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1 **A quantitative review of on-farm feeding practices to enhance the**  
2 **quality of grassland-based ruminant dairy and meat products**

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18

19 **ABSTRACT**

20 In the last decades, a large body of evidence has highlighted the major  
21 role of feeding management practices in improving specific nutritional,  
22 technological and sensory quality traits of ruminant products. However,  
23 results have been mostly obtained under controlled conditions, and have  
24 been rarely validated on-farm. Therefore, a quantitative review was  
25 conducted to quantify the effects of on-farm feeding management  
26 practices on carotenoids, fat-soluble vitamins, colour, fatty acids (FA),  
27 terpenes and sensory properties in the main animal products categories  
28 (PC): dairy products from cattle (DC), sheep (DS) and goat (DG), and  
29 meat from cattle (MC) and sheep (MS). Four feeding scenarios were  
30 selected according to the consistency of on-farm studies in the literature:  
31 a) feeding “Fresh herbage” instead of conserved forages; b) ban any form  
32 of silage (“Silage-free”) c) ban maize silage (“Maize silage-free”); d)  
33 feeding forages from permanent grasslands rich in species or plant  
34 secondary metabolites (PSM) (“PSM-rich permanent grassland”). Feeding  
35 fresh herbage increased the concentration of carotenoids, fat-soluble  
36 vitamin, n-3 FA, rumenic acid, and branched chain FA (BCFA), and  
37 reduced the concentration of saturated FA, for all PC, with overall stronger  
38 effect for dairy products than for meat. The texture of meat and dairy  
39 products was marginally affected, whereas feeding fresh herbage  
40 decreased lactic and increased vegetal notes in DC. The “Silage-free”  
41 feeding scenario resulted in increased vaccenic acid, rumenic acid, BCFA,

42 and C18:3n-3 in DC. The “Maize silage-free” feeding scenario lowered n-6  
43 FA whereas increased n-3, rumenic acid and BCFA concentrations in DC.  
44 Feeding ruminants with forages from “PSM-rich permanent grasslands”,  
45 increased monounsaturated FA, n-3 FA and rumenic acid and decreased  
46 n-6 FA in dairy products, and only marginally affected meat FA  
47 composition. The DC from “PSM-rich permanent grasslands” showed  
48 higher intense, spicy and animal notes. Overall, the differences between  
49 feeding management practices observed on farm were smaller than those  
50 observed under controlled trials. Several confounding factors, not  
51 controlled when operating under on-farm conditions, could be at the origin  
52 of these divergences (i.e. mixed diets, forage characteristics, animal-  
53 related factors). This review confirmed that farming practices may  
54 differently affect several quality traits of ruminant products. It also  
55 highlighted the uneven knowledge on the effect of feeding management  
56 depending on the PC: larger for milk than for meat and decreasing when  
57 moving from cattle to sheep and from sheep to goat.

58 **Keywords:** fatty acids, carotenoids, colour, terpenoids, sensory  
59 properties.

60

## 61 **Implications**

62 Feeding management practices are the most impacting factors to improve  
63 nutritional, technological and sensory quality of ruminant products in  
64 controlled experiments. However, most studies were conducted under

65 controlled conditions. This review aims at quantifying these effects of  
66 feeding management on farm. We identified common feeding  
67 management practices able to enhance the quality of cattle and small  
68 ruminants meat and dairy products. Factors weakening the expected  
69 effects on quality traits on farm were highlighted. This review provides  
70 sound information to the stakeholders of ruminant production chains for  
71 implementing effective feeding management practices to achieve the  
72 targeted quality of ruminant products.

73

#### 74 **Introduction**

75 Globally, consumers are increasingly demanding for animal products with  
76 a high safety standard, nutritional value, and sensory quality, which are, at  
77 the same time, obtained through environment- and animal-friendly  
78 practices. To achieve these goals, feeding management is one of the most  
79 effective strategies (Prache *et al.*, 2020; Cabiddu *et al.* 2019; Minchin *et*  
80 *al.*, 2010). By feeding herbage to ruminants (particularly when grazed),  
81 dairy and meat products with specific traits are produced. They are rich in  
82 carotenoids, vitamins A and E (Nozière *et al.*, 2006; Prache *et al.*, 2020),  
83 volatile organic compounds (VOCs), and fatty acids (FA) favourable for  
84 human nutrition [e.g. monounsaturated FA (MUFA), polyunsaturated FA  
85 (PUFA), and n-3 FA] (Coppa *et al.*, 2019; Cabiddu *et al.*, 2019; Scerra *et*  
86 *al.*, 2011), and have specific sensory characteristics, preferred by  
87 consumers (Martin *et al.*, 2005). For some products, however, the

88 opposite is true. For instance, certain maize silage and concentrate-based  
89 dairy products, such as butter, have been historically preferred for their  
90 firmness because the high melting point of fats therein [due to the richness  
91 in saturated FA (SFA)], as this make them easy to be transported and  
92 commercialised even far from the production area (Prache *et al.*, 2020).  
93 Similarly, the U.S. population prefers the sensory characteristics of grain-  
94 finished animals (Gwin, 2009).

95 Most feeding strategies that improve the quality of animal products have  
96 been tested under controlled conditions (Ferlay *et al.*, 2006; Hurtaud *et al.*,  
97 2009 for dairy products from cattle; Cabiddu *et al.* 2019 for dairy products  
98 from small ruminant; Fraser *et al.*, 2009; and Luciano *et al.*, 2009 for  
99 meat). However, under on-farm conditions, other uncontrolled and  
100 unstandardised factors (e.g. forage characteristics, animal status, feeding  
101 behaviour, and farm management, among others) may interact and thus  
102 amplify, confound, or overrule the effects of the employed practices,  
103 ultimately affecting the product quality in controlled trials.

104 Furthermore, most studies focused on one or a few specific quality traits of  
105 certain products. To the best of our knowledge, a quantitative review  
106 underlining the common effects of on-farm management practices on the  
107 quality of ruminant-derived products (meat and dairy) is lacking. Such an  
108 approach is highly relevant for the selection of effective management  
109 practices to be included in the specification of quality-labelled animal  
110 products.

111 To this end, the aim of the present quantitative review was to elucidate the  
112 effects of specific management practices on the quality traits of animal  
113 products, focusing exclusively on experiments conducted under on-farm  
114 conditions, and to identify which factors effective under controlled  
115 conditions remain effective on-farm and to what extent. Furthermore,  
116 common management practices that can enhance the quality of  
117 grassland-based meat and dairy products derived from cattle and small  
118 ruminants are identified. Finally, possible factors explaining the differences  
119 in the degree of effect of feeding management on qualitative traits  
120 between controlled trials and on-farm studies are discussed.

## 121 **Materials and methods**

### 122 ***Data collection and selection of quality traits***

123 Scientific publications were identified through an initial search of literature  
124 in the Web of Knowledge and Scopus databases using several search  
125 keywords related to the effect of farm management practices on different  
126 quality traits of animal products (i.e. pasture\*, fresh herbage\*, silage\*,  
127 maize\*, hay\*, and biodiversity\*). Animal species, animal product type, and  
128 each quality trait were used as the keywords. Experiments performed  
129 under controlled conditions or on experimental farms were excluded, but  
130 those reporting data from commercial farms were selected. The data on  
131 animal product quality traits and farming practices were collected from  
132 peer-reviewed papers and conference proceedings that were published  
133 between 1996 and 2019, included proper statistical analyses, and reported

134 probability values for the investigated factors. Only studies that provided  
135 detailed information on the proportion of feedstuff on a DM basis and in  
136 which at least two farming practices were compared were included. A  
137 complete list of the included studies is provided in the supplementary  
138 material. A total of 98 studies were included, 70 of which were on dairy  
139 products and 28 on meat products; 45 studies dealt with cattle, 12 with  
140 goat, and 41 with sheep. There was no study on goat meat. Five product  
141 categories (PC) were defined by combining the animal product type and  
142 species: dairy cattle (DC), dairy goats (DG), dairy sheep (DS), meat cattle  
143 (MC), and meat sheep (MS). Quality traits having an interest for human  
144 nutrition and health or with an effect on the sensory profile of animal  
145 products were evaluated, as well as the sensory profile itself. In particular,  
146 fat-soluble vitamins and carotenoids were considered due to the  
147 antioxidant potential for humans and their influence on dairy products  
148 colour (Nozière *et al.*, 2006). The MUFA, PUFA, C18:1cis9, C18:3n-3 (the  
149 main n-3 FA in animal products) and its ratio to C18:2n-6 (the main n-6 FA  
150 in animal products), branched chain FA (BCFA), rumenic acid  
151 (CLAcis9trans11) and its precursor C18:1trans11 were included because  
152 of their potential positive effect on human health (potential contribution to  
153 the prevention against cardiovascular diseases, cancer, obesity, etc.)  
154 (Givens, 2010). The effect positive or negative effect of SFA and C18:2n-  
155 6 on human health is still in debate: i.e. Hooper *et al.*, (2020) showed that  
156 a reduction in SFA intake could help to prevent cardiovascular diseases,

157 but Astrup *et al.*, (2020) highlighted that the intake of SFA from whole fat  
158 dairy and unprocessed meat is not associated with increased risk of  
159 cardiovascular diseases. Some FA (SFA, MUFA, PUFA, C18:1cis9/C16:0)  
160 affect the fat melting point with consequences on the texture of animal  
161 products. Moreover, PUFA can contribute to develop odour active  
162 compounds through oxidation (Martin *et al.*, 2005). Mono-, sesqui-, and  
163 total terpenes can potentially play a role on sensory profile as odour active  
164 compounds (Martin *et al.*, 2005). Both instrumentally measured sensory  
165 traits, such as colour and texture, pH at 24 h (only for meat), and those  
166 evaluated by panel tests (colour, appearance, texture, odour, flavour, and  
167 taste) were considered. Only quality traits for which data from at least  
168 three publications in a feeding scenario were available were included in  
169 the statistical analysis. Several other quality traits were also found in the  
170 literature (i.e. other FA, single terpenes, total antioxidant capacity, muscle  
171 water holding capacity and microstructure, and cheese granular texture),  
172 but the available data were limited to yield reliable statistics; thus, such  
173 traits were not considered in the present review. As sensory attributes are  
174 often specific to a product (particularly dairy products), they were grouped  
175 under sensory families, as described by Piccinali (2012), based on odour,  
176 flavour, and taste: intensity, spicy, lactic (acid, milk, yoghurt, cream,  
177 fermented cream, and butter), fruity (hazelnut), vegetal (grassy, boiled  
178 vegetables, garlic, and onion), brown (caramel, smoked, sweet, and  
179 vanilla), animal (animal, stable, barn, and manure), and others (salty,

180 bitter, silage, mould, mothball, and cheese mite). Data on floral and spicy  
181 sensory families were limited. Furthermore, texture properties (firm and  
182 elastic), including meat tenderness, fattiness, juiciness, and visually  
183 estimated intramuscular fat, were considered.

