_k + e_{ijk}$, where Y is the dependent variable, μ is the overall mean, A_i is the effect of the sampling period (i = 1–4 or i = 1–3), B_j is the effect of the cropping system (j = 1–2), and $(AB)_k$ is the effect of the interaction between the cropping system and the sampling period. (k = 1). All data are expressed as mean ± standard deviation. A stepwise multiple comparisons Student–Newman–Keuls (SNK) test was used to identify sample means between Conven-A and Conser-A that differed from each other. When *p*-values were below 5%, the treatment effect was considered a significant change, and at 10%, the treatment effect was considered a trend of change.

3. Results

3.1. Biomass and Nutritive Value of Wheat Stubbles

According to the data in Table 1, the cropping system did not affect stubble total BM-fw, but resulted in an increasing trend ($0.05 < p < 0.10$) for leaf BM and total BM-dw in Conser-A compared to Conven-A immediately after wheat harvesting (Day 0). A significant effect ($p < 0.001$) of the sampling period was observed for BM-dw (Table 2). In fact, BM-dw progressively decreased with sampling time in both Conven-A (from 814.91 at Day 0 to 315.00 kg·ha^{-1} at Day 45) and Conser-A (from 931.04 at Day 0 to 380.40 kg·ha^{-1} at Day 45) plots. The decrease was markedly more pronounced at the second sampling time (26.04% and 42.72% for Conven-A and Conser-A, respectively). Decreases in BM-dw were related to decreases in leaf BM, head BM, and grass BM. By the end of the experiment, no grass or weed remained on the plots. In contrast, stem BM progressively increased with sampling time (Table 1).

Table 1. Stubble fraction yields of wheat grown under conventional tillage and no-tillage cropping systems.

Sampling Period (d)	Biomass	Cropping System		*p* Value
		Conventional (Tillage) Agriculture	Conservation (No-Till) Agriculture	
Day 0	Leaves (kg ha^{-1}) fw	476.90 ± 14.58	522.38 ± 17.00	**0.065**
	Stems (kg ha^{-1}) fw	469.12 ± 11.71	420.36 ± 19.12	**0.092**
	Heads (kg ha^{-1}) fw	32.32 ± 6.81	32.49 ± 4.32	0.980
	Grasses (kg ha^{-1}) fw	21.68 ± 7.90	24.81 ± 2.19	0.774
	Total biomass (kg ha^{-1}) fw	1002.02 ± 41.00	1000.04 ± 42.62	0.914
	Total biomass (kg ha^{-1}) dw	814.91 ± 38.02	931.04 ± 28.64	**0.061**
Day 15	Leaves (kg ha^{-1}) fw	442.48 ± 21.86	409.64 ± 16.82	0.264
	Stems (kg ha^{-1}) fw	512.84 ± 13.38	544.93 ± 19.05	0.272
	Heads (kg ha^{-1}) fw	26.60 ± 8.38	25.24 ± 3.89	0.927
	Grasses (kg ha^{-1}) fw	18.12 ± 5.50	20.03 ± 4.07	0.850
	Total biomass (kg ha^{-1}) fw	1000.04 ± 49.12	999.84 ± 43.83	0.956
	Total biomass (kg ha^{-1}) dw	602.68 ± 31.26	533.25 ± 18.14	0.304
Day 30	Leaves (kg ha^{-1}) fw	406.97 ± 12.53	379.61 ± 26.59	0.359
	Stems (kg ha^{-1}) fw	565.22 ± 12.29	599.76 ± 19.44	0.233
	Heads (kg ha^{-1}) fw	18.24 ± 6.64	11.04 ± 4.83	0.614
	Grasses (kg ha^{-1}) fw	9.57 ± 2.75	9.60 ± 5.34	0.998
	Total biomass (kg ha^{-1}) fw	1000.00 ± 34.21	1000.01 ± 56.20	0.997
	Total biomass (kg ha^{-1}) dw	403.23 ± 30.86	451.38 ± 24.00	0.471
	Leaves (kg ha^{-1}) fw	383.32 ± 10.62	360.60 ± 12.29	0.401

Table 1. *Cont.*

Sampling Period (d)	Biomass	Cropping System		*p* Value
		Conventional (Tillage) Agriculture	Conservation (No-Till) Agriculture	
Day 45	Stems (kg ha^{-1}) fw	607.16 ± 15.48	636.06 ± 20.36	0.287
	Heads (kg ha^{-1}) fw	9.50 ± 4.99	3.30 ± 2.07	0.630
	Grasses (kg ha^{-1}) fw	0.00 ± 0.00	0.00 ± 0.00	1.000
	Total biomass (kg ha^{-1}) fw	999.98 ± 31.09	999.96 ± 34.72	0.932
	Total biomass (kg ha^{-1}) dw	315.00 ± 30.55	380.40 ± 17.33	0.304

Data are expressed as mean ± standard deviation. fw = fresh weigh. dw = dry weight. *p* values in bold indicate a significant change ($p < 0.05$; Student–Newman–Keuls (SNK) test) or a trend of change ($p < 0.10$; SNK test).

