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Communication

Case study on the Impact of Water Resources in Beef Production: Corn vs. Triticale Silage in the Diet of Limousine × Podolian Young Bulls

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Simple Summary: Agriculture accounts for 92% of the global freshwater footprint (WF), of which more than a quarter is used in livestock production for feed, mixing feed, watering animals and agricultural activities. This study has shown that replacing maize silage with triticale silage in the diet of beef calves resulted in a relevant reduction in water consumption per cattle per day, without changing growth performance. It also shows how feed choice can help improve the water balance of livestock production and thus reduce the pressure that the sector puts on water resources.

Abstract: In this study, we have included the water footprint (WF) in the process of optimising animal feed rations. The global footprint of cattle production accounts for the largest share (33%) of the global water footprint of livestock production. Using two homogeneous groups of Limousine × Podolian young bulls, two different diets were compared: corn silage feeding (CSF), with corn silage-based diet; and the triticale silage feeding (TSF), with triticale silage-based diet. Silage constituted about 41% and 46% of the feed composition (for CSF and TSF, respectively). Diets were characterised by the same energy and protein content. Despite the lower WF in the TSF group than in the CSF group (7726 vs 8571 l/day/calf respectively), no significant differences were found in animal performances (i.e., daily weight gain and final weight), feed conversion and income over feed costs. These results show that simple production decisions can have a significant impact on water resource. Therefore, the use of triticale silage should be further promoted, especially in world regions with limited water resources where low WF feed formulation is more strategic than elsewhere.

Keywords: Limousine × Podolian young bulls; beef production; feeding efficiency; water footprint

1. Introduction

Our dependence on water resources will increase significantly in the future, posing problems for future food security and environmental sustainability [1–3]. The relationship between the freshwater resource and human productive activities, the Water Footprint Assessment (WFA), was developed to assess the amount of water consumed and water polluted. This concept was introduced by Hoekstra [4] and then elaborated and validated by Chapagain and Hoekstra [5]. Cattle farming accounts for the largest share (33%) of the global water footprint of livestock production, followed by pigs (19%), dairy cows (19%) and poultry (11%) [6,7]. Poultry has indeed proven to be the most efficient livestock sub-sector in terms of utilising natural resources and providing protein to meet growing global demand [8], requiring 11 times less feed (in dry matter) than beef production [6]. The feeding of cattle has a fundamental function in the economic and technical efficiency of livestock farming and accounts for about 60% of total costs. Its production requires and pollutes large amounts of water, especially for the production of feed [9–11]. Feed composition of the is one of the most important factors directly affecting feed conversion in terms of farm income [12–14]. Water footprint

is inversely related to feed conversion efficiency. Therefore, in order to maximise feed conversion efficiency, barn income must be increased and water footprint reduced [15]. In this view, the present study investigated the effect of replacing corn silage with triticale silage in the diet of Limousine × Podolian young bulls.

2. Materials and Methods

The trial was conducted on a farm in the Basilicata region, Italy, at an altitude of 600 m a.s.l. with 40 Limousine × Podolian young bulls. Podolian cattle are an autochthonous breed belonging to the Hungarian Grey Steppe group and are reared in southern Italy [16]. They are often crossed with specialized breeds to maximise meat production. During the experimental period, the animals, ageing 130 ± 11 days, were kept in two different boxes with straw bedding (8.5 m²/head) in the same barn. Their initial average weight (mean ± SE) was 347.4 ± 0.741 kg in group 1 and 341.3 ± 0.636 kg in group 2. The manure management system used on the farm is the liquid/slurry, where the manure is stored in the excreted form or with a minimal addition of water either in tanks or earthen ponds outside the barn, usually for a period of less than one year.

2.1. Diet composition and feeding

Two different diets were used: Corn Silage Feed (CSF) for group 1 and Triticale Silage Feed (TSF) for group 2. Triticale has a biological cycle that develops during the cold season (maize microtherm) and prefers high temperatures at the end of its cycle, therefore the WF is lower than maize, which shows an opposite behaviour in terms of heat and water requirements. The diets were formulated to be isoenergetic (0.90 UFV kg DM, 1 UFV 1820 kcal net energy) [17], with the same concentration of crude protein, crude fibre, starch and with the same feed cost. Feeding was administered using the Total Mixed Ration (TMR) method [18,19] according to the composition given in Table 1. The TMR was sampled monthly and using a NIRSYSTEM 5000 (Foss, Hillerød, Denmark) the following parameters were analysed: dry matter (DM), crude protein (CP), crude fiber (CF), neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), ether extract (EE), ash and starch. The percentage of energy and PDI requirements of cattle were calculated according to the method proposed by Garcia et al. [20]. TMR was administered *ad libitum* to each group. Feed intake and feed refusal were measured every 14 days for each experimental group. There were no individual measurements of feed intake as the young bulls of each group were housed in the same box. The average feed intake for the group was calculated every 14 days according to the following relationship:

Average daily feed intake (g/d) = (Total feed administered – Total feed refusal) / 20.