184 When quality traits were expressed using different units of measurement  
185 in different studies, the data were converted to a common unit [ $\text{mg}\cdot\text{kg}^{-1}$   
186 DM to  $\text{mg}\cdot\text{kg}^{-1}$  fat for fat-soluble vitamins,  $\text{g}\cdot 100\text{ g}^{-1}$  milk or  $\text{g}\cdot 100\text{ g}^{-1}$  DM to  
187  $\text{g}\cdot 100\text{ g}^{-1}$  FA for FA,  $10^6$  arbitrary area unit (AAU) to  $\ln$  (natural logarithm)  
188 of AAU for terpenes, and 0-n to a 0–10 scale for sensory descriptors].

### 189 ***Selection of management practices***

190 As most studies focused on specific feeding practices, a common ground  
191 for analysis was achieved by grouping them under four main feeding  
192 scenarios. The %DM of feedstuffs in the diet, representing the explanatory  
193 variables for the quantified effect, was also recorded.

194 The collected data were attributed to the following main feeding scenarios:

- 195 1. Inclusion of fresh herbage in the diet instead of feeding conserved  
196 forage and/or concentrates (*fresh herbage*)
- 197 2. Renunciation to feed any form of silages in conserved forage- or  
198 pasture-based systems during the winter period (but approval to feed  
199 hay) (*silage-free*)
- 200 3. Renunciation to feed maize silage, including the winter periods in  
201 pasture-based systems, but approval to feed grass silage (*maize silage-*  
202 *free*)

203 4. Use of forages from permanent grasslands rich in species or plant  
204 secondary metabolites (PSM) instead of temporary grasslands  
205 dominated by grasses or poor in PSM (*PSM-rich permanent*  
206 *grasslands*).

207 Each main feeding scenario was analysed with the aim of quantifying the  
208 effects of feeding practices. Similarities and differences in effects for cattle  
209 and small ruminant meat or dairy products between controlled and on-farm  
210 conditions as well as possible confounding factors under on-farm  
211 conditions were highlighted.

#### 212 ***Statistical analysis***

213 For each study included in the statistical analysis, the mean across  
214 replicates, years, and other factors not addressed in the present review  
215 were computed for each feeding practice and considered a statistical unit.  
216 To evaluate the significance and extent of effect of the most frequent  
217 feeding scenario (inclusion of fresh herbage in the diet instead of feeding  
218 conserved forage and/or concentrates), a paired sample *t*-test was  
219 performed for each quality trait within each PC. When the paired sample *t*-  
220 test detected significant differences in a quality trait within a PC, the  
221 percent relative change ( $\Delta\%$ ) for each data pair was calculated as follows:

$$222 \quad \Delta\% = \frac{X1 - X0}{X0} \times 100$$

223 where X0 is the reference value and X1 is the value to be compared with  
224 X0.

225 Then, general linear model (GLM) analysis was performed, considering  
226 the respective DM  $\Delta\%$  of fresh herbage in the diet as a covariate. PC and  
227 their interactions with the covariate were included as the fixed effects to  
228 estimate the differences among PC and detecting various responses to  
229 the corresponding feeding practice. Considering the great variability of  
230 experimental conditions in different studies included, eight or more cases  
231 was considered the minimum number for each PC to be included in the  
232 GLM analysis. Bonferroni post hoc test was performed to analyse  
233 differences in PC and their interactions with the covariate (respective DM  
234  $\Delta\%$  of fresh herbage in the diet). For other main feeding scenarios,  
235 sufficient data were not available to perform the same analysis. All the  
236 statistical analyses were performed using Minitab v. 14.1 (Minitab Inc.,  
237 State College, PA, USA).

## 238 **Results and discussion**

### 239 ***Structure of the dataset***

240 Among all farming practices considered in this review, the effect of fresh  
241 herbage inclusion in animal diets was the most studied under on-farm  
242 conditions, but the number of available data varied according to the PCs  
243 and quality traits considered. Overall, DC was the most studied category  
244 (40 studies), followed by MS and DS (22 and 18 studies, respectively).  
245 However, there were a few studies on DG (12 studies) and very few on  
246 MC (5 studies); there was no study on goat meat. Furthermore, the studies  
247 assessed the effects of feeding hay instead of silage or grass silage

248 instead of maize silage under on-farm conditions on DC alone, and studies  
249 on other PCs were lacking. Moreover, the studies assessed the effects of  
250 pasture plant diversity under on-farm conditions on DC, DS, and MS  
251 alone. Furthermore, among the various quality traits, major FA  
252 composition of dairy and meat products was the most widely studied for all  
253 farming management practices analysed (61 studies), followed by colour  
254 and carotenoids (18 studies), sensory characteristics (11 studies), and  
255 total terpene content (7 studies).

256 The fresh herbage proportion (%DM) of animal diet in the dataset used to  
257 investigate the 'fresh herbage' feeding scenario showed marked  
258 differences between the "fresh herbage" and the "conserved forages"  
259 groups (Table 1); its average proportion in the fresh herbage group ranged  
260 between 61 and 100% within a PC, with a mean paired-sample difference  
261 of 54-94%. The fresh herbage proportion of animal diet in the dataset used  
262 to test the 'PSM-rich permanent grasslands' feeding scenario was  
263 comparable between the high- and low-biodiversity groups, regardless of  
264 the PC (85-100%, with a mean paired-sample difference of 1-2%; Table  
265 1). Regarding the 'silage-free' feeding scenario, the proportion (%DM) of  
266 hay in dairy cattle diet was  $61 \pm 21.3\%$  (average  $\pm$  standard deviation;  
267 range: 41-100%) and  $8 \pm 8.1\%$  (range: 0-28%) in the hay and silage  
268 groups, respectively, with a paired-sample difference of  $53 \pm 24.0\%$   
269 (range: 25-100%). In the 'maize silage-free' feeding scenario, the grass  
270 silage proportion (%DM) of dairy cattle diet was  $48 \pm 12.4\%$  (range 31-

271 61%) and  $6 \pm 7.3\%$  (range: 0-18%) in the grass silage and maize silage  
272 groups, respectively, with a paired-sample difference of  $46 \pm 12.4\%$  (range  
273 31-91%). Conversely, the maize silage proportion (%DM) was  $1 \pm 1.9\%$   
274 (range 0-4%) and  $49 \pm 12.7\%$  (range 39-60%) in the grass silage and  
275 maize silage groups, respectively, with a paired-sample difference of  $49 \pm$   
276  $14.8\%$  (range 39-59%).

### 277 ***Fresh herbage vs. conserved forage and concentrates***

#### 278 *Carotenoids and colour*

279 A fresh herbage-containing diet increased the content of all carotenoids in  
280 dairy and meat products (except retinol content in DC) compared with the  
281 conserved forage (Table 2). This may be because carotenoids in herbage  
282 are photodegraded during forage harvesting and drying (Nozière *et al.*,  
283 2006). For DC,  $\Delta\%$  was +30% for  $\alpha$ -tocopherol, +41% for  $\beta$ -carotene,  
284 +45% for zeaxanthin, and +63% for lutein. The  $\alpha$ -tocopherol and  $\beta$ -  
285 carotene content increased by respectively 0.9% and 1.8% per unit  
286 increase in the fresh herbage proportion of animal diet ( $R^2 = 0.67$  and  
287  $0.82$ , respectively; Table 3). The extent of these differences is consistent  
288 with the findings of controlled trials (Nozière *et al.*, 2006; Prache *et al.*,  
289 2020). For DG, a similar increase was noted for retinol content and a  
290 much larger increase for  $\alpha$ -tocopherol content (approximately +480%).  
291 This may be because only four data sources were available for DG, mostly  
292 from studies conducted in Mediterranean shrubby areas, where shrub  
293 leaves contain high amounts of  $\alpha$ -tocopherol precursors to prevent

294 photooxidative damage in arid environments (Gratani and Varone, 2014).  
295 Fresh herbage inclusion in animal diet also increased  $\alpha$ -tocopherol content  
296 (by 73%) in MS. The lack of difference in retinol content in DC contradicts  
297 the increase in its content with fresh herbage inclusion in the diet found in  
298 controlled trials (Nozière *et al.*, 2006). However, Chassaing *et al.* (2016)  
299 highlighted the variability in the retinol content of milk in cattle receiving  
300 conserved forage on commercial farms. Indeed, grass silage contains  
301 more retinol than hay (Nozière *et al.*, 2006).  
302 Although carotenoid content is related to colour (Nozière *et al.*, 2006;  
303 Luciano *et al.*, 2009), no significant difference in  $b^*$ ,  $a^*$ , or  $L^*$  value were  
304 found in products derived from animals fed on fresh herbage and  
305 conserved forage. The sole exception was the yellower products of grazed  
306 DG (+20%). This overall lack of colour differences regardless of significant  
307 differences in carotenoid content is unexpected and difficult to explain.  
308 This could partially be due to the structure of the dataset. Indeed,  
309 carotenoids and colour were extracted by different studies given the lack  
310 of studies reporting the results for both. Although correlated, both colour  
311 and carotenoid content strongly vary according to the forage type and  
312 characteristics (later discussed) (Nozière *et al.*, 2006), inducing high  
313 variability and probably concurring to confound the effect under a certain  
314 feeding scenario. Furthermore, carotenoids are usually expressed on fat  
315 unit, whereas colour is measured on the whole products; different fat or fat

316 on dry matter contents could have contributed to weaken colour  
317 differences.

### 318 *Terpenoids*

319 A fresh herbage-containing diet increased monoterpene (+10%) and total  
320 terpene (+5%) content in DS compared with conserved forage. A similar  
321 tendency ( $P < 0.1$ ) was also observed for monoterpenes in DC (+9%).  
322 Terpenes are PSM that are particularly abundant in dicots (Mariaca *et al.*,  
323 1997) and can be transferred directly from herbage to milk and then to  
324 cheese (Tornambé *et al.*, 2006). Being volatile, some of these compounds  
325 are lost during forage harvesting and conservation, resulting in a lower  
326 terpene content in dairy products derived from animals fed conserved  
327 forage in controlled trials (Croissant *et al.*, 2007; Cabiddu *et al.*, 2019).  
328 Thus, it was quite unexpected that neither monoterpenes nor total  
329 terpenes in DC and sesquiterpenes in DS were affected by the presence  
330 of fresh herbage in the animal diet. This lack of differences, contrary to  
331 that observed in controlled trials, could be attributed to several  
332 confounding factors, such as forage characteristics (discussed later) and  
333 the terpene analytical methods used, which makes it difficult to generalise  
334 the differences found in single studies (Abilleira *et al.*, 2010).