Table 2. *p* values from combined analysis of variance for the biomass and nutritive value of the stubble of wheat grown under conventional tillage and no-tillage systems, and the body weight and rumen fermentation characteristics of ewes grazing on the stubbles.

Varaiable	Sampling Period	Cropping System	Sampling Period × Cropping System
Leaf biomass	**<0.001**	0.512	0.173
Stem biomass	**<0.001**	0.405	0.101
Epic biomass	**0.030**	0.590	0.979
Vegetation biomass	**0.010**	0.814	0.990
Total biomass fw	0.840	0.786	0.913
Total biomass dw	**<0.001**	0.227	0.245
Dry matter	**0.004**	0.584	0.141
Crude protein	**<0.001**	**0.099**	**0.075**
Neutral detergent fiber	**<0.001**	0.125	0.247
Total ashes	**<0.001**	**0.046**	**<0.001**
Body weight	0.776	0.359	0.990
Body weight change	**0.091**	0.998	0.386
Forage allowance	**<0.001**	0.160	0.209
pH	**<0.001**	0.456	0.214
Ammonia nitrogen	**<0.001**	0.143	0.321
Acetic acid	**0.027**	0.187	0.115
Propionic acid	**<0.001**	**0.010**	0.015
Butyric acid	**0.010**	0.274	0.567
Total volatile fatty acids	**0.032**	0.626	0.943
Acetic acid/propionic acid	**<0.001**	**0.002**	**0.076**

p values in bold indicate a significant change ($p < 0.05$; SNK test) or a trend of change ($p < 0.10$; SNK test).

DM, CP, and NDF tended to be lower in Conser-A- than Conven-A-grown stubble, with a significant effect on Day 15. For example, DM was 883.36 g kg^{-1} in Conven-A and 850.46 g kg^{-1} in Conser-A on Day 15 (Table 3). With time, DM and NDF tended to increase for both cropping systems, while the opposite trend was observed for CP. Both the sampling time and cropping system significantly affected the AC (Table 2). AC was lower in Conser-A- than Conven-A-grown stubble on Days 0 and 15. On Day 30, the opposite was found, with no difference on Day 45 (Table 3).

Table 3. Nutritive value of the stubble of wheat grown under conventional tillage and no-tillage cropping systems.

Sampling Period (d)	Nutritive Value	Cropping System		*p* Value
		Conventional (Tillage) Agriculture	Conservation (No-Till) Agriculture	
Day 0	Dry matter (g kg^{-1})	866.67 ± 2.84	845.09 ± 27.91	0.979
	Crude protein (g kg^{-1})	36.58 ± 1.40	37.2 ± 6.27	0.804
	Neutral detergent fiber (g kg^{-1})	442.83 ± 29.79	431.45 ± 32.07	0.259
	Total ashes (g kg^{-1})	90.26 ± 1.93	80.97 ± 2.43	**<0.001**
Day 15	Dry matter (g kg^{-1})	883.33 ± 12.81	850.46 ± 9.85	**0.037**
	Crude protein (g kg^{-1})	38.06 ± 1.89	29.15 ± 0.24	**0.004**
	Neutral detergent fiber (g kg^{-1})	476.29 ± 6.04	455.70 ± 15.45	**0.040**
	Total ashes (g kg^{-1})	89.60 ± 2.97	71.24 ± 6.49	**<0.001**
Day 30	Dry matter (g kg^{-1})	893.42 ± 8.33	900.07 ± 12.67	0.275
	Crude protein (g kg^{-1})	32.74 ± 1.56	29.88 ± 7.43	0.330
	Neutral detergent fiber (g kg^{-1})	471.99 ± 6.57	465.41 ± 21.00	0.508
	Total ashes (g kg^{-1})	66.63 ± 2.54	82.46 ± 0.58	**<0.001**
Day 45	Dry matter (g kg^{-1})	900.05 ± 45.00	900.65 ± 28.55	1.000
	Crude protein (g kg^{-1})	22.69 ± 2.65	23.67 ± 1.34	0.744
	Neutral detergent fiber (g kg^{-1})	517.11 ± 36.04	524.64 ± 27.45	0.441
	Total ashes (g kg^{-1})	72.92 ± 16.23	74.50 ± 1.40	0.547

Data are expressed as mean ± standard deviation. *p* values in bold indicate a significant change ($p < 0.05$; SNK test).