Table 1. Composition, estimated nutritive values and costs of diet ¹.

Components	CSF	TSF
Diet composition, %		
Corn Silage	41.1	-
Triticale Silage	-	45.9
Corn Meal	13.7	13.7
Wheat Straw	13.7	6.9
Barley Meal	1.4	5.5
Corn Gluten Meal	-	3.8
Sunflower Meal	-	6.9
Soybean Meal Extraction	10.27	-
Beet Pressed Pulp	3.4	5.5
Corn Distillers	3.4	1.7
Hydrogenated Fat	1.0	-
Vitamin Mineral Supplement	1.4	1.4
NaHCO ₃	1.0	1.0

NaCl	0.7	1.03
Water Mixing	8.9	6.8
DM	58.4	58.3
Feed cost		
€/kg DM	0.42	0.42
Chemical composition, g/kg DM ^a		
CP	147.4	147.0
CF	166.4	167.6
NDF	367.5	390.7
ADF	212.3	239.7
ADL	42.7	46.3
EE	43.0	27.1
Ash	78.9	87.9
Starch	248.8	249.7
Nutritive value, kg/DM		
UFV ^b	0.9	0.9
PDIN ^c	96.5	106.0
PDIE ^d	105.1	111.8
PDIA ^e	51.5	59.5

¹ CSF: Corn silage feeding; TSF: Triticale silage feeding; ^a Calculated by analysis of TMR; ^b UFV: Feed unit for meat production (net energy); ^c PDIN: Protein digested in the small intestine when rumen-fermentable nitrogen is limited; ^d PDIE: Protein digestible in the small intestine; ^e PDIA = Protein digestible in the small intestine supplied by rumen-undegraded dietary protein.

2.2. Live Weight and Daily Weight Gain

Live Weight (LW) was measured every 14 days (approximately 6 hours after administration of the daily ration) and Average Daily Gain (ADG) in each period was calculated.

2.3. Feed Conversion ratio and Income Over Feed Cost

The assessment of the technical and economic feed rations given to each group during the experimental period was done by calculating, in each interval of 14 days, Feed Conversion ratio (FCR) and Income Over Feed Cost (IOFC). FCR is defined as consumed kg DM/kg LW produced and is used to evaluate the effects of feed quality, environment and management practises on production efficiency in cattle rearing and fattening [21]. The IOFC measures the difference between the production meat value and the feed cost and was calculated according to the following formula proposed by Bailey et al. [22]:

IOFC = PLW *DWG – DFC, where:

(1)

PLW = farm-gate price of calf live weight (€/kg); DWG= daily weight gain (kg/d); DFC = daily feed cost (€/head);

2.4. Water footprint estimation

The WF of the Live Weight Gain was calculated by adding feed WF (water for feed production), feed mix WF (water for feed mix), drinking WF (water intake) and service WF (water for cleaning the pen) according to the following formula [5,23]:

WFA meat = WF feed + WF feed mixing + WF drinking + WF service

(2)

Green, blue and grey water were estimated during the experimental period for indirect and direct water footprint and live weight gain in kg. The green water footprint refers to soil moisture generated by evaporation of precipitation and used for crop production or moisture present in the product. The blue water footprint refers to evaporated surface or groundwater that enters the product or is reused elsewhere. The grey water footprint is defined as the amount of freshwater required to

assimilate the pollutant load based on existing water quality standards [24]. Data from the literature were used to calculate the indirect water footprint of the feed used for both forages [6], while the other fractions (watering, mixing and service) were assessed on the farm using a mechanical water metre. The water used for mixing the animal feed was added to the blue water component in the feed ration.

2.5. Statistical analysis

Data were expressed as mean \pm SE and differences between groups were tested by Student's *t*-test.

3. Results and discussions

No significant differences were found between the groups in the daily intake of DM. The intake of DM throughout the trial period was 8.00 kg/day for the CSF group and 7.80 kg/day for the TSF (Table 2).

Table 2. Average daily dry matter intake ($\bar{x} \pm$ SE) ¹.