### 335 *Fatty acids*

336 Not all FA showed significant differences in all PCs (Table 4). Feeding  
337 fresh herbage similarly affected the content of several FA in both dairy and  
338 meat products. Specifically, it reduced the content of C16:0 (between -6%

339 and -10%) and SFA (approximately -5%) in dairy products of all studied  
340 animals (not significant for SFA in DG) and meat products of sheep (-5%  
341 and -6%, respectively) (Table 4). This effect of fresh herbage in animal  
342 diets on reducing the C16:0 content of meat and dairy products is well-  
343 documented under controlled conditions (Elgersma *et al.*, 2015; Daley *et*  
344 *al.*, 2010; Sinclair, 2007), although it appears to be stronger than that  
345 found in the present study (between -11 and -31% for both in DC) (Ferlay  
346 *et al.*, 2006; Cabiddu *et al.*, 2019). C16:0 is partially derived from intake,  
347 and its content is low in fresh herbage (Elgersma *et al.*, 2015). It is also  
348 partially synthesised *de novo* in the mammary gland and partially inhibited  
349 when high amounts of PUFA are transferred to the mammary gland  
350 (Elgersma *et al.*, 2015). In our study, the C16:0 and SFA content  
351 decreased by respectively -0.2% and -0.1% with per unit increase in the  
352 fresh herbage proportion of animal diet, regardless of the PC (Table 3).

353 The BCFA (content) of the products of DC increased when the animals  
354 were fed fresh herbage rather than conserved forage (+11%; Table 4).  
355 These FA are derived from ruminal cellulolytic bacteria (Buccioni *et al.*,  
356 2012). In controlled trials (Couvreur *et al.*, 2006; Ferlay *et al.*, 2006), their  
357 content in the milk of fresh herbage-fed cattle has been reported to be  
358 higher because of the higher cellulose and hemicellulose content and fibre  
359 digestibility of fresh herbage than of conserved forage (Couvreur *et al.*,  
360 2006; Ferlay *et al.*, 2006).

361 Feeding fresh herbage instead of conserved forage increased the  
362 C18:1cis9 and MUFA content in DC (+7% and +9%, respectively) and DS  
363 (+13% and +17%, respectively), but did not affect the content of these FA  
364 in meat, except for MUFA in MS (+6%) (Table 4). The C18:1cis9 content  
365 of dairy products and that of MUFA in MS increased linearly by 0.2% with  
366 per unit increase in the fresh herbage proportion of diet. A high C18:1cis9  
367 content of animal products is related to fresh herbage intake (Elgersma *et*  
368 *al.*, 2015). However, this FA is derived from multiple pathways. It can  
369 originate from lipid mobilisation or mammary  $\Delta^9$ -desaturase action  
370 (Chilliard *et al.*, 2007). The C18:1cis9/C16:0 ratio increased with the  
371 increasing proportion of fresh herbage in DC (+17%) and DS (+22%); this  
372 was expected because of the abovementioned results of single FA. Its  
373 value increased by 0.3% with per unit increase in the fresh herbage  
374 proportion of animal diet. This ratio, also called the spreadability index, is  
375 related to the texture and sensory properties of dairy products (Hurtaud *et*  
376 *al.*, 2009; Giaccone *et al.*, 2016; Chilliard *et al.*, 2007).

377 Furthermore, feeding fresh herbage strongly increased the content of  
378 C18:3n-3, the major FA of fresh herbage (Elgersma *et al.*, 2015), in both  
379 dairy and meat products of all species studied (+41% and +73%,  
380 respectively) (Table 4). However, it decreased the C18:2n-6 content of  
381 dairy (-14% in DC) and meat (between -15 and -18%). The C18:3n-3  
382 content linearly increased by 1.1% with per unit increase in the fresh  
383 herbage proportion of animal diet, regardless of the animal product ( $R^2 =$

384 0.42; Table 3). Similar results were observed for C18:2n-6 (-0.2 % per unit  
385 increase in the fresh herbage proportion of animal diet), although the  
386 model fit was poor ( $R^2 = 0.12$ ; Table 3). The C18:2n-6 is the second major  
387 constituent of herbage lipids, but it is also abundant in maize silage and  
388 cereal concentrates (Elgersma *et al.*, 2015). This implies that its content in  
389 various products also depends on the type and proportion of conserved  
390 forage and concentrate in the diet (Chilliard *et al.*, 2007; Daley *et al.*, 2010;  
391 Sinclair, 2007). According to the differences observed for C18:3n-3 and  
392 C18:2n-6, their ratio greatly increased (between 52 and 71% in dairy  
393 products and between 77 and 124% in meat) when fresh herbage was  
394 provided instead of conserved forages (Table 4). This ratio linearly  
395 increased by 1.1% with per unit increase in the fresh herbage proportion of  
396 animal diet, regardless of the animal products ( $R^2 = 0.65$ ; Table 3). The  
397 observed increase in the C18:3n-3 content by feeding fresh herbage-  
398 based diets was greater (between 80 and 150%) in controlled trials  
399 (Couvreur *et al.*, 2006; Biondi *et al.*, 2008; Daley *et al.*, 2010, Scerra *et al.*,  
400 2011); however, the trend was similar, albeit sometimes not significant, for  
401 C18:2n-6 (Couvreur *et al.* 2006; Khanal *et al.*, 2008), largely depending on  
402 the type of conserved forage and concentrate. Compared to that in  
403 conserved forage, C18:3n-3 in fresh herbage can be more efficiently  
404 transferred to the animal products, as this FA is allocated to the  
405 membrane lipids (Buccioni *et al.*, 2012).

406 The C18:1trans11 and CLAcis9trans11 content increased by respectively  
407 72% and 94% in dairy products with the inclusion of fresh herbage in  
408 animal diet (Table 4), consistent with the increase in C18:3n-3 and  
409 C18:2n-6 content. In fact, C18:3n-3 and C18:2n-6 are partially  
410 biohydrogenated to C18:1trans11 (Buccioni *et al.*, 2012), which is  
411 desaturated in the mammary gland to CLAcis9trans11 (Chilliard *et al.*,  
412 2007). Similarly, the C18:1trans11 content was significantly increased in  
413 MS (+59%) and the CLAcis9trans11 content was increased in MC (+48%)  
414 when the animals were fed fresh herbage. Such increases for both FA  
415 have also been reported in controlled trials, albeit with a greater variability.  
416 Ferlay *et al.* (2006) and Coppa *et al.* (2015) have reported consistent  
417 increases under on-farm conditions, while other studies have reported  
418 larger increases (between +150 and +478% for C18:1trans11 and  
419 between +177 and +380%, with an extreme of +16% at the lower range,  
420 for CLAcis9trans11) (Khanal *et al.*, 2008; Biondi *et al.*, 2008; Daley *et al.*,  
421 2010). The C18:1trans11 content in all PCs linearly increased by 2.1%  
422 with per unit increase in the fresh herbage proportion of animal diet ( $R^2 =$   
423 0.64;  $P < 0.01$ , Table 3). The CLAcis9trans11 content showed different  
424 increasing trends between dairy and meat products; in the former, it  
425 linearly increased by 0.7% and 0.6% with per unit increase in the fresh  
426 herbage proportion of cattle and sheep diets, respectively, not differing  
427 between dairy product category, but the slope coefficient of  
428 CLAcis9trans11 in MC was not significant (Table 3). This difference in MC

429 could be due to the lower activity of  $\Delta^9$ -desaturase in the adipose tissue  
430 than in the mammary gland (Chilliard *et al.* 2007) or partially due to the  
431 heterogeneity of the dataset in terms of animal age and sex (De la Torre *et*  
432 *al.*, 2006), coupled with a relatively low number (8) of available studies.

433 The PUFA content in dairy products increased between 17 and 23% with a  
434 fresh herbage-based diet (Table 4), whereas no effect was observed for  
435 meat. Its content in all dairy products increased by 0.6% with per unit  
436 increase in the fresh herbage proportion of animal diet ( $R^2 = 0.57$ ;  $P <$   
437  $0.01$ ) (Table 3). These results are consistent with those of controlled trials  
438 on cattle (Chilliard *et al.* 2007) and goats (Mancilla-Leyton *et al.* 2013),  
439 although controversial results have been reported for DS, perhaps  
440 because of the variability induced by mixed diets, as discussed later  
441 (Biondi *et al.* 2008; Cabiddu *et al.* 2019). Such an increase of PUFA  
442 content in dairy products is relevant both for the sensory properties of milk  
443 and cheese and for human nutrition, as an increase in PUFA intake is  
444 considered a preventive factor against cardiovascular diseases. High  
445 PUFA content in dairy products has been associated to a less firm and  
446 more melting texture and to a greater richness in odour active compounds  
447 and sensory descriptors (Hurtaud *et al.*, 2009; Giaccone *et al.*, 2016;  
448 Fréтин *et al.*, 2018).

#### 449 *Sensory properties*

450 The evaluation of sensory properties of several diverse dairy and meat  
451 products is a scientific challenge, as sensory descriptors are often specific

452 to a single product. The choice of grouping specific and heterogeneous  
453 sensory descriptors in sensory families implied an increase in the  
454 variability of the dataset. This is particularly the case for different cheese  
455 types, as the cheesemaking technology employed is one of the most  
456 influential factors for the sensory profile of cheese (Martin *et al.*, 2005).  
457 Thus, a substantial loss of the significance of the effect of farming  
458 practices was expected. However, several sensory families of dairy and  
459 meat products were affected by the inclusion of fresh herbage in animal  
460 diets (Table 5). This diet tended ( $P < 0.1$ ) to make the meat more elastic in  
461 DS (+18%) than conserved forage, which is consistent with the results of  
462 the C18:1cis9/C16:0 ratio and MUFA and PUFA content (Martin *et al.*,  
463 2005; Hurtaud *et al.*, 2009; Fréтин *et al.*, 2019). Differences in cheese  
464 texture between fresh herbage and conserved forage diets and across  
465 cheesemaking processes (Martin *et al.*, 2005; Farruggia *et al.*, 2014) have  
466 been well documented in controlled trials. As such, cheese derived from  
467 fresh herbage-fed animals is less firm and more elastic and melts more  
468 easily. However, the lack of effect on cheese texture under on-farm  
469 conditions is not surprising. Cheesemakers can indeed reduce textural  
470 variations by adapting curd draining. Conversely, flavour, odour, and taste  
471 are more difficult to control, as shown by the differences we observed in  
472 these traits under on-farm conditions. In particular, fresh herbage-based  
473 diets reduced lactic notes in cheese compared with conserved forage for  
474 both DC and DS (-10% and -21%, respectively; Table 5). Under controlled

475 conditions, cheese lactic notes were suppressed with a reduction of fresh  
476 herbage proportion of diet in DC and DS (Giaccone *et al.*, 2016;  
477 Valdivieso *et al.*, 2016).

478 Fresh herbage inclusion in diet increased vegetal family notes for DC  
479 (+30%). Giaccone *et al.* (2016) showed that cheese derived from grazing  
480 cattle had more pronounced vegetal notes, which may be related to the  
481 high unsaturated FA (UFA) content of cheese. The authors hypothesised  
482 that the oxidation of UFA, which have a low oxidative stability, produces  
483 several odour-active compounds during cheese ripening, such as  
484 alcohols, esters, aldehydes, and ketones, which are associated with  
485 vegetal and herbaceous notes. However, Frétin *et al.* (2019) have  
486 proposed a microbial origin of such flavour differences related to fresh  
487 herbage inclusion in cattle diets. Fresh herbage increased animal family  
488 notes in MS compared with conserved forage (+12%; Table 5). Fresh  
489 herbage increased the indole and skatole content of sheep meat  
490 compared with conserved forages (Vasta *et al.*, 2006; Schreurs *et al.*  
491 2007). Skatole is produced by ruminal bacteria-mediated degradation of  
492 tryptophan, and its availability increases with a high protein content and  
493 high protein/readily digestible carbohydrate ratio, as in fresh herbage-  
494 based diet (Vasta *et al.*, 2006).