3.2. Body Weight and Rumen Fermentation Profile of Barbarine Ewes

For all sampling times, the cropping system did not affect the BW of ewes. However, forage allowance tended to be higher for Conser-A plots than Conven-A plots, with a significant effect at D0 (Table 4). The mean three-day values of rumen fermentation parameters of Barbarine ewes during pre- and post-feeding are presented in Table 5. The cropping system had no effect ($p > 0.100$) on rumen pH (Table 2). Regardless of the cropping system, rumen pH decreased after grazing. For example, before grazing on Conser-A, the pH was 6.96. After two h of grazing, rumen pH decreased to 6.74. The lowest value of rumen pH (6.50) was obtained 4 h after the start of grazing (Table 5). Rumen NH_3-N increased two h after grazing and stabilized after four h. NH_3-N was not affected by the cropping system, but displayed a decreasing trend ($p = 0.092$) in Conser-A relative to Conven-A (Table 5). Three VFAs, acetic, propionic, and butyric acids, were successfully identified and quantified in this study. Of all three VFAs analyzed—acetic acid, propionic acid, and butyric acid—only propionic acid concentration was affected by the cropping system. Propionic acid concentration was lower in ewes grazing on Conser-A than those grazing on Conven-A stubbles, with significant effects at H0 and H2. Owing to the decreased propionic acid concentration, the ratio of acetic acid/propionic acid tended to be higher in ewes grazing on Conser-A than those grazing on Conven-A stubbles. Acetic acid concentration tended to increase with sampling time, while butyric acid concentration clearly decreased with sampling time, with 36.48% and 9.75% between H0 and H4 for Conven-A and Conser-A, respectively (Table 5).

Table 4. Body weight and forage allowance of ewes grazing on the stubble of wheat grown under conventional tillage and no-tillage cropping systems.

Sampling Period (d)		Cropping System		*p* Value
		Conventional (Tillage) Agriculture	Conservation (No-Till) Agriculture	
Day 0	Body weight (kg)	41.21 ± 0.68	40.72 ± 4.25	0.725
	Body weight change from D0 (kg)	0.00 ± 0.00	0.00 ± 0.00	0.999
	Forage allowance (kg dw kg^{-1} weight)	0.65 ± 0.02	0.76 ± 0.01	**0.043**
Day 15	Body weight (kg)	41.45 ± 6.04	40.97 ± 2.54	0.710
	Body weight change from D0 (kg)	0.24 ± 0.06	0.25 ± 1.71	0.351
	Forage allowance (kg dw kg^{-1} weight)	0.43 ± 0.08	0.48 ± 0.05	0.232
Day 30	Body weight (kg)	40.26 ± 7.11	39.82 ± 2.36	0.804
	Body weight change from D0 (kg)	−0.95 ± 0.43	−0.90 ± 0.08	0.860
	Forage allowance (kg dw kg^{-1} weight)	0.33 ± 0.08	0.38 ± 0.07	0.347
Day 45	Body weight (kg)	41.29 ± 4.68	40.70 ± 0.73	0.723
	Body weight change from D0 (kg)	0.08 ± 0.04	−0.02 ± 0.05	0.957
	Forage allowance (kg dw kg^{-1} weight)	0.25 ± 0.04	0.31 ± 0.16	0.173

Data are expressed as mean ± standard deviation. *p* values in bold indicate a significant change ($p < 0.05$; SNK test).

Table 5. Rumen fermentation of ewes grazing on the stubble of wheat grown under conventional tillage and no-tillage cropping systems.

Sampling Period (h)		Cropping System		*p* Value
		Conventional (Tillage) Agriculture	Conservation (No-Till) Agriculture	
H0	pH	6.91 ± 0.03	6.96 ± 0.12	0.356
	Ammonia nitrogen (mg L^{-1})	55.72 ± 3.02	63.40 ± 4.46	0.109
	Acetic acid (mmol L^{-1})	69.07 ± 2.51	69.24 ± 3.85	0.960
	Propionic acid (mmol L^{-1})	17.30 ± 0.15	16.72 ± 0.17	**0.013**
	Butyric acid (mmol L^{-1})	15.46 ± 5.62	11.08 ± 3.06	0.474
	Total volatile fatty acids (mmol L^{-1})	101.83 ± 8.28	97.04 ± 7.08	0.601
	Acetic acid/propionic acid	4.05 ± 0.04	4.29 ± 0.01	**0.078**
H2	pH	6.72 ± 1.04	6.74 ± 2.73	0.860
	Ammonia nitrogen (mg L^{-1})	89.81 ± 2.49	78.09 ± 5.11	**0.092**
	Acetic acid (mmol L^{-1})	69.53 ± 0.37	69.83 ± 1.38	0.175
	Propionic acid (mmol L^{-1})	18.75 ± 0.15	17.00 ± 0.01	**0.010**
	Butyric acid (mmol L^{-1})	9.73 ± 0.16	9.98 ± 2.88	0.737
	Total volatile fatty acids (mmol L^{-1})	98.01 ± 0.68	96.73 ± 4.27	0.601
	Acetic acid/propionic acid	3.70 ± 0.01	3.92 ± 0.03	**0.017**
H4	pH	6.50 ± 0.87	6.50 ± 1.39	0.999
	Ammonia nitrogen (mg L^{-1})	87.93 ± 6.14	77.91 ± 10.33	0.685
	Acetic acid (mmol L^{-1})	71.14 ± 3.71	71.08 ± 4.32	0.658
	Propionic acid (mmol L^{-1})	17.45 ± 0.12	17.04 ± 0.32	0.134
	Butyric acid (mmol L^{-1})	9.82 ± 9.99	10.00 ± 0.18	0.897
	Total volatile fatty acids (mmol L^{-1})	98.41 ± 13.82	98.12 ± 4.82	0.601
	Acetic acid/propionic acid	4.19 ± 0.03	4.26 ± 0.03	0.141

