BIOGAS PRODUCTION FROM THISTLE (*Cynara cardunculus* L.) SILAGES

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Keywords: biogas; ensiling duration; fermentation quality; stage of maturity; thistle silage.

INTRODUCTION

The demand for alternative energy crops for biogas production has been increased in the recent years in order to obtain crops that produce large amount of biomass with low input and can be grown on marginal lands. Thistle (*Cynara cardunculus* L.), is suitable as energy crop since its high growth rate, production of biomass harvested relatively dry, low-input management (Angelini et al., 2009; Pari et al., 2017) and capability to well ferment and to be conserved as silage (Pesce et al., 2017). The aim of this work was to evaluate the fermentation quality and the biogas production of thistle crop harvested at two different stages of maturity and treated or not with a lactic acid bacteria (LAB) inoculum.

MATERIALS AND METHODS

Thistle crop was harvested as a whole plant, at two different stages of maturity (full bloom, stage I; and seed ripening, stage II). The crop was chopped with a self-propelled forage harvester (Claas Jaguar 950) and untreated (C) or inoculated with a mixture of *L. buchneri*, *L. plantarum*, and *L. casei* (L) at $3*10^5$ cfu/g. The forages were ensiled in 20-L plastic silos at a density of 716±24 and 378±20 kg/m^3 of fresh matter (FM) for stage I and II, respectively, and opened after 160 and 320 d of ensiling. The silages were analyzed for dry matter (DM) content, ash, pH, fermentative profile and DM losses calculated as the difference between the forage weight at ensiling and at silo opening. The biological methane potential (BMP) of both the fresh herbage and the silages was afterwards assessed by batch assays according to the VDI 4630 (2006) standard methodology. Data were analyzed for their statistical significance, via analysis of variance, using the GLM of SPSS (v. 24 for Windows, SPSS Inc., Chicago, IL). The data were analyzed utilizing the treatments (T) and harvesting stage (S) as the fixed factor, with three replicates.

RESULTS AND DISCUSSION

The DM content at harvest was 24% (wet) and 45% (dry) for harvesting stages I and II, respectively (Table 1). The biogas production of the fresh forage was higher (+14%) in stage I than in II. As previously reported by Pesce et al. (2017) thistle well fermented with absence of butyric acid in all the silages and lactic acid, acetic acid and ethanol as main fermentative end products (Table 2). The main factor affecting the fermentation was the stage of maturity whereas the use of the inoculum did not show any practical difference. The lactic acid decreased during ensiling duration and was 7 and 10 times higher in wet silages than in dry ones at 160 and 320 d, respectively. A larger amount of ethanol (>43 g/kg DM) was found in wet silages than in the dry ones (<2 g/kg DM) probably due to a possible yeast activity during early phase of fermentation. The weight losses reached around 6% and 2% for wet and dry silages, respectively. The production of biogas was affected by stage of maturity only after 320 d of conservation where it was higher in wet than in dry silages (+15%). The percentage of methane was not influenced neither by stage nor by inoculum and was around 50%. Even if no statistical differences were found, the application of the inoculum allowed to increase or keep constant the production of biogas during the ensiling period unlike the control in which the biogas production decreased from 160 to 320 d of ensiling. In agreement with the results of this study, Pesce et al. (2017) found a methane production ranging from 196 to 249 m^3_N /t VS in three different thistle silages. Thistle growth require lower input than corn but the mean production of methane in this study (247 m^3_N/t VS) is comparable to 232 m^3_N /t VS found by Menardo et al. (2015) in corn stalk silages or by Dinuccio et al. (2010) in several biomass residues and lower than 350 m^3_N /t VS found by Hermann et al. (2015) in corn silages.

Parameters	Stage I	Stage II
DM (%)	24.3 ± 0.15	45.2 ± 3.46
Ash (% DM)	8.23 ± 0.44	9.37 ± 0.81
DM yield (t/ha)	6.49 ± 0.38	11.15 ± 0.74
Biogas yield (m^3_N /t VS)	531 ± 30	465 ± 27
Methane yield (m^3_N /t VS)	253 ± 28	231 ± 17
Potential methane yield per hectare (m^3_N/ha)	1505 ± 88	2342 ± 151

Tab 1: chemical characteristics and biogas production of the thistle herbages prior to ensiling. The values represent the mean of 3 replicates ± standard deviation (DM = dry matter, VS = solid volatiles).

Parameters		Stage I		Stage II					
	day	C	L	C	L	Treat	Stage	T*S	SEM
DM (%)	160	20.6	22.1	44.7	43.1	NS	***	NS	3.44
	320	22.1	22.4	44.1	42.2	NS	***	NS	3.00
Ash (% DM)	160	8.79	8.98	9.53	8.85	NS	NS	NS	0.284
	320	8.80	8.88	9.59	8.69	NS	NS	*	0.199
pH	160	4.13	4.11	4.90	4.78	**	***	NS	0.110
	320	4.14	4.07	4.74	4.72	NS	***	NS	0.091
Lactic acid (g/kg DM)	160	77.3	68.5	8.6	11.1	NS	***	NS	9.76
	320	55.4	61.3	6.6	6.2	NS	***	NS	7.59
Acetic acid (g/kg DM)	160	21.5	18.4	31.6	32.9	NS	***	NS	2.076
	320	18.4	19.5	31.7	35.2	NS	***	NS	2.26
Ethanol (g/kg DM)	160	49.5	43.7	0.7	1.4	NS	***	NS	6.85
	320	58.5	55.4	0.6	1.7	*	***	*	7.94
Weight losses (% DM)	160	6.05	5.87	1.97	1.95	NS	***	NS	0.604
	320	6.65	5.96	2.23	2.21	***	***	***	0.593
Biogas yield (m^3_N /t VS)	160	577	442	482	462	NS	NS	NS	19.7
	320	556	528	422	465	NS	**	NS	9.9
Methane yield (m^3_N /t VS)	160	293	218	244	236	NS	NS	NS	10.3
	320	282	265	209	231	NS	**	NS	5.3

Tab. 2: dry matter, fermentative profile and biogas production of thistle silages (C = control; d =day of ensiling; DM = dry matter; L = lactic acid bacteria inoculum; SEM = standard error of the mean).

CONCLUSION

Using thistle as an energy crop and conserving it through ensiling represent a good opportunity for biogas production. Harvesting stage affected the DM content of the crop and final fermentation quality, with late harvesting (i.e., seed ripening) leading to higher methane potential yield per hectare. The low cultivation input makes thistle competitive with other crops or their residues, such as corn, for biogas production.

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