495 Intramuscular fat in meat sheep decreased when animals were fed fresh  
496 herbage (-31%). A number of intrinsic (age, breed, and sex) and extrinsic  
497 factors (pasture quality and physical activity) may contribute to the

498 variation in intramuscular fat deposition (De Brito *et al.*, 2016). According  
499 to Gallo *et al.* (2019), the overall lack of concentrates in diet of grazing  
500 sheep reduces the availability of propionate at the ruminal level, which is a  
501 precursor of glucose and glycogen at the muscular level. Moreover,  
502 enhanced lipid mobilisation due to a lower energy intake may favour lean  
503 muscle deposition in grazing animals.

#### 504 ***Hay vs. silage***

505 Feeding grass silage instead of hay increased the  $\alpha$ -tocopherol content in  
506 DC (+10%; Table 6). This may be due to shorter exposure to  
507 photodegrading UV light during silage making (Noziere *et al.*, 2006).  
508 Furthermore, when herbage is ensiled, it is often harvested at an earlier  
509 phenological stage than hay, and the content of  $\alpha$ -tocopherol in herbage  
510 decreases with herbage maturation, with a pivotal role played by the  
511 decreased stem/leaf ratio (Noziere *et al.*, 2006). However, although this  
512 decrease was common to all carotenoids, no differences in  $\beta$ -carotene and  
513 retinol content were observed between silage and hay. Feeding hay  
514 instead of silage increased the content of C18:1trans11 (+19%),  
515 CLAcis9trans11 (+18%), and BCFA (+14%), while slightly increasing  
516 trends were observed for the C18:3n-3 content and C18:3n-3/C18:2n-6  
517 ratio (+17% and +20%, respectively, both  $P < 0.1$ ) (Table 6). These  
518 findings corroborate the results obtained under controlled conditions,  
519 although the extent of increase under the controlled conditions was higher  
520 (between 22% and 48% for all listed FA; Ferlay *et al.*, 2006). The FA

521 profile of milk derived from hay-fed animals was consistent with a higher  
522 transfer rate of C18:3n-3 from a hay-based than a silage-based diet  
523 (Chilliard *et al.*, 2007). In addition, maize silage was poor in C18:3n-3 but  
524 rich in C18:2n-6, which differently affected milk FA profiles depending to  
525 the type of silage (grass or maize) fed to the animals.

### 526 ***Grass silage vs. maize silage***

527 The  $\alpha$ -tocopherol and  $\beta$ -carotene content in DC did not differ between  
528 maize silage- and grass silage-based diets (Table 7). Although milk  
529 derived from animals fed maize silage-based diets is poor in  $\alpha$ -tocopherol  
530 (Stergiadis *et al.*, 2015; Botana *et al.* 2018), maize silage is often not the  
531 exclusive conserved forage under on-farm conditions, and grass silage is  
532 also present in non-negligible proportions in cattle diet, particularly in  
533 intensive farming systems (Stergiadis *et al.*, 2015). Indeed, Botana *et al.*  
534 (2018) showed that diets containing exclusively maize or grass silage as  
535 forage led to differences in the vitamin and carotenoid content of milk.

536 Feeding grass silage instead of maize silage decreased the milk content of  
537 C16:0 (-4%;  $P < 0.1$ ) and of C18:2n-6 (-9%) but increased in milk content  
538 of C18:3n-3 (+34%), CLAcis9trans11 (+24%;  $P < 0.1$ ), PUFA (+7%),  
539 BCFA (+15%) as well as the ratio of C18:3n-3/C18:2n-6 (+39%) in DC.  
540 The extent of these changes was consistent with findings obtained under  
541 controlled trials (Ferlay *et al.*, 2006; Chilliard *et al.*, 2007; Khanal *et al.*  
542 2008). Furthermore, maize silage is rich in starch, and a shift in the

543 ruminal population from cellulolytic to amylolytic bacteria reduces the  
544 BCFA content of milk (Buccioni *et al.*, 2012).

545 ***Permanent grasslands rich in species or in plant secondary***  
546 ***metabolites vs. temporary grasslands***

547 Most experiments related to the effects of pasture plant diversity have  
548 revealed significant differences in quality traits such as terpenes, FA,  
549 carotenoids, and sensory properties (among others Ferlay *et al.*, 2006;  
550 Tornambé *et al.*, 2006; Cabiddu *et al.*, 2019; Serrano *et al.*, 2011).  
551 However, under on-farm conditions, increasing plant diversity tended to  
552 decrease retinol content (-10%;  $P < 0.1$ ) in DC (Table 8). The results for  
553 carotenoids are consistent with those for colour.

554 Similarly, although a number of experimental studies have shown that the  
555 terpene content of dairy products was strongly affected by grassland  
556 biodiversity (Abilleira *et al.*, 2010; Bovolenta *et al.* 2014), no difference in  
557 terpene content in dairy products was detected depending on the  
558 biodiversity of grazed pastures (Table 8).

559 Grazing on permanent grasslands with a high plant diversity rather than on  
560 temporary grassland with a low diversity reduced the C16:0 content in MS  
561 (-11%). Sheep operate a remarkable selection of forage plants to meet  
562 their nutritive requirements (Villalba *et al.*, 2011). A greater herbage  
563 species diversity in permanent grasslands may promote their selective  
564 behaviour toward patches with a high nutritive value and abundant PUFA,

565 thus modifying the FA composition of the ingested diet in the favour of  
566 PUFA and decreasing the accumulation of *de novo*-synthesised FA.

567 The high botanical diversity of pastures decreased the SFA content (-4%)  
568 but increased the C18:1trans11 (+10%), C18:1cis9/C16:0 (+13%),  
569 C18:2n-6 (+10%), C18:3n-3 (+13%), CLAcis9trans11 (+15%), MUFA  
570 (+7%), and PUFA (+13%) content and the C18:3n-3/C18:2n-6 (+6%) ratio  
571 in DC. It also increased the C18:2n-6 (+10%), C18:3n-3 (+19%),  
572 CLAcis9trans11 (+15%), MUFA (+3 %), and PUFA (+15%) content in DS  
573 (Table 9). Similar results for these FA have been reported under controlled  
574 conditions, albeit at greater extents (between 29 and 53%; Farruggia *et al.*,  
575 2014; Cabiddu *et al.*, 2019). The high concentration of unsaturated FA  
576 (notably C18:3n-3, C18:2n-6, and their ruminal biohydrogenation  
577 intermediates) is consistent with the partial inhibition of ruminal microbial  
578 activity by PSMs, which are usually abundant in botanically diverse  
579 pasture (Buccioni *et al.*, 2012). Moreover, the greater outflow of PUFA  
580 from the rumen as a result of the inhibition of biohydrogenation may have  
581 reduced the deposition of C16:0 in MS.

582 Grazing on pastures with a high plant diversity affected the sensory profile  
583 of products in DC by increasing their intensity (+10%), spicy (+100%), and  
584 animal (+57%;  $P < 0.1$ ) notes (Table 8). These results are particularly  
585 relevant as they corroborate some findings observed in controlled trials  
586 (Farruggia *et al.*, 2014; Bovolenta *et al.* 2014), although the extent of these  
587 changes was much larger under on-farm conditions. This can partially be

588 due to the smaller cheese size and shorter ripening period often applied in  
589 controlled trials than in practices on commercial farms. Larger size  
590 changes the rind–paste ratio and slows microbial dynamics within a wheel.  
591 Indeed, cheeses from pastures with a high botanical diversity require  
592 longer ripening periods to fully develop their aromatic potential than those  
593 from temporary grassland, allowing differentiation in the sensory profile  
594 only after a long ripening period (Agabriel *et al.*, 2004; Farruggia *et al.*,  
595 2014).

596 There is no straightforward explanation for the effects of grassland  
597 biodiversity on hardness in MS. Highly diversified grasslands are rich in  
598 PSMs, which exhibit strong antioxidant activity (Vasta and Priolo, 2006).  
599 Therefore, a greater intake of PSM may protect phospholipids from  
600 oxidative damage to a greater extent in the cell membranes in the muscle  
601 of sheep grazing on diversified pasture, which may in turn improve water  
602 retention. In addition, the difference in hardness could be due to the  
603 uneven availability of nutrients in the two types of pasture. In particular,  
604 the greater availability of plant species in highly diversified grasslands may  
605 enable (or favour) the selection of a more balanced diet in terms of  
606 nutrients and allow animals to reach the target slaughtering weight earlier.

607 ***Factors weakening the effect of feeding management practices under***  
608 ***on-farm conditions***

609 Overall, we found differences in fewer traits between farming practices  
610 than did previous controlled trials. Furthermore, the extent of differences

611 observed here under on-farm conditions was generally lower than that  
612 under controlled conditions. Indeed, several confounding factors may be  
613 acting on farms, increasing variability and thus weakening the differences  
614 observed in controlled trials (Bronkema *et al.*, 2019; Coppa *et al.*, 2019).

615 First, in controlled experiments, well-contrasted diets are usually  
616 compared, whereas on-farm, diets are often characterised by other forage  
617 components at a minor proportion relative to the dominant one (Coppa *et al.*  
618 *et al.*, 2019; Biondi *et al.*, 2008; Monteils and Sibra, 2019). In particular, this  
619 may explain the lack of differences in the retinol content of milk of animals  
620 fed fresh herbage or conserved forage, as mineral supplements or  
621 concentrates, often enriched in vitamin A, may be added to such diets  
622 (Nozière *et al.*, 2006). The same may be true for the FA composition  
623 between hay- and silage-based diets, as different proportions of grass or  
624 maize silage may be included in the animal diets (Ferlay *et al.*, 2006;  
625 Hurtaud *et al.*, 2009; Chilliard *et al.*, 2007; Minchin *et al.*, 2010). In  
626 addition, the level and type of concentrate supplementation may have  
627 weakened the differences in the quality traits between the addressed  
628 practices within each feeding management scenario (Chilliard *et al.*, 2007;  
629 Minchin *et al.*, 2010).