Data are expressed as mean ± standard deviation. *p* values in bold indicate a significant change ($p < 0.05$; SNK test) or a trend of change ($p < 0.10$; SNK test). H0 = 1 h before grazing; H2 = 2 h after grazing; H4 = 4 h after grazing.

Of all parameters, an interaction between the cropping system and sampling period was only found for CP ($p = 0.075$), AC ($p < 0.001$), and acetic acid/propionic acid ($p = 0.076$) (Table 2).

4. Discussion

4.1. Ewes May Eat the No-Tillage Stubble Faster Than the Conventional Tillage Stubble

In this study, the stubble characteristics of wheat grown under two agricultural systems (Conven-A and Conser-A) and grazed for two months were evaluated. Immediately after wheat harvesting, total dry BM tended to be higher in stubble from no-tillage plots than stubble from maximum tillage plots (Table 1). Ewes were found to consume the stubble heads first, followed by the leaves and grasses. In a study on direct-seeded durum wheat, Ben Said et al. [8] found that stubble heads and leaves disappeared within one month of grazing on the land. Similar results were reported for barley stubble [29]. Head stubbles have been reported to be more palatable and nutritive than other parts of the stubble [30]. As a result, grazing ewes first select these energy-rich parts. Therefore, the intake of ligneous stems with spines and sheaths will increase only when most of the heads, leaves, and grasses are consumed. Interestingly, stem BM increased progressively with time, indicating that roots continued to support the growth of the stems after the grains were picked. At the beginning of the study, the ewes displayed different foraging styles depending on whether they were grazing on the Conser-A or Conven-A plots. The daily intake of the dry period ratio appeared to be higher for ewes grazing on Conser-A than Conven-A. Indeed, the proportion of leaves and heads in the stubble decreased more quickly for Conser-A than for Conven-A at all sampling times. At the end of the experiment, the leaves decreased in Conser-A by 30.97% and Conven-A by 19.62%; heads decreased by 89.84% in Conser-A and 70.61% in Conven-A (Table 1).

4.2. Stubbles from the No-Tillage System Tend to Be Less Nutritive Than Stubbles from the Conventional Tillage

In the current experiment, DM, CP, NDF, and AC were lower in wheat stubble from Conser-A than wheat stubble from Conven-A on Day 15. A decrease was also observed for some of the parameters at the other sampling periods (Table 3). These data demonstrate that although the no-tillage system accelerates the accumulation of carbohydrates and increases the biomass and yield of crop plants [7,10,11,29], it can lead to reduced nutritional

quality, thereby decreasing the value of the foliage as a resource for animals [9,19,20]. These results disproved our assumption that no-tillage practices by enhancing soil quality would lead to both increased stubble biomass and quality. An inverse relationship between forage yield and CP has been reported in the literature, in simulated grazing leaf removal conditions [30]. Follow-up studies related to the underlying factors controlling the negative correlation between yield and quality in this study are needed. As ewes consumed more stubble from Conser-A on Day 15, it can be assumed that the ewes compensated for the lower nutritional (e.g., lower CP) quality of the stubbles by increasing their feeding rates when grazing on the no-tillage plots. CP decreased with sampling time, as reported in other studies [8,29,31]. However, this decrease may not be due to protein degradation. Mechanisms, such as growth dilution, might determine the relative concentration of CP, as DM and NDF tended to increase with time for both cropping systems (Table 3).