Trial day	CSF		TSF	
	DM	SE	DM	SE
0	6.56	0.039	6.41	0.033
14	6.80	0.041	6.64	0.035
28	7.03	0.043	6.86	0.036
42	7.26	0.044	7.09	0.037
56	7.49	0.046	7.31	0.039
70	7.71	0.048	7.52	0.04
84	7.93	0.049	7.73	0.042
98	8.14	0.051	7.94	0.043
112	8.35	0.052	8.15	0.044
126	8.55	0.054	8.34	0.045
140	8.75	0.055	8.54	0.046
154	8.95	0.057	8.73	0.048
168	9.13	0.058	8.91	0.049
182	9.32	0.059	9.09	0.05
All	8.00	0.05	7.80	0.04

¹ CSF: Corn silage feeding; TSF: Triticale silage feeding; DM: Dry matter.

The CSF and TSF groups achieved 596.43 and 585.91 kg LW and 1,365 and 1,341 kg/day DWG, respectively (Table 3). No significant differences were found between the two groups in terms of final LW and DWG.

Table 3. Live weight (LW) and average daily gain (ADG)($\bar{x} \pm$ SE) ¹.

Trial day	LW, kg				ADG, kg/day			
	CSF	SE	TSF	SE	CSF	SE	TSF	SE
1	347.43	0.741	341.30	0.636	1.42	0.003	1.39	0.003
14	367.32	0.783	360.84	0.673	1.42	0.003	1.40	0.003
28	387.26	0.826	380.43	0.709	1.43	0.003	1.40	0.003
42	407.19	0.868	400.01	0.746	1.42	0.003	1.40	0.003
56	427.07	0.911	419.53	0.782	1.42	0.003	1.39	0.003
70	446.84	0.953	438.95	0.818	1.41	0.003	1.38	0.003
84	466.45	0.994	458.23	0.854	1.40	0.003	1.37	0.003
98	485.88	1.036	477.31	0.89	1.38	0.003	1.36	0.003
112	505.07	1.077	496.16	0.925	1.36	0.003	1.34	0.002

126	524.00	1.117	514.75	0.959	1.34	0.003	1.32	0.002
140	542.62	1.157	533.05	0.993	1.32	0.003	1.30	0.002
154	560.92	1.196	551.02	1.027	1.30	0.003	1.27	0.002
168	578.86	1.234	568.65	1.06	1.27	0.003	1.25	0.002
182	596.43	1.272	585.91	1.092	1.24	0.003	1.22	0.002
All	-	-	-	-	1.365	0.003	1.341	0.002

¹CSF: Corn silage feeding; TSF: Triticale silage feeding.

Over the entire experimental period, FCR was 5.896 for the SF group and 5.857 for the AF group (Table 4).

Table 4. Feed conversion ratio (FCR) ($\bar{x} \pm SE$) ¹. .

Trial day	FCR			
	CSF	SE	TSF	SE
0	4.629	0.08	4.603	0.09
14	4.777	0.05	4.748	0.03
28	4.935	0.09	4.904	0.02
42	5.104	0.11	5.072	0.12
56	5.285	0.07	5.251	0.06
70	5.477	0.06	5.442	0.05
84	5.682	0.07	5.645	0.05
98	5.900	0.07	5.860	0.04
112	6.131	0.06	6.089	0.09
126	6.376	0.09	6.332	0.03
140	6.635	0.05	6.589	0.09
154	6.91	0.07	6.861	0.07
168	7.200	0.08	7.149	0.05
182	7.507	0.07	7.454	0.09
All	5.896	0.05	5.857	0.09

¹CSF: Corn silage feeding; TSF: Triticale silage feeding.

During the same period, the income over feed cost (PLW = 3.50 €/kg LW; DFC = 0.420 €/kg DM * DM daily intake) 1.418 €/day in both groups over the whole experimental period was (Table 5).

Table 5. Income over feed costs (IOFC) ($\bar{x} \pm SE$)¹.

Trial day	IOFC			
	CSF	SE	TSF	SE
0	2.215	0.25	2.173	0.13
14	2.114	0.13	2.111	0.11
28	2.052	0.09	2.019	0.15
42	1.921	0.15	1.922	0.09
56	1.824	0.08	1.795	0.13
70	1.697	0.10	1.672	0.20
84	1.569	0.11	1.548	0.12
98	1.411	0.11	1.425	0.10
112	1.253	0.09	1.267	0.14
126	1.099	0.10	1.117	0.08
140	0.945	0.12	0.963	0.16
154	0.791	0.14	0.778	0.08
168	0.610	1.13	0.633	0.11
182	0.426	1.11	0.452	0.13
All	1.418	0.90	1.418	0.11

¹CSF: Corn silage feeding; TSF: Triticale silage feeding

The average water footprint of the ADG calculated over the whole experimental period was 6221.29 L in the CSF group and 5703.60 L in the TSF group. Therefore, the WF difference per kg LWG was 517.70 L between the two groups (Figure 1). The daily average intake of green, blue and grey water in the groups CSF and TSF was 76.09%, 13.59%, 10.32% and 82.45%, 6.37%, 11.18%, respectively. Gerbens-Leenes et al. [10], in a study on WF industrial beef production in four countries, report values (L/kg LW) in the interval 4000-5000 in NL and USA, and close to 9000 in Brazil and 13000 in China. This study illustrated also that choosing feed ingredients and sourcing wisely, and particularly substituting crops with co-products or crop residues, will help to improve the WP of livestock products, thus reducing the pressure the sector puts on scarce water resources. Highest total WF for beef production was instead evidenced in Brazil by Palhares et al. [25] with values ranging from 9249 to 23521 L/kg LW. In another study in Arcadia Valley (MO-USA) Eady et al. [26] compared two rearing forms in beef cattle production 634-cow enterprise turning off weaner cattle and 720-cow enterprise turning off finished cattle, green water use ranged from 7400 to 12700 L/kg LW depending on class of livestock, with on-farm blue water use of 51-96 L/kg liveweight and off-farm blue water use of 0.1-59 L/kg LW.

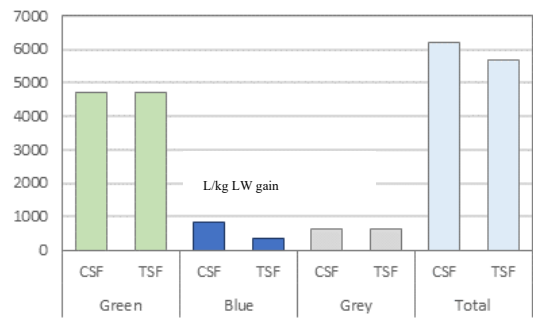


Figure 1. Water footprint (L/kg ADG) calculated over the entire experimental period ^{1,1} CSF: Corn silage feeding; TSF: Triticale silage feeding.

The percentage of WF in the consumed feed components observed during the trial period was similar to the data reported by Hoekstra et. al (2011) [23] for industrially bred cattle. As shown in Table 6, the percentage of WF feed was higher in the CSF group than in the TSF group (8471 vs 7726), as there was a relevant water saving (745 L per bovine per day) in the TSF group.

Table 6. Trial period water footprint average (L/day/animal)¹.

Groups ¹	Indirect water footprint		Direct water footprint		WF Average L/day/animal
	WF _{Feed}	WF _{Feed Mixing}	WF _{Drinking}	WF _{Service}	
	Estimated		Observed		
CSF	8471	1.439	23.99	75	8571
TSF	7626	1.756	23.41	75	7726

¹ CSF: Corn silage feeding; TSF: Triticale silage feeding.

According to Mekonnen and Hoekstra [6], feed consumption accounts for the largest share of water consumption in livestock production (98.83% and 98.70% in our study, in TSF and AF respectively), while the share of drinking, industrial and mixed water is quite low for both types of feed administration (< 3%). Mourad et al. [27] observed a mean percentage of water allocation for WF of 98.3% in the central and north-eastern region of Africa. Given the many variables involved in determining WF, it has been suggested by various authors [25,28] that general recommendations cannot be made on a large scale, e.g., to formulate policy recommendations, but only for individual operations. Furthermore, Broom [29], in a study that considered land use and conserved water data from different parts of the world, showed the large impact of farming systems on water resource use

and the need to consider all systems when considering the impact of beef or other products on the global environment.

4. Conclusions

The use of triticale silage in the diet instead of corn, when properly optimised, showed a lower water footprint in meat production, while maintaining the same technical and economic efficiency as feeding corn silage to cattle. These results confirm the possibility of including the water footprint parameter in ration optimisation and show that simple production decisions can have a significant impact on water resources.

This study used data collected at the regional level, the use of which, rather than national average data for food ingredient production characteristics, provides a more accurate estimate of water resource impacts in beef production. One criticism of the present study could be that it was conducted for a single beef production system. The organization of primary data from individual studies into databases and expanding WF studies for the beef product, will contribute to a better understanding of how water efficiency can be improved in this sector through a bottom-up approach.

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