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ABSTRACT: In order to improve the supply of home-grown proteins in dairy farms, legume silage management is considered. The factors that affects fermentative quality and protein degradation during ensiling of tannin containing (sulla, sainfoin) and non tannin-containing (lucerne, field pea) legumes are discussed. The main considered factors are: wilting management, DM content, stage of growth and use of additives (lactic acid bacteria (LAB) inoculants and chestnut tannin).

Key words: Legume silage, "Home-grown" proteins, Stage of growth, Additives.

INTRODUCTION – Ensiling legumes is a good way of providing a cheaper, non-animal-based and traceable (source-verified) home-grown protein that may improve the efficiency of production system in dairy farms. However, it is known that most legumes undergo butyric acid fermentation when ensiled without additives at low DM content, due to the high buffering capacity (BC) and generally low water soluble carbohydrate (WSC) content (McDonald *et al.*, 1991). Furthermore, when conserving legumes as silage, severe protein degradation occurs. It is known that several factors affect the level of proteolysis during ensiling, such as the DM content of the crop at ensiling, the stage of maturity and the use of additives. Wilting markedly reduces proteolysis in the silo and the faster the rate of drying, the more effective wilting is at reducing proteolysis. Furthermore, due to the reversible protein-binding properties of tannin, species containing tannin have shown to undergo less protein degradation during ensiling than species that do not contain tannin. The aim of the paper is to summarize the results of four ensiling experiments conducted on different legumes crops in order to evaluate the effects of wilting, stage of growth, and added or natural tannins on the overall quality and on the protein quality of the resulting silages.

MATERIAL AND METHODS - Four experiments on the ensiling of legumes were carried out between 1997 and 2002. The species considered were: semi-leafless field pea (*Pisum sativum* L.) (Borreani *et al.*, 2006, Cavallarin *et al.*, 2006), lucerne (*Medicago sativa* L.) (Cavallarin *et al.*, 2000; Tabacco *et al.*, 2006), condensed tannin-containing sainfoin (*Onobrychis viciifolia* Scop.) (Cavallarin *et al.,* 2005) and sulla (*Hedysarum coronarium* L.) (Valente *et al.*, 1999). All the trials were carried out in the western Po Valley, Italy (44°50'N lat., 7°40'E long.), except for the sulla trial which was performed near Ancona, Italy (43°32'N lat., 13°23'E long.). The studied effects were: the wilting level in sulla, sainfoin and semi-leafless field pea, the speed of wilting in sainfoin, the stage of growth in sulla and semi-leafless field pea, LAB inoculants (*Lactobacillus plantarum* at 1×10^6 CFU g^{-1}) and chestnut tannin addition (4% DM) in lucerne. The experiments were conducted in laboratory silos, except for the lucerne, which was ensiled in wrapped round bales. The conservation period ranged from 60 to 120 days. The herbage chemical composition, the fermentative pattern and losses and the nitrogen fractions were determined as described in Cavallarin *et al.* (2005).

RESULTS AND CONCLUSIONS – The ensilability characteristics of herbage at cut indicates a great variability among the species, particularly in DM content, WSC and BC values (Table 1).
WSC ranged from 48 (lucerne) to 189 g kg^{-1} DM (pea) and BC ranged from 349 (pea at late cut) to 525 meq kg^{-1} DM (pea at early cut). These values show that the difficulties in ensiling legumes vary among species, and that lucerne

Table 1. Legume herbages at cut. Chemical composition and nitrogen fractions.

Crop	Sulla		Semi-leafless pea		Sainfoin	Lucerne
Stage	Early bud	Early flowering	Beginning of pod filling	Beginning of ripening	Early bud	Full flowering
DM (g kg^{-1})	96	126	170	223	123	236
WSC (g kg^{-1} DM) [A]	176	114	189	111	92	48
BC (meq kg^{-1} DM)	389	350	525	349	360	435
TN (g kg^{-1} DM)	35	30	33	33	28	27
NPN(g kg^{-1} TN)	-	-	301	208	122	170
Free AA-N (g kg^{-1} TN)	-	-	215	90	304	80
TAA (mol kg^{-1} TN)	-	-	34.9	36.2	39.6	38.5
Protein yield (kg ha^{-1})	1750	1875	1050	1345	920	625 (2950)B

[A] BC = buffering capacity; free AA= free amino acid nitrogen; NPN = non protein nitrogen; TAA = total amino acids, WSC = water soluble carbohydrates. [B] average annual yield of five cut schedule in brackets.

shows to be the most difficult crop to ensile due to its low WSC and high BC. The TN content ranged from 27 (lucerne) to 35 g kg^{-1} DM (sulla at early bud). The protein yield ranged from 625 to 1875 kg CP ha^{-1} for the different species to reach 2950 kg CP ha^{-1} for the whole year five cut schedule for lucerne. The high moisture content of all the crops at cutting makes these legumes unsuitable for direct ensiling and they therefore require a wilting period, in order to avoid poor fermentation and effluent production. In sulla, the higher moisture content of herbage at early bud almost doubled the wilting time required to reach a DM content of around 350 g kg^{-1}.