4.3. Both No-Tillage and Conventional Tillage Systems Can Support Crop–Livestock Integration

Despite differences in stubble nutritional values (Table 2), BW per ewe did not vary between the cropping systems, although Conser-A plots were found to maintain a higher forage allowance than Conven-A plots, with a significant effect at D0 (Table 4). When the four point-in-time measures (D0, D15, D30, and D45) were averaged to describe forage allowance over the entire grazing period of two months, forage allowance increased by 14.29% (p = 0.233) in Conser-A compared to Conven-A. Typically, a positive relationship exists between forage allowance and animal weight gain [25], which suggests that grazing efficiency and animal performance might increase in the long term with Conserv-A. However, animal performance responses to forage allowance may be affected by the average quality of the allowed forage and selection possibilities [21,31]. BW per ewe did not vary among the sampling periods (Table 4). Other researchers found that after 48 days of grazing, ewes lose weight owing to a decrease in the nutritional quality and digestibility of stubbles [31]. The findings of this study demonstrate that stubble BM in the experimental plots was not limiting in the animal density used and was sufficient to sustain and preserve the body condition of ewes, even in the absence of supplementation. For the system to be considered conservative, at least 30% of crop residue (mulch) must be left on the soil surface before planting [32]. In this study, 100% of crop residue was maintained in the field. At the end of the two-month experimental period, for Conven-A and Conser-A, 38.65% and 40.86% of biomass remained in the soil (more than 100% and 100% stems, 80.38% and 69.03% leaves, 29.39% and 10.16% heads, 0% and 0% grasses, respectively) (Table 1). Such findings demonstrate the potential of integrating livestock and crops into the Conser-A system. However, the Conser-A system did not present a significant advantage over the Conven-A system in terms of the amount of surface residue remaining after grazing. To gain more from mulch for soil fertility, concentrate feed supply would be requested in addition to stubble feeding.

4.4. Rumen Fermentation Parameters Suggest a Less Efficient Energy Utilization by Ewes Grazing on No-Tillage Plots Relative to Conventional Tillage Plots

The pH values at all sampling times were within the range considered appropriate (6.0 to 7.0) for fiber and protein digestion [33]. Rumen pH decreased after grazing; this decrease could be explained by an increase in the levels of some VFAs (e.g., acetic acid) in ruminal fluid before the morning feeding (0 h) and after 4 h of grazing (Table 5). NH_3-N increased after grazing, reflecting the continuity of the microbial proteolytic activity simultaneously with a peak of proteolytic deaminase activity [33]. A negative correlation between pH and VFA was reported in studies conducted on sheep fed diets containing fibrous residues [34,35]. VFAs originate from the fermentation of dietary carbohydrates by rumen microflora and provide the principal source of energy for ruminant animals. Furthermore, the relative concentrations of VFAs are related to efficient energy utilization and milk fat production [27]. In this study, however, total VFA concentration tended to decrease after feed intake, due to a significant drop in butyric acid levels. Exposure

of animals to elevated temperatures often results in increased rectal temperature and decreased butyric acid absorption [36]. Thus, it is reasonable to assume that these decreases were related to the high ambient temperatures measured during the grazing period. Indeed, the average temperature was 23.34 °C before grazing and 31.12 °C after grazing. Propionic acid concentration was lower in ewes grazing on Conser-A than those grazing on Conven-A stubbles, with significant effects at H0 and H2. The production of VFAs is influenced by nutritional factors in the diet (e.g., fibers) [37–39]. Further, a decrease in propionic acid concentration could be explained by low levels of nutrients in the stubble from Conser-A.

5. Conclusions

Although stubble biomass tended to be higher in Conser-A than Conven-A immediately after wheat harvesting, the nutritive value of the stubble was lower in plants grown using the latter agricultural system. Consequently, some rumen fermentation parameters (e.g., propionic acid concentration) were lower in ewes grazed on Conser-A than Conven-A. The ewes preferred stubble heads, followed by leaves, grasses, and stems. The amount of crop residue in the soil after grazing was similar between the two cropping systems. Further, the BW of the animals was not affected by the cropping system. One limitation of the present study is a lack of focus on the relationship between stubble quality and stubble digestibility and intake. Measurements of stubble intake and nutritive value would have allowed a better assessment of the effects of no-tillage on the performance of animals, and these are aspects to be considered in future studies. As ewes performed similarly when grazing on Conven-A and Conser-A-stubbles, farmers will be encouraged to adopt cereal conservation agriculture mainly because of the production cost, grain yield, and improved soil properties. However, of note, a no-tillage system should be adjusted to the soil type, agro-ecological conditions, and the optimal nutrient supply before drawing definitive conclusions. More studies are thus needed to measure and compare the economic returns in no-tillage and conventional-tillage production systems.

Author Contributions: Conceptualization, N.M.; methodology, H.G., C.D., P.G., S.B.Y., M.C., H.B.S., H.T. and N.M.; software, P.G. and M.C.; validation, H.G., C.D. and S.B.Y.; formal analysis, M.C. and H.B.S.; investigation, H.G., C.D., P.G., S.B.Y., M.C., H.B.S., H.T. and N.M.; resources, H.T. and N.M.; data curation, S.B.Y.; writing—original draft preparation, H.G.; writing—review and editing, H.G., C.D., P.G., S.B.Y., M.C., H.B.S., H.T. and N.M.; visualization, P.G.; supervision, N.M.; project administration, N.M.; funding acquisition, H.T. and N.M. All authors have read and agreed to the published version of the manuscript.