630 Second, the characteristics of forage fed to animals, particularly of fresh  
631 herbage, can significantly affect the extent of differences expected on the  
632 quality traits. Advanced phenological stages of herbage decreased the  
633 content of C18:1trans 11, CLAcis9trans11, and C18:3n-3 but increased

634 the content of C16:0 in milk (Coppa *et al.*, 2015; Cabiddu *et al.*, 2019). The  
635 herbage and milk terpene content increased from the vegetative to  
636 flowering stage (Tornambé *et al.*, 2006; Cabiddu *et al.*, 2019), probably  
637 affecting the differences expected at the pasture biodiversity level. In  
638 addition, grazing selection by animals (Coppa *et al.*, 2011; Coppa *et al.*,  
639 2015; Molle *et al.* 2017) may be considered a confounding factor, as it can  
640 change according to pasture botanical composition, plant morphology,  
641 maturity stage, slope, and grazing management (Coppa *et al.*, 2011;  
642 Cabiddu *et al.*, 2017). Under the availability of numerous species at  
643 different phenological stages, ruminants are expected to preferably select  
644 plants at an earlier developmental stage, which contain low levels of  
645 PSMs. Restriction of selection in grazing pastures with a high plant  
646 diversity increased the milk monoterpene content by up to 200%  
647 (Tornambé *et al.*, 2006). Similarly, the milk SFA content changed by  
648 approximately 10% from the beginning to the end of a paddock (Coppa *et*  
649 *al.*, 2015). Plant composition can also significantly affect the extent of  
650 differences expected in carotenoid and fat-soluble vitamin content of cattle  
651 milk (Bovolenta *et al.* 2014), as legumes usually have a lower  $\alpha$ -tocopherol  
652 content but a higher  $\beta$ -carotene content than grasses (Nozière *et al.*,  
653 2006). Herbage terpene content is also highly variable between plant  
654 species (Mariaca *et al.*, 1997; Cabiddu *et al.*, 2019), conferring specific  
655 terpene fingerprints to dairy products (Bovolenta *et al.*, 2014; Aprea *et al.*  
656 2016). Accordingly, single terpenoids may allow for a more robust

657 discrimination than total terpenes between animal products from  
658 grasslands with different biodiversity levels (Moran *et al.*, 2019). However,  
659 for the same botanical intraspecific variability, this result of terpene profile  
660 is valuable only under controlled experimental conditions and cannot be  
661 generalised to on-farm conditions. Recently Renna *et al.* (2020) reported  
662 an important scientific upgrade on the effect of pasture characteristics on  
663 DC. The authors studied the hierarchy of herbage-related factors affecting  
664 milk FA composition. However, there is no such study for other quality  
665 traits and animal PCs.

666 Finally, another important confounding factor may be the animal  
667 characteristics. Even if animal-related factors (e.g. lactation stage, breed,  
668 and parity) only marginally affect the quality traits of dairy products, this is  
669 not the case for meat (Prache *et al.*, 2020). Animal breed, age, sex, and  
670 duration and type of the finishing period affect meat quality. In particular,  
671 fattening period duration and initial weight at the beginning of this period  
672 affect meat composition and sensory traits in small and large ruminants  
673 depending on the animal category (Soulat *et al.*, 2016; De Brito *et al.*,  
674 2016). Regarding MS, studies conducted in different regions (both under  
675 controlled or on farm conditions) have drawn different conclusions, and  
676 their results should be generalised with caution. For instance, young male  
677 lambs are almost exclusively destined for a short fattening period in the  
678 Mediterranean regions, whereas older sheep of both sexes are  
679 slaughtered in Australia. Moreover, different levels of intramuscular fat

680 affect the meat FA profile. In several studies aimed at comparing the  
681 effects of different feeding systems on meat FA, the diets offered to the  
682 animals were periodically adjusted to achieve comparable growth rates  
683 (Luciano *et al.*, 2009; Scerra *et al.*, 2011).

## 684 **Conclusions**

685 To the best of our knowledge, this is the first quantitative review to  
686 investigate the effects of farming practices on a wide array of quality traits  
687 (carotenoids, fat-soluble vitamins, colour, FA, terpenes, and sensory  
688 properties) of dairy and meat products in cattle and small ruminants. The  
689 effects under controlled trials reported in the literature were corroborated  
690 on farms only for a part of the addressed quality traits, and when these  
691 differences were significant, the extent of effect under on-farm conditions  
692 was lower than under controlled conditions. Several confounding factors,  
693 for which there is no experimental control when operating on farm, may be  
694 the reason of these differences (i.e. mixed diets, phenological stage, and  
695 botanical composition of herbage, and animal-related factors). However,  
696 differences in several quality traits according to farming practices were  
697 confirmed. Specifically, feeding fresh herbage instead of conserved forage  
698 to animals affected the quality traits common to several PC, particularly FA  
699 composition, probably because of the higher number of studies conducted  
700 on farms on these quality traits. It is not surprising that differences  
701 between farming practices emerged more frequently for parameters with a  
702 higher number of available studies within a PC. However, the high

703 variability in the reference dataset resulting from the pooling of data  
704 obtained under heterogeneous conditions on farms could only be partially  
705 compensated by the high number of studies included in the statistical  
706 analysis. Further studies are required to reinforce the available knowledge  
707 on the effect of the studied farming practices: this is the case for meat  
708 products (MC in particular) and for all goat products.

709

#### 710 **Ethics approval**

711 Not applicable

712

#### 713 **Data and model availability statement**

714 Neither the data nor the model were deposited in an official repository.

715

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723 **Author Contribution**

724 A. Cabiddu: validation, data curation, writing - original draft; G. Peratoner:  
725 conceptualization, validation, writing - review & editing, supervision; B.  
726 Valenti: data curation, writing - original draft; V. Monteils: data curation,  
727 writing - original draft; B. Martin: data curation, validation, writing - original  
728 draft; M. Coppa: conceptualization, methodology, formal analysis, writing -  
729 original draft, writing - review & editing, supervision.

730

731 **Declaration of interest**

732 None

733

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753

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## TABLES

981 **Table 1.** Fresh herbage proportion (%DM) in ruminants' diet according to  
 982 the feeding scenario within each group.

| Including fresh herbage in the diet instead of feeding conserved forage and/or concentrates |                |                |  |   |                                       |
|---|----------------|----------------|--|---|---------------------------------------|
| Product   | Animal species | n <sup>1</sup> | Fresh Herbage group <sup>2</sup>         | Conserved Forages group <sup>2</sup>    | Paired sample difference <sup>2</sup> |
| Dairy   | Cattle         | 66             | 61±22.7 (37-100)                         | 8±24.4 (0-45)                           | 54±21.1 (25-100)                      |
|   | Sheep          | 50             | 85±21.1 (32-100)                         | 7±15.5 (0-48)                           | 78±21.2 (30-100)                      |
|   | Goat           | 16             | 79±23.1 (48-100)                         | 0±0 (0-0)                               | 79±17.2 (48-100)                      |
| Meat  | Cattle         | 12             | 66±20.5 (45-100)                         | 0±0 (0-0)                               | 66±20.5 (45-100)                      |
|   | Sheep          | 35             | 100±0.0 (100-100)                        | 6±19.3 (0-40)                           | 94±20.8 (60-100)                      |
| Use of forages from permanent grasslands rich in species or PSM <sup>3</sup>                |                |                |  |   |                                       |
| Product   | Animal species | n <sup>1</sup> | High biodiversity/PSM group <sup>2</sup> | Low biodiversity/PSM group <sup>2</sup> | Paired sample difference <sup>2</sup> |
| Dairy   | Cattle         | 28             | 87±24.2 (30-100)                         | 85±17.1 (32-100)                        | 2±1.0 (0-10)                          |
|   | Sheep          | 9              | 100±0.0 (100-100)                        | 100±1.5 (97-100)                        | 1±1.5 (0-3)                           |
| Meat  | Sheep          | 14             | 93±13.2 (70-100)                         | 95±18.3 (50-100)                        | 2±3.8 (0-10)                          |

983 <sup>1</sup> n, number of data.

984 <sup>2</sup> average ± standard deviation (minimum-maximum).

985 <sup>3</sup> PSM, plant secondary metabolites.

986

987 **Table 2.** Effect of feeding fresh herbage instead of conserved forage  
 988 and/or concentrates on the carotenoids, fat-soluble vitamins, and terpene  
 989 content, colour and pH of different animal products.

| Item                                 | Product | Animal species | n <sup>1</sup> | Fresh Herbage group | Conserved Forages group | SEM <sup>2</sup> | Significance <sup>3</sup> |
|--------------------------------------|---------|----------------|----------------|---------------------|-------------------------|------------------|---------------------------|
| Carotenoids and vitamins (mg/kg fat) |         |                |                |                     |                         |                  |                           |
| α-Tocopherol                         | Dairy   | Cattle         | 20             | 23.39               | 17.95                   | 1.458            | **                        |
|                                      |         | Goat           | 3              | 37.20               | 6.37                    | 0.306            | ***                       |
| Retinol                              | Meat    | Sheep          | 3              | 5.88                | 3.39                    | 0.155            | **                        |
|                                      |         | Cattle         | 7              | 6.88                | 5.91                    | 0.977            | ns                        |
| β-Carotene                           | Dairy   | Goat           | 3              | 9.17                | 7.20                    | 0.503            | *                         |
|                                      |         | Cattle         | 18             | 6.20                | 4.40                    | 0.579            | **                        |
| Lutein                               | Dairy   | Cattle         | 8              | 0.67                | 0.41                    | 0.101            | *                         |
|                                      |         | Cattle         | 7              | 0.10                | 0.07                    | 0.023            | †                         |
| Zeaxanthin                           | Dairy   | Cattle         | 3              | 12.48               | 11.32                   | 2.419            | ns                        |
|                                      |         | Sheep          | 5              | 18.84               | 17.88                   | 0.289            | *                         |
| Terpenes tot (ln AAU)                | Dairy   | Cattle         | 3              | 11.22               | 10.34                   | 2.937            | †                         |
|                                      |         | Sheep          | 5              | 17.99               | 16.36                   | 0.33             | **                        |
| Monoterpenes tot (ln AAU)            | Dairy   | Cattle         | 3              | 11.73               | 9.67                    | 1.820            | ns                        |
|                                      |         | Sheep          | 5              | 18.85               | 10.38                   | 5.170            | ns                        |
| Sesquiterpenes tot (ln AAU)          | Dairy   | Cattle         | 3              | 11.73               | 9.67                    | 1.820            | ns                        |
|                                      |         | Sheep          | 5              | 18.85               | 10.38                   | 5.170            | ns                        |
| Colour                               |         |                |                |                     |                         |                  |                           |
| b*                                   | Dairy   | Cattle         | 9              | 15.99               | 14.76                   | 3.134            | ns                        |
|                                      |         | Goat           | 4              | 2.56                | 2.14                    | 0.288            | *                         |
| a*                                   | Meat    | Cattle         | 4              | 11.25               | 10.80                   | 0.318            | ns                        |
|                                      |         | Sheep          | 8              | 6.38                | 6.40                    | 1.088            | ns                        |
| L*                                   | Dairy   | Cattle         | 9              | -1.85               | -2.08                   | 0.693            | ns                        |
|                                      |         | Cattle         | 4              | 21.95               | 21.80                   | 0.952            | ns                        |
| pH 24h                               | Meat    | Sheep          | 10             | 13.10               | 13.24                   | 0.881            | ns                        |
|                                      |         | Cattle         | 9              | 76.30               | 76.88                   | 2.590            | ns                        |
| pH 24h                               | Meat    | Cattle         | 4              | 39.30               | 38.10                   | 0.346            | †                         |
|                                      |         | Sheep          | 10             | 40.65               | 42.78                   | 1.429            | **                        |
| pH 24h                               | Meat    | Sheep          | 14             | 5.72                | 5.72                    | 0.070            | ns                        |

990 <sup>1</sup> n, number of data.