The semi-leafless pea unexpectedly dried to a DM content higher than 300 g kg^{-1} within 1 day from cutting, due to crop characteristics and favourable weather conditions at harvest. In sainfoin the mechanical conditioning of forage at cutting greatly increased the speed of drying and reduced the field wilting time from 3 to 1 day (to reach a DM content around 400 g kg^{-1}). Silages made at a DM content below 300 g kg^{-1} showed butyric acid fermentation in all the species (Table 2).Wilting improved the fermentation quality, as well as LAB inoculants, especially when ensiling herbage below 350 g DM kg^{-1}.

Sulla silages underwent a good fermentation when ensiled at a DM content of at least 350 g kg^{-1} at early bud stage, while they already showed a good fermentation when ensiled at 250 g kg^{-1} at early flowering stage. In semi-leafless pea, extensive proteolysis took place in silages harvested at the early stage, characterized by a higher protein content in the leaf and stem tissue than in the seed tissue. In silages made from the beginning of ripening stage, where most of the protein was localized in the seed, the level of proteolysis was reduced and a good fermentation was observed in peas ensiled after a short wilting period. LAB inoculation in pea silages greatly improved the fermentative profile. In sainfoin the increase in the drying speed due to conditioning decreased proteolysis. Low levels (4% on a DM basis) of hydrolysable chestnut tannin added to lucerne prior to ensiling did not affect fermentation, which was good both in the control and treated silages, but improved protein quality, by reducing the ammonia and NPN values. When comparing the NPN values of these silages to those of untreated lucerne (Cavallarin *et al.*, 2000), in relation to DM content at ensiling they showed lower levels, close to those found for the condensed tannin-containing sulla (1.6-2.7 % of condensed tannin on a DM basis) and sainfoin (2.1-3.2 % condensed tannin on a DM basis) (Figure 1). The data clearly indicate that there were differences among the legume forage species in the rates of proteolysis after ensiling. Since protein degradation in the silo is widely recognised to be the most limiting factor in legume silage-based diets for high

Figure 1. NPN content in non-containing (full symbols) , containing tannin (empty symbols) and added with tannin (grey symbols) forage legumes silages.

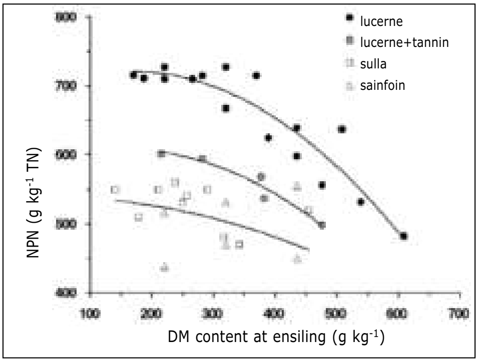

Table 2. Legume silages. Chemical composition and nitrogen fractions at different wilting level and under different stages of growth or treatments (mechanical treatment of herbage and use of chestnut tannin and LAB inoculants as additives at ensiling).

Crop	Sulla				Semi-leafless pea								Sainfoin				Lucerne		
Stage	Early bud		Early flowering		Beginning of pod filling				Beginning of ripening				Early bud				Full flowering		
Wilting level	I	II	I	II	I		II		I		II		I		II				
Treatment [A]	-	-	-	-	C	LAB	C	LAB	C	LAB	C	LAB	C	CON	C	CON	C	T4%	LAB
DM	228	348	243	335	163	158	284	283	212	209	348	340	210	219	432	420	415	382	432
pH	4.3	4.6	4.0	4.5	4.2	3.9	4.6	4.0	4.8	4.0	4.7	4.1	4.3	5.1	5.2	5.2	5.15	5.4	4.8
Lactic a.	53	22	43	14	140	185	88	140	63	99	56	82	83	39	32	33	33	35	63
Acetic a.	7	7	15	11	20	22	13	13	13.5	21	7.8	12	16	6	7	7	13	11	18
Butyric a.	21	0.3	UDL	UDL	4	5	8	4	27	2	5	0.6	1	34	UDL	UDL	UDL	UDL	UDL
DM loss	116	50	48	39	48	42	56	35	78	47	63	44	18	75	16	16	24	25	25
NH3-N	97	55	60	59	116	52	135	38	132	105	60	36	144	120	136	81	104	61	99
NPN	560	540	530	470	728	708	728	720	517	503	409	433	516	438	555	450	612	537	590
Free AA-N	-	-	-	-	371	293	427	306	226	241	192	171	379	313	318	255	336	343	383
TAA	-	-	-	-	28.9	22.3	29.2	35.4	32.2	31.2	32.9	34.1	34.3	37.1	35.7	38.4	33.2	36.9	
36.9																			

[A] C = control treatment; CON= mechanical conditioning; DM = dry matter (g kg^{-1}); DM loss (g kg^{-1}); free AA= free amino acid nitrogen (g kg^{-1} TN); LAB = lactic acid bacteria inoculants; NH_3-N (g kg^{-1} TN); NPN (g kg^{-1} TN); T4% = chestnut tannin 4% DM; TAA = total amino acids (mol kg^{-1} TN); UDL = under detection limit; lactic, acetic and butyric acids (g kg^{-1} DM).

yield dairy cows, future research should focus on methods for reducing the rate and the extent of NPN formation in silages. Possible approaches include the adoption of harvesting techniques that reduce field wilting time, the use of protein protection agents during ensiling such as tannins, or the choice of natural tannin-containing legume species.

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