Funding: The work received funding from ICARDA (International Center for Agricultural Research in the Dry Areas) and IFAD (International Fund for Agricultural Development) under the CLCA Project (Phase 1—*Integrated crop–livestock conservation agriculture for sustainable intensification of cereal-based systems in North Africa and Central Asia*), and from the Ecosystems and Aquatic Resources Research Unit of INAT assigned by the Tunisian Ministry of Higher Education and Scientific Research of Tunisia. This work was also supported by the Fundação para a Ciência e a Tecnologia (grant number UIDB/04033/2020).

Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Management Committee of "Bourbiaa" Experimental Farm of INRAT (National Institute of Agronomic Research of Tunisia), which serves as an institutional animal care and use committee (project code I-R-1393-ICARDA of 15 June 2015).

Informed Consent Statement: Not applicable.

Data Availability Statement: The data that support the findings of this study are available within the article.

Acknowledgments: The authors thank Donzilia Botelho and Aurea Queirós of Departamento de Agronomia of Universidade de Tras-os-Montes e Alto Douro in Portugal for facilitating laboratory experiments.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

References

1. Mohamed, A.H.; Squires, V.R. Drylands of the Mediterranean Basin: Challenges, Problems and Prospects. In *Climate Variability Impacts on Land Use and Livelihoods in Drylands*, 1st ed.; Gaur, M., Squires, V., Eds.; Springer: Cham, Switzerland, 2018; pp. 223–239. [CrossRef]
2. Kühling, I.; Atoev, S.; Trautz, D. Sustainable Intensification in Dryland Cropping Systems—Perspectives for Adaptions across the Western Siberian Grain Belt. *Agriculture* **2018**, *8*, 63. [CrossRef]
3. Swamila, M.; Philip, D.; Akyoo, A.M.; Sieber, S.; Bekunda, M.; Kimaro, A.A. Gliricidia Agroforestry Technology Adoption Potential in Selected Dryland Areas of Dodoma Region, Tanzania. *Agriculture* **2020**, *10*, 306. [CrossRef]
4. Ben Nasr, J.; Chaar, H.; Bouchiba, F.; Zaibet, L. Assessing and building climate change resilience of farming systems in Tunisian semi-arid areas. *Environ. Sci. Pollut. Res.* **2021**, *28*, 46797–46808. [CrossRef]
5. Serrano, J.; Shahidian, S.; Machado, E.; Paniagua, L.L.; Carreira, E.; Moral, F.; Pereira, A.; De Carvalho, M. Floristic Composition: Dynamic Biodiversity Indicator of Tree Canopy Effect on Dryland and Improved Mediterranean Pastures. *Agriculture* **2021**, *11*, 1128. [CrossRef]
6. Derdous, O.; Bouamrane, A.; Mrad, D. Spatiotemporal analysis of meteorological drought in a Mediterranean dry land: Case of the Cheliff basin–Algeria. *Model. Earth Syst. Environ.* **2021**, *7*, 135–143. [CrossRef]
7. Jat, R.A.; Wani, S.P.; Sahrawat, K.L. Conservation agriculture in the semi-arid tropics: Prospects and problems. *Adv. Agron.* **2012**, *117*, 191–273. [CrossRef]
8. Ben Said, S.; Mahouachi, M.; El Ayeb, H.; Ben Hammouda, M. Evolution of the Characteristics of Stubble in Plots Conducted in Direct Seeding and Grazed by Sheep. *Cah. Options Mediterr. A.* **2011**, *100*, 335–339. Available online: http://om.ciheam.org/om/pdf/a100/00801525.pdf (accessed on 18 December 2021).
9. De Vita, P.; Di Paolo, E.; Fecondo, G.; Di Fonzo, N.; Pisante, M. No-tillage and conventional tillage effects on durum wheat yield, grain quality and soil moisture content in southern Italy. *Soil Tillage Res.* **2007**, *92*, 69–78. [CrossRef]
10. Kassam, A.; Friedrich, T.; Shaxson, F.; Pretty, J. The spread of conservation agriculture: Justification, sustainability and uptake. *Int. J. Agric. Sustain.* **2009**, *7*, 292–320. [CrossRef]
11. Hobbs, P.R.; Sayre, K.; Gupta, R. The role of conservation agriculture in sustainable agriculture. *Philos. Trans. R. Soc. Lond. B Biol. Sci.* **2007**, *363*, 543–555. [CrossRef]
12. Guesmi, H.; Ben Salem, H.; Moujahed, N. Integration Crop-Livestock under Conservation Agriculture System. *J. New Sci. Agri. Biotechnol.* **2019**, *65*, 4061–4065. Available online: https://www.jnsciences.org/agri-biotech/96-volume-65/578-integration-crop-livestock-under-conservation-agriculture-system.html (accessed on 18 December 2021).
13. Alary, V.; Moulin, C.-H.; Lasseur, J.; Aboul-Naga, A.; Sraïri, M.T. The dynamic of crop-livestock systems in the Mediterranean and future prospective at local level: A comparative analysis for South and North Mediterranean systems. *Livest. Sci.* **2019**, *224*, 40–49. [CrossRef]
14. Ameur, W.; Frija, A.; Abdeladhim, M.A.; Thabet, C. Patterns of Use of Residue Biomass in Cereal–Sheep Production Systems of North Africa: Case of Tunisia. *Agriculture* **2021**, *11*, 612. [CrossRef]
15. Cheruiyot, D.; Midega, C.A.O.; Pittchar, J.O.; Pickett, J.A.; Khan, Z.R. Farmers' Perception and Evaluation of Brachiaria Grass (Brachiaria spp.) Genotypes for Smallholder Cereal-Livestock Production in East Africa. *Agriculture* **2020**, *10*, 268. [CrossRef]
16. Guesmi, H.; Moujahed, N.; Ben Youssef, S.; Darej, C.; Chakroun, M.; Ben Salem, H. Performances of Barbarine ewes Grazing on Wheat Stubble under Conventional and Conservation Agricultural Conditions in a Tunisian Semi-Arid Area. *Cah. Options Mediterr. A* **2019**, *123*, 235–239. Available online: https://om.ciheam.org/om/pdf/a123/00007891.pdf (accessed on 18 December 2021).
17. Baudron, F.; Sylvestre, D.; Marc, C.; Juan, H.M.; Pablo, T. Multi-scale trade-off analysis of cereal residue use for livestock feeding vs. soil mulching in the Mid-Zambezi Valley, Zimbabwe. *Agric. Syst.* **2015**, *134*, 97–106. [CrossRef]
18. El-Shater, T.; Yigezu, Y.A. Can Retention of Crop Residues on the Field Be Justified on Socioeconomic Grounds? A Case Study from the Mixed Crop-Livestock Production Systems of the Moroccan Drylands. *Agronomy* **2021**, *11*, 1465. [CrossRef]
19. Simić, M.; Dragičević, V.; Mladenović Drinić, S.; Vukadinović, J.; Kresović, B.; Tabaković, M.; Brankov, M. The Contribution of Soil Tillage and Nitrogen Rate to the Quality of Maize Grain. *Agronomy* **2020**, *10*, 976. [CrossRef]
20. Park, E.Y.; Baik, B.-K.; Machado, S.; Gollany, H.T.; Fuerst, E.P. Functional and Nutritional Characteristics of Soft Wheat Grown in No-Till and Conventional Cropping Systems. *Cereal Chem.* **2015**, *92*, 332–338. [CrossRef]
21. Rao, S.C.; Dao, T.H. Straw Quality of 10 Wheat Cultivars under Conventional and No-Till Systems. *Agron. J.* **1994**, *86*, 833–837. [CrossRef]
22. Tucke, C.B.; MacNeil, M.D.; Delta, G.; Webster, A.B. *Guide for the Care and Use of Agricultural Animals in Research and Teaching*, 4th ed.; The Federation of Animal Science Societies (ADSA, ASAS, Poultry Science): Champaign, IL, USA, 2020; pp. 1–227. Available online: https://www.asas.org/docs/default-source/default-document-library/agguide_4th.pdf?sfvrsn=56b44ed1_2 (accessed on 18 December 2021).
23. Goufo, P.; Ferreira, L.M.M.; Carranca, C.; Rosa, E.A.S.; Trindade, H. Effect of elevated carbon dioxide concentration on rice quality: Proximate composition, dietary fibres and free sugars. *Cereal Chem.* **2014**, *91*, 293–299. [CrossRef]

24. Van Soest, P.J.; Robertson, J.B.; Lewis, R.A. Methods for dietary fiber, neutral detergent fiber, and non-starch polysaccharides in relation to animal nutrition. *J. Dairy Sci.* **1991**, *74*, 3583–3597. [CrossRef]
25. Sollenberger, L.E.; Moore, J.E.; Allen, V.G.; Pedreira, C.G.S. Reporting forage allowance in grazing experiments. *Crop Sci.* **2005**, *45*, 896–900. [CrossRef]
26. Muizelaar, W.; Bani, P.; Kuhla, B.; Larsen, M.; Tapio, I.; Yáñez-Ruiz, D.; Van Gastelen, S. Rumen fluid sampling via oral stomach tubing method. In *Methods in Cattle Physiology and Behaviour—Recommendations from the SmartCow Consortium*, 1st ed.; Mesgaran, S.D., Baumont, R., Munksgaard, L., Humphries, D., Kennedy, E., Dijkstra, J., Dewhurst, R., Ferguson, H., Terré, M., Kuhla, B., Eds.; PUBLISSO: Cologne, Germany, 2020; pp. 1–6. [CrossRef]
27. Erwin, E.S.; Marco, G.J.; Emery, E.M. Volatile fatty acid analyses of blood and rumen fluid by Gas Chromatography. *J. Dairy Sci.* **1961**, *44*, 1768–1771. [CrossRef]
28. Conway, E.J.; O'Malley, E. Microdiffusion methods. Ammonia and urea using buffered absorbents. (Revised methods for ranges greater than 10 p.g N). *Biochem. J.* **1941**, *36*, 655–661. [CrossRef]
29. Moujahed, N.; Abidi, S.; Ben Youssef, S.; Darej, C.; Chakroun, M.; Ben Salem, H. Effect of stocking rate on biomass variation and lamb performances for barley stubble in Tunisian semi-arid region and under conservation agriculture conditions. *Afr. J. Agric. Res.* **2015**, *10*, 4584–4590. [CrossRef]
30. Tahmasebi, P.; Manafian, N.; Ebrahimi, A.; Omidipour, R.; Faal, M. Managing Grazing Intensity Linked to Forage Quantity and Quality Trade-off in Semiarid Rangelands. *Rangel. Ecol. Manag.* **2020**, *73*, 53–60. [CrossRef]
31. Houmani, M. Evolution of the Nutritional Value of Durum Wheat Stubble and Interest for Pregnant Ewes. *Rech. Agron.* **2002**, *11*, 49–56. Available online: http://www.webreview.dz/IMG/pdf/EVOLUTION_DE_LA_VALEUR_NUTRITIVE_DES_CHAUMES_DE_BL_DUR.pdf (accessed on 18 December 2021).
32. Thierfelder, C.; Rusinamhodzi, L.; Ngwira, A.; Mupangwa, W.; Nyagumbo, I.; Kassie, G.; Cairns, J. Conservation agriculture in Southern Africa: Advances in knowledge. *Renew. Agric. Food Syst.* **2015**, *30*, 328–348. [CrossRef]
33. Budel, J.C.C.; Ramos, A.F.O.; Araújo, G.S.; Lima, A.C.S.; Martorano, L.G.; Nahúm, B.S.; Sousa, L.F.; Silva, A.G.M.; Junior, J.B.L. Fermentation kinetics and ruminal parameters of animals fed diets containing Brazil nut cake inclusion levels. *Semin. Ciências Agrárias* **2017**, *38*, 1605–1616. [CrossRef]
34. Sheikh, G.; Bhat, S.; Sheikh, F.; Ganai, A.; Bilal, S. Postprandial Changes in Rumen Microflora and Fermentation Pattern in Sheep Fed Paddy Straw Based Complete Feed Supplemented with Probiotics Mix. *Int. J. Livest. Res.* **2018**, *8*, 265–275. [CrossRef]
35. Geron, L.J.V.; Garcia, J.; Costa, F.G.; Aguiar, S.C.; Oliveira, E.B.; Silva, M.I.L.; Cabral, L.S.; Pierangeli, M.A.P.; Zeoula, L.M.; Mexia, A.A. Ruminal parameters and nitrogen balance in sheep fed diets containing residue from the extraction of tamarind pulp. *Semin. Ciências Agrárias* **2015**, *36*, 3411–3420. [CrossRef]
36. Bedford, A.; Beckett, L.; Harthan, L.; Wang, C.; Jiang, N.; Schramm, H.; Guan, L.L.; Daniels, K.M.; Hanigan, M.D.; White, R.R. Ruminal volatile fatty acid absorption is affected by elevated ambient temperature. *Sci. Rep.* **2020**, *10*, 13092. [CrossRef]
37. Syapura, S.; Bata, M.; Pratama, W.S. Improving of rice straw quality and its effect on ability nutrient digestibility and rumen metabolism products of Buffalo in-vitro with feces as inoculum source. *J. Agripet* **2013**, *13*, 59–67. [CrossRef]
38. Roman-Garcia, Y.; Denton, B.L.; Mitchell, K.E.; Lee, C.; Socha, M.T.; Firkins, J.L. Conditions stimulating neutral detergent fiber degradation by dosing branched-chain volatile fatty acids. I: Comparison with branched-chain amino acids and forage source in ruminal batch cultures. *J. Dairy Sci.* **2021**, *104*, 6739–6755. [CrossRef] [PubMed]
39. Horst, E.H.; López, S.; Neumann, M.; Giráldez, F.J.; Bumbieris Junior, V.H. Effects of Hybrid and Grain Maturity Stage on the Ruminal Degradation and the Nutritive Value of Maize Forage for Silage. *Agriculture* **2020**, *10*, 251. [CrossRef]