991 <sup>2</sup> SEM, standard error of the mean; AAU, arbitrary area units.

992 <sup>3</sup> \*\*\*, P < 0.001; \*\*, P < 0.01; \*, P < 0.05; †, P < 0.1; ns, not significant.

993

994

995 **Table 3.** Effect of the relative increase ( $\Delta\%$ ) of fresh herbage proportion in animal diet on the relative variation ( $\Delta\%$ ) of  
 996 the quality traits in different animal products based on fresh herbage compared to conserved forages-based diets.

997

| Item <sup>1</sup>        | Product category |                |                       |       | $\Delta\%$ fresh herbage          |       | N <sup>2</sup> | SE <sup>3</sup><br>model | R <sup>2</sup> | Significance (Sign.) <sup>4</sup> |                          |             |
|--------------------------|------------------|----------------|-----------------------|-------|-----------------------------------|-------|----------------|--------------------------|----------------|-----------------------------------|--------------------------|-------------|
|                          | Product          | Animal species | Intercept ( $\pm$ SE) | Sign. | Covariate coefficient ( $\pm$ SE) | Sign. |                |                          |                | Product category                  | $\Delta\%$ fresh herbage | Interaction |
| Carotenoids and vitamins |                  |                |                       |       |                                   |       |                |                          |                |                                   |                          |             |
| $\alpha$ -Tocopherol     | Dairy            | Cattle         | -9.1 ( $\pm$ 6.33)    | ns    | 0.9 ( $\pm$ 0.14)                 | ***   | 20             | 12.37                    | 0.67           | nd                                | ***                      | nd          |
| $\beta$ -Carotene        | Dairy            | Cattle         | -26.6 ( $\pm$ 9.39)   | *     | 1.8 ( $\pm$ 0.21)                 | ***   | 18             | 18.85                    | 0.82           | nd                                | ***                      | nd          |
| Fatty acids              |                  |                |                       |       |                                   |       |                |                          |                |                                   |                          |             |
| C16:0                    | Dairy            | Cattle         | -5.4 ( $\pm$ 0.99)    | c     | -0.2 ( $\pm$ 0.02)                | ***   | 42             | 5.39                     | 0.38           | ***                               | ***                      | ns          |
|                          |                  | Goat           | 2.5 ( $\pm$ 1.39)     | ab    |                                   |       | 10             |                          |                |                                   |                          |             |
|                          |                  | Sheep          | -3 ( $\pm$ 1.19)      | bc    |                                   |       | 25             |                          |                |                                   |                          |             |
| C18:1trans11             | Dairy            | Sheep          | 5.9 ( $\pm$ 3.17)     | a     | 2.1 ( $\pm$ 0.22)                 | ***   | 17             | 37.78                    | 0.64           | ns                                | ***                      | ns          |
|                          |                  | Cattle         | -22.1 ( $\pm$ 11.86)  | †     |                                   |       | 41             |                          |                |                                   |                          |             |
| C18:1cis9                | Dairy            | Sheep          | 4.3 ( $\pm$ 3.42)     | *     | 0.2 ( $\pm$ 0.04)                 | ***   | 24             | 8.52                     | 0.38           | ***                               | **                       | ns          |
|                          |                  | Cattle         |                       |       |                                   |       | 42             |                          |                |                                   |                          |             |
| C18:2n-6                 | Dairy            | Cattle         | 1.1 ( $\pm$ 4.27)     | ns    | -0.2 ( $\pm$ 0.07)                | **    | 41             | 15.53                    | 0.12           | ns                                | **                       | ns          |
|                          |                  | Meat           |                       |       |                                   |       | 8              |                          |                |                                   |                          |             |
|                          |                  | Cattle         |                       |       |                                   |       | 48             |                          |                |                                   |                          |             |
| C18:3n-3                 | Dairy            | Goat           |                       |       | 1.1 ( $\pm$ 0.13)                 | ***   | 10             | 35.93                    | 0.42           | ns                                | ***                      | ns          |
|                          |                  | Sheep          | -8 ( $\pm$ 8.58)      | ns    |                                   |       | 26             |                          |                |                                   |                          |             |
|                          |                  | Cattle         |                       |       |                                   |       | 8              |                          |                |                                   |                          |             |
| CLAcis9trans11           | Dairy            | Sheep          |                       |       | 0.7 ( $\pm$ 0.25)                 | a     | 19             | 3672                     | 0.65           | ns                                | ***                      | *           |
|                          |                  | Cattle         | 0.7 ( $\pm$ 14.3)     | ns    |                                   |       | 53             |                          |                |                                   |                          |             |
|                          |                  | Sheep          |                       |       | 0.6 ( $\pm$ 0.25)                 | a     | 26             |                          |                |                                   | *                        |             |

|                   |       |        |                            |     |                           |     |    |       |      |     |     |    |  |
|-------------------|-------|--------|----------------------------|-----|---------------------------|-----|----|-------|------|-----|-----|----|--|
|                   | Meat  | Cattle |                            |     | 0.2 (± 0.13) <sup>b</sup> | ns  | 8  |       |      |     |     |    |  |
| SFA               | Dairy | Cattle | 0 (± 0.54) <sup>a</sup>    | ns  |                           |     | 50 |       |      |     |     |    |  |
|                   |       | Sheep  | -2.4 (± 0.6) <sup>b</sup>  | *** | -0.1 (± 0.01)             | *** | 25 | 2.94  | 0.44 | **  | *** | ns |  |
|                   | Meat  | Cattle | 2.4 (± 1.65) <sup>a</sup>  | **  |                           |     | 8  |       |      |     |     |    |  |
| MUFA              | Dairy | Cattle | -1.3 (± 1.67) <sup>b</sup> | ns  |                           |     | 50 |       |      |     |     |    |  |
|                   |       | Sheep  | 7.9 (± 1.93) <sup>a</sup>  | *** | 0.2 (± 0.04)              | *** | 24 | 9.99  | 0.32 | **  | **  | ns |  |
|                   | Meat  | Sheep  | -6.6 (± 5) <sup>b</sup>    | *   |                           |     | 11 |       |      |     |     |    |  |
| PUFA              | Dairy | Cattle |                            |     |                           |     | 50 |       |      |     |     |    |  |
|                   |       | Goat   | -12.4 (± 3.99)             | **  | 0.6 (± 0.07)              | *** | 10 | 14.6  | 0.57 | ns  | *** | ns |  |
| C18:1cis9/C16:0   | Dairy | Sheep  |                            |     |                           |     | 25 |       |      |     |     |    |  |
|                   |       | Cattle | 11.1 (± 3.98)              | *   | 0.3 (± 0.06)              | *** | 47 | 12.88 | 0.30 | **  | *** | ns |  |
| C18:3n-3/C18:2n-6 | Dairy | Goat   | 24 (± 7.64)                | **  |                           |     | 41 |       |      |     |     |    |  |
|                   |       | Sheep  | -35 (± 11.41)              | **  |                           |     | 10 |       |      |     |     |    |  |
|                   | Meat  | Cattle | 27.9 (± 8.54)              | **  | 2.1 (± 0.17)              | *** | 26 | 39.4  | 0.65 | *** | *** | ns |  |
|                   |       | Sheep  | 4.9 (± 12.6)               | ns  |                           |     | 8  |       |      |     |     |    |  |
|                   |       | Sheep  | -21.9 (± 20.77)            | *   |                           |     | 19 |       |      |     |     |    |  |

998 <sup>1</sup> SFA, sum of straight-chain FA form C4:0 to C24:0, MUFA, sum of monounsaturated FA form C10:1 to C24:1; PUFA, sum of  
999 polyunsaturated FA form C18:2 to C22:6.

1000 <sup>2</sup> n, number of data.

1001 <sup>3</sup> SE, standard error.

1002 <sup>4</sup> \*\*\*, P < 0.001; \*\*, P < 0.01; \*, P < 0.05; †, P < 0.1; ns, not significant; nd: not determinable.

1003

1004

1005 **Table 4.** Effect of feeding fresh herbage instead of conserved forage  
 1006 and/or concentrates on the fatty acid profile of different animal products.

| Fatty acids (g/100 g FA) <sup>1</sup> | Product | Animal species | n <sup>2</sup> | Fresh Herbage group | Conserved Forages group | SEM <sup>3</sup> | Significance <sup>4</sup> |
|---------------------------------------|---------|----------------|----------------|---------------------|-------------------------|------------------|---------------------------|
| C16:0                                 | Dairy   | Cattle         | 42             | 28.18               | 31.28                   | 0.660            | ***                       |
|                                       |         | Goat           | 10             | 26.02               | 27.67                   | 2.023            | **                        |
|                                       |         | Sheep          | 22             | 21.45               | 23.08                   | 0.656            | ***                       |
|                                       | Meat    | Cattle         | 8              | 24.64               | 24.99                   | 0.400            | ns                        |
|                                       |         | Sheep          | 17             | 21.77               | 23.15                   | 0.677            | **                        |
| C18:1trans11                          | Dairy   | Cattle         | 41             | 2.44                | 1.30                    | 0.155            | ***                       |
|                                       |         | Goat           | 5              | 1.81                | 1.22                    | 0.594            | ns                        |
|                                       |         | Sheep          | 21             | 3.63                | 2.11                    | 0.337            | ***                       |
|                                       | Meat    | Cattle         | 3              | 3.94                | 2.80                    | 0.520            | ns                        |
|                                       |         | Sheep          | 8              | 1.57                | 0.99                    | 0.375            | *                         |
| C18:1cis9                             | Dairy   | Cattle         | 42             | 20.79               | 19.39                   | 0.315            | ***                       |
|                                       |         | Goat           | 11             | 18.10               | 18.13                   | 1.071            | ns                        |
|                                       |         | Sheep          | 22             | 19.46               | 17.20                   | 0.994            | **                        |
|                                       | Meat    | Cattle         | 4              | 34.80               | 34.63                   | 1.687            | ns                        |
|                                       |         | Sheep          | 16             | 34.46               | 35.36                   | 1.460            | ns                        |
| C18:2n-6                              | Dairy   | Cattle         | 41             | 1.52                | 1.77                    | 0.085            | ***                       |
|                                       |         | Goat           | 10             | 2.38                | 2.30                    | 0.228            | ns                        |
|                                       |         | Sheep          | 23             | 3.75                | 4.24                    | 1.014            | ns                        |
|                                       | Meat    | Cattle         | 8              | 2.30                | 2.72                    | 0.488            | †                         |
|                                       |         | Sheep          | 19             | 6.00                | 7.29                    | 0.623            | *                         |
| C18:3n-3                              | Dairy   | Cattle         | 48             | 0.81                | 0.57                    | 0.046            | ***                       |
|                                       |         | Goat           | 10             | 0.68                | 0.48                    | 0.063            | **                        |
|                                       |         | Sheep          | 23             | 1.73                | 1.11                    | 0.177            | ***                       |
|                                       | Meat    | Cattle         | 8              | 1.00                | 0.69                    | 0.053            | **                        |
|                                       |         | Sheep          | 19             | 2.00                | 1.16                    | 0.176            | **                        |
| CLAcis9trans11                        | Dairy   | Cattle         | 53             | 1.20                | 0.65                    | 0.707            | ***                       |
|                                       |         | Goat           | 6              | 0.83                | 0.46                    | 0.225            | †                         |
|                                       |         | Sheep          | 23             | 2.09                | 1.08                    | 0.352            | **                        |
|                                       | Meat    | Cattle         | 8              | 0.79                | 0.53                    | 0.046            | **                        |
|                                       |         | Sheep          | 7              | 0.91                | 0.75                    | 0.168            | ns                        |
| SFA                                   | Dairy   | Cattle         | 50             | 63.78               | 66.93                   | 0.783            | ***                       |
|                                       |         | Goat           | 10             | 68.42               | 69.11                   | 3.510            | ns                        |
|                                       |         | Sheep          | 22             | 61.01               | 64.30                   | 1.614            | **                        |
|                                       | Meat    | Cattle         | 8              | 48.74               | 49.86                   | 0.651            | *                         |
|                                       |         | Sheep          | 13             | 45.39               | 46.24                   | 1.327            | ns                        |
| MUFA                                  | Dairy   | Cattle         | 50             | 28.27               | 26.04                   | 0.393            | ***                       |
|                                       |         | Goat           | 10             | 20.22               | 20.33                   | 1.186            | ns                        |
|                                       |         | Sheep          | 21             | 23.35               | 20.00                   | 1.147            | ***                       |
|                                       | Meat    | Cattle         | 8              | 44.01               | 43.51                   | 1.066            | ns                        |
|                                       |         | Sheep          | 11             | 39.98               | 37.78                   | 1.701            | *                         |
| PUFA                                  | Dairy   | Cattle         | 50             | 4.61                | 3.78                    | 0.207            | ***                       |
|                                       |         | Goat           | 10             | 4.29                | 3.68                    | 0.235            | *                         |
|                                       |         | Sheep          | 22             | 6.31                | 5.13                    | 0.351            | ***                       |
|                                       | Meat    | Cattle         | 8              | 6.08                | 5.55                    | 0.931            | ns                        |
|                                       |         | Sheep          | 15             | 16.50               | 17.60                   | 2.107            | ns                        |
| BCFA                                  | Dairy   | Cattle         | 32             | 2.34                | 2.10                    | 0.140            | **                        |
| C18:1cis9/C16:0                       | Dairy   | Cattle         | 47             | 0.77                | 0.65                    | 0.023            | ***                       |

|                   |       |        |    |      |      |       |     |
|-------------------|-------|--------|----|------|------|-------|-----|
|                   |       | Goat   | 10 | 0.73 | 0.69 | 0.087 | ns  |
|                   |       | Sheep  | 22 | 0.92 | 0.75 | 0.493 | *** |
|                   | Meat  | Cattle | 4  | 1.47 | 1.41 | 0.070 | ns  |
|                   |       | Sheep  | 16 | 1.61 | 1.56 | 0.069 | ns  |
|                   | Dairy | Cattle | 41 | 0.53 | 0.33 | 0.036 | *** |
|                   |       | Goat   | 10 | 0.34 | 0.22 | 0.036 | *** |
| C18:3n-3/C18:2n-6 | Meat  | Sheep  | 23 | 0.64 | 0.37 | 0.799 | *** |
|                   |       | Cattle | 8  | 0.51 | 0.29 | 0.050 | **  |
|                   |       | Sheep  | 19 | 0.39 | 0.18 | 0.041 | *** |

1007 <sup>1</sup> SFA, sum of straight-chain FA from C4:0 to C24:0, MUFA, sum of  
1008 monounsaturated FA from C10:1 to C24:1; PUFA, sum of polyunsaturated FA  
1009 form C18:2 to C22:6, BCFA, sum of branched chain FA from C13:0-iso to C18:0-  
1010 iso.

1011 <sup>2</sup> n, number of data.

1012 <sup>3</sup> SEM, standard error of the mean.

1013 <sup>4</sup> \*\*\*, P < 0.001; \*\*, P < 0.01; \*, P < 0.05; †, P < 0.1; ns, not significant.

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1015

1016 **Table 5.** Effect of feeding fresh herbage instead of conserved forage  
 1017 and/or concentrates on the sensory properties of different animal products.

| Item <sup>1</sup> | Product | Animal Species | n <sup>2</sup> | Fresh herbage group | Conserved Forages group | SEM <sup>3</sup> | Significance <sup>4</sup> |
|-------------------|---------|----------------|----------------|---------------------|-------------------------|------------------|---------------------------|
| Elastic           | Dairy   | Cattle         | 4              | 2.54                | 2.44                    | 1.120            | ns                        |
|                   |         | Sheep          | 3              | 3.40                | 2.80                    | 0.200            | †                         |
| Tenderness        | Meat    | Cattle         | 5              | 5.60                | 5.60                    | 0.231            | ns                        |
|                   |         | Sheep          | 8              | 5.56                | 5.28                    | 0.330            | ns                        |
| Intensity         | Dairy   | Cattle         | 3              | 3.90                | 3.27                    | 0.100            | ns                        |
|                   |         | Sheep          | 3              | 1.10                | 0.74                    | 0.150            | ns                        |
|                   | Meat    | Cattle         | 4              | 5.80                | 5.70                    | 0.577            | ns                        |
|                   |         | Sheep          | 10             | 4.75                | 3.99                    | 0.375            | ns                        |
| Lactic            | Dairy   | Cattle         | 17             | 3.01                | 3.34                    | 0.361            | *                         |
|                   |         | Sheep          | 6              | 2.22                | 2.80                    | 0.381            | *                         |
| Vegetable         | Meat    | Cattle         | 6              | 3.13                | 3.72                    | 0.517            | ns                        |
|                   |         | Sheep          | 6              | 3.13                | 3.72                    | 0.517            | ns                        |
| Brown             | Dairy   | Cattle         | 15             | 3.25                | 2.51                    | 0.360            | ***                       |
| Animal            | Dairy   | Cattle         | 12             | 2.19                | 1.71                    | 0.495            | ns                        |
|                   |         | Cattle         | 8              | 2.64                | 2.23                    | 0.859            | ns                        |
| Others            | Meat    | Sheep          | 6              | 5.12                | 4.50                    | 0.247            | **                        |
|                   |         | Cattle         | 15             | 3.00                | 2.65                    | 0.539            | †                         |
| Fattiness         | Meat    | Cattle         | 8              | 2.02                | 1.91                    | 0.116            | ns                        |
|                   |         | Cattle         | 4              | 5.30                | 5.20                    | 0.058            | ns                        |
| Juiciness         | Meat    | Sheep          | 8              | 4.37                | 4.62                    | 0.465            | ns                        |
|                   |         | Sheep          | 8              | 1.94                | 2.81                    | 0.370            | *                         |
| Intramuscular fat | Meat    | Sheep          | 8              | 1.94                | 2.81                    | 0.370            | *                         |

1018 <sup>1</sup> Sensory properties were grouped under sensory families, as described by  
 1019 Piccinali (2012), based on odour, flavour, and taste: intensity, lactic (acid, milk,  
 1020 yoghurt, cream, fermented cream, and butter), vegetable (grassy, boiled  
 1021 vegetables, garlic, and onion), “brown” (caramel, smoked, sweet, and vanilla),  
 1022 animal (animal, stable, barn, and manure), and others (salty, bitter, silage, mould,  
 1023 mothball, and cheese mite). Sensory traits data were converted to a common 0–  
 1024 10 scale.

1025 <sup>2</sup> n, number of data.

1026 <sup>3</sup> SEM, standard error of the mean.

1027 <sup>4</sup> \*\*\*, P < 0.001; \*\*, P < 0.01; \*, P < 0.05; †, P < 0.1; ns, not significant.

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1030 **Table 6.** Effect of feeding hay instead of silage on the quality traits of  
 1031 cattle dairy products.

| Item <sup>1</sup>                    | n <sup>2</sup> | Hay group | Silage group | SEM <sup>3</sup> | Significance <sup>4</sup> |
|--------------------------------------|----------------|-----------|--------------|------------------|---------------------------|
| Carotenoids and vitamins (mg/kg fat) |                |           |              |                  |                           |
| α-Tocopherol                         | 4              | 9.01      | 9.91         | 0.358            | *                         |
| Retinol                              | 4              | 5.73      | 5.84         | 0.945            | ns                        |
| β-Carotene                           | 3              | 2.46      | 2.65         | 0.930            | ns                        |
| Fatty acids (g/100 g FA)             |                |           |              |                  |                           |
| C16:0                                | 15             | 31.31     | 32.11        | 0.711            | ns                        |
| C18:1trans11                         | 12             | 1.23      | 1.00         | 0.090            | *                         |
| C18:1cis9                            | 14             | 19.10     | 18.52        | 0.569            | ns                        |
| C18:2n-6                             | 15             | 1.88      | 1.93         | 0.153            | ns                        |
| C18:3n-3                             | 15             | 0.54      | 0.45         | 0.043            | †                         |
| CLAcis9trans11                       | 15             | 0.58      | 0.47         | 0.032            | *                         |
| SFA                                  | 15             | 65.95     | 66.61        | 2.610            | ns                        |
| MUFA                                 | 15             | 25.42     | 25.07        | 0.714            | ns                        |
| PUFA                                 | 15             | 3.69      | 3.49         | 0.217            | ns                        |
| BCFA                                 | 12             | 1.83      | 1.57         | 0.193            | *                         |
| C18:1cis9/C16:0                      | 15             | 0.61      | 0.59         | 0.027            | ns                        |
| C18:3n-3/C18:2n-6                    | 15             | 0.33      | 0.26         | 0.034            | †                         |

1032 <sup>1</sup> SFA, sum of straight-chain FA from C4:0 to C24:0; MUFA, sum of  
 1033 monounsaturated FA from C10:1 to C24:1; PUFA, sum of polyunsaturated FA  
 1034 from C18:2 to C22:6, BCFA, sum of branched chain FA from C13:0-iso to C18:0-  
 1035 iso.

1036 <sup>2</sup> n, number of data.

1037 <sup>3</sup> SEM, standard error of the mean.

1038 <sup>4</sup> \*\*\*, P < 0.001; \*\*, P < 0.01; \*, P < 0.05; †, P < 0.1; ns, not significant.

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1041

1042 **Table 7.** Effect of feeding grass silage instead of maize silage on the  
 1043 quality traits of cattle dairy products.

| Item <sup>1</sup>                    | n <sup>2</sup> | Grass silage group | Maize silage group | SEM <sup>3</sup> | Significance <sup>4</sup> |
|--------------------------------------|----------------|--------------------|--------------------|------------------|---------------------------|
| Carotenoids and vitamins (mg/kg fat) |                |                    |                    |                  |                           |
| α-Tocopherol                         | 3              | 14.26              | 13.98              | 5.455            | ns                        |
| β-Carotene                           | 3              | 6.68               | 3.11               | 0.965            | ns                        |
| Fatty acids (g/100 g FA)             |                |                    |                    |                  |                           |
| C16:0                                | 6              | 32.72              | 33.96              | 1.137            | †                         |
| C18:1trans11                         | 6              | 1.13               | 0.93               | 0.231            | ns                        |
| C18:1cis9                            | 6              | 17.80              | 17.32              | 0.875            | ns                        |
| C18:2n-6                             | 7              | 1.57               | 1.71               | 0.161            | *                         |
| C18:3n-3                             | 7              | 0.62               | 0.40               | 0.050            | *                         |
| CLAcis9trans11                       | 7              | 0.54               | 0.41               | 0.699            | †                         |
| SFA                                  | 7              | 69.00              | 69.92              | 0.707            | ns                        |
| MUFA                                 | 7              | 24.71              | 24.22              | 1.100            | ns                        |
| PUFA                                 | 7              | 3.33               | 3.10               | 0.240            | *                         |
| BCFA                                 | 5              | 1.91               | 1.62               | 0.287            | *                         |
| C18:1cis9/C16:0                      | 6              | 0.55               | 0.51               | 0.337            | ns                        |
| C18:3n-3/C18:2n-6                    | 7              | 0.41               | 0.25               | 0.044            | *                         |

1044 <sup>1</sup> SFA, sum of straight-chain FA from C4:0 to C24:0; MUFA, sum of  
 1045 monounsaturated FA from C10:1 to C24:1; PUFA, sum of polyunsaturated FA  
 1046 form C18:2 to C22:6, BCFA, sum of branched chain FA from C13:0-iso to C18:0-  
 1047 iso.

1048 <sup>2</sup> n, number of data.

1049 <sup>3</sup> SEM, standard error of the mean.

1050 <sup>4</sup> \*\*\*, P < 0.001; \*\*, P < 0.01; \*, P < 0.05; †, P < 0.1; ns, not significant.

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1052

1053 **Table 8.** Effect of feeding forages from permanent grasslands, botanically  
 1054 diversified or rich in plant secondary metabolites (PSM) instead of  
 1055 temporary grasslands dominated by grasses on the carotenoids, fat-  
 1056 soluble vitamins, and terpene content, colour and sensory properties of  
 1057 different animal products.

| Item <sup>1</sup>                    | Product | Animal species | n <sup>2</sup> | High biodiversity group | Low biodiversity group | SEM <sup>3</sup> | Significance <sup>4</sup> |
|--------------------------------------|---------|----------------|----------------|-------------------------|------------------------|------------------|---------------------------|
| Carotenoids and vitamins (mg/kg fat) |         |                |                |                         |                        |                  |                           |
| α-Tocopherol                         | Dairy   | Cattle         | 7              | 13.55                   | 12.35                  | 2.228            | ns                        |
| Retinol                              | Dairy   | Cattle         | 5              | 5.36                    | 5.93                   | 0.488            | †                         |
| β-Carotene                           | Dairy   | Cattle         | 7              | 5.23                    | 3.87                   | 0.919            | ns                        |
| Terpenes tot (ln AAU)                | Dairy   | Cattle         | 4              | 7.62                    | 7.46                   | 1.432            | ns                        |
| Colour                               |         |                |                |                         |                        |                  |                           |
| b*                                   | Dairy   | Cattle         | 4              | 15.79                   | 15.68                  | 4.114            | ns                        |
| a*                                   | Dairy   | Cattle         | 4              | -1.77                   | -1.66                  | 1.086            | ns                        |
| L*                                   | Dairy   | Cattle         | 4              | 76.28                   | 77.60                  | 3.169            | ns                        |
| Sensory properties                   |         |                |                |                         |                        |                  |                           |
| Hardness                             | Meat    | Sheep          | 4              | 3.55                    | 3.83                   | 0.144            | *                         |
| Tenderness                           | Meat    | Sheep          | 4              | 6.45                    | 6.10                   | 0.212            | ns                        |
| Intensity                            | Dairy   | Cattle         | 4              | 4.11                    | 3.74                   | 0.094            | *                         |
| Spicy                                | Dairy   | Cattle         | 4              | 4.67                    | 2.23                   | 0.770            | *                         |
| Animal                               | Dairy   | Cattle         | 4              | 4.98                    | 3.18                   | 0.067            | †                         |
| Others                               | Meat    | Sheep          | 6              | 2.97                    | 2.44                   | 0.453            | ns                        |
| Fattiness                            | Meat    | Sheep          | 10             | 2.94                    | 2.98                   | 0.484            | ns                        |
| Juiciness                            | Meat    | Sheep          | 10             | 12.93                   | 10.95                  | 3.845            | ns                        |
| Juiciness                            | Meat    | Sheep          | 10             | 13.39                   | 11.36                  | 3.732            | ns                        |

1058 <sup>1</sup> Sensory properties were grouped under sensory families, as described by  
 1059 Piccinali (2012), based on odour, flavour, and taste: intensity, spicy (clover,  
 1060 nutmeg, pepper, mint), animal (animal, stable, barn, and manure), and others  
 1061 (salty, bitter, silage, mould, mothball, and cheese mite). Sensory traits data were  
 1062 converted to a common 0–10 scale.

1063 <sup>2</sup> n, number of data.

1064 <sup>3</sup> SEM, standard error of the mean; AAU, arbitrary area units.

1065 <sup>4</sup> \*\*\*, P < 0.001; \*\*, P < 0.01; \*, P < 0.05; †, P < 0.1; ns, not significant.

1066

1067 **Table 9.** Effect of feeding forages from permanent grasslands, botanically  
 1068 diversified or rich in plant secondary metabolites (PSM) instead of  
 1069 temporary grasslands dominated by grasses on the fatty acid profile of  
 1070 different animal products.

| Fatty acids<br>(g/100 g FA) <sup>1</sup> | Product | Animal<br>species | n <sup>2</sup> | High<br>biodiversity<br>group | Low<br>biodiversity<br>group | SEM <sup>3</sup> | Significance <sup>4</sup> |
|--|---------|-------------------|----------------|-------------------------------|------------------------------|------------------|---------------------------|
| C16:0                                    | Dairy   | Cattle            | 16             | 25.21                         | 25.04                        | 1.547            | ns                        |
|  |         | Sheep             | 8              | 20.94                         | 21.62                        | 0.669            | ns                        |
|  | Meat    | Sheep             | 14             | 21.63                         | 24.27                        | 1.083            | *                         |
| C18:1trans11                             | Dairy   | Cattle            | 12             | 3.37                          | 3.07                         | 0.190            | **                        |
|  |         | Sheep             | 9              | 5.18                          | 4.49                         | 0.487            | ns                        |
|  | Meat    | Sheep             | 6              | 3.14                          | 3.15                         | 0.794            | ns                        |
| C18:1cis9                                | Dairy   | Cattle            | 19             | 22.63                         | 21.78                        | 1.347            | ns                        |
|  |         | Sheep             | 8              | 19.02                         | 19.17                        | 0.536            | ns                        |
|  | Meat    | Sheep             | 14             | 31.12                         | 30.97                        | 1.540            | ns                        |
| C18:2n-6                                 | Dairy   | Cattle            | 19             | 1.80                          | 1.64                         | 0.083            | *                         |
|  |         | Sheep             | 9              | 2.46                          | 2.23                         | 0.142            | *                         |
|  | Meat    | Sheep             | 14             | 5.27                          | 5.34                         | 0.764            | ns                        |
| C18:3n-3                                 | Dairy   | Cattle            | 16             | 0.93                          | 0.82                         | 0.051            | *                         |
|  |         | Sheep             | 9              | 1.61                          | 1.35                         | 0.080            | *                         |
|  | Meat    | Sheep             | 14             | 2.14                          | 2.28                         | 0.225            | ns                        |
| CLAcis9trans11                           | Dairy   | Cattle            | 19             | 1.40                          | 1.22                         | 0.092            | *                         |
|  |         | Sheep             | 9              | 2.48                          | 2.15                         | 0.219            | †                         |
|  | Meat    | Sheep             | 10             | 0.92                          | 0.86                         | 0.090            | ns                        |
| SFA                                      | Dairy   | Cattle            | 18             | 60.51                         | 62.63                        | 1.164            | **                        |
|  |         | Sheep             | 8              | 65.70                         | 65.94                        | 2.714            | ns                        |
|  | Meat    | Sheep             | 15             | 46.78                         | 47.36                        | 1.606            | ns                        |
| MUFA                                     | Dairy   | Cattle            | 16             | 31.81                         | 29.86                        | 0.904            | **                        |
|  |         | Sheep             | 8              | 24.68                         | 24.03                        | 0.558            | *                         |
|  | Meat    | Sheep             | 14             | 37.43                         | 37.44                        | 1.150            | ns                        |
| PUFA                                     | Dairy   | Cattle            | 18             | 5.43                          | 4.82                         | 0.267            | **                        |
|  |         | Sheep             | 8              | 6.71                          | 5.82                         | 0.417            | *                         |
|  | Meat    | Sheep             | 15             | 11.91                         | 11.61                        | 1.591            | ns                        |
| BCFA                                     | Dairy   | Cattle            | 13             | 2.19                          | 2.11                         | 0.170            | ns                        |
|  |         | Sheep             | 5              | 5.74                          | 5.48                         | 0.585            | ns                        |
|  | Meat    | Sheep             | 16             | 0.90                          | 0.79                         | 0.036            | **                        |
| C18:1cis9/C16:0                          | Dairy   | Cattle            | 16             | 0.90                          | 0.79                         | 0.036            | **                        |
|  |         | Sheep             | 8              | 1.28                          | 1.30                         | 0.179            | ns                        |
|  | Meat    | Sheep             | 8              | 0.19                          | 1.17                         | 0.125            | ns                        |
| C18:3n-3/C18:2n-6                        | Dairy   | Cattle            | 16             | 0.56                          | 0.53                         | 0.027            | *                         |
|  |         | Sheep             | 8              | 0.67                          | 0.62                         | 0.056            | ns                        |
|  | Meat    | Sheep             | 14             | 0.57                          | 0.61                         | 0.141            | ns                        |

1071 <sup>1</sup> SFA, sum of straight-chain FA from C4:0 to C24:0; MUFA, sum of  
 1072 monounsaturated FA from C10:1 to C24:1; PUFA, sum of polyunsaturated FA  
 1073 form C18:2 to C22:6, BCFA, sum of branched chain FA from C13:0-iso to C18:0-  
 1074 iso.

1075 <sup>2</sup> n, number of studies.

1076 <sup>3</sup> SEM, standard error of the mean.

1077 <sup>4</sup> \*\*\*, P < 0.001; \*\*, P < 0.01; \*, P < 0.05; †, P < 0.1; ns, not